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SAGA-CORE-WG

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A Simple API for Grid Applications (SAGA)

Status of This Document

This document provides information to the grid community, proposing the core components for an extensible Simple API for Grid Applications (SAGA Core API). It is supposed to be used as input to the definition of language specific bindings for this API, and by implementors of these bindings. Distribution is unlimited.

In 2010/2011, a number of errata have been applied to this document. A complete changelog can be found in the appendix. Note that the API specified in this document version is thus labelled as version 1.1, and as such obsoletes the previous API version 1.0. Most changes should be backward compatible with the original specification (for details see changelog).

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Abstract

This document specifies the core components for the Simple API for Grid Applications (SAGA Core API), a high level, application-oriented API for grid application development. The scope of this API is derived from the requirements specified in GFD.71 ("A Requirements Analysis for a Simple API for Grid Applications"). It will in the future be extended by additional API extensions.

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Contents

1 Introduction

This document specifies SAGA CORE, the Core of the Simple API for Grid Applications. SAGA is a high-level API that directly addresses the needs of application developers. The purpose of SAGA is two-fold:

1. Provide an **simple** API that can be used with much less effort compared to the vanilla interfaces of existing grid middleware. A guiding principle for achieving this simplicity is the 80–20 rule: serve 80 % of the use cases with 20 % of the effort needed for serving 100 % of all possible requirements.
2. Provide a standardized, common interface across various grid middleware systems and their versions.

1.1 How to read this Document

This document is an API *specification*, and as such targets *implementors of the API*, rather than its end users. In particular, this document should not be confused with a SAGA Users' Guide. This document might be useful as an API reference, but, in general, the API users' guide and reference should be published as separate documents, and should accompany SAGA implementations. The latest version of the users guide and reference can be found at `http://saga.cct.lsu.edu`

An implementor of the SAGA API should read the complete document carefully. It will very likely be insufficientunlikely be sufficient to extract the embedded SIDL specification of the API and implement a SAGA-compliant API. In particular, the general design considerations in Section 2 give essential, additional information to be taken into account for any implementation in order to be SAGA compliant.

This document is structured as follows. This Section focuses on the formal aspects of an OGF recommendation document. Section 2 outlines the general design considerations of the SAGA API. Sections 3 and 4 contain the SAGA API specification itself. Section 5 gives author contact information and provides disclaimers concerning intellectual property rights and copyright issues, according to OGF policies. Finally, Appendix A gives illustrative, non-normative, code examples of using the SAGA API.

1.2 Notational Conventions

The key words MUST , MUST NOT , REQUIRED , SHALL , SHALL NOT , SHOULD , SHOULD NOT , RECOMMENDED , MAY , and OPTIONAL are to be interpreted as described in RFC 2119 [6].

1.3 Security Considerations

As the SAGA API is to be implemented on different types of grid (and non-grid) middleware, it does not specify a single security model, but rather provides hooks to interface to various security models – see the documentation of the `saga::context` class in Section 3.6 for details.

A SAGA implementation is considered secure if and only if it fully supports (i.e. implements) the security models of the middleware layers it builds upon, and neither provides any (intentional or unintentional) means to by-pass these security models, nor weakens these security models' policies in any way.

2 General Design Considerations

This section addresses those aspects of the SAGA API specification common to most or all of the SAGA packages as defined in Sections 3 and 4.

2.1 API Scope and Design Process

The scope and requirements of the SAGA API have been defined by OGF's Simple API for Grid Applications Research Group (SAGA-RG). The SAGA-RG has collected as broad as possible a set of use cases which has been published as GFD.70 [17]. The requirements for the SAGA API were derived from this use cases document, an analysis of which has been published as GFD.71 [18]. The formal specification and resulting document is the work of the SAGA-CORE Working Group which was spawned from the SAGA-RG.

2.1.1 Requirements from the SAGA Requirement Analysis

The SAGA Requirement Analysis [18] lists the following functional and non-functional requirements of the SAGA API:

Functional Requirements

- Job submission and management should be supported by the SAGA API.
- Resource discovery should be supported by the SAGA API.
- Data management should be supported by the SAGA API.
- Efficient data access should be supported by the SAGA API.
- Data replication should be supported by the SAGA API.
- Persistent storage of application specific information should be supported by the SAGA API.
- Streaming of data should be supported by the SAGA API.
- Support for messages on top of the streaming API should be considered by the SAGA API.
- Asynchronous notification should be supported by the SAGA API.
- Application level event generation and delivery should be supported by the SAGA API.

- Application steering should be supported by the SAGA API, but more use cases would be useful.
- GridRPC should be supported by the SAGA API.
- Further communication schemes should be considered as additional use cases are submitted to the group.
- Access to data-bases does not currently require explicit support in the SAGA API.

Non-functional Requirements

- Asynchronous operations should be supported by the API.
- Bulk operations should be supported by the API.
- The exception handling of the API should allow for application level error recovery strategies.
- The SAGA API should be implementable on a variety of security infrastructures.
- The SAGA API should expose only a minimum of security details, if any at all.
- Auditing, logging and accounting should not be exposed in the API.
- Workflows do not require explicit support on API level.
- QoS does not require explicit support on API level.
- Transactions do not require explicit support on API level.

2.1.2 Requirement Adoption Strategy

The use cases expressed the above requirements different levels of importance or urgency. This reflects the fact that some functionality is considered more important or even vital (like file access and job submission) while other functionality is seen as "nice to have" by many use cases (like application steering). Also, the group of active people in the SAGA specification process constitutes a specific set of expertise and interest – and this set is, to some extent, reflected in the selection of SAGA packages specified in this document.

For example, as there were no use cases from the enterprise user community, nor was there any active participation from that community in the SAGA standardization process, no enterprise specific API package is included here. This does not imply that we consider them unnecessary, but rather reflects the wish and need to derive the API on real use cases, and to avoid the creation of an API from perceived use cases, and half-baked expertise.

Scope of the SAGA API

As various sides expressed their need for the availability of a useful (i.e. implementable and usable) API specification as quickly as possible, the SAGA-CORE-WG decided to follow a two-phase approach. The SAGA API, as described in this document, covers all requirements that are considered both urgent and sufficiently well understood to produce an API. Addressing the other the less urgent or well understood requirements is deferred to future versions, or extensions, of the SAGA API. Based upon this reasoning, areas of functionality (from now on referred to as *packages*) that are included in SAGA API are the following:

- jobs
- files (and logical files)
- streams
- remote procedure calls [19]
- auxiliary API's for
  - session handle and security context
  - asynchronous method calls (tasks)
  - access control lists
  - attributes
  - monitoring
  - error handling

Possible extensions to be included in future SAGA versions or extensions are:

- steering and extended monitoring
- possibly combining logical/physical files (read on logical files)
- persistent information storage (see, e.g. the GAT Advert Service [2])
- GridCPR [11]
- task dependencies (simple work flows and task batches)
- extensions to existing classes, based on new use cases

The packages as listed above do not imply a hierarchy of API interfaces: all packages are motivated by their use cases; there is no split into 'lower level' and 'higher level' packages. The only exception is the group of auxiliary APIs, which is considered orthogonal to the non-auxiliary SAGA packages.

Dependencies between packages have been kept to a minimum, so as to allow each package to be used independently of any other; this will also allow partially compliant API implementations (see below).

The term *CORE* in SAGA CORE refers to the fact that the scope of the API encompasses an initial required set of API objects and methods, which is perceived to be essential to the received use cases. It is important to reiterate, that the term, , does not imply any hierarchy of API packages, such as CORE and SHELL packages etc. We will drop the use of CORE when referring to the API and use the term in the context of the Working Group.

2.1.3 Relation to OGSA

The SAGA API specification effort has often been compared to, and seen as overlapping in scope and functionality to the OGSA standardization effort [10]. This perceived overlap in scope and functionality is misleading for the following reasons:

- OGSA applies to the service and middleware level.

  SAGA applies to the application level.
- OGSA aims at service and middleware developers.

  SAGA aims at application developers.
- OGSA is an architecture.

  SAGA is an API.
- OGSA strives to be complete, and to fully cover any potential grid service in its architectural frame.

  SAGA is by definition incomplete (80:20 rule), and aims to cover the mostly used grid functionalities at the application level.
- OGSA cannot sensibly interface to SAGA.

  SAGA implementations can interface to (a subset of) OGSA compliant services (and in fact usually will do so).

For these and more reasons we think that SAGA and OGSA are complementary, but by no means competitive. The only commonality we are aware of is the breadth of both approaches: both OGSA and SAGA strive to cover more than one specific area of middleware and application functionality, respectively.

There have been discussions between the SAGA and OGSA groups of the OGF, which tried to ensure that the SAGA specification does not imply any specific middleware properties, and in particular does not imply any state management which would contradict OGSA based middleware. Until now, we are not aware of any such conflict, and will continue to ensure seemless implementability on OGSA based middleware.

2.2 The SIDL Interface Definition Language

For the SAGA API, an object oriented (OO) approach was adopted, as it is easier to produce a procedural API from an OO API than the converse, and one of the goals of SAGA is to provide APIs which are as natural as possible in each implementation language. Advanced OO features such as polymorphism were avoided, both for simplicity and also to avoid complications when mapping to procedural languages.

The design team chose to use SIDL, the *Scientific Interface Definition Language* [4], for specifying the API. This provides a programming-language neutral representation of the API, but with well-defined syntax and clear mapping to implementation languages.

This document, however, slightly deviates from the original SIDL language definition. This section gives a brief introduction to SIDL, describes the respective deviations used, and also contains a number of notes to implementors on how to interpret this specification.

SIDL, from the Babel project, is similar to COM and CORBA IDL, but has an emphasis on scientific computing, with support for multi-dimensional arrays, etc. Although the SAGA specification does not use these features extensively, the multilanguage scope of Babel for mappings from SIDL to programming languages appealed to the authors of this specification.

The key SIDL concepts used in this document are:

`package:`	specifies a name space (see note below)
`interface:`	set of methods
`class:`	stateful object and the associated set of methods
`method:`	service that can be invoked on a object
`type:`	constraint to value of method parameters

SIDL supports single inheritance of classes, and multiple inheritance of interfaces.

Method definitions have signatures, which define which parameters are accepted on method invocation. These parameters can be:

- `in`: input parameter, passed by value, assumed constant

- `out`: output parameter, passed by reference
- `inout`: input and output parameter, passed by reference

2.2.1 Deviations from SIDL in this Document

SIDL has the notion of packages, which are equivalent to Java packages or C++ name spaces. Packages are used in this specification, for the purpose of cross referencing different API sections. The packages are not required to show up in the implementation's class names or name spaces, apart from the top level 'saga' name space.

SIDL also has the notion of 'versions', which are actually required on packages. We do not use versions in this specification, as the specification itself is versioned, and we do not intend to introduce versioning on classes and interfaces.

SIDL allows multi-dimensional arrays, in the form `array<type,dim>`. As SAGA uses only one-dimensional arrays, this document uses the simplified notation `array<type>`.

SIDL defines a string to be a `char*`. We feel, however, that strings have more powerful and native expressions in some languages (such as C++, Perl and Java), and use `string` for these types. `char*`, conventionally used for binary inout memory chunks, is expressed in this document as `array<byte>`.

This specification defines all method calls as `void` (or rather does not specify any return type for method calls at all). Instead of explicit return values, we define `out` parameters, which are in SIDL parameters which are passed by reference. However, for this specification we expect language bindings to use the first specified output parameter as return value of function calls where appropriate, in particular for the synchronous versions of the function calls. The asynchronous versions will, by their very nature, stick to the `out` parameter scheme, as described in Section 3.10.

2.2.2 Default Parameter Values

This document, in several places, adds default values in the SIDL part of the API specification. It is up to the language bindings to exploit any native means for default parameter values. If this is not possible, the language binding CAN abstain from default parameter values. Also, if asynchronous method calls require additional parameters, which might affect the handling of default parameters in languages such as C and C++, the language binding CAN deviate from this document in that respect.

2.2.3 Constness

SIDL method parameters specified as `in` parameters are considered to be `const`, and MUST NOT be changed by the implementation. The SAGA language bindings SHOULD utilize language mechanisms to enforce constness of these parameters, if possible.

To our knowledge, SIDL does not allow the specification of constness at method level. This means, SIDL does not permit a specification of which methods must leave the state of the object unchanged. We considered the introduction of const modifiers, to achieve consistent semantics over different implementations. However, a short analysis of various implementation techniques convinced us that requiring method constness would raise significant limitations to SAGA implementors (e.g. for implementations with late binding), with no immediately visible advantage to SAGA users. Hence, we waived any method level constness requirements for now, but this topic might get picked up in future versions of the API, e.g. with respect to object serialization (which implies known and consistent object state at serialization points).

2.2.4 Attributes and Metrics

The SIDL sections in this specification contain additional normative information which are inserted as SIDL comments. In particular these are definitions for *attributes* and *metrics*. Format definitions and meaning for these entities and specifications can be found in Section 3.8 *"SAGA Attributes Interface"* and Section 3.9 *"SAGA Monitoring Model"*, respectively.

2.2.5 Method Specification Details

All methods defined in the SIDL specification sections are further explained in the `'Specification Details'` sections in this document. These details to method specifications are *normative*. They are formatted as follows (example taken from the `saga::file` class):

```
- read
  Purpose:  reads up to len_in bytes from the file into
            the buffer.
  Format:   read                (inout buffer      buf,
                                 in    int         len_in = -1,
                                 out   int         len_out);
  Inputs:   len_in:              number of bytes to be read
  InOuts:   buf:                 buffer to read data into
  Outputs:  len_out:             number of bytes successfully
                                 read
  PreCond:  -
  PostCond: - the data from the file are available in the
              buffer.
  Perms:    Read
  Throws:   NotImplemented
            BadParameter
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - the actual number of bytes read into buffer
              is returned in len_out.  It is not an error
              to read less bytes than requested, or in fact
              zero bytes, e.g. at the end of the file.
            - errors are indicated by returning negative
              values for len_out, which correspond to
              negatives of the respective POSIX ERRNO error
              code.
            - the file pointer is positioned at the end of
              the byte area successfully read during this
              call.
            - the given buffer must be large enough to
              store up to len_in bytes, or managed by the
              implementation - otherwise a 'BadParameter'
              exception is thrown.
            - the notes about memory management from the
              buffer class apply.
            - if the file was opened in write-only mode (i.e.
              no 'Read' or 'ReadWrite' flag was given), this
              method throws an 'PermissionDenied' exception.
            - if len_in is smaller than 0, or not given,
              the buffer size is used for len_in.
              If that is also not available, a
              'BadParameter' exception is thrown.
            - similar to read (2) as specified by POSIX
```

The following sections are used in these detailed specifications of class methods:

`Purpose:`	the aim of the method
`Format:`	the SIDL prototype of the method
`Inputs:`	descriptions of `in` parameters
`InOuts:`	descriptions of `inout` parameters
`Outputs:`	descriptions of `out` parameters
`PreCond:`	conditions for successful invocation
`PostCond:`	effects of successful invocation
`Perms:`	permissions required for the method
`Throws:`	list of exceptions the method can throw
`Notes:`	other details

`PreCond`'ition: an example for a precondition is a specific object state. An implementation MUST check these Preconditions, and MUST refuse to execute the method if they are not met, and throw an exception accordingly.

`PostCond`'tion: an example for a postcondition is a changed object state. An implementation MUST ensure that the postconditions are met upon successful method invocation, and MUST flag an error otherwise.

`Throws:` the exceptions listed in this section are the only SAGA exceptions which can be thrown by the method.

`Perms:` this section lists the permissions required to perform the method. If that permission is not available to the caller, a `PermissionDenied` exception MUST be thrown by the implementation.

`Notes:` can contain, for example, references to the origin and use of the method, conditions on which exceptions are to be raised, semantic details of invocations, consistency implications of invocations, and more. These `Notes` are normative!

2.2.6 Inheritance

The SAGA API specification limits class inheritance to *single inheritance* – a class can, nevertheless, implement multiple interfaces. Similar to the original SIDL syntax, this document uses the qualifiers `extends` to signal inheritance relations of a class, and `implements` to signal an interface to be provided by a class.

Almost all SAGA classes implement the `saga::object` interface (which provides, for example, a unique instance id and the `saga::error_handler` interface), but the classes usually implement several other interfaces as well.

For inherited classes and implemented interfaces holds: if methods are overloaded (i.e. redefined with the same name), the semantics of the overloaded methods from the base class still apply (i.e. all `Notes` given on the detailed method description apply). This also holds for `CONSTRUCTOR`s and `DESTRUCTOR`s, and also, for example, for a `close()` which is implicitly called on the base class' destruction.

2.2.7 The SAGA Interfaces

For some SAGA objects, such as for `saga::logical_file`, SAGA interfaces, like the attribute interface, can allow access to remote entities. These methods should thus (a) also be available asynchronously, and (b) allow to apply the permission interface. However, asynchronous method calls and permissions make no sense for other, local SAGA objects, in particular on the SAGA Look-&-Feel level.

Thus, instead of implementing the `saga::async` and `saga::permissions` interface in the various interfaces in general, this specification defines that SAGA implementations MUST apply the following rules:

- SAGA classes and interfaces, which implement the `saga::async` interface, and thus implement the SAGA task model, MUST also implement that task model for the methods defined in the following interfaces:
  - `saga::attributes`
  - `saga::permissions`
  - `saga::monitorable`
  - `saga::steerable`
- SAGA classes and interfaces, which implement the `saga::permissions` interface, and thus implement the SAGA permission model, MUST also implement that permission model for the methods defined in the following interfaces:
  - `saga::attributes`
  - `saga::monitorable`
  - `saga::steerable`

2.3 Language Binding Issues

The abstract SAGA API specification, as provided by this document, is language independent, object oriented, and specified in SIDL. Normative bindings for specific languages, both object oriented and procedural, will be defined in additional documents.

This document contains several examples illustrating the use of the API, and these have naturally been shown in specific languages, such as C++. These examples should not be taken as normative, but merely as illustrative of the use of the API. When normative language bindings are available, these examples may be revised to reflect these bindings. In order to give an impression of the Look-&-Feel in other languages, Appendix A lists some of the examples in different languages. Again, Appendix A is illustrative, not normative.

Language bindings of the SAGA API shall provide the typical Look-&-Feel of the respective programming language. This comprises the syntax for the entities (objects, methods, classes, etc.), but also, to some degree, semantic details for which it makes sense to vary them with the programming language. We summarize the semantic details here.

- In this document, flags are denoted as bitfields (specifically, integer enums which can be combined by logical AND and OR). This is for notational convenience, and a language binding should use the most natural mechanism available.
- Language bindings MAY want to express array style arguments as variable argument lists, if that is appropriate.
- This document specifies file lengths, buffer lengths and offsets as `int` types. We expect implementations to use suitably large native data types, and to stick to language specific types where possible (such as `size_t` for buffer lengths in `C`, and `off_t` for file lengths in `C`). The SAGA language bindings MUST include the types to be used by the implementations. In particular, 64 bit types SHOULD be used if they are available.
- The SAGA attribute interface defines attribute keys to be strings. The SAGA monitorable interface defines metric names to be strings. At the same time, many attributes and metrics are predefined in this specification. In order to avoid typos, and improve interoperability between multiple implementations, we expect language bindings to exploit native mechanisms to have these predefined attributes and metric names specified as literal constants. For example, in C/C++ we would expect the following defines for the stream package (amongst others):

```
#define SAGA_METRIC_STATE    "state"
#define SAGA_STREAM_NODELAY  "nodelay"
```

- Language bindings MAY define additional constants for special parameter values. For example, in C/C++ we would expect the following defines for timeout values (amongst others):

```
#define SAGA_WAIT_FOREVER    -1.0
#define SAGA_NOWAIT           0.0
```

- Object lifetime management may be language specific. See Section 2.5.3.

- Concurrency control may be language specific. See Section 2.6.4.
- Thread safety may be language specific. See Section 2.6.5.

2.4 Compliant Implementations

A SAGA implementation MUST follow the SAGA API specification, and the language binding(s) for its respective programming language(s), both syntactically and semantically. With respect to syntax, the language binding documents overrule this document, in case of contradictions. This means that any method MUST be implemented with the syntax and with the semantics specified in this document and the applicable language bindings, or not be implemented at all (i.e. MUST then throw the `NotImplemented` exception).

The `NotImplemented` exception MUST, however, be used only in necessary cases, for example if an underlying grid middleware does not provide some capability, and if this capability can also not be emulated. The implementation MUST carefully document and motivate the use of the `NotImplemented` exception.

An implementation of the SAGA API is a *"SAGA compliant implementation"* if it implements all objects and methods of the SAGA API specification, possibly using the `NotImplemented` exception, as outlined above.

An implementation of the SAGA API is a *" SAGA compliant partial implementation"* if it implements only some packages, but implements those completely. It is, as with compliant implementations, acceptable to have methods that are not implemented at all (and thus throw a `NotImplemented` error).

All other implementations of the SAGA API are *"not SAGA compliant implementations"*.

The SAGA Look-&-Feel classes and interfaces (see Section 3) (`exception`, `error_handler`, `object`, `url`, `session`, `context`, `permissions`, `buffer`, `attributes`, `callback`, `metric`, `monitorable`, `steerable`, `async`, `task`, and `task_container`) SHOULD be implemented completely for an implementation to be compliant. A partially compliant implementation SHOULD implement those SAGA Look-&-Feel classes and interfaces which are used by the packages the implementation intends to provide.

It may, however, not always be possible to implement the Look-&-Feel classes completely independent from the middleware, at least to a full extent. In particular `permissions`, `attributes`, `monitorable`, `steerable`, `async`, and `task` may need explicit support from the backend system, when used by functional API packages. In such cases, methods in these four packages MAY throw a

`NotImplemented` exception. In all other cases in the SAGA Look-&-Feel MUST NOT throw a `NotImplemented` exception.

Note that the exposure of additional (e.g. backend specific) classes, methods, or attributes within the SAGA API (e.g. within the `saga` name space) is considered to *break SAGA compliance*, unless *explicitly* allowed by this specification, as such extensions would bind applications to this specific implementation, and limit their portability, the latter being a declared goal of the SAGA approach.

The SAGA CORE Working Group will strive to provide, along with the language binding documents, compliance tests for implementors. It should also be noted that the SAGA language binding documents MAY specify deviations from the API syntax and semantics specified in this documents. In this case, the language binding specification supersedes this language independent specification. The language binding specifications MUST strive to keep the set of differences to this specification as small as possible.

2.4.1 Early versus late binding

An implementation may choose to use late binding to middleware. This means that the middleware binding might change between subsequent SAGA calls. For example, a `file.open()` might be performed via the HTTP binding, but a subsequent `read()` on this file might fail, and instead be performed with GridFTP.

Late binding has some advantages in terms of flexibility and error recovery. However, it implies a certain amount of object state to be kept on client side, which might have semantic consequences. For example, a `read()` operation might fail on HTTP for some reasons, but might succeed via GridFTP. The situation might be reversed for `write()`. In order to allow alternating access via both protocols, the file pointer information (e.g. the file object state) must be held on client side.

It is left to a later experience document about the SAGA API implementations to discuss potential problems arising from early/late binding implementations, with respect to semantic conformance to the SAGA API specification. It should be noted here that method-level constness would represent a major obstacle for late binding implementations.

Late binding MUST NOT delay the check of error conditions if this is semantically required by the specification. For example, a `file.open()` should check for the existence of the file, even if the implementation may bind to a different middleware on subsequent operations on this file.

2.5 Object Management

The API specification in Sections 3 and 4 defines various kinds of objects. Here, we describe generic design considerations about managing these objects.

2.5.1 Session Management

The specification introduces a `saga::session` object, which acts as session handle. A session thereby identifies objects and operations which are sharing information, such as security details. Also, objects and methods from different sessions MUST NOT share any information. This will allow an application to communicate with different grids and VOs at the same time, or to assume different IDs at the same time. Many applications, however, will have no need for explicit session handling. For those cases, a default SAGA session is used if no explicit `saga::session` object is created and used.

Any SAGA object is associated with a session at creation time, by using the respective `saga::session` instance as first argument to the constructor. If the session argument is omitted, the object is associated with the default session. SAGA objects created from other SAGA objects (such as a `saga::file` instance created by calling `open()` on a `saga::directory` instance) inherit the parent's session. The remainder of the document refers to the default session instance as `theSession`.

A `saga::context` instance is used to encapsulate a virtual identity, such as a Globus certificate or an ssh key pair. Multiple context instances can be associated with one session, and only that context information MUST be used to perform any operation in this session (i.e. on objects associated with this session). If no `saga::context` instances are explicitly added to a SAGA session, the SAGA implementation MAY associate one or more default contexts with any new session, including the default session. In fact, the default session can ONLY use these default contexts.

2.5.2 Shallow versus Deep Copy

Copy operations on SAGA objects are, by default, shallow. This applies, for example, when SAGA objects are passed by value, or by assignment operations. Shallow copy means that the original object instance and the new (copied) instance share state. For example, the following code snippet

Code Example

```
saga::file f1 (url);        // file pointer is at 0
saga::file f2 = f1;         // shallow copy
```

```

cout << "f1 is at " << f1.seek (0, Current) << "\n";
cout << "f2 is at " << f2.seek (0, Current) << "\n";

f1.seek (10, Current);      // change state

cout << "f1 is at " << f1.seek (0, Current) << "\n";
cout << "f2 is at " << f2.seek (0, Current) << "\n";
```

would yield the following output (comments added):

```
f1 is at 0
f2 is at 0   -> shallow copy of f1

f1 is at 10  -> state of f1 changes
f2 is at 10  -> state of f2 changes too: it is shared
```

The SAGA API allows, however, to perform deep copies on all SAGA objects, by explicitly using the `clone()` method. The changed code snippet:

Code Example

```
saga::file f1 (url);        // file pointer is at 0
saga::file f2 = f1.clone(); // deep copy

cout << "f1 is at " << f1.seek (0, Current) << "\n";
cout << "f2 is at " << f2.seek (0, Current) << "\n";

f1.seek (10, Current);      // change state

cout << "f1 is at " << f1.seek (0, Current) << "\n";
cout << "f2 is at " << f2.seek (0, Current) << "\n";
```

would then yield the following output (comments added):

```
f1 is at 0
f2 is at 0   -> deep copy of f1

f1 is at 10  -> state of f1 changes
f2 is at 0   -> state of f2 did not change, it is not shared
```

SAGA language bindings MAY deviate from these semantics if (and only if) these semantics would be non-intuitive in the target language.

If a SAGA object gets (deeply) copied by the `clone` method, its complete state is copied, with the exception of:

- the object id (a new id is assigned, see Section 3.2),
- information about previous error conditions (is not copied, see Section 3.1),
- callbacks on metrics (are not copied, see Section 3.9).
- the session the object was created in (is shallow copied, see Section 3.5),

Not copying previous error conditions disambiguates error handling. Not copying the session ensures that the same session is continued to be shared between objects in that session, as intended. Not copying registered callbacks is required to ensure proper functioning of the callback invocation mechanism, as callbacks have an inherent mechanism to allow callbacks to be called *exactly* once. Copying callbacks would undermine that mechanism, as callbacks could be called more than once (once on the original metric, once on the copied metric).

Note that a copied object will, in general, point to the same remote instance. For example, the copy of a `saga::job` instance will not cause the spawning of a new remote job, but will merely create a new handle to the same remote process the first instance pointed to. The new object instance is just a new handle which is in the same state as the original handle – from then on, the two handles have a life of their own. Obviously, operations on one SAGA object instance may still in fact influence the copied instance, e.g. if `cancel()` is called on either one.

Note also, that the deep/shallow copy semantics is the same for synchronous and asynchronous versions of any SAGA method call. If not otherwise specified by the language binding, the copy occurs at the point where the SAGA method is called.

Note also, that instances of the following SAGA classes are always deep copied: `url`, `context`, `metric`, `exception`, `job_description` and `task_container`.

2.5.3 Object State Lifetime

In general, the lifetime of SAGA object instances is defined as natively expected in the respective languages, so it is usually explicitly managed, or implicitly defined by scoping, or in some languages implicitly managed by garbage collection mechanisms.

The SAGA API semantics, in particular asynchronous operations, tasks, and monitoring metrics require, however, that the state of certain objects must be able to survive the lifetime of the context in which they were created. As state in these situations is shared with the original object instance, this may imply in some languages that the respective objects must survive as well.

In particular, object state MUST be available in the following situations:

- The state of a `saga::object` instance MUST be available to all tasks created on this object instance.
- The state of a `saga::object` instance MUST be available to all metrics created on this object instance.
- The state of a `saga::session` instance MUST be available to all objects created in this session.
- The state of a `saga::context` instance MUST be available to all sessions this context instance was added to.
- The state of the default session MUST be available to the first invocation of any SAGA API method, and SHOULD be available for the remaining lifetime of the SAGA application.

Due to the diversity of lifetime management used in existing programming languages, this document can not prescribe a single mechanism to implement objects or object states that survive the context they were created in. It is subject to individual language binding documents to prescribe such mechanisms, and to define responsibilities for object creation and destruction, both for SAGA implementations and for application programs, in order to match requirements and common-sense in the respective languages.

The SAGA specification implies that object state is shared in the following situations:

- an asynchronous operation is invoked on an object, creating a task instance;
- a SAGA object is passed as argument to a (synchronous or asynchronous) method call.

Those method calls that deviate from these semantics denote this in their `PostCond`'itions (e.g. prescribe that a deep copy of state occurs).

2.5.4 Freeing of Resources and Garbage Collection

The destruction of objects in distributed systems has its own subtle problems, as has the interruption of remote operations. In particular it cannot be assumed that a destructor can both return timely *and* ensure the de-allocation of all (local and remote) resources. In particular, as a remote connection breaks, no guarantees whatsoever can be made about the de-allocation of remote resources.

In particular for SAGA tasks, which represent asynchronous remote operations, we expect implementations to run into this problem space, for example if `cancel()` is invoked on this task. To have common semantic guidelines for resource de-allocation, we define:

1. On explicit or implicit object destruction, and on explicit or implicit interruption of synchronous and asynchronous method invocations, SAGA implementations MUST make a best-effort attempt to free associated resources immediately[1].
2. If the immediate de-allocation of resources is not possible, for whichever reasons, the respective interrupting or destructing methods MUST return immediately, but the resource de-allocation MAY be delayed indefinitely. However, as of (1), the best effort strategy to free these resources eventually MUST stay in place.
3. Methods whose semantics depend on successful or unsuccessful de-allocation of resources (such as `task.cancel()` or `file.close()`) allow for an optional `float` argument, which defines a timeout for this operation (see Section 2.6.3). If resource de-allocation does not succeed within this timeout period, a `NoSuccess` exception MUST be thrown. Negative values imply to wait forever. A value of zero (the default) implies that the method can return immediately; no exception is thrown, even if some resources could not be de-allocated. In any case, the best-effort policy as described above applies.

SAGA implementations MUST motivate and document any deviation from this behavior. See also Section 2.4 on compliant implementations.

2.5.5 Destructors and `close()`

Destructors are implying a call to `close()` of the respective object (if a `close()` is defined for that class), unless, as described above, tasks are still using the respective resources – then the close is delayed until the last of these tasks is

[1] *Immediately* in the description above means: within the expected response time of the overall system, but not longer.

destroyed (see 2.5.3). It must be noted that, unlike when using a direct call to `close()`, exceptions occurring on such an implicit `close()` cannot be communicated to the application: throwing exceptions in destructors is, in general, considered unclean design, and is in many languages outright forbidden. Thus, an explicit `close()` should be used by the application if feedback about eventual error conditions is required. Otherwise, an implicit `close()` on object destruction will silently discard such error conditions (exceptions).

2.6 Asynchronous Operations and Concurrency

In this section, we describe the general design considerations related to asynchronous operations, concurrency control, and multithreading.

2.6.1 Asynchronous Function Calls

The need for asynchronous calls was explicitly stated by the use cases, as reasonable synchronous behavior cannot always be expected from grids. The SAGA task interface allows the creation of an asynchronous version of each SAGA API method call. The SIDL specification lists only the synchronous version of the API methods, but all classes implementing the task interface MUST provide the various asynchronous methods as well. Please see Section 3.10 for details on the task interface.

2.6.2 Asynchronous Notification

Related to this topic, the group also discussed the merits of callback and polling mechanisms and agreed that a callback mechanism should be used in SAGA to allow for asynchronous notification. In particular, this mechanism should allow for notification on the completion of asynchronous operations, i.e. task state changes. However, polling for states and other events is also supported.

2.6.3 Timeouts

Several methods in the SAGA API support the synchronization of concurrent operations. Often, those methods accept a `float` timeout parameter. The semantics of this parameter MUST be as follows:

`timeout < 0.0` – wait forever
`timeout = 0.0` – return immediately
`timeout > 0.0` – wait for this many seconds

These methods MUST not cause a `Timeout` exception as the timeout period passes, but MUST return silently. For a description of the `Timeout` exception, see Section 3.1.

The various methods often define *different* default timeouts. For timeouts on `close()` methods, the description of resource de-allocation policies in Section 2.5.4 is also relevant.

2.6.4 Concurrency Control

Although limited, SAGA defines a de-facto concurrent programming model, via the task model and the asynchronous notification mechanism. Sharing of object state among concurrent units (e.g. tasks) is intentional and necessary for addressing the needs of various use cases. Concurrent use of shared state, however, requires concurrency control to avoid unpredictable behavior.

(Un)fortunately, a large variety of concurrency control mechanisms exist, with different programming languages lending themselves to certain flavors, like object locks and monitors in Java, or POSIX mutexes in C-like languages. For some use cases of SAGA, enforced concurrency control mechanisms might be both unnecessary and counter productive, leading to increased programming complexity and runtime overheads.

Because of these constraints, SAGA does not enforce concurrency control mechanisms on its implementations. Instead, it is the responsibility of the application programmer to ensure that her program will execute correctly in all possible orderings and interleavings of the concurrent units. The application programmer is free to use any concurrency control scheme (like locks, mutexes, or monitors) in addition to the SAGA API.

2.6.5 Thread Safety

We expect implementations of the SAGA API to be thread safe. Otherwise, the SAGA task model would be difficult to implement, and would also be close to useless. However, we acknowledge that specific languages might have trouble with (a) expressing the task model as it stands, and (b) might actually be successful to implement the API single threaded, and non-thread safe. Hence, we expect the language bindings to define if compliant implementations in this language MUST or CAN be thread safe – with MUST being the default, and CAN requiring good motivation.

2.7 State Diagrams

Several objects in SAGA have a *state* attribute or metric, which implies a state diagram for these objects. That means, that instances of these objects can undergo well defined state transitions, which are either triggered by calling specific methods on these object instances, or by calling methods on other object instances affecting these instances, or are triggered by internal events, for example by backend activities. State diagrams as shown in Figure 1 are used to define the available states, and the allowed state transitions. These diagrams are *normative*.

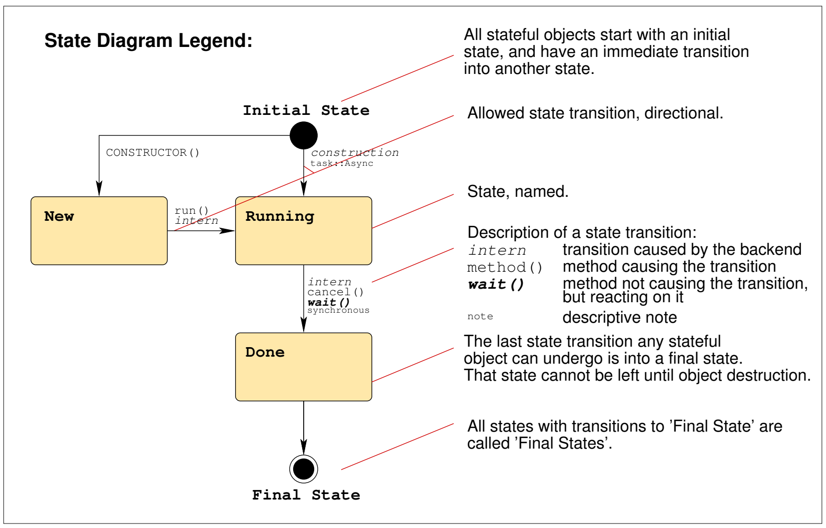

Figure 1: **The SAGA state diagrams follow the notations shown here.**

2.8 Execution Semantics and Consistency Model

A topic related to concurrency control concerns execution semantics of the operations invoked via SAGA's API calls. Unlike Section 2.6, here we are dealing with the complete execution "chain," reaching from the client API to the server side, based on whichever service or middleware layer is providing access to the server itself.

SAGA API calls on a single service or server can occur concurrently with (a) other tasks from the same SAGA application, (b) tasks from other SAGA applications, or also (c) calls from other, independently developed (non-SAGA) applications. This means that the user of the SAGA API should not rely on any specific execution order of concurrent API calls. However, implementations MUST guarantee that a synchronous method is indeed finished when the method returns, and that an asynchronous method is indeed finished when the task instance representing this method is in a final state. Further control of execution order, if needed, has to be enforced via separate concurrency control mechanisms, preferably provided by the services themselves, or on application level.

Most SAGA calls will invoke services that are remote to the application program, hence becoming vulnerable to errors caused by remote (network-based) invocation. Therefore, implementors SHOULD strive to implement "At Most Once" semantics, enforcing that, in case of failures, an API call either fails (does not get executed), or succeeds, but never gets executed more than once. This seems to be (a) generally supported by most grid middleware, (b) implementable in distributed systems with reasonable effort, and (c) useful and intuitively expected by most end users. Any deviation from these semantics MUST be carefully documented by the implementation.

Beyond this, the SAGA API specification does *not* prescribe any consistency model for its operations, as we feel that this would be very hard to implement across different middleware platforms. A SAGA implementation MAY specify some consistency model, which MUST be documented. A SAGA implementation SHOULD always allow for application level consistency enforcement, for example by use of of application level locks and mutexes.

2.9 Optimizing Implementations, Latency Hiding

Distributed applications are usually very sensitive to communication latencies. Several use cases in SAGA explicitly address this topic, and require the SAGA API to support (a) asynchronous operations, and (b) bulk operations, as both are commonly accepted latency hiding techniques. The SAGA task model (see Section 3.10) provides asynchronous operations for the SAGA API. Bulk operations have no explicit expression in SAGA. Instead, we think that implementations should be able to exploit the concurrency information available in the SAGA task model to transparently support bulk optimizations. In particular, the `saga::task_container` allows the application to run multiple asynchronous operations at the same time – implementations are encouraged to apply bulk optimizations in that situation. A proof-of-concept implementation in C++ demonstrates that bulk optimizations for task containers are indeed implementable, and perform very well [13]. We feel that this leaves the SAGA API simple, and at the same time allows for performance critical use cases.

Other optimizations are more explicit in the API, most notably the additional I/O operations for the `saga::file` class – those are described in more detail in Section 4.3.

Implementations are encouraged to exploit further optimizations; these MUST NOT change the semantics of the SAGA API though.

2.10 Configuration Management

Defining deployment and configuration related parts of an API normatively raises a number of issues, such as:

- As different SAGA implementations bind to different middleware, that middleware might need configuration information, such as the location of a GridRPC config file (see [19]), or the location of a service endpoint.
- If such configuration information is to be provided by the end user, the end user might face, eventually, a plethora of SAGA implementation and middleware specific configuration files, or environment variables, or other configuration mechanisms, which would break the SAGA abstraction from the middleware for the end user.
- Defining a SAGA configuration file format might succeed syntactically (e.g. ini file format), but must fail semantically, as it will be impossible to foresee on which middleware SAGA gets implemented, and to know which configuration information that middleware requires.

This leaves the dilemma that a configuration mechanism seems impossible to define generically, but by leaving it undefined, we break the abstraction SAGA is supposed to provide to the end user.

For the time being, this problem is left to (a) the middleware developers, (b) to the SAGA implementors, and (c) to the SAGA deployment (i.e. system administrators). Experience gathered by these groups will hopefully allow to revise this topic, and to define a generic, simple, *and* abstract approach to the configuration problem.

2.11 The 'URL Problem'

The end user might expect the SAGA API, as a high level and simple API, to handle protocol specific issues transparently. In particular, she might expect that SAGA gracefully and intelligently handles a URL such as

```
http://host.net//tmp/file
```

even if HTTP as a protocol is, in fact, not available at `host.net`, but for example the FTP protocol is.

However, this innocently looking problem has far reaching consequences, and in fact is, to the best of our knowledge, unresolved. Consider the following server setup on host.net:

FTP server root:	`/var/ftp/pub/`
HTTP server root:	`/var/http/htdocs/`

The entities described by the two URLs

```
http://host.net//tmp/file
ftp://host.net//tmp/file
```

hence refer to different files on host.net! Even worse: it might be (and often is) impossible to access the HTTP file space via the FTP service, and vice versa.

Similar considerations hold for file names relative to the user's home directory. Consider:

```
http://host.net/~user/tmp/file
```

This URL may point to

```
file:////home/user/public_html/tmp/file
```

and not, as could have been expected, to

```
file:////home/user/tmp/file
```

Hence, a reliable translation of URLs between different protocols (or protocol schemes) is only possible, if the exact server setup of all affected protocol serving services is known. This knowledge is often not available.

Further, even if a correct translation of protocols and hence URLs succeeds, there is no guarantee that the referred file is actually available via this protocol, with the same permissions etc. – this again depends on the service configuration.

SAGA 'solution' to the 'URL Problem'

1. A SAGA compliant implementation MAY be able to transparently translate URLs, but is not required to do so. Further, this behavior CAN vary during the runtime of the program.
2. A SAGA compliant implementation MUST provide the `translate` method as part of the `saga::url` class. That method allows the end user to check if a specific URL translation can be performed.
3. The SAGA API specification allows the use of the placeholder 'any' (as in `any://host.net/tmp/file`). A SAGA compliant implementation MAY

be able to choose a suitable protocol automatically, but CAN decline the URL with an `IncorrectURL` exception.

4. Abstract name spaces, such as the name space used by replica systems, or by grid file systems, hide this problem efficiently and transparently from the end user. We encourage implementations to use such name spaces.

5. A URL which cannot be handled for the stated reasons MUST cause the exception `IncorrectURL` to be thrown. Note that this holds only for those cases where a given URL cannot be handled *as such*, e.g. because the protocol is unsupported, `any://` cannot be handled, or a necessary URL translation failed. The detailed error message SHOULD give advice to the end user which protocols are supported, and which types of URL translations can or cannot be expected to work. The `IncorrectURL` exception is thus listed on all methods which handle URLs as parameters, but is not individually motivated in the detailed method specifications.

6. Any other error related to the URL (e.g. invalid file name) MUST be indicated by the exceptions as listed in the method specifications in this document (in most cases a `BadParameter` exception) is applicable.

We are aware that this 'solution' is sub-optimal, but we also think that, if cleverly implemented with the help of information services, service level setup information, and global name spaces, this approach can simplify the use of the SAGA API significantly. We will carefully watch the work of related OGF groups, such as the global naming efforts in the Grid FileSystem Working Group (GFS-WG), and will revise this specification if any standard proposal is put forward to address the described problem.

Note that SAGA, unlike other Grid APIs such as the GAT[2], is fully adopting RFC 3986[5]: URLs which include a scheme can, according to that RFC, not express relative locations. The following two URLs are thus expected to point to the same location:

```
gridftp://remote.host.net/bin/date
gridftp://remote.host.net//bin/date
```

2.12 Miscellaneous Issues

2.12.1 File Open Flags

For files, flags are used to specify if an `open` is truncating, creating, and/or appending to an existing entity. For jobs, and in particular for file staging, the LSF scheme is used (e.g. `'url >> local_file'` for appending a remote file to a local one after staging). We are aware of this seeming inconsistency. However, we think that a forceful unification of both schemes would be more awkward to use, and at the same time less useful.

2.12.2 Byte Ordering

Applications on grids as inherent homogeneous environments will often face different native byte orders on different resources. In general, SAGA always operates in the locally native byte ordering scheme, unless explicitly notified. The byte oriented I/O interfaces (files and streams) are naturally ignorant to the byte ordering. Finally, any byte order conversion on data exchange between two SAGA applications, e.g. by using files, streams or remote procedure calls, must be taken care of in application space, unless noted otherwise.

3 SAGA API Specification – Look & Feel

The SAGA API consists of a number of interface and class specifications. The relation between these is shown in Figure 2 on Page 32. This figure also marks which interfaces are part of the SAGA Look-&-Feel, and which classes are combined into packages.

This and the next section form the normative part of the SAGA Core API specification. It has one subsection for each package, starting with those interfaces that define the SAGA Look-&-Feel, followed by the various, capability-providing packages: job management, name space management, file management, replica management, streams, and remote procedure call.

The SAGA Look-&-Feel is defined by a number of classes and interfaces which ensure the non-functional properties of the SAGA API (see [18] for a complete list of non-functional requirements). These interfaces and classes are intended to be used by the functional SAGA API packages, and are hence thought to be orthogonal to the functional scope of the SAGA API.

Section 2.4 contains important notes on the extent the SAGA Look-&-Feel needs to be implemented by compliant implementations. The `NotImplemented` exception is listed for a number of method calls, but MUST only be used under the circumstances described in 2.4. Similarly, the `IncorrectURL` exception is listed when appropriate, but is not, in general, separately motivated or detailed – the semantic conventions for this exception are as defined in Section 2.11.

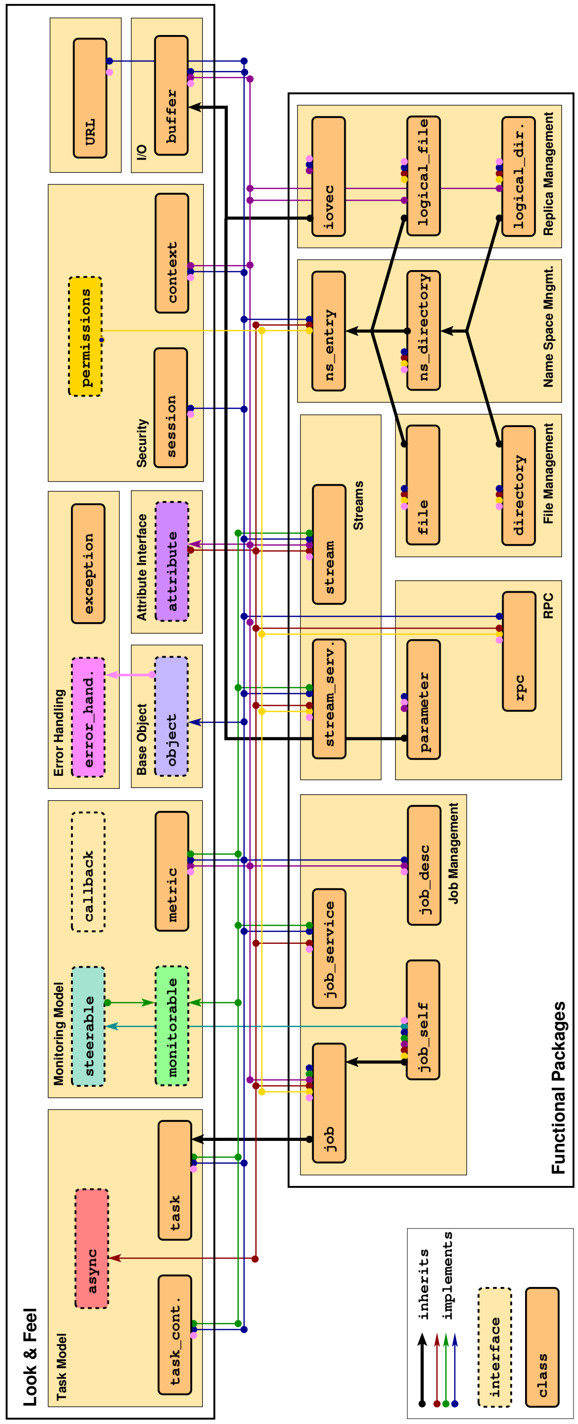

Figure 2: The SAGA class and interface hierarchy.
added URL class, moved iovec and parameter.

3.1 SAGA Error Handling

Note that these changes to the SAGA error handling should be backward compatible to the original specification, as far as they do not correct errors.

All objects in SAGA implement the `error_handler` interface, which allows a user of the API to query for the latest error associated with a SAGA object (pull). In languages with exception-handling mechanisms, such as Java, C++ and Perl, the language binding MAY allow exceptions to be thrown instead. If an exception handling mechanism is included in a language binding, the `error_handler` MUST NOT be included in the same binding. Bindings for languages without exception handling capabilities MUST stick to the `error_handler` interface described here, but MAY define additional language-native means for error reporting. This document describes error conditions in terms of exceptions.

For objects implementing the `error_handler` interface, each synchronous method invocation on that object resets any error caused by a previous method invocation on that object. For asynchronous operations, the error handler interface is provided by the task instance performing the operation, and not by the object which created the task. If an error occurs during object creation, then the error handler interface of the session the object was to be created in will report the error.

In languages bindings where this is appropriate, some API methods MAY return POSIX `errno` codes for errors. This is the case in particular for `read()`, `write()` and `seek()`, for `saga::file` and `saga::stream`. The respective method descriptions provide explicit details of how `errno` error codes are utilized. In any case, whenever numerical `errno` codes are used, they have to be conforming to POSIX.1 [21].

Each SAGA API call has an associated list of exceptions it may throw. These exceptions all extend the `saga::exception` class described below. The SAGA implementation MUST NOT throw any other SAGA exception on that call.

SAGA exceptions can be hierarchical – for details, see below.

3.1.1 Specification

```
package saga.error
{
  enum exception_type
  {
    IncorrectURL         =  1,
    BadParameter         =  2,
    AlreadyExists        =  3,
    DoesNotExist         =  4,
    IncorrectState       =  5,
    IncorrectType        =  6,
    PermissionDenied     =  7,
    AuthorizationFailed  =  8,
    AuthenticationFailed =  9,
    Timeout              = 10,
    NoSuccess            = 11,
    NotImplemented       = 12
  }

  class exception
  {
    CONSTRUCTOR          (in  object           obj,
                          in  string           message,
                          out exception        e);
    CONSTRUCTOR          (in  string           message,
                          out exception        e);
    DESTRUCTOR           (void);

    // top level exception information
    get_message          (out string           message);
    get_object           (out object           obj);
    get_type             (out exception_type   t);

    // recursive exception information
    get_all_exceptions   (out array<exception> elist);
    get_all_messages     (out array<string>    mlist);
  }


  class incorrect_url         : extends saga::exception { }
  class bad_parameter         : extends saga::exception { }
  class already_exists        : extends saga::exception { }
  class does_not_exist        : extends saga::exception { }
```

```
    class incorrect_state        : extends saga::exception { }
    class incorrect_type         : extends saga::exception { }
    class permission_denied      : extends saga::exception { }
    class authorization_failed   : extends saga::exception { }
    class authentication_failed  : extends saga::exception { }
    class timeout                : extends saga::exception { }
    class no_success             : extends saga::exception { }
    class not_implemented        : extends saga::exception { }


    interface error_handler
    {
      has_error            (out boolean        has_error);
      get_error            (out exception      error);
    }
  }
```

3.1.2 Specification Details

SAGA provides a set of well-defined exceptions (error states) which MUST be supported by the implementation. As to whether these error states are critical, non-critical or fatal depends on, (a) the specific implementation (one implementation might be able to recover from an error while another implementation might not), and (b) the specific application use case (e.g. the error 'file does not exist' may or may not be fatal, depending on whether the application really needs information from that file).

In language bindings where this is appropriate, some SAGA methods do not raise exceptions on certain error conditions, but return an error code instead. For example, `file.read()` might return an error code indicating that not enough data is available right now. The error codes used in SAGA are based on the definitions for `errno` as defined by POSIX, and MUST be used in a semantically identical manner.

For try/catch blocks which cover multiple API calls, on multiple SAGA objects, the `get_object()` method allows to retrieve the object which caused the exception to be thrown. In general, it will not be possible, however, to determine the method call which caused the exception post mortem. `get_object()` can also be used for exceptions raised by asynchronous method calls (i.e. on `task::rethrow()`, to retrieve the object on which that task instance was created.

This specification defines the set of allowed exceptions for each method explicitly – this set is normative: other SAGA exceptions MUST NOT be thrown on these methods. Also, implementations MUST NOT specify or use other SAGA exceptions than listed in this specification.

Additionally, an implementation MAY throw other, non-SAGA exceptions, e.g. on system errors, resource shortage etc. These exception SHOULD only signal local errors, raised by the SAGA implementation, not errors raised by the Grid backend. SAGA implementations MUST, translate grid middleware-specific exceptions and error conditions into SAGA exceptions whenever possible, in order to avoid middleware specific exception handling on applications level – that would clearly contradict the intent of SAGA to be middleware independent.

In the SAGA language bindings, exceptions are either derived from the base SAGA exception types, or are error codes with that specific name etc. Note that the detailed description for `saga::exception` below does not list the `CONSTRUCTOR` s and `DESTRUCTOR` s for all exception classes individually, but only for the base exception class. The individual exception classes MUST NOT add syntax or semantics to the base exception class.

The string returned by `get_message()` MUST be formatted as follows:

```
"<ExceptionName>: message"
```

where `<ExceptionName>` MUST match the literal exception type enum as defined in this document, and `message` SHOULD be a detailed, human readable description of the cause of the exception. The error message SHOULD include information about the middleware binding, and information about the remote entities and remote operation which caused the exception. It CAN contain newlines. When messages from multiple errors are included in the returned string, then each of these messages MUST follow the format defined above, and the individual messages MUST be delimited by newlines. Also, indentation SHOULD be used to structure the output for long messages.

Hierarchical SAGA Exceptions

SAGA implementations may be late binding, i.e. may allow to interface to multiple backends at the same time, for a single SAGA API call. In such implementations, more than one exception may be raised for a single API call. This specification proposes an algorithm to determine the most 'interesting' exception, which is to be throw by the API call. SAGA implementations MAY implement other algorithms, but MUST document how it determines the exception to be thrown from the list of backend exceptions. Further, the thrown exception MUST allow for inspection of the complete list of backend exceptions, via `get_all_exceptions()`, and `get_all_messages()`. Further, the error message of the thrown (top level) exception MUST include information about the other (lower level) exceptions.

In the exception list returned by `get_all_exceptions()`, the top level (thrown) exception MUST be included again, as first member of the list, to allow for a uniform handling of all exceptions. To avoid infinite recursion, however, that copy MUST NOT have any sub-exceptions, i.e. the list returned by a call to `get_all_exceptions()` MUST be empty. See at the end of this section for an extensive example.

Enum `exception_type`

The exception types available in SAGA are listed below, with a number of explicit examples on when exceptions should be thrown. These examples are not normative, but merely illustrative. As discussed above, multiple exceptions may apply to a single SAGA API call, in the case of late binding implementations. In that case, the implementation must pick one of the exceptions to be thrown as 'top level' exception, with all other exceptions as subordinate 'lower level' exceptions. In general, that top level exception SHOULD be that exception which is most interesting to the user or application. Although we are fully aware of the fact that the notion of 'interesting' is vague, and highly context dependent, we propose the following mechanism to derive the top level exception – implementations MAY use other schemes to determine the top level exception, but MUST document that mechanism:

1. NotImplemented is only allowed as top level exception, if no other exception types are present.
2. Exceptions from a backend which previously performed a successful API call on the same remote entity, or on the same SAGA object instance, are more interesting than exceptions from other backends, and are in particular more interesting than exceptions from backends which did not yet manage to perform any successful operation on that entity or instance.

3. Errors which get raised early when executing the SAGA API call are less interesting than errors which occur late. E.g. BadParameter from the FTP backend is less interesting than PermissionDenied from the WWW backend, as the WWW backend seemed to at least be able to handle the parameters, to access the backend server, and to perform authentication, whereas the FTP backend bailed out early, on the functions parameter check.

In respect to item 3 above, the list of exceptions below is sorted, with the most specific (i.e. interesting) exceptions listed first and least specific last. This list is advisory, i.e. implementation MAY use a different sorting, which also may vary in different contexts.

.

• `IncorrectURL`

This exception is thrown if a method is invoked with a URL argument that could not be handled. This error specifically indicates that an implementation cannot handle the specified protocol, or that access to the specified entity via the given protocol is impossible. The exception MUST NOT be used to indicate any other error condition. See also the notes to 'The URL Problem' in Section 2.11.

Examples:

- An implementation based on gridftp might be unable to handle http-based URLs sensibly, and might be unable to translate them into gridftp based URLs internally. The implementation should then throw an `IncorrectURL` exception if it encounters a http-based URL.
- A URL is well formed, but includes characters or path elements which are not supported by the SAGA implementation or the backend. Then, an `IncorrectURL` exception is thrown, with detailed information on why the URL could not be used.

• `BadParameter`

This exception indicates that at least one of the parameters of the method call is ill-formed, invalid, out of bounds or otherwise not usable. The error message MUST give specific information on what parameter caused the exception, and why.

Examples:

- a specified context type is not supported by the implementation

- a file name specified is invalid, e.g. too long, or contains characters which are not allowed
- an ivec for scattered read/write is invalid, e.g. has offsets which are out of bounds, or refer to non-allocated buffers
- a buffer to be written and the specified lengths are incompatible
- an enum specified is not known
- flags specified are incompatible (`ReadOnly` and `Truncate`)

• `AlreadyExists`

This exception indicates that an operation cannot succeed because an entity to be created or registered already exists or is already registered, and cannot be overwritten. Explicit flags on the method invocation may allow the operation to succeed, e.g. if they indicate that Overwrite is allowed.

Examples:

- a target for a file move already exists
- a file to be created already exists
- a name to be added to a logical file is already known
- a metric to be added to a object has the same name as an existing metric on that object

• `DoesNotExist`

This exception indicates that an operation cannot succeed because a required entity is missing. Explicit flags on the method invocation may allow the operation to succeed, e.g. if they indicate that Create is allowed.

Examples:

- a file to be moved does not exist
- a directory to be listed does not exist
- a name to be deleted is not in a replica set
- a metric asked for is not known to the object
- a context asked for is not known to the session
- a task asked for is not in a task container
- a job asked for is not known by the backend
- an attribute asked for is not supported

- `IncorrectState`

This exception indicates that the object a method was called on is in a state where that method cannot possibly succeed. A change of state might allow the method to succeed with the same set of parameters.

Examples:

- calling read on a stream which is not connected
- calling run on a task which was canceled
- calling resume on a job which is not suspended

- `IncorrectType`

This exception indicates that a specified type does not match any of the available types. This exception is in particular reserved for places in the SAGA API which specify function return types in a template like manner, such as for `task.get_result()`. Language binding MAY replace that exception by language specific means of explicit/implicit type conversion, and SHOULD try to enforce type mismatch errors on compile time instead of linktime or runtime.

Examples:

- calling `get_result <string> ()` on task which actually encapsulates an `int` typed `file.get_size ()` operation.

- `PermissionDenied`

An operation failed because the identity used for the operation did not have sufficient permissions to perform the operation successfully. The authentication and authorization steps have been completed successfully.

Examples:

- attempt to change or set a ReadOnly attribute
- attempt to change or update a ReadOnly metric
- calling write on a file which is opened for read only
- calling read on a file which is opened for write only
- although a user could login to a remote host via GridFTP and could be mapped to a local user, the write on /etc/passwd failed.

- `AuthorizationFailed`

An operation failed because none of the available contexts of the used session could be used for successful authorization. That error indicates that the resource could not be accessed at all, and not that an operation was not available due to restricted permissions. The authentication step has been completed successfully.

The differences between AuthorizationFailed and PermissionDenied are, admittedly, subtle. Our intention for introducing both exceptions was to allow to distinguish between administrative authorization failures (on VO and DN level), and backend related authorization failures (which can often be resolved on user level).

The AuthorizationFailed exception SHOULD be thrown when the backend does not allow the execution of the requested operation at all, whereas the PermissionDenied exception SHOULD be thrown if the operation was executed, but failed due to insufficient privileges.

Examples:

  - although a certificate was valid on a remote GridFTP server, the distinguished name could not be mapped to a valid local user id. A call to file.copy() should then throw an AuthorizationFailed exception.

- `AuthenticationFailed`

An operation failed because none of the available session contexts could successfully be used for authentication, or the implementation could not determine which context to use for the operation.

Examples:

  - a remote host does not accept a X509 certificate because the respective CA is unknown there. A call to file.copy() should then throw an AuthenticationFailed exception.

- `Timeout`

This exception indicates that a remote operation did not complete successfully because the network communication or the remote service timed out. The time waited before an implementation raises a `Timeout` exception depends on implementation and backend details, and SHOULD be documented by the implementation. This exception MUST NOT be thrown if a timed `wait()` or similar method times out. The latter is not an error condition and gets indicated by the method's return value.

Examples:

- a remote file authorization request timed out
- a remote file read operation timed out
- a host name resolution timed out
- a started file transfer stalled and timed out
- an asynchronous file transfer stalled and timed out

- `NoSuccess`

This exception indicates that an operation failed semantically, e.g. the operation was not successfully performed. This exception is the least specific exception defined in SAGA, and CAN be used for all error conditions which do not indicate a more specific exception specified above. The error message SHOULD always contain some further detail, describing the circumstances which caused the error condition.

Examples:

- a once open file is not available right now
- a backend response cannot be parsed
- a remote procedure call failed due to a corrupted parameter stack
- a file copy was interrupted mid-stream, due to shortage of disk space

- `NotImplemented`

If a method is specified in the SAGA API, but cannot be provided by a specific SAGA implementation, this exception MUST be thrown. Object constructors can also throw that exception, if the respective object is not implemented by that SAGA implementation at all. See also the notes about compliant implementations in Section 2.4.

Examples:

- An implementation based on Unicore might not be able to provide streams. The `saga::stream_server` constructor should throw a NotImplemented exception for such an implementation.

Class `exception`

This is the exception base class inherited by all exceptions thrown by a SAGA object implementation. Wherever this specification specifies the occurrence of an instance of this class, the reader MUST assume that this could also be an instance of any subclass of `saga::exception`, as specified by this document.

Note that `saga::exception` does not implement the `saga::object` interface.

```
- CONSTRUCTOR
  Purpose:  create the exception
  Format:   CONSTRUCTOR   (in  object         obj,
                           in  string         message
                           out exception      e);
  Inputs:   obj:           the object associated with the
                           exception.
            message:       the message to be associated
                           with the new exception
  InOuts:   -
  Outputs:  e:             the newly created exception
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   -
  Notes:    -


- CONSTRUCTOR
  Purpose:  create the exception,  without associating
            a saga object instance
  Format:   CONSTRUCTOR   (in  string         message
                           out exception      e);
  Inputs:   message:       the message to be associated
                           with the new exception
  InOuts:   -
  Outputs:  e:             the newly created exception
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   -
  Notes:    -


- DESTRUCTOR
  Purpose:  destroy the exception
  Format:   DESTRUCTOR    (in  exception e);
  Inputs:   e:             the exception to destroy
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   -
```

```
  Notes:    -


- get_message
  Purpose:  gets the message associated with the exception
  Format:   get_message   (out string message);
  Inputs:   -
  InOuts:   -
  Outputs:  message:       the error message
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   -
  Notes:    - the returned string MUST be formatted as
              described earlier in this section.


- get_object
  Purpose:  gets the SAGA object associated with exception
  Format:   get_object     (out object obj);
  Inputs:   -
  InOuts:   -
  Outputs:  obj:            the object associated with the
                            exception
  PreCond:  - an object was associated with the exception
              during construction.
  PostCond: -
  Perms:    -
  Throws:   DoesNotExist
            NoSuccess
  Notes:    - the returned object is a shallow copy of the
              object which was used to call the method which
              caused the exception.
            - if the exception is raised in a task, e.g. on
              task.rethrow(), the object is the one which the
              task was created from.  That allows the
              application to handle the error condition
              without the need to always keep track of
              object/task relationships.
            - an 'DoesNotExist' exception is thrown when no
              object is associated with the exception, e.g.
              if an 'NotImplemented' exception was raised
              during the construction of an object.

- get_type
  Purpose:  gets the type associated with the exception
```

```
    Format:   get_type      (out exception_type type);
    Inputs:   -
    InOuts:   -
    Outputs:  type:          the error type
    PreCond:  -
    PostCond: -
    Perms:    -
    Throws:   -
    Notes:    -

  - get_all_exceptions
    Purpose:  gets list of lower level exceptions
    Format:   get_all_exceptions (out array<exception> el);
    Inputs:   -
    InOuts:   -
    Outputs:  el:            list of exceptions
    PreCond:  -
    PostCond: -
    Perms:    -
    Throws:   -
    Notes:    - a copy of the exception upon which this
                method is called MUST be the first element
                of the list, but that copy MUST NOT return
                any exceptions when get_all_exceptions()
                is called on it.

  - get_all_messages
    Purpose:  gets list of lower level error messages
    Format:   get_all_messages    (out array<string> ml);
    Inputs:   -
    InOuts:   -
    Outputs:  ml:            list of error messages
    PreCond:  -
    PostCond: -
    Perms:    -
    Throws:   -
    Notes:    - a copy of the error message of the exception
                upon which this method is called MUST be the
                first element of the list.
```

Interface error_handler

The error_handler interface allows the application to retrieve exceptions. An alternative approach would be to return an error code for all method invocations. This, however, would put a significant burden on languages with exception handling, and would also complicate the management of return values. Language bindings for languages with exception support will thus generally *not* implement the error_handler interface, but use exceptions instead.

Implementations which are using the interface maintain an internal error state for each class instance providing the interface. That error state is false by default, and is set to true whenever an method invocation meets an error condition which would, according to this specification, result in an exception to be thrown.

The error state of an object instance can be tested with has_error(), and the respective exception can be retrieved with get_error(). The get_error() call clears the error state (i.e. resets it to false). Note that there is no other mechanism to clear an error state – that means in particular that any successful method invocation on the object leaves the error state unchanged. If two or more subsequent operations on an object instance fail, then only the last exception is returned on get_error(). That mechanism allows the execution of a number of calls, and to check if they resulted in any error condition, somewhat similar to try/catch statements in languages with exception support. However, it must be noted that an exception does *not* cause subsequent methods to fail, and does not inhibit their execution.

If get_error() is called on an instance whose error state is false, an IncorrectState exception is returned, which MUST state explicitly that the get_error() method has been invoked on an object instance which did not encounter an error condition.

```
  - has_error
    Purpose:  tests if an object method caused an exception
    Format:   has_error     (out bool       has_error);
    Inputs:   -
    InOuts:   -
    Outputs:  has_error:     indicates that an exception was
                             caught.
    PreCond:  -
    PostCond: - the internal error state is unchanged.
    Perms:    -
    Throws:   -
    Notes:    -
```

```
- get_error
  Purpose:  retrieve an exception catched during a member
            method invocation.
  Format:   get_error     (out exception  e);
  Inputs:   -
  InOuts:   -
  Outputs:  e:             the caught exception
  PreCond:  - the internal error state is true.
  PostCond: - the internal error state is false.
  Perms:    -
  Throws:   IncorrectState
  Notes:    - an 'IncorrectState' exception is thrown
              if the internal error state is false.
```

3.1.3 Examples

Code Example

```
////////////////////////////////////////////////////////////////
//
// C++ examples for exception handling in SAGA
//
////////////////////////////////////////////////////////////////

////////////////////////////////////////////////////////////////
//
// simple exception handling
//
int main ()
{
  try
  {
    saga::file f ("file://remote.host.net/etc/passwd");
    f.copy ("file:///usr/tmp/passwd.bak");
  }

  catch ( const saga::exception::PermissionDenied & e )
  {
    std::cerr << "SAGA error: No Permissions!" << std::endl;
    return (-1);
  }

  catch ( const saga::exception & e )
  {
    std::cerr << "SAGA error: "
              << e.get_message ()
              << std::endl;
    return (-1);
  }

  return 0;
}


////////////////////////////////////////////////////////////////
//
// recursive exception handling
//
int main ()
{
  try
  {
    saga::file f ("any://remote.host.net/etc/passwd");
    f.copy ("any:///usr/tmp/passwd.bak");
```

```
    }

    // handle a specific error condition
    catch ( const saga::permission_denied & e )
    {
      ...
    }

    // handle all error conditions
    catch ( const saga::exception & e )
    {
       std::cerr << e.what () << std::endl;
       // prints complete set of error messages:
       // DoesNotExist: ftp adaptor: /etc/passwd does not exist
       //   DoesNotExist: ftp adaptor: /etc/passwd: does not exist
       //   DoesNotExist: www adaptor: /etc/passwd: access denied

       // handle backend exceptions individually
       std::list <saga::exception> el = e.get_all_exceptions ();

       for ( int i = 0; i < el.size (); i++ )
       {
         saga::exception esub = el[i];
         std::list <saga::exception> esubl = esub.get_all_exceptions ();
         // subl MUST be empty for i==0
         // subl MAY  be empty for i!=0

         switch ( sub.get_type () )
         {
           // handle individual exceptions
           case saga::exception::DoesNotExist:
             ...
           case saga::exception::PermissionDenied:
             ...
         }
       }


       // handle backend exception messages individually
       std::list <saga::exception> ml = e.get_all_messages ();

       for ( int i = 0; i < ml.size (); i++ )
       {
         std::cerr << ml[i] << std::endl;
       }
       // the loop above will result in
       // DoesNotExist: ftp adaptor: /etc/passwd: does not exist
       // DoesNotExist: www adaptor: /etc/passwd: access denied
    }

```

```
  return 0;
}


////////////////////////////////////////////////////////////////
//
// exception handling for tasks
//
int main ()
{
  saga::file f ("file://remote.host.net/etc/passwd");

  saga::task t = f.copy <saga::task::Async>
                        ("file:///usr/tmp/passwd.bak");

  t.wait ();

  if ( t.get_state () == saga::task::Failed )
  {
    try {
      task.rethrow ();
    }
    catch ( const saga::exception & e )
    {
      std::cout << "task failed: "
                << e.what ()
                << std::endl;
    }
    return (-1);
  }
  return (0);
}
```

3.2 SAGA Base Object

The SAGA object interface provides methods which are essential for all SAGA objects. It provides a unique ID which helps maintain a list of SAGA objects at the application level as well as allowing for inspection of objects type and its associated session.

The object id MUST be formatted as UUID, as standardized by the Open Software Foundation (OSF) as part of the Distributed Computing Environment (DCE). The UUID format is also described in the IETF RFC-4122 [16].

Note that there are no object IDs for the various SAGA exceptions, but only one ID for the `saga::exception` base class. Also, it is not possible to inspect a SAGA object instance for the availability of certain SAGA interfaces, as they are fixed and well defined by the SAGA specification. Language bindings MAY, however, add such inspection, if that is natively supported by the language.

3.2.1 Specification

```
package saga.object
{
  enum object_type
  {
    URL               =   1,
    Buffer            =   2,
    Session           =   3,
    Context           =   4,
    Task              =   5,
    TaskContainer     =   6,
    Metric            =   7,
    NSEntry           =   8,
    NSDirectory       =   9,
    IOVec             =  10,
    File              =  11,
    Directory         =  12,
    LogicalFile       =  13,
    LogicalDirectory  =  14,
    JobDescription    =  15,
    JobService        =  16,
    Job               =  17,
    JobSelf           =  18,
    StreamService     =  19,
    Stream            =  20,
```

```
      Parameter        =  21,
      RPC              =  22,
    }


    interface object : implements saga::error-handler
    {
      get_id       (out string      id     );
      get_type     (out object_type type   );
      get_session  (out session     s      );

      // deep copy
      clone        (out object      clone  );
    }
  }
```

3.2.2 Specification Details

Enum `object_type`

The SAGA `object_type` enum allows for inspection of SAGA object instances. This, in turn, allows to treat large numbers of SAGA object instances in containers, without the need to create separate container types for each specific SAGA object type. Bindings to languages that natively support inspection on object types MAY omit this enum and the `get_type()` method.

SAGA extensions which introduce new SAGA objects (i.e. introduce new classes which implement the `saga::object` interface) MUST define the appropriate `object_type` enums for inspection. SAGA implementations SHOULD support these enums for all packages which are provided in that implementation, even for classes which are not implemented.

Interface `object`

```
    - get_id
      Purpose:  query the object ID
      Format:   get_id               (out string id);
      Inputs:   -
      InOuts:   -
      Outputs:  id:                   uuid for the object
```

```
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   -
  Notes:    -


- get_type
  Purpose:  query the object type
  Format:   get_type             (out object_type type);
  Inputs:   -
  InOuts:   -
  Outputs:  type:                 type of the object
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   -
  Notes:    -


- get_session
  Purpose:  query the objects session
  Format:   get_session          (out session s);
  Inputs:   -
  InOuts:   -
  Outputs:  s:                    session of the object
  PreCond:  - the object was created in a session, either
              explicitly or implicitly.
  PostCond: - the returned session is shallow copied.
  Perms:    -
  Throws:   DoesNotExist
  Notes:    - if no specific session was attached to the
              object at creation time, the default SAGA
              session is returned.
            - some objects do not have sessions attached,
              such as job_description, task, metric, and the
              session object itself.  For such objects, the
              method raises a 'DoesNotExist' exception.


// deep copy:
-------------

- clone
  Purpose:  deep copy the object
  Format:   clone                (out object clone);
```

```
Inputs:   -
InOuts:   -
Outputs:  clone:               the deep copied object
PreCond:  -
PostCond: - apart from session and callbacks, no other
            state is shared between the original object
            and it's copy.
Perms:    -
Throws:   NoSuccess
Notes:    - that method is overloaded by all classes
            which implement saga::object, and returns
            a deep copy of the respective class type
            (the method is only listed here).
          - the method SHOULD NOT cause any backend
            activity, but is supposed to clone the client
            side state only.
          - the object id is not copied -- a new id MUST
            be assigned instead.
          - for deep copy semantics, see Section 2.
```

3.2.3 Examples

Code Example

```
// c++ example

// have 2 objects, streams and files, and do:
//  - read 100 bytes
//  - skip 100 bytes
//  - read 100 bytes

int  out;
char data1[100];
char data2[100];
char data[100];

saga::buffer buf1 (data1, 100);
saga::buffer buf2 (data2, 100);
saga::buffer buf;

// create objects
saga::file   f (url[1]);
saga::stream s (url[2]);

// f is opened at creation, s needs to be connected
s.connect ();
```

```
  // create tasks for reading first 100 bytes ...
  saga::task t1 = f.read <saga::task> (100, buf1);
  saga::task t2 = s.read <saga::task> (100, buf2);

  // create and fill the task container ...
  saga::task_container tc;

  tc.add (t1);
  tc.add (t2);

  // ... and wait who gets done first
  while ( saga::task t = tc.wait (saga::task::Any) )
  {
     // depending on type, skip 100 bytes then create a
     // new task for the next read, and re-add to the tc

     switch ( t.get_object().get_type () )
     {
       case saga::object::File :
         // point buf to results
         buf = buf1;

         // get back file object
         saga::file f = saga::file (t.get_object ());

         // skip for file type (sync seek)
         saga::file (f.seek (100, SEEK_SET);

         // create a new read task
         saga::task t2 = f.read <saga::task> (100, buf1));

         // add the task to the container again
         tc.add (t2);

         break;

       case saga::object::Stream :
         // point buf to results
         buf = buf2;

         // get back stream object
         saga::stream s = saga::stream (t.get_object ());

         // skip for stream type (sync read and ignore)
         saga::stream (s.read (100, buf2);

         // create a new read task
         saga::task t2 = s.read <saga::task> (100, buf2));

```

```
        // add the task to the container again
        tc.add (t2);

        break;

      default:
        throw exception ("Something is terribly wrong!");
    }

    std::cout << "found: '" << out << " bytes: "
                            << buf.get_data ()
                            << std::endl;

    // tc is filled again, we run forever, read/seeking from
    // whatever we find after the wait.
  }
```

3.3 SAGA URL Class

In many places in the SAGA API, URLs are used to reference remote entities. In order to

- simplify the construction and the parsing of URLs on application level,
- allow for sanity checks within and outside the SAGA implementation,
- simplify and unify the signatures of SAGA calls which accept URLs,

a SAGA URL class is used. This class provides means to set and access the various elements of a URL. The class parses the URL in conformance to RFC-3986 [5].

In respect to the URL problem (stated in Section 2.11), the class provides the method `translate (in string scheme)`, which allows to translate a URL from one scheme to another – with all the limitations mentioned in Section 2.11.

Note that resolving relative URLs (or, more specific, relative path components in URLs) is often non-trivial. In particular, such resolution may need to be deferred until the URL is used, as the resolution will usually depend on the context of usage. If not otherwise specified in this document, a URL used in some object method will be considered relative to the object's CWD, if that is available, or otherwise to the application's working directory.

URLs require some characters to be escaped, in order to allow for the URLS to be well formatted. The setter methods described below MUST perform character escaping transparently. That may not always be possible for the `CONSTRUCTOR` and `set_string()`, which will then raise a `BadParameter` exception. The getter methods MUST return unescaped versions of the URL components. However, the string returned by the method `get_escaped()` MUST NOT contain unescaped characters.

This specification is silent about URL encoding issues – those are left to the implementation. For additional notes on URL usage and implementation, see Section 4.2.

```
package saga.url
{
  class url : implements   saga::object
          // from object  saga::error_handler
  {
    CONSTRUCTOR   (in  string     url       ,
                   out buffer     obj       );
    DESTRUCTOR    (in  buffer     obj       );

    set_string    (in  string     url       = "");
    get_string    (out string     url       );
    get_escaped   (out string     url       );

    set_scheme    (in  string     scheme    = "");
    get_scheme    (out string     scheme    );

    set_host      (in  string     host      = "");
    get_host      (out string     host      );

    set_port      (in  int        port      = "");
    get_port      (out int        port      );

    set_fragment  (in  string     fragment  = "");
    get_fragment  (out string     fragment  );

    set_path      (in  string     path      = "");
    get_path      (out string     path      );

    set_query     (in  string     query     = "");
    get_query     (out string     query     );

    set_userinfo  (in  string     userinfo  = "");
    get_userinfo  (out string     userinfo  );

    translate     (in  session    s         ,
                   in  string     scheme    ,
                   out url        url       );
    translate     (in  string     scheme    ,
                   out url        url       );
  }
}
```

3.3.1 Specification Details

Class `url`

```
- CONSTRUCTOR
  Purpose:  create a url instance
  Format:   CONSTRUCTOR          (in  string url = "",
                                  out url    obj);
  Inputs:   url:                  initial URL to be used
  InOuts:   -
  Outputs:  url:                  the newly created url
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   BadParameter
            NoSuccess
  Notes:    - if the implementation cannot parse the given
              url, a 'BadParameter' exception is thrown.
            - if the implementation cannot perform proper
              escaping on the url, a 'BadParameter'
              exception is thrown.
            - this constructor will never throw an
              'IncorrectURL' exception, as the
              interpretation of the URL is not part of the
              functionality of this class.
            - the implementation MAY change the given
              URL as long as that does not change the
              resource the URL is pointing to.  For
              example, an implementation may normalize the
              path element of the URL.


- DESTRUCTOR
  Purpose:  destroy a url
  Format:   DESTRUCTOR           (in  url obj);
  Inputs:   obj:                  the url to destroy
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   -
  Notes:    -
```

```
- set_string
  Purpose:  set a new url
  Format:   set_string           (in  string url = "");
  Inputs:   url:                  new url
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   BadParameter
  Notes:    - the method is semantically equivalent to
              destroying the url, and re-creating it with
              the given parameter.
            - the notes for the DESTRUCTOR and the
              CONSTRUCTOR apply.


- get_string
  Purpose:  retrieve the url as string
  Format:   get_string           (out string url);
  Inputs:   -
  InOuts:   -
  Outputs:  url:                  string representing the url
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   -
  Notes:    - the URL may be empty, e.g. after creating the
              instance with an empty url parameter.
            - the returned string is unescaped.


- get_escaped
  Purpose:  retrieve the url as string with escaped
            characters
  Format:   get_escaped          (out string url);
  Inputs:   -
  InOuts:   -
  Outputs:  url:                  string representing the url
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   -
  Notes:    - the URL may be empty, e.g. after creating the
```

```
                instance with an empty url parameter.
              - as get_string(), but all characters are
                escaped where required.


  - set_*
    Purpose:  set an url element
    Format:   set_<element>       (in  string <element> = "");
              set_scheme          (in  string scheme    = "");
              set_host            (in  string host      = "");
              set_port            (in  int    port      = "");
              set_fragment        (in  string fragment  = "");
              set_path            (in  string path      = "");
              set_query           (in  string query     = "");
              set_userinfo        (in  string userinfo  = "");
    Inputs:   <element>:           new url <element>
    InOuts:   -
    Outputs:  -
    PreCond:  -
    PostCond: - the <element> part of the URL is updated.
    Perms:    -
    Throws:   BadParameter
    Notes:    - these calls allow to update the various
                elements of the url.
              - the given <element> is parsed, and if it is
                either not well formed (see RFC-3986), or the
                implementation cannot handle it, a
                'BadParameter' exception is thrown.
              - if the given <element> is empty, it is removed
                from the URL.  If that results in an invalid
                URL, a 'BadParameter' exception is thrown.
              - the implementation MAY change the given
                elements as long as that does not change the
                resource the URL is pointing to.  For
                example, an implementation may normalize the
                path element.
              - the implementation MUST perform character
                escaping for the given string.


  - get_*
    Purpose:  get an url element
    Format:   get_<element>       (out string <element>);
              get_scheme          (out string scheme   );
              get_host            (out string host     );
              get_port            (out int    port     );
```

```
          get_fragment       (out string fragment );
          get_path           (out string path     );
          get_query          (out string query    );
          get_userinfo       (out string userinfo );
Inputs:   -
InOuts:   -
Outputs:  <element>:          the url <element>
PreCond:  -
PostCond: -
Perms:    -
Throws:   -
Notes:    - these calls allow to retrieve the various
            elements of the url.
          - the returned <element> is either empty, or
            guaranteed to be well formed (see RFC-3986).
          - the returned string is unescaped.
          - if the requested value is not known, or
            unspecified, and empty string is returned,
            or '-1' for get_port().


- translate
  Purpose:  translate an URL to a new scheme
  Format:   translate           (in  session s,
                                 in  string  scheme,
                                 out url     url);
  Inputs:   s:                   session for authorization/
                                 authentication
            scheme:              the new scheme to
                                 translate into
  InOuts:   -
  Outputs:  url:                 string representation of
                                 the translated url
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   BadParameter
            NoSuccess
  Notes:    - the notes from section 'The URL Problem' apply.
            - if the scheme is not supported,  a
              'BadParameter' exception is thrown.
            - if the scheme is supported, but the url
              cannot be translated to the scheme, a
              'NoSuccess' exception is thrown.
            - if the url can be translated, but cannot be
              handled with the new scheme anymore, no
```

```
                  exception is thrown.  That can only be
                  detected if the returned string is again used
                  in a URL constructor, or with set_string().
                - the call does not change the URL represented
                  by the class instance itself, but the
                  translation is only reflected by the returned
                  url string.
                - the given session is used for backend
                  communication.

    - translate
      Purpose:  translate an URL to a new scheme
      Format:   translate            (in  string scheme,
                                      out url    url);
      Inputs:   scheme:               the new scheme to
                                      translate into
      InOuts:   -
      Outputs:  url:                  string representation of
                                      the translated url
      PreCond:  -
      PostCond: -
      Perms:    -
      Throws:   BadParameter
                NoSuccess
      Notes:    - all notes from the overloaded translate()
                  method apply.
                - the default session is used for backend
                  communication.
```

3.3.2 Examples

Code Example

```
// C++ URL examples

int main (int argc, char ** argv)
{
  if ( argc < 1 )
    return -1;

  std::string url_string = argv[1];

  try
  {
    saga::url url (url_string);

```

```
    cout << "url      : " << url.get_string    () << endl;
    cout << "===================================" << endl;
    cout << "scheme   : " << url.get_scheme    () << endl;
    cout << "host     : " << url.get_host      () << endl;
    cout << "port     : " << url.get_port      () << endl;
    cout << "fragment : " << url.get_fragment  () << endl;
    cout << "path     : " << url.get_path      () << endl;
    cout << "query    : " << url.get_query     () << endl;
    cout << "userinfo : " << url.get_userinfo  () << endl;
    cout << "===================================" << endl;

    url.set_scheme    ("ftp");
    url.set_host      ("ftp.remote.net");
    url.set_port      (1234);
    url.set_fragment  ("");
    url.set_path      ("/tmp/data");
    url.set_query     ("");
    url.set_userinfo  ("ftp:anon");

    cout << "===================================" << endl;
    cout << "scheme   : " << url.get_scheme    () << endl;
    cout << "host     : " << url.get_host      () << endl;
    cout << "port     : " << url.get_port      () << endl;
    cout << "fragment : " << url.get_fragment  () << endl;
    cout << "path     : " << url.get_path      () << endl;
    cout << "query    : " << url.get_query     () << endl;
    cout << "userinfo : " << url.get_userinfo  () << endl;
    cout << "===================================" << endl;
    cout << "url      : " << url.get_string    () << endl;
  }
}
```

3.4 SAGA I/O Buffer

The SAGA API includes a number of calls which perform byte-level I/O operations, e.g. `read()`/`write()` on files and streams, and `call()` on rpc instances. Future SAGA API extensions are expected to increase the number of I/O methods. The `saga::buffer` class encapsulates a sequence of bytes to be used for such I/O operations – that allows for uniform I/O syntax and semantics over the various SAGA API packages.

The class is designed to be a simple container containing one single element (the opaque data). The data can either be allocated and maintained in application memory, or can be allocated and maintained by the SAGA implementation. The latter is the default, and applies when no data and no size are specified on buffer construction.

For example, an application that has data memory already allocated and filled, can create and use a buffer by calling

```
// create buffer with application memory
char data[1000];
saga::buffer b (data, 1000);
```

The same also works when used with the respective I/O operations:

```
// write to a file using a buffer with application  memory
char data[1000] = ...;
file.write (saga::buffer (data, 1000));
```

Another application, which wants to leave the buffer memory management to the SAGA implementation, can use a second constructor, which causes the implementation to allocate memory on the fly:

```
// create empty, implementation managed buffer
saga::buffer b;  // no data nor size given!

// read 100 byte from file into buffer
file.read (b, 100);

// get memory from SAGA
const char * data = b.get_data ();

// or use data directly
std::cout << "found: " << b.get_data () << std::endl;
```

Finally, an application can leave memory management to the implementation, as above, but can specify how much memory should be allocated by the SAGA implementation:

```
// create an implementation managed buffer of 100  byte
saga::buffer b (100);

// get memory from SAGA
const char * data = b.get_data ();

// fill the buffer
memcpy (data, source, b.get_size ());

// use data for write
file.write (b);
```

Application-managed memory MUST NOT be re- or de-allocated by the SAGA implementation, and implementation-managed memory MUST NOT be re- or de-allocated by the application. However, an application CAN change the *content* of implementation managed memory, and vice versa.

Also, a buffer's contents MUST NOT be changed by the application while it is in use, i.e. while any I/O operation on that buffer is ongoing. For asynchronous operations, an I/O operation is considered ongoing if the associated `saga::task` instance is not in a final state.

If a buffer is too small (i.e. more data are available for a read, or more data are required for a write), only the available data are used, and an error is returned appropriately. If a buffer is too large (i.e. read is not able to fill the buffer completely, or write does not need the complete buffer), the remainder of the buffer data MUST be silently ignored (i.e. not changed, and not set to zero). The error reporting mechanisms as listed for the specific I/O methods apply.

Implementation-managed memory is released when the buffer is destroyed, (either explicitly by calling `close()`, or implicitly by going out of scope). It MAY be re-allocated, and reset to zero, if the application calls `set_size()`.

Application-managed memory is released by the application. In order to simplify memory management, language bindings (in particular for non-garbage-collecting languages) MAY allow to register a callback on buffer creation which is called on buffer destruction, and which can be used to de-allocate the buffer memory in a timely manner. The `saga::callback` class SHOULD be used for that callback – those language bindings SHOULD thus define the buffer to be `monitorable`, i.e. it should implement the `saga::monitorable` interface. After the callback's invocation, the buffer MUST NOT be used by the implementation anymore.

When calling `set_data()` for application-managed buffers, the implementation MAY copy the data internally, or MAY use the given data pointer as is. The application SHOULD thus not change the data while an I/O operation is in progress, and only consider the data pointer to be unused after another `set_data()` has been called, or the buffer instance was destroyed.

Note that these conventions on memory management allow for zero- copy SAGA implementations, and also allow to reuse buffer instances for multiple I/O operations, which makes, for example, the implementation of pipes and filters very simple.

The buffer class is designed to be inherited by application-level I/O buffers, which may, for example, add custom data getter and setter methods (e.g. `set_jpeg()` and `get_jpeg()`. Such derived buffer classes can thus add both data formats and data models transparently on top of SAGA I/O. For developers who program applications for a specific community it seems advisable to standardize both data format and data model, and possibly to standardize derived SAGA buffers – that work is, at the moment, out of scope for SAGA. The SAGA API MAY, however, specify such derived buffer classes in later versions, or in future extensions of the API.

A buffer does not belong to a session, and a buffer object instance can thus be used in multiple sessions, for I/O operations on different SAGA objects.

Note that even if a buffer size is given, the `len_in` parameter to the SAGA I/O operations supersedes the buffer size. If the buffer is too small, a `'BadParameter'` exception will be thrown on these operations. If `len_in` is omitted and the buffer size is not known, a `'BadParameter'` exception is also thrown.

Note also that the `len_out` parameter of the SAGA I/O operations has not necessarily the same value as the buffer size, obtained with `buffer.get_size()`. A read may read only a part of the requested data, and a write may have written only a part of the buffer. That is not an error, as is described in the notes for the respective I/O operations.

SAGA language bindings may want to define a `const`-version of the buffer, in order to allow for safe implementations. A non-const buffer SHOULD then inherit the `const` buffer class, and add the appropriate constructor and setter methods. The same holds for SAGA classes which inherit from the `buffer`.

Also, language bindings MAY allow buffer constructors with optional `size` parameter, if the size of the given data is implicitly known. For example, the C++ bindings MAY allow an buffer constructor `buffer (std::string s)`. The same holds for SAGA classes that inherit from the `buffer`.

3.4.1 Specification

```
package saga.buffer
{
  class buffer : implements   saga::object
            // from object  saga::error_handler
  {
    CONSTRUCTOR (in  array<byte>  data,
                 in  int          size,
                 out buffer       obj);
    CONSTRUCTOR (in  int          size = -1,
                 out buffer       obj);
    DESTRUCTOR  (in  buffer       obj);

    set_size    (in  int          size = -1);
    get_size    (out int          size);

    set_data    (in  array<byte>  data,
                 in  int          size);
    get_data    (out array<byte>  data);

    close       (in  float        timeout = -0.0);
  }
}
```

3.4.2 Specification Details

Class `buffer`

```
  - CONSTRUCTOR
    Purpose:  create an I/O buffer
    Format:   CONSTRUCTOR          (in  array<byte> data,
                                    in  int         size,
                                    out buffer      obj);
    Inputs:   data:                 data to be used
              size:                 size of data to be used
    InOuts:   -
    Outputs:  buffer:               the newly created buffer
    PreCond:  - size >= 0
    PostCond: - the buffer memory is managed by the
```

```
                application.
    Perms:    -
    Throws:   BadParameter
              NoSuccess
    Notes:    - see notes about memory management.
              - if the implementation cannot handle the
                given data pointer or the given size, a
                'BadParameter' exception is thrown.
              - later method descriptions refer to this
                CONSTRUCTOR as 'first CONSTRUCTOR'.


  - CONSTRUCTOR
    Purpose:  create an I/O buffer
    Format:   CONSTRUCTOR          (in  int         size = -1,
                                    out buffer      obj);
    Inputs:   size:                 size of data buffer
    InOuts:   -
    Outputs:  buffer:               the newly created buffer
    PreCond:  -
    PostCond: - the buffer memory is managed by the
                implementation.
              - if size > 0, the buffer memory is allocated by
                the implementation.
    Perms:    -
    Throws:   BadParameter
              NoSuccess
    Notes:    - see notes about memory management.
              - if the implementation cannot handle the
                given size, a 'BadParameter' exception is
                thrown.
              - later method descriptions refer to this
                CONSTRUCTOR as 'second CONSTRUCTOR'.


  - DESTRUCTOR
    Purpose:  destroy a buffer
    Format:   DESTRUCTOR           (in  buffer obj);
    Inputs:   obj:                  the buffer to destroy
    InOuts:   -
    Outputs:  -
    PreCond:  -
    PostCond: -
    Perms:    -
    Throws:   -
    Notes:    - if the instance was not closed before, the
```

```
              DESTRUCTOR performs a close() on the instance,
              and all notes to close() apply.


  - set_data
    Purpose:  set new buffer data
    Format:   set_data            (in  array<byte> data,
                                   in  int         size);
    Inputs:   data:                data to be used in buffer
              size:                size of given data
    InOuts:   -
    Outputs:  -
    PreCond:  -
    PostCond: - the buffer memory is managed by the
                application.
    Perms:    -
    Throws:   BadParameter
              IncorrectState
    Notes:    - the method is semantically equivalent to
                destroying the buffer, and re-creating it with
                the first CONSTRUCTOR with the given size.
              - the notes for the DESTRUCTOR and the first
                CONSTRUCTOR apply.


  - get_data
    Purpose:  retrieve the buffer data
    Format:   get_data            (out array<byte> data);
    Inputs:   -
    InOuts:   -
    Outputs:  data:                buffer data to retrieve
    PreCond:  -
    PostCond: -
    Perms:    -
    Throws:   DoesNotExist
              IncorrectState
    Notes:    - see notes about memory management
              - if the buffer was created as implementation
                managed (size = -1), but no I/O operation has
                yet been successfully performed on the buffer,
                a 'DoesNotExist' exception is thrown.


  - set_size
    Purpose:  set size of buffer
    Format:   set_size          (in  int   size = -1);
```

```
  Inputs:   size:               value for size
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: - the buffer memory is managed by the
              implementation.
  Perms:    -
  Throws:   BadParameter
            IncorrectState
  Notes:    - the method is semantically equivalent to
              destroying the buffer, and re-creating it with
              the second CONSTRUCTOR using the given size.
            - the notes for the DESTRUCTOR and the second
              CONSTRUCTOR apply.


- get_size
  Purpose:  retrieve the current value for size
  Format:   get_size           (out int   size);
  Inputs:   -
  InOuts:   -
  Outputs:  size               value of size
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   IncorrectState
  Notes:    - if the buffer was created with negative size
              with the second CONSTRUCTOR, or the size was
              set to a negative value with set_size(), this
              method returns '-1' if the buffer was not yet
              used for an I/O operation.
            - if the buffer was used for a successful I/O
              operation where data have been read into the
              buffer, the call returns the size of the
              memory which has been allocated by the
              implementation during that read operation.


- close
  Purpose:  closes the object
  Format:   close              (in  float timeout = 0.0);
  Inputs:   timeout             seconds to wait
  InOuts:   -
  Outputs:  -
  Perms:    -
  PreCond:  -
```

```
    PostCond: - any operation on the object other than
                close() or the DESTRUCTOR will cause
                an 'IncorrectState' exception.
    Throws:   -
    Notes:    - any subsequent method call on the object
                MUST raise an 'IncorrectState' exception
                (apart from DESTRUCTOR and close()).
              - if the current data memory is managed by the
                implementation, it is freed.
              - close() can be called multiple times, with no
                side effects.
              - if the current data memory is managed by the
                application, it is not accessed anymore by the
                implementation after this method returns.
              - if close() is implicitly called in the
                DESTRUCTOR, it will never throw an exception.
              - for resource deallocation semantics, see
                Section 2.
              - for timeout semantics, see Section 2.
```

3.4.3 Examples

Code Example

```
///////////////////////////////////////////////////////////////////
// C++ I/O buffer examples
///////////////////////////////////////////////////////////////////

///////////////////////////////////////////////////////////////////
//
// general examples
//
// all following examples ignore the ssize_t return value, which
// should be the number of bytes successfully read
//
///////////////////////////////////////////////////////////////////
{
  char data[x][y][z];
  char* target = data + 200;
  buffer b;

  // the following four block do exactly the same, reading
  // 100 byte (the read parameter supersedes the buffer size)

  // apps managed memory
  {
```

```
    b.set_data (target);
    stream.read (b, 100);
    printf ("%100s", target);
  }

  {
    b.set_data (target, 100);
    stream.read (b);
    printf ("%100s", target);
  }

  {
    b.set_data (target, 100);
    stream.read (b, 100);
    printf ("%100s", target);
  }

  {
    b.set_data (target, 200);
    stream.read (b, 100);
    printf ("%100s", target);
  }


  // now for impl managed memory
  {
    b.set_size (100);
    stream.read (b);
    printf ("%100s", b.get_data ());
  }

  {
    b.set_size (-1);
    stream.read (b, 100);
    printf ("%100s", b.get_data ());
  }

  {
    b.set_size (200);
    stream.read (b, 100);
    printf ("%100s", b.get_data ());
  }


  // these two MUST throw, even if there is
  // enough memory available

  // app managed memory
  {
    b.set_data (target, 100);
```

```
    stream.read (b, 200);
  }

  // impl. managed memory
  {
    b.set_size (100);
    stream.read (b, 200);
  }
}


//////////////////////////////////////////////////////////////////
//
// the next 4 examples perform two reads from a stream,
// first 100 bytes, then 200 bytes.
//
//////////////////////////////////////////////////////////////////

// impl managed memory
{
  {
    buffer b;

    stream.read (b, 100);
    printf ("%100s", b.get_data ());

    stream.read (b, 200);
    printf ("%200s", b.get_data ());

  } // b dies here, data are gone after that
}


// same as above, but with explicit c'tor
{
  {
    buffer b (100);
    stream.read (b);
    printf ("%100s", b.get_data ());

    b.set_size (200);
    stream.read (b);
    printf ("%200s", b.get_data ());

  } // b dies here, data are gone after that
}


// apps managed memory
{
```

```
  char   data[x][y][z]; // the complete data set
  char * target = data; // target memory address to read into...
  target += offset;     // ... is somewhere in the data space.

  stream.read (buffer (target,       100));
  stream.read (buffer (target + 100, 200));

  printf ("%300s", target);

  // data must be larger than offset + 300, otherwise bang!
}


// same as above with explicit buffer c'tor
{
  char   data[x][y][z]; // the complete data set
  char * target = data; // target memory address to read into...
  target += 200;          // ... is somewhere in the data space.

  {
    buffer b (target, 100);
    stream.read (b);

    b.set_data (target + 100, 200);
    stream.read (b);

  } // b dies here.  data are intact after that

  printf ("%300s", target);

  // data must be larger than offset + 300, otherwise bang!
}


/////////////////////////////////////////////////////////////////
//
// the next two examples perform the same reads,
// but switch memory management in between
//
/////////////////////////////////////////////////////////////////

// impl managed memory, then apps managed memory
{
  {
    char [x][y][z] data;
    char* target = data + 200;

    buffer b;

    // impl managed
```

```
    stream.read (b, 100);
    printf ("%100s", target);

    b.set_data (target, 200); // impl data are gone after this

    // apps managed
    stream.read (b);
    printf ("%200s", target);

  } // b dies here, apps data are ok after that, impl data are gone
}


// apps managed memory, then impl managed
{
  {
    char [x][y][z] data;
    char* target = data + 200;

    buffer b (target);

    // apps managed
    stream.read (b, 100);
    printf ("%100s", target);

    b.set_size (-1);

    // impl managed
    stream.read (b, 200);
    printf ("%200s", target);

  } // b dies here, apps data are ok after that, impl data are gone
}


///////////////////////////////////////////////////////////////
//
// now similar for write
//
///////////////////////////////////////////////////////////////

///////////////////////////////////////////////////////////////
//
// general part
//
// all examples ignore the ssize_t return value, which should be
// the number of bytes successfully written
//
///////////////////////////////////////////////////////////////
{
```

```
char data[x][y][z];
char* target = data + 200;
buffer b;

// the following four block do exactly the same, writing
// 100 byte (the write parameter supersedes the buffer size)

// apps managed memory
{
  b.set_data (target);
  stream.write (b, 100);
}

{
  b.set_data (target, 100);
  stream.write (b);
}

{
  b.set_data (target, 100);
  stream.write (b, 100);
}

{
  b.set_data (target, 200);
  stream.write (b, 100);
}


// now for impl managed memory
{
  b.set_size (100);
  memcpy (b.get_data (), target, 100);
  stream.write (b);
}

{
  b.set_size (200);
  memcpy (b.get_data (), target, 200);
  stream.write (b, 100);
}


// these two MUST throw, even if there is
// enough memory available

// app managed memory
{
  b.set_data (target, 100);
  stream.write (b, 200); // throws BadParameter
```

```
    }

    // impl. managed memory
    {
      b.set_size (100);
      memcpy (b.get_data (), target, 200); // apps error
      stream.write (b, 200); // throws BadParameter
    }
  }


  ////////////////////////////////////////////////////////////////
  //
  // the next 4 examples perform two writes to a stream,
  // first 100 bytes, then 200 bytes.
  //
  ////////////////////////////////////////////////////////////////

  // impl managed memory
  {
    char   data[x][y][z]; // the complete data set
    char * target = data; // target memory address to write into...
    target += offset;     // ... is actually somewhere in the data space.

    {
      buffer b (200);

      memcpy (b.get_data (), target, 100);
      stream.write (b, 100);

      memcpy (b.get_data (), target + 100, 200);
      stream.write (b, 200);

    } // b dies here, data are gone after that
  }


  // same as above, but using set_size ()
  {
    char   data[x][y][z]; // the complete data set
    char * target = data; // target memory address to write into...
    target += offset;     // ... is actually somewhere in the data space.

    {
      buffer b (100);
      memcpy (b.get_data (), target, 100);
      stream.write (b);

      b.set_size (200);
      memcpy (b.get_data (), target + 100, 200);
```

```
    stream.write (b);

  } // b dies here, data are gone after that
}


// apps managed memory
{
  char   data[x][y][z]; // the complete data set
  char * target = data; // target memory address to write into...
  target += offset;     // ... is actually somewhere in the data space.

  stream.write (buffer (target,       100));
  stream.write (buffer (target + 100, 200));

  // data must be larger than offset + 300, otherwise bang!
}


// same as above with explicit buffer c'tor
{
  char   data[x][y][z]; // the complete data set
  char * target = data; // target memory address to write into...
  target += 200;          // ... is actually somewhere in the data space.

  {
    buffer b (target, 100);
    stream.write (b);

    b.set_data (target + 100, 200);
    stream.write (b);

  } // b dies here.  data are intact after that


  // data must be larger than offset + 300, otherwise bang!
}


/////////////////////////////////////////////////////////////////
//
// the next two examples perform the same reads,
// but switch memory management in between
//
/////////////////////////////////////////////////////////////////

// impl managed memory, then apps managed memory
{
  {
    char [x][y][z] data;
```

```
    char* target = data + 200;

    buffer b (100);

    // impl managed
    memcpy (b.get_data (), target, 100);
    stream.write (b, 100);

    b.set_data (target + 100, 200); // apps managed now
                                    // impl data are gone after this

    // apps managed
    stream.write (b);

  } // b dies here, apps data are ok after that, impl data are gone
}


// apps managed memory, then impl managed
{
  {
    char [x][y][z] data;
    char* target = data + 200;

    buffer b (target);

    // apps managed
    stream.write (b, 100);

    b.set_size (200); // impl managed now
    memcpy (b.get_data (), target + 100, 200);

    // impl managed
    stream.write (b);

  } // b dies here, apps data are ok after that, impl data are gone
}
```

3.5 SAGA Session Management

The session object provides the functionality of a session, which isolates independent sets of SAGA objects from each other. Sessions also support the management of security information (see `saga::context` in Section 3.6).

3.5.1 Specification

```
package saga.session
{
  class session : implements   saga::object
              // from object  saga::error_handler
  {
    CONSTRUCTOR        (in  bool             default = true,
                        out session          obj);
    DESTRUCTOR         (in  session          obj);

    add_context        (in  context          context);
    remove_context     (in  context          context);
    list_contexts      (out array<context,1> contexts);
  }
}
```

3.5.2 Specification Details

Class `session`

Almost all SAGA objects are created in a SAGA session, and are associated with this (and only this) session for their whole life time.

A session instance to be used on object instantiation can explicitly be given as first parameter to the SAGA object instantiation call (`CONSTRUCTOR`).

If the session is omitted as first parameter, a default session is used, with default security context(s) attached. The default session can be obtained by passing `true` to the session `CONSTRUCTOR`.

Code Example

```
// Example in C++:

// create a file object in a specific session:
saga::file f1 (session, url);

// create a file object in the default session:
saga::file f2 (url);
```

SAGA objects created from another SAGA object inherit its session, such as, for example, `saga::streams` from `saga::stream_server`. Only some objects do not need a session at creation time, and can hence be shared between sessions. These include:

```
saga::exception
saga::buffer
saga::iovec
saga::parameter
saga::context
saga::job_description
saga::metric
saga::exception
saga::task
saga::task_container
```

Note that tasks have no explicit session attached. The `saga::object` the task was created from, however, has a `saga::session` attached, and that session instance is indirectly available, as the application can obtain that object via the `get_object` method call on the respective task instance.

Multiple sessions can co-exist.

If a `saga::session` object instance gets destroyed, or goes out of scope, the objects associated with that session survive. The implementation MUST ensure that the session is internally kept alive until the last object of that session gets destroyed.

If the session object instance itself gets destroyed, the resources associated with that session MUST be freed immediately as the last object associated with that session gets destroyed. The lifetime of the default session is, however, only limited by the lifetime of the SAGA application itself (see Notes about life time management in Section 2.5.3).

Objects associated with different sessions MUST NOT influence each other in any way - for all practical purposes, they can be considered to be running in different application instances.

Instances of the `saga::context` class (which encapsulates security information in SAGA) can be attached to a `saga::session` instance. The context instances are to be used by that session for authentication and authorization to the backends used.

If a `saga::context` gets removed from a session, but that context is already/still used by any object created in that session, the context MAY continue to be used by these objects, and by objects which inherit the session from these objects, but not by any other objects. However, a call to `list_contexts` MUST NOT list the removed context after it got removed.

For the default `session` instance, the list returned by a call to `list_contexts()` MUST include the default `saga::context` instances. These are those contexts that are added to any `saga::session` by default, e.g. because they are picked up by the SAGA implementation from the application's run time environment. An application can, however, subsequently remove default contexts from the default session. A new, non-default session has initially no contexts attached.

A SAGA implementation MUST document which default context instances it may create and attach to a saga::session. That set MAY change during runtime, but SHOULD NOT be changed once a `saga::session` instance was created. For example, two `saga::session` instances might have different default `saga::context` instances attached. Both sessions, however, will have these attached for their complete lifetime – unless they expire or get otherwise invalidated.

Default `saga::context` instances on a session can be removed from a session, with a call to `remove_context()`. That may result in a session with no contexts attached. That session is still valid, but likely to fail on most authorization points.

```
  - CONSTRUCTOR
    Purpose:  create the object
    Format:   CONSTRUCTOR          (in  bool    default = true,
                                    out session obj)
    Inputs:   default:              indicates if the default
                                    session is returned
    InOuts:   -
    Outputs:  obj:                  the newly created object
    PreCond:  -
    PostCond: -
    Perms:    -
    Throws:   NoSuccess
    Notes:    - the created session has no context
                instances attached.
```

```
                - if 'default' is specified as 'true', the
                  constructor returns a shallow copy of the
                  default session, with all the default
                  contexts attached.  The application can then
                  change the properties of the default session,
                  which is continued to be implicetly used on
                  the creation of all saga objects, unless
                  specified otherwise.


  - DESTRUCTOR
    Purpose:  destroy the object
    Format:   DESTRUCTOR           (in  session obj)
    Inputs:   obj:                  the object to destroy
    InOuts:   -
    Outputs:  -
    PreCond:  -
    PostCond: - See notes about lifetime management
                in Section 2
    Perms:    -
    Throws:   -
    Notes:    -


  - add_context
    Purpose:  attach a security context to a session
    Format:   add_context          (in context  c);
    Inputs:   c:                    Security context to add
    InOuts:   -
    Outputs:  -
    PreCond:  -
    PostCond: - the added context is deep copied, and no
                state is shared.
              - after the deep copy, the implementation MAY
                try to initialize those context attributes
                which have not been explicitely set, e.g. to
                sensible default values.
              - any object within that session can use the
                context, even if it was created before
                add_context was called.
    Perms:    -
    Throws:   NoSuccess
              TimeOut
    Notes:    - if the session already has a context attached
                which has exactly the same set of attribute
                values as the parameter context, no action is
```

```
                taken.
              - if the implementation is not able to
                initialize the context, and cannot use the
                context as-is, a NoSuccess exception is
                thrown.
              - if the context initialization implies remote
                operations, and that operations times out, a
                TimeOut exception is thrown.


  - remove_context
    Purpose:  detach a security context from a session
    Format:   remove_context       (in context  c);
    Inputs:   c:                    Security context to remove
    InOuts:   -
    Outputs:  -
    Throws:   DoesNotExist
    PreCond:  - a context with completely identical attributes
                is available in the session.
    PostCond: - that context is removed from the session, and
                can from now on not be used by any object in
                that session, even if it was created before
                remove_context was called.
    Perms:    -
    Notes:    - this methods removes the context on the
                session which has exactly the same set of
                parameter values as the parameter context.
              - a 'DoesNotExist' exception is thrown if no
                context exist on the session which has the
                same attributes as the parameter context.


  - list_contexts
    Purpose:  retrieve all contexts attached to a session
    Format:   list_contexts        (out array<context>
                                                 contexts);
    Inputs:   -
    InOuts:   -
    Outputs:  contexts:             list of contexts of this
                                    session
    PreCond:  -
    PostCond: -
    Perms:    -
    Throws:   -
    Notes:    - a empty list is returned if no context is
                attached.
```

```
                  - contexts may get added to a session by
                    default, hence the returned list MAY be
                    non-empty even if add_context() was never
                    called before.
                  - a context might still be in use even if not
                    included in the returned list.  See notes
                    about context life time above.
                  - the contexts in the returned list MUST be
                    deep copies of the session's contexts.
```

3.5.3 Examples

Code Example

```
// c++ example
saga::session s;
saga::context c (saga::context::X509);

s.add_context   (c);

saga::directory  d (s, "gsiftp://remote.net/tmp/");
saga::file       f = d.open ("data.txt");

// file has same session attached as dir,
// and can use the same contexts
```

Code Example

```
// c++ example
saga::task    t;
saga::session s;

{
  saga::context c ("X509");

  s.add_context (c);

  saga::file f (s, url);

  t = f.copy <saga::task::Task> (target);

  s.remove_context (c);
}

// As it leaves the scope, the X509 context gets 'destroyed'.
// However, the copy task and the file object MAY continue to
// use the context, as its destruction is actually delayed
```

```
// until the last object using it gets destroyed.

t.run (); // can still use the context
```

3.6 SAGA Context Management

The saga::context class provides the functionality of a security information container. A context gets created, and attached to a session handle. As such it is available to all objects instantiated in that session. Multiple contexts can co-exist in one session – it is up to the implementation to choose the correct context for a specific method call. Also, a single saga::context instance can be shared between multiple sessions. SAGA objects created from other SAGA objects inherit its session and thus also its context(s). Section 3.5 contains more information about the saga::session class, and also about the management and lifetime of saga::context instances associated with a SAGA session.

A typical usage scenario is:

Code Example

```
// context usage scenario in c++

saga::context c_1, c_2;

// c_1 will use a Globus proxy.  Set the type to Globus, pick
// up the default Globus settings, and then identify the proxy
// to be used
c_1.set_attribute ("Type", "Globus");
c_1.set_attribute ("UserProxy", "/tmp/special_x509up_u500");

// c_2 will be used as ssh context, and will just pick up the
// public/private key from $HOME/.ssh
c_2.set_attribute ("Type", "ssh");

// a saga session gets created, and uses both contexts
saga::session s;
s.add_context (c_1);
s.add_context (c_2);

// a remote file in this session can now be accessed via
// gridftp or ssh
saga::file f (s, "any://remote.net/tmp/data.txt");
f.copy ("data.bak");
```

A context has a set of attributes which can be set/get via the SAGA attributes interface. Exactly which attributes a context actually evaluates, depends upon its type (see documentation to the set_defaults() method.

An implementation CAN implement multiple types of contexts. The implementation MUST document which context types it supports, and which values to the `Type` attribute are used to identify these context types. Also, the implementation MUST document what default values it supports for the various context types, and which attributes need to be or can be set by the application.

The lifetime of `saga::context` instances is defined by the lifetime of those `saga::session` instances the contexts are associated with, and of those SAGA objects which have been created in these sessions. For detailed information about lifetime management, see Section 2.5.3, and the description of the SAGA session class in Section 3.5.

For application level Authorization (e.g. for streams, monitoring, steering), contexts are used to inform the application about the requestor's identity. These contexts represent the security information that has been used to initiate the connection to the SAGA application. To support that mechanism, a number of specific attributes are available, as specified below. They are named `"Remote<attribute>"`. An implementation MUST at least set the `Type` attribute for such contexts, and SHOULD provide as many attribute values as possible.

For example, a SAGA application *A* creates a `saga::stream_server` instance. A SAGA application *B* creates a 'globus' type context, and, with a session using that context, creates a `saga::stream` instance connecting to the stream server of *A*. *A* should then obtain a context upon connection accept (see Sections on Monitoring, 3.9, and Streams, 4.5, for details). That context should then also have the type 'globus', its 'RemoteID' attribute should contain the distinguished name of the user certificate, and its attributes 'RemoteHost' and 'RemotePort' should have the appropriate values.

Note that `UserID` s SHOULD be formatted so that they can be used as user identifiers in the SAGA permission model – see Section 3.7 for details.

3.6.1 Specification

```
package saga.context
{
  class context : implements   saga::object
                  implements   saga::attributes
               // from object  saga::error_handler
  {
    CONSTRUCTOR      (in  string       type = "",
                      out context      obj);
    DESTRUCTOR       (in  context      obj);
```

```
// Attributes:
//
//   name:  Type
//   desc:  type of context
//   mode:  ReadWrite
//   type:  String
//   value: naming conventions as described above apply
//
//   name:  Server
//   desc:  server which manages the context
//   mode:  ReadWrite
//   type:  String
//   value: -
//   note:  - a typical example would be the contact
//            information for a MyProxy server, such as
//            'myproxy.remote.net:7512', for a 'myproxy'
//            type context.
//
//   name:  CertRepository
//   desc:  location of certificates and CA signatures
//   mode:  ReadWrite
//   type:  String
//   value: -
//   note:  - a typical example for a globus type context
//            would be "/etc/grid-security/certificates/".
//
//   name:  UserProxy
//   desc:  location of an existing certificate proxy to
//          be used
//   mode:  ReadWrite
//   type:  String
//   value: -
//   note:  - a typical example for a globus type context
//            would be "/tmp/x509up_u<uid>".
//
//   name:  UserCert
//   desc:  location of a user certificate to use
//   mode:  ReadWrite
//   type:  String
//   value: -
//   note:  - a typical example for a globus type context
//            would be "$HOME/.globus/usercert.pem".
//
//   name:  UserKey
//   desc:  location of a user key to use
```

```
//   mode:  ReadWrite
//   type:  String
//   value: -
//   note:  - a typical example for a globus type context
//            would be "$HOME/.globus/userkey.pem".
//
//   name:  UserID
//   desc:  user id or user name to use
//   mode:  ReadWrite
//   type:  String
//   value: -
//   note:  - a typical example for a ftp type context
//            would be "anonymous".
//
//   name:  UserPass
//   desc:  password to use
//   mode:  ReadWrite
//   type:  String
//   value: -
//   note:  - a typical example for a ftp type context
//            would be "anonymous@localhost".
//
//   name:  UserVO
//   desc:  the VO the context belongs to
//   mode:  ReadWrite
//   type:  String
//   value: -
//   note:  - a typical example for a globus type context
//            would be "O=dutchgrid".
//
//   name:  LifeTime
//   desc:  time up to which this context is valid
//   mode:  ReadWrite
//   type:  Int
//   value: -1
//   note:  - format: time and date specified in number of
//            seconds since epoch
//          - a value of -1 indicates an infinite lifetime.
//
//   name:  RemoteID
//   desc:  user ID for an remote user, who is identified
//          by this context.
//   mode:  ReadOnly
//   type:  String
//   value: -
//   note:  - a typical example for a globus type context
```

```
    //            would be
    //            "/O=dutchgrid/O=users/O=vu/OU=cs/CN=Joe Doe".
    //
    //   name:  RemoteHost
    //   desc:  the hostname where the connection origininates
    //          which is identified by this context.
    //   mode:  ReadOnly
    //   type:  String
    //   value: -
    //
    //   name:  RemotePort
    //   desc:  the port used for the connection which is
    //          identified by this context.
    //   mode:  ReadOnly
    //   type:  String
    //   value: -
    //
  }
}
```

3.6.2 Specification Details

Class `context`

```
  - CONSTRUCTOR
    Purpose:  create a security context
    Format:   CONSTRUCTOR          (in  stringt type = "",
                                    out context obj);
    Inputs:   type:                 initial type of context
    InOuts:   -
    Outputs:  obj:                  the newly created object
    PreCond:  -
    PostCond: -
    Perms:    -
    Throws:   IncorrectState
              Timeout
              NoSuccess
    Notes:    -

  - DESTRUCTOR
```

```
Purpose:  destroy a security context
Format:   DESTRUCTOR           (in context obj);
Inputs:   obj:                  the object to destroy
InOuts:   -
Outputs:  -
PreCond:  -
PostCond: - See notes about lifetime management
            in Section 2
Perms:    -
Throws:   -
Notes:    -
```

3.7 SAGA Permission Model

A number of SAGA use cases imply the ability of applications to allow or deny specific operations on SAGA objects or grid entities, such as files, streams, or monitorables. This packages provides a generic interface to query and set such permissions, for (a) everybody, (b) individual users, and (c) groups of users.

Objects implementing this interface maintain a set of permissions for each object instance, for a set of IDs. These permissions can be queried, and, in many situations, set. The SAGA specification defines which permissions are available on a SAGA object, and which operations are expected to respect these permissions.

A general problem with this approach is that it is difficult to anticipate how users and user groups are identified by various grid middleware systems. In particular, any translation of permissions specified for one grid middleware is likely not completely translatable to permissions for another grid middleware.

For example, assume that a `saga::file` instance gets created via ssh, and permissions are set for the file to be readable and executable by a specific POSIX user group ID. Which implications do these permissions have with respect to operations performed with GridFTP, using a Globus certificate? The used X509 certificates have (a) no notion of groups (groups are implicit due to the mapping of the `grid-mapfile`), and (b) are not mappable to group ids; and (c) GridFTP ignores the executable flag on files.

For this reason, it is anticipated that the permission model described in this section has the following, undesired consequences and limitations:

- Applications using this interface are not expected to be fully portable between different SAGA implementations. (In cases like having two SAGA implementations that use different middleware backends for accessing the same resources.)
- A SAGA implementation MUST document which permission it supports, for which operations.
- A SAGA implementation MUST document if it supports group level permissions.
- A SAGA implementation MUST document how user and group IDs are to be formed.

Note that there are no separate calls to get/set user, group and world permissions: this information must be part of the IDs the methods operate upon. To set/get permissions for 'world' (i.e. anybody), the ID `'*'` is used.

IDs

SAGA can not, by design, define globally unique identifiers in a portable way. For example, it would be impossible to map, transparently and bi-directionally, a Unix user ID and an associated X509 Distinguished Name on any resource onto the same hypothetical SAGA user ID, at least not without explicit support by the grid middleware (e.g., by having access to the Globus `grid-mapfile`). That support is, however, rarely available.

It is thus required that SAGA implementations MUST specify how the user and group IDs are formed that they support. In general, IDs which are valid for the `UserID` attribute of the SAGA `context` instances SHOULD also be valid IDs to be used in the SAGA permission model.

A typical usage scenario is (extended from the context usage scenario):

Code Example

```
// context and permission usage scenario in C++

saga::context c_1 ("globus")
saga::context c_2 ("ssh");

// c_1 is a globus proxy.  Identify the proxy to be used,
// and pick up the other default globus settings
c_1.set_attribute ("UserProxy", "/tmp/special_x509up_u500");
c_1.set_defaults  ();

// c_2 is a ssh context, and will just pick up the
// public/private key from $HOME/.ssh
c_2.set_defaults ();

// a saga session gets created, and uses both contexts
saga::session s;
s.add_context (c_1);
s.add_context (c_2);

// a remote file in this session can now be accessed via
// gridftp or ssh
saga::file f (s, "any://remote.net/tmp/data.txt");
f.copy ("data.bak");

// write permissions can be set for both context IDs
f.permission_allow (c_1.get_attribute ("UserID"), Write);
f.permission_allow (c_2.get_attribute ("UserID"), Write);
```

For middleware systems where group and user ids can clash, the IDs should be implemented as `'user-<id>'` and `'group-<id>'`. For example: on Unix, the name 'mail' can (and often does) refer to a user and a group. In that case, the IDs should be expressed as `'user-mail'` and `'group-mail'`, respectively. The ID `'*'` is always reserved, as described above.

Permissions for a user ID supersede the permissions for a group ID, which supersede the permissions for `'*'` (all). If a user is in multiple groups, and the group's permissions differ, the most permissive permission applies.

3.7.1 Permissions for Multiple Backends

In SAGA, an entity which provides the `permissions` interface always has exactly one owner, for one middleware backend. However, this implies that for SAGA implementations with multiple backend bindings, multiple owner IDs may be valid. For example, `"/O=dutchgrid/O=users/O=vu/OU=cs/CN=Joe Doe"` and `"user-jdoe"` might be equally valid IDs, at the same time, if the implementation supports local Unix access and GridFTP access to a local file. As long as the ID spaces do not conflict, the `permissions` interface obviously allows to set permissions individually for both backends. In case of conflicts, the application would need to create new SAGA objects from sessions that contain only a single context, representing the desired backend's security credentials. As such situations are considered to be very rare exceptions in the known SAGA use cases, we find this limitation accetable.

Note that, for SAGA implementations supporting multiple middleware backends, the `permissions` interface can operate on permissions for any of these backends, not only for the one that was used by the original creation of the object instance. Such a restriction would basically inhibit implementations with dynamic ("late") binding to backends.

Conflicting Backend Permission Models

Some middleware backends may not support the full range of permissions, e.g., they might not distinguish between `Query` and `Read` permissions. A SAGA implementation MUST document which permissions are supported. Trying to set an unsupported permission reults in a `BadParameter` exception, and NOT in a `NotImplemented` exception – that would indicate that the method is not available at all, i.e. that no permission model at all is available for this particular implementation.

An implementation MUST NOT silently merge permissions, according to its own model – that would break for example the following code:

```
file.permissions_allow ("user-jdoe", Query);
file.permissions_deny  ("user-jdoe", Read );
off_t file_size = file.get_size ();
```

If an implementation binds to a system with standard Unix permissions and does not throw a `BadParameter` exception on the first call, but silently sets `Read` permissions instead, because that does also allow query style operations on Unix, then the code in line three would fail for no obvious reason, because the second line would revoke the permissions from line one.

Initial Permission Settings

If new grid entities get created via the SAGA API, the owner of the object is set to the value of the `'UserID'` attribute of the context used during the creation. Note that for SAGA implementations with support for multiple middleware backends, and support for late binding, this may imply that the owner is set individually for one, some or all of the supported backends.

Creating grid entities may require specific permissions on other entities. For example:

- file creation requires `Write` permissions on the parent directory.
- executing a file requires `Read` permissions on the parent directory.

An implementation CAN set initial permissions other than `Owner`. An implementation SHOULD document which initial permission settings an application can expect.

The specification of the `ReadOnly` flag on the creation or opening of SAGA object instances, such as `saga::file` instances, causes the implementation to behave as if the `Write` permission on the entity on that instance is not available, even if it is, in reality, available. The same holds for the `WriteOnly` flag and the availability of the `Read` permission on that entity.

Permission Definitions in the SAGA specification

The SAGA specification normatively defines for each operation, which permissions are required for that operation. If a permission is supported, but not set, the method invocation MUST cause a `PermissionDenied` exception. An implementation MUST document any deviation from this scheme, e.g., if a specified permission is not supported at all, or cannot be tested for a particular method. An example of such a definition is (from the `monitorable` interface):

```
  - list_metrics
    Purpose:  list all metrics associated with the object
    Format:   list_metrics       (out array<string>   names);
    Inputs:   -
    InOuts:   -
    Outputs:  names:              array of names identifying
                                  the metrics associated with
                                  the object instance
    PreCond:  -
    PostCond: -
    Perms:    Query
    Throws:   NotImplemented
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
              Timeout
              NoSuccess
    Notes:    - [...]
```

This example implies that for the session in which the `list_metrics()` operation gets performed, there must be at least one context for which's attribute `'UserID'` the `Query` permission is both supported and available; otherwise, the method MUST throw a `PermissionDenied` exception. If `Query` is not supported by any of the backends for which a context exists, the implementation MAY try the backends to perform the operation anyway.

For some parts of the specification, namely for attributes and metrics, the `mode` specification is normative for the respective, required permission. For example, the mode attribute `ReadOnly` implies that a `Write` permission, required to change the attribute, is never available.

The `PermissionDenied` exception in SAGA

SAGA supports a `PermissionDenied` exception, as documented in Section 3.1. This exception can originate from various circumstances, that are not necessarily related to the SAGA permission model as described here. However, if the reason why that exception is raised maps onto the SAGA permission model, the exception's error message MUST have the following format (line breaks added for readability):

```
PermissionDenied: no <PERM> permission
                  on <ENTITY> <NAME>
                  for <ID>
```

Here, `<PERM>` denotes which permission is missing, `<ENTITY>` denotes on what kind of entity this permission is missing. `<NAME>` denotes which entity misses that permission, and `<ID>` denotes which user is missing that permission.

`<PERM>` is the literal string of the `permission` enum defined in this section. `<ENTITY>` is the type of backend entity which is missing the permission, e.g. `file`, `directory`, `job_service` etc. Whenever possible, the literal class name of the respective SAGA class name SHOULD be used. `<NAME>` SHOULD be a URL or literal name which allows the end user to uniquely identify the entity in question. `<ID>` is the value of the `UserID` attribute of the context used for the operation (the notes about user IDs earlier in this section apply).

Some examples for complete error messages are:

```
PermissionDenied: no Read permission
                  on file http:////tmp/test.dat
                  for user-jdoe

PermissionDenied: no Write permission
                  on directory http:////tmp/
                  for user-jdoe

PermissionDenied: no Query permission
                  on logical_file rls:////tmp/test
                  for /O=ca/O=users/O=org/CN=Joe Doe

PermissionDenied: no Query permission
                  on job [fork://localhost]-[1234]
                  for user-jdoe

PermissionDenied: no Exec permission
                  on RPC [rpc://host/matmult] for
                  for /O=ca/O=users/O=org/CN=Joe Doe
```

Note to users

The description of the SAGA permission model above should have made clear that, in particular, the support for multiple backends makes it difficult to strictly enforce the permissions specified on application level. Until a standard for permission management for Grid application emerges, this situation is unlikely to change. Applications should thus be careful to trust permissions specified in SAGA, and should ensure to use an implementation which fully supports and enforces the permission model, e.g., they should choose an implementation which binds to a single backend.

3.7.2 Specification

```
package saga.permissions
{
  enum permission
  {
    None      =  0,
    Query     =  1,
    Read      =  2,
    Write     =  4,
    Exec      =  8,
    Owner     = 16,
    All       = 31
  }

  interface permissions : implements saga::async
  {
    // setter / getters
    permissions_allow       (in  string          id,
                             in  int             perm);
    permissions_deny        (in  string          id,
                             in  int             perm);
    permissions_check       (in  string          id,
                             in  int             perm,
                             out bool            value);
    get_owner               (out string          owner);
    get_group               (out string          group);
  }
}
```

3.7.3 Specification Details

Enum `permission`

This enum specifies the available permissions in SAGA. The following examples demonstrate which type of operations are allowed for certain permissions, and which aren't. To keep these examples concise, they are chosen from the following list, with the convention that those operations in this list, which are not listed in the respective example section, are *not* allowed for that permission. In general, the availability of one permission does not imply the availability of any other permission (with the exception of `Owner`, as described below).

- provide information about a metric, and its properties
- provide information about file size, access time and ownership
- provide information about job description, ownership, and runtime
- provide information about logical file access time and ownership
- provide access to a job's I/O streams
- provide access to the list of replicas of a logical file
- provide access to the contents of a file
- provide access to the value of a metric
- provide means to change the ownership of a file or job
- provide means to change the permissions of a file or job
- provide means to fire a metric
- provide means to connect to a stream server
- provide means to manage the entries in a directory
- provide means to manipulate a file or its meta data
- provide means to manipulate a job's execution or meta data
- provide means to manipulate the list of replicas of a logical file
- provide means to run an executable

The following permissions are available in SAGA:

`Query`

This permission identifies the ability to *access all meta data of an entity*, and thus to obtain any information about an entity. If that permission is not available for an actor, that actor MUST NOT be able to obtain any information about the queried entity, if possible not even about its existence. If that permission is available for an actor, the actor MUST be able to query for any meta data on the object which (a) do imply changes on the entities state, and (b) are part of the *content* of the entity (i.e., do not comprise its data).

Note that for logical files, attributes are part of the data of the entities (i.e., the meta data belong to the logical file's data).

An authorized `Query` operation can:

- provide information about a metric, and its properties
- provide information about file size, access time and ownership
- provide information about job description, ownership, and runtime

- provide information about logical file access time and ownership

`Read`

This permission identifies the ability to *access the contents and the output of an entity*. If that permission is not available for an actor, that actor MUST NOT be able to access the data of the entity. That permission does not imply the authorization to change these data, or to manipulate the entity. That permission does also not imply `Query` permissions, i.e. the permission to access the entity's meta data.

An authorized `READ` operation can:

- provide access to a job's I/O streams
- provide access to the list of replicas of a logical file
- provide access to the contents of a file
- provide access to the value of a metric

`Write`

This permission identifies the ability to *manipulate the contents of an entity*. If that permission is not available for an actor, that actor MUST NOT be able to change neither data nor meta data of the entity. That permission does not imply the authorization to read these data of the entity, nor to manipulate the entity. That permission does also not imply `Query` permissions, i.e., the permission to access the entity's meta data.

Note that, for a directory, its entries comprise its data. Thus, `Write` permissions on a directory allow to manipulate all entries in that directory – but do not imply the ability to change the data of these entries. For example, `Write` permissions on the directory `'/tmp'` allows to move `'/tmp/a'` to `'/tmp/b'`, or to remove these entries, but does not imply the ability to perform a `read()` operation on `'/tmp/a'`.

An authorized `Write` operation can:

- provide means to manage the entries in a directory
- provide means to manipulate a file or its meta data
- provide means to manipulate a job's execution or meta data
- provide means to manipulate the list of replicas of a logical file

`Exec`

This permission identifies the ability to *perform an action on an entity*. If that permission is not available for an actor, that actor MUST NOT be able to perform that action. The actions covered by that permission are usually those which affect the state of the entity, or which create a new entity.

An authorized `Exec` operation can:

- provide means to fire a metric
- provide means to connect to a stream server
- provide means to run an executable

`Owner`

This permission identifies the ability to *change permissions and ownership of an entity*. If that permission is not available for an actor, that actor MUST NOT be able to change any permissions or the ownership of an entity. As this permission indirectly implies full control over all other permissions, it does also imply that an actor with that permission can perform *any* operation on the entity. `Owner` is not listed as additional required permission in the specification details for the individual methods, but only listed for those methods, where `Owner` is an explicit permission requirement which cannot be replaced by any other permission.

An authorized `Owner` operation can:

- provide means to change the ownership of a file or job
- provide means to change the permissions of a file or job
- perform *any* other operation, including all operations from the original list of examples above

Note that only one user can own an entity. For example, the following sequence:

```
file.permissions_allow ("Tarzan", saga::permission::Owner);
file.permissions_allow ("Jane",   saga::permission::Owner);
```

would result in a file ownership by `'Jane'`.

Also note that

```
file.permissions_allow ("*", saga::permission::Owner);
```

or

```
file.permissions_deny (id, saga::permission::Owner);
```

will never be possible, and will throw a `BadParameter` exception.

Interface `permissions`

```
- permissions_allow
  Purpose:  enable permission flags
  Format:   permissions_allow    (in  string     id,
                                  in  int        perm);
  Inputs:   id:                   id to set permission for
            perm:                 permissions to enable
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: - the permissions are enabled.
  Perms:    Owner
  Throws:   NotImplemented
```

```
            BadParameter
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - an id '*' sets the permissions for all (world)
            - whether an id is interpreted as a group id is up to
              the implementation.  An implementation MUST
              specify how user and group id's are formed.
            - the 'Owner' permission can not be set to the
              id '*' (all).
            - if the given id is unknown or not supported, a
              'BadParameter' exception is thrown.


- permissions_deny
  Purpose:  disable permission flags
  Format:   permissions_deny     (in  string     id,
                                  in  int        perm);
  Inputs:   id:                   id to set permissions for
            perm:                 permissions to disable
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: - the permissions are disabled.
  Perms:    Owner
  Throws:   NotImplemented
            BadParameter
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - an id '*' sets the permissions for all (world)
            - whether an id is interpreted as a group id is up to
              the implementation.  An implementation MUST
              specify how user and group id's are formed.
            - the 'Owner' permission can not be set to the
              id '*' (all).
            - if the given id is unknown or not supported, a
              'BadParameter' exception is thrown.


- permissions_check
  Purpose:  check permission flags
```

```
  Format:   permissions_check    (in  string     id,
                                  in  int        perm,
                                  out bool       allow);
  Inputs:   id:                   id to check permissions for
            perm:                 permissions to check
  InOuts:   -
  Outputs:  allow:                indicates if, for that id,
                                  the permissions are granted
                                  (true) or not.
  PreCond:  -
  PostCond: -
  Perms:    Query
  Throws:   NotImplemented
            BadParameter
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - an id '*' gets the permissions for all (world)
            - 'true' is only returned when all permissions
              specified in 'perm' are set for the given id.
            - if the given id is unknown or not supported, a
              'BadParameter' exception is thrown.


- get_owner
  Purpose:  get the owner of the entity
  Format:   get_owner            (out string     owner);
  Inputs:   -
  InOuts:   -
  Outputs:  owner:                id of the owner
  PreCond:  -
  PostCond: -
  Perms:    Query
  Throws:   NotImplemented
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - returns the id of the owner of the entity
            - an entity, on which the permission interface is
              available, always has exactly one owner: this
              method MUST NOT return an empty string, and
              MUST NOT return '*' (all), and MUST NOT return
```

```
                a group id.


    - get_group
      Purpose:  get the group owning the entity
      Format:   get_group            (out string     group);
      Inputs:   -
      InOuts:   -
      Outputs:  group:                id of the group
      PreCond:  -
      PostCond: -
      Perms:    Query
      Throws:   NotImplemented
                PermissionDenied
                AuthorizationFailed
                AuthenticationFailed
                Timeout
                NoSuccess
      Notes:    - returns the id of the group owning the entity
                - this method MUST NOT return '*' (all), and
                  MUST NOT return a user id.
                - if the implementation does not support groups,
                  the method returns an empty string.
```

3.7.4 Examples

Code Example

```

// c++ example
{
  // create a file in the default session
  saga::file f (url, saga::file::Create
                   | saga::file::Exclusive):

  // get all contexts of the default session, and for each...
  std::list <saga::context> ctxs = theSession.list_contexts ();

  for ( int i = 0; i < ctxs.size (); i++ )
  {
    saga::context ctx = ctxs[i];

    // set the file to be executable
    f.permission_allow (ctx.get_attribute ("UserID"),
                        saga::permission::Exec);
  }
```

```

  // the file should now be usable for job submission for all
  // contexts in the default session.  Often, however, only
  // one context will succeed in setting the permission: the
  // one which was used for creation in the first place.  In
  // that case, job submission is most likely to succeed with
  // that context, too.
}
```

3.8 SAGA Attribute Model

There are various places in the SAGA API where attributes need to be associated with objects, for instance for job descriptions and metrics. The `attributes` interface provides a common interface for storing and retrieving attributes.

Objects implementing this interface maintain a set of attributes. These attributes can be considered as a set of key-value pairs attached to the object. The key-value pairs are string based for now, but might cover other value types in later versions of the SAGA API specification.

The interface name `attributes` is somewhat misleading: it seems to imply that an object implementing this interface `IS-A` set of attributes. What we actually mean is that an object implementing this interface `HAS` attributes. In the absence of a better name, we left it `attributes`, but implementors and users should be aware of the actual meaning (the proper interface name would be 'attributable', which sounds awkward).

Several functional classes will need to implement attributes as remote functionality, and such an implementation is by definition middleware dependent, and thus not always implementable. That is why the `NotImplemented` exception is listed for all attribute interface methods. However, SAGA Look-&-Feel classes which MUST be implemented by SAGA compliant implementations (see intro to Section 3, on page 31), and which do implement the `attributes` interface, MUST NOT throw the `NotImplemented` exception, ever.

The SAGA specification defines attributes which MUST be supported by the various SAGA objects, and also defines their default values, and those which CAN be supported. An implementation MUST motivate and document if a specified attribute is not supported.

3.8.1 Specification

```
package saga.attributes
{
  interface attributes
  {
    // setter / getters
    set_attribute          (in  string          key,
                            in  string          value);
    get_attribute          (in  string          key,
                            out string          value);
    set_vector_attribute   (in  string          key,
```

```
                               in  array<string>   values);
      get_vector_attribute    (in  string          key,
                               out array<string>   values);
      remove_attribute        (in  string          key);

      // inspection methods
      list_attributes         (out array<string>   keys);
      find_attributes         (in  array<string>   pattern,
                               out array<string>   keys);
      attribute_exists        (in  string          key,
                               out bool            test);
      attribute_is_readonly   (in  string          key,
                               out bool            test);
      attribute_is_writable   (in  string          key,
                               out bool            test);
      attribute_is_removable  (in  string          key,
                               out bool            test);
      attribute_is_vector     (in  string          key,
                               out bool            test);
    }
  }
```

3.8.2 Specification Details

The `attributes` interface in SAGA provides a uniform paradigm to set and query parameters and properties of SAGA objects. Although the `attributes` interface is generic by design (i.e. it allows arbitrary keys and values to be used), its use in SAGA is mostly limited to a finite and well defined set of keys.

In several languages, attributes can much more elegantly be expressed by native means - e.g. by using hash tables in Perl. Bindings for such languages MAY allow to use a native interface *additionally* to the one described here.

Several SAGA objects have very frequently used attributes. To simplify usage of these objects, setter and getter methods MAY be defined by the various language bindings, again *additionally* to the interface described below. For attributes of native non-string types, these setter/getters MAY be typed.

For example, additionally to:

```
  stream.set_attribute ("BufferSize", "1024");
```

a language binding might allow:

```
stream.set_buffer_size (1024);  // int type
```

Further, in order to limit semantic and syntactic ambiguities (e.g., due to spelling deviations), language bindings MUST define known attribute keys as constants, such as (in C):

```
#define SAGA_BUFFERSIZE "BufferSize"
...
stream.set_attribute (SAGA_BUFFERSIZE, "1024");
```

The distinction between scalar and vector attributes is supposed to help those languages where this aspect of attributes cannot be handled transparently, e.g. by overloading. Bindings for languages such as Python, Perl and C++ CAN hide this distinction as long as both access types are supported.

Elements of vector attributes are ordered. This order MUST be preserved by the SAGA implementation. Comparison also relies on ordering (i.e. `'one two'` does not equal `'two one'`). For example, this order is significant for the `saga::job_description` attribute `'Arguments'`, which represents command line arguments for a job.

Attributes are expressed as string values. They have, however, a type, which defines the formatting of that string. The allowed types are `String`, `Int`, `Enum`, `Float`, `Bool`, and `Time` (the same as metric value types). Additionally, attributes are qualified as either `Scalar` or `Vector`. The default is `Scalar`.

Values of `String` type attributes are expressed as-is.

Values of `Int` (i.e. Integer) type attributes are expressed as they would in result of a printf of the format `'%lld'`, as defined by POSIX.

Values of `Enum` type attributes are expressed as strings, and have the literal value of the respective enums as defined in this document. For example, the initial task states would have the values `'New'`, `'Running'`, `'Done'`, etc.

Values of `Float` (i.e. floating point) type attributes are expressed as they would in result of a printf of the format `'%Lf'`, as defined by POSIX.

Values of `Bool` type attributes MUST be expressed as 'True' or 'False'.

Values of `Time` type attributes MUST be expressed as they would in result of a call to `ctime()`, as defined by POSIX. Applications can also specify these attribute values as seconds since epoch (this formats the string as an `Int` type), but all time attributes set by the implementation MUST be in `ctime()` format. Applications should be aware of the `strptime()` and `strftime()` methods defined in POSIX, which assist time conversions.

3.8.3 Attribute Definitions in the SAGA specification

The SAGA specification defines a number of attributes which MUST or CAN be supported, for various SAGA objects. An example of such a definition is (from the Metric object):

```
class metric ...
{
  ...

  // Attributes:
  //   name:  Name
  //   desc:  name of metric
  //   mode:  ReadOnly
  //   type:  String
  //   value: -
  //   notes: naming conventions as described below apply
  //
  //   ...
}
```

These specifications are NORMATIVE, even if described as comments in the SIDL specification! The specified attributes MUST be supported by an implementation, unless noted otherwise, as:

```
// mode:  ReadOnly, optional
// mode:  ReadWrite, optional
```

If an attribute MUST be supported, but the SAGA implementation cannot support that attribute, any set/get on that attribute MUST throw a `NotImplemented` exception, and the error message MUST state `"Attribute <name> not available in this implementation"`.

If the default value is denoted as '–', then the attribute is, by default, not set at all.

Attribute support can 'appear' and 'go away' during the lifetime of an object (e.g., as late binding implementations switch the backend). Any set on an attribute which got removed ('dead attribute') MUST throw a `DoesNotExist` exception. However, dead attributes MUST stay available for read access. The SAGA implementation MUST NOT change such an attribute's value, as long as it is not available. Allowed values for mode are `ReadOnly` and `ReadWrite`.

It is not allowed to add attributes other than those specified in this document, unless explicitly allowed, as:

```
//  Attributes (extensible):
```

The `find_attributes()` method accepts a list of patterns, and returns a list of keys for those attributes which match any one of the specified patterns (`OR` semantics). The patterns describe both attribute keys and values, and are formatted as:

```
<key-pattern>=<value-pattern>
```

Both the `key-pattern` and the `value-pattern` can contain wildcards as defined in the description of the SAGA `namespace` package. If a `key-pattern` contains an `'='` character, that character must be escaped by a backslash, as must any backslash character itself. The `value-pattern` can be empty, and the method will then return all attribute keys which match the `key-pattern`. The equal sign `'='` can then be omitted from the pattern.

Interface `attributes`

```
- set_attribute
  Purpose:  set an attribute to a value
  Format:   set_attribute        (in string key,
                                  in string value);
  Inputs:   key:                  attribute key
            value:                value to set the
                                  attribute to
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: -
  Perms:    Write
  Throws:   NotImplemented
            BadParameter
            DoesNotExist
            IncorrectState
            PermissionDenied
            AuthorizationFailed
```

```
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - an empty string means to set an empty value
              (the attribute is not removed).
            - the attribute is created, if it does not exist
            - a 'PermissionDenied' exception is thrown if the
              attribute to be changed is ReadOnly.
            - only some SAGA objects allow to create new
              attributes - others allow only access to
              predefined attributes.  If a non-existing
              attribute is queried on such objects, a
              'DoesNotExist' exception is raised
            - changes of attributes may reflect changes of
              endpoint entity properties.  As such,
              authorization and/or authentication may fail
              for settings such attributes, for some
              backends.  In that case, the respective
              'AuthenticationFailed', 'AuthorizationFailed',
              and 'PermissionDenied' exceptions are thrown.
              For example, an implementation may forbid to
              change the saga::stream 'BufSize' attribute.
            - if an attribute is not well formatted, or
              outside of some allowed range, a 'BadParameter'
              exception with a descriptive error message is
              thrown.
            - if the operation is attempted on a vector
              attribute, an 'IncorrectState' exception is
              thrown.
            - setting of attributes may time out, or may fail
              for other reasons - which causes a 'Timeout' or
              'NoSuccess' exception, respectively.


- get_attribute
  Purpose:  get an attribute value
  Format:   get_attribute        (in  string key,
                                  out string value);
  Inputs:   key:                  attribute key
  InOuts:   -
  Outputs:  value:                value of the attribute
  PreCond:  -
  PostCond: -
  Perms:    Query
  Throws:   NotImplemented
            DoesNotExist
```

```
              IncorrectState
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
              Timeout
              NoSuccess
    Notes:    - queries of attributes may imply queries of
                endpoint entity properties.  As such,
                authorization and/or authentication may fail
                for querying such attributes, for some
                backends.  In that case, the respective
                'AuthenticationFailed', 'AuthorizationFailed',
                and 'PermissionDenied' exceptions are thrown.
                For example, an implementation may forbid to
                read the saga::stream 'BufSize' attribute.
              - reading an attribute value for an attribute
                which is not in the current set of attributes
                causes a 'DoesNotExist' exception.
              - if the operation is attempted on a vector
                attribute, an 'IncorrectState' exception is
                thrown.
              - getting attribute values may time out, or may
                fail for other reasons - which causes a
                'Timeout' or 'NoSuccess' exception,
                respectively.


  - set_vector_attribute
    Purpose:  set an attribute to an array of values.
    Format:   set_vector_attribute (in string         key,
                                    in array<string>   values);
    Inputs:   key:                  attribute key
              values:               array of attribute values
    InOuts:   -
    Outputs:  -
    PreCond:  -
    PostCond: -
    Perms:    Write
    Throws:   NotImplemented
              BadParameter
              DoesNotExist
              IncorrectState
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
              Timeout
```

```
             NoSuccess
  Notes:     - the notes to the set_attribute() method apply.
             - if the operation is attempted on a scalar
               attribute, an 'IncorrectState' exception is
               thrown.


- get_vector_attribute
  Purpose:   get the array of values associated with an
             attribute
  Format:    get_vector_attribute (in string          key,
                                   out array<string>  values);
  Inputs:    key:                  attribute key
  InOuts:    -
  Outputs:   values:               array of values of the
                                   attribute.
  PreCond:   -
  PostCond:  -
  Perms:     Query
  Throws:    NotImplemented
             DoesNotExist
             IncorrectState
             PermissionDenied
             AuthorizationFailed
             AuthenticationFailed
             Timeout
             NoSuccess
  Notes:     - the notes to the get_attribute() method apply.
             - if the operation is attempted on a scalar
               attribute, an 'IncorrectState' exception is
               thrown.


- remove_attribute
  Purpose:   removes an attribute.
  Format:    remove_attribute     (in string key);
  Inputs:    key:                  attribute to be removed
  InOuts:    -
  Outputs:   -
  PreCond:   -
  PostCond:  - the attribute is not available anymore.
  Perms:     Write
  Throws:    NotImplemented
             DoesNotExist
             PermissionDenied
             AuthorizationFailed
```

```
              AuthenticationFailed
              Timeout
              NoSuccess
    Notes:    - a vector attribute can also be removed with
                this method
              - only some SAGA objects allow to remove
                attributes.
              - a ReadOnly attribute cannot be removed - any
                attempt to do so throws a 'PermissionDenied'
                exception.
              - if a non-existing attribute is removed, a
                'DoesNotExist' exception is raised.
              - exceptions have the same semantics as defined
                for the set_attribute() method description.


  - list_attributes
    Purpose:  Get the list of attribute keys.
    Format:   list_attributes      (out array<string>   keys);
    Inputs:   -
    InOuts:   -
    Outputs:  keys:                 existing attribute keys
    PreCond:  -
    PostCond: -
    Perms:    Query
    Throws:   NotImplemented
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
              Timeout
              NoSuccess
    Notes:    - exceptions have the same semantics as defined
                for the get_attribute() method description.
              - if no attributes are defined for the object,
                an empty list is returned.


  - find_attributes
    Purpose:  find matching attributes.
    Format:   find_attributes      (in  array<string>   pattern,
                                    out array<string>   keys);
    Inputs:   pattern:              search patterns
    InOuts:   -
    Outputs:  keys:                 matching attribute keys
    PreCond:  -
    PostCond: -
```

```
  Perms:    Query
  Throws:   NotImplemented
            BadParameter
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - the pattern must be formatted as described
              earlier, otherwise a 'BadParameter' exception
              is thrown.
            - exceptions have the same semantics as defined
              for the get_attribute() method description.


- attribute_exists
  Purpose:  check the attribute's existence.
  Format:   attribute_exists     (in  string key,
                                  out bool   test);
  Inputs:   key:                  attribute key
  InOuts:   -
  Outputs:  test:                 bool indicating success
  PreCond:  -
  PostCond: -
  Perms:    Query
  Throws:   NotImplemented
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - This method returns TRUE if the attribute
              identified by the key exists.
            - exceptions have the same semantics as defined
              for the get_attribute() method description,
              apart from the fact that a DoesNotExist
              exception is never thrown.


- attribute_is_readonly
  Purpose:  check the attribute mode.
  Format:   attribute_is_readonly(in  string key,
                                  out bool   test);
  Inputs:   key:                  attribute key
  InOuts:   -
  Outputs:  test:                 bool indicating success
```

```
    PreCond:  -
    PostCond: -
    Perms:    Query
    Throws:   NotImplemented
              DoesNotExist
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
              Timeout
              NoSuccess
    Notes:    - This method returns TRUE if the attribute
                identified by the key exists, and can be read
                by get_attribute() or get_vector attribute(),
                but cannot be changed by set_attribute() and
                set_vector_attribute().
              - exceptions have the same semantics as defined
                for the get_attribute() method description.


  - attribute_is_writable
    Purpose:  check the attribute mode.
    Format:   attribute_is_writable(in  string key,
                                    out bool   test);
    Inputs:   key:                  attribute key
    InOuts:   -
    Outputs:  test:                 bool indicating success
    PreCond:  -
    PostCond: -
    Perms:    Query
    Throws:   NotImplemented
              DoesNotExist
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
              Timeout
              NoSuccess
    Notes:    - This method returns TRUE if the attribute
                identified by the key exists, and can be
                changed by set_attribute() or
                set_vector_attribute().
              - exceptions have the same semantics as defined
                for the get_attribute() method description.


  - attribute_is_removable
    Purpose:  check the attribute mode.
```

```
  Format:   attribute_is_removable (in  string key,
                                    out bool   test);
  Inputs:   key:                    attribute key
  InOuts:   -
  Outputs:  test:                   bool indicating success
  PreCond:  -
  PostCond: -
  Perms:    Query
  Throws:   NotImplemented
            DoesNotExist
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - This method returns TRUE if the attribute
              identified by the key exists, and can be
              removed by remove_attribute().
            - exceptions have the same semantics as defined
              for the get_attribute() method description.


- attribute_is_vector
  Purpose:  check the
  Format:   attribute_is_vector  (in  string key,
                                  out bool   test);
  Inputs:   key:                  attribute key
  InOuts:   -
  Outputs:  test                  bool indicating if
                                  attribute is scalar
                                  (false) or vector (true)
  PreCond:  -
  PostCond: -
  Perms:    Query
  Throws:   NotImplemented
            DoesNotExist
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - This method returns TRUE if the attribute
              identified by key is a vector attribute.
            - exceptions have the same semantics as defined
              for the get_attribute() method description.
```

3.8.4 Examples

Code Example

```
// c++ example:
saga::job::description jd;

std::list <std::string> hosts;
hosts.push_back ("host_1");
hosts.push_back ("host_2");

// vector attributes
jd.set_attribute ("ExecutionHosts", hosts);

// scalar attribute
jd.set_attribute ("MemoryUsage", "1024");

...
```

3.9 SAGA Monitoring Model

The ability to query grid entities about state is requested in several SAGA use cases. Also, the SAGA task model introduces numerous new use cases for state monitoring.

This package definition approaches the problem space of monitoring to unify the various usage patterns (see details and examples), and to transparently incorporate SAGA task monitoring. The paradigm is realized by introducing monitorable SAGA objects, which expose *metrics* to the application, representing values to be monitored. Metrics thus represent monitorable entities.

A closely related topic is Computational Steering, which is (for our purposes) not seen independently from Monitoring: in the SAGA approach, the steering mechanisms extend the monitoring mechanisms with the ability to push values back to the monitored entity, i.e. to introduce writable metrics (see `fire()`). Thus, metrics can also represent steerable entities.

3.9.1 Specification

```
package saga.monitoring
{
  // callbacks are used for asynchronous notification of
  // metric changes (events)
  interface callback
  {
    cb              (in  monitorable     mt,
                     in  metric          metric,
                     in  context         ctx,
                     out bool            keep);
  }


  // a metric represents an entity / value to be monitored.
  class metric : implements   saga::object
                 implements   saga::attributes
              // from object  saga::error_handler
  {
    CONSTRUCTOR        (in  string          name,
                        in  string          desc,
                        in  string          mode,
                        in  string          unit,
                        in  string          type,
```

```
                   in  string          value,
                   out metric          obj);
DESTRUCTOR        (in  metric          obj);

// callback handling
add_callback      (in  callback        cb,
                   out int             cookie);
remove_callback   (in  int             cookie);

// actively signal an event
fire              (void);


// Attributes:
//   name:  Name
//   desc:  name of the metric
//   mode:  ReadOnly
//   type:  String
//   value: -
//   notes: naming conventions as described below apply
//
//   name:  Description
//   desc:  description of the metric
//   mode:  ReadOnly
//   type:  String
//
//   name:  Mode
//   desc:  access mode of the metric
//   mode:  ReadOnly
//   type:  String
//   value: 'ReadOnly', 'ReadWrite' or 'Final'
//
//   name:  Unit
//   desc:  unit of the metric
//   mode:  ReadOnly
//   type:  String
//
//   name:  Type
//   desc:  value type of the metric
//   mode:  ReadOnly
//   type:  String
//   value: 'String', 'Int', 'Enum', 'Float', 'Bool',
//          'Time' or 'Trigger'
//
//   name:  Value
//   desc:  value of the metric
```

```
    //   mode:  depending on the mode attribute above
    //   type:  String
    //   value: -
    //   notes: see description of value formatting below
  }


  // SAGA objects which provide metrics and can thus be
  // monitored implement the monitorable interface
  interface monitorable
  {
    // introspection
    list_metrics       (out array<string>   names);
    get_metric         (in  string          name,
                        out metric          metric);

    // callback handling
    add_callback       (in  string          name,
                        in  callback        cb,
                        out int             cookie);
    remove_callback    (in  int             cookie);
  }


  // SAGA objects which can be steered by changing their
  // metrics implement the steerable interface
  interface steerable : implements monitorable
  {
    // metric handling
    add_metric         (in  metric          metric,
                        out bool            success);
    remove_metric      (in  string          name);
    fire_metric        (in  string          name);
  }
}
```

3.9.2 Specification Details

Interface `callback`

The callback interface is supposed to be implemented by custom, application level classes. Instances of these classes can then be passed to monitorable SAGA objects, in order to have their `cb` method invoked on changes of metrics upon these monitorables.

The callback classes can maintain state between initialization and successive invocations. The implementation MUST ensure that a callback is only called once at a time, so that no locking is necessary for the end user.

But also, the callback may remove conditions to be called again, i.e. shut down the metric, read more than one message, etc. Implementations MUST be able to handle this.

If an invoked callback returns true, it stays registered and can be invoked again on the next metric change. If it returns false, it is not invoked again.

A callback can throw an `AuthorizationFailed` exception if the passed context (i.e. the remote party) is not deemed trustworthy. In this case, the callback is not removed. The implementation MUST catch this exception, and interpret it as a decline of the operation which caused the callback.

For example, if a `saga::stream_server` instance invokes a callback on a Client-Connect metric, and the `cb` method raises an `AuthorizationFailed` exception, the created client stream must be closed.

As another example, if a job instance invokes a callback on a MemoryUsage metric, and the `cb` method raises an `AuthorizationFailed` exception, the previous value of the memory usage metric MUST be restored, and the declined value MUST NOT influence the memory high water mark. Essentially, the exception indicates that the new metric value was not trustworthy.

Callbacks are passed (e.g. added to a metric) by reference. If a callback instance is used with multiple metrics, the application must use appropriate locking mechanisms.

```
- cb
  Purpose:  asynchronous handler for metric changes
  Format:   cb                 (in  monitorable mt,
                                in  metric      metric,
                                in  context     ctx,
                                out bool        keep);
  Inputs:   mt:                 the saga monitorable object
                                which causes the callback
                                invocation
            metric:             the metric causing the
                                callback invocation
            ctx:                the context associated with
                                the callback causing entity
  InOuts:   -
  Outputs:  keep:               indicates if callback stays
```

```
                                registered
      PreCond:  - the passed context is authenticated.
      PostCond: - if 'keep' is returned as true, the callback
                  stays registered, and will be invoked again on
                  the next metric update.
                - if 'keep' is returned as false, the callback
                  gets unregistered, and will not be invoked
                  again on metric updates, unless it gets
                  re-added by the user.
      Perms:    -
      Throws:   NotImplemented
                AuthorizationFailed
      Notes:    - 'metric' is the metric the callback is
                  invoked on - that means that this metric
                  recently changed.  Note that this change is
                  semantically defined by the metric, e.g. the
                  string of the 'value' attribute of the metric
                  might have the same value in two subsequent
                  invocations of the callback.
                - 'mt' is the monitorable object the metric
                  'metric' belongs to.
                - the context 'ctx' is the context which allows
                  the callback to authorize the metric change.
                  If the cb method decides not to authorize this
                  particular invocation, it MUST throw an
                  'AuthorizationFailed' exception.
                - if no context is available, a context of type
                  'Unknown' is passed, with no attributes
                  attached.  Note that this can also indicate
                  that a non-authenticated party connected.
                - a callback can be added to a metric multiple
                  times.  A 'false' return value (no keep) will
                  remove only one registration, and keep the
                  others.
                - a callback can be added to multiple metrics at
                  the same time.  A false return (no keep) will
                  only remove the registration on the metric the
                  callback was invoked on.
                - the application must ensure appropriate locking
                  of callback instances which are used with multiple
                  metrics.
                - a callback added to exactly one metric exactly
                  once is guaranteed to be active at most once at
                  any given time.  That implies that the SAGA
                  implementation MUST queue pending requests
                  until a callback invocation is finished.
```

Class `metric`

The fundamental object introduced in this package is a `metric`. A metric represents an observable item, which can be readable, or read/writable. The availability of a readable observable corresponds to monitoring; the availability of a writable observable corresponds to steering. A metric is `Final` when its values cannot change anymore, (i.e. progress is `100%`, job state is `Done` etc).

The approach is severely limited by the use of SAGA attributes for the description of a metric, as these are only defined in terms of string-typed keys and values. An extension of the attribute definition by typed values will greatly improve the usability of this package, but will also challenge its semantic simplicity.

The metric MUST provide access to following attributes (examples given):

```
name:      short human readable name.
             - ex:  file.copy.progress

desc:      extensive human readable description
             - ex:  "This metric gives the state of
                     an ongoing file transfer as
                     percent completed."

mode:      "ReadOnly", "ReadWrite" or "Final"
             - ex:  "ReadWrite"

unit:      Unit of values
             - ex:  "percent (%)"
             - ex:  "Unit"

type:      "String", "Int", "Enum", "Float", "Bool",
           "Time", "Trigger"
             - ex:   "Float"

value:     value of the metric
             - ex:   "20.5"
```

The name of the metric must be unique, as it is used in several methods to identify the metric of interest. The use of a dot-delimited name space for metrics as in the example above is encouraged, as it greatly benefits the interactive handling of metrics. The first element of the name space SHOULD be the SAGA class the metric belongs to, the second element SHOULD be the operation the metric describes (if applicable, otherwise leave out), the third element SHOULD indicate the description of the metric (e.g. 'state' or 'progress' or 'temperature'). Illustrative examples for metric names are:

```
file.copy.progress
file.move.progress
file.size
job.state
drive.temperature  // a custom observable
```

The name, description, type and mode attributes are `ReadOnly` – so only unit and value can be changed by the application. All attributes are initialized in the metric constructor. The `mode`, `unit` and `value` attributes can be changed internally, i.e. by the SAGA implementation or lower layers. Such a change does cause the metric to *fire*. For example, a metric fires if its `mode` changes from `ReadWrite` to `Final`.

The `name` attribute MUST be interpreted case insensitive: An implementation MAY change that attribute to all-lowercase on metric creation.

If `fire()` is called on a metric, it returns immediately, but any callbacks registered on that metric are not invoked immediately. Instead, the remote entity which is represented by the metric gets invoked first, and only if it acknowledges the changes, the callbacks are invoked. A fire can thus fail in the sense that the remote entity declines the changes. It is good practice to have at least one callback registered on the metric before calling `fire()`, in order to confirm the operation.

The metric `type`s are the same as defined for attributes, and the metric `value`s are to be formatted as described for the respective attribute types. The only exception is a metric of type `Trigger` which has no value at all – an attempt to access the value of that metric MUST result in a `DoesNotExist` exception.

Metric definitions in the SAGA specification

The SAGA specification defines a number of metrics which MUST or CAN be supported, for various SAGA objects. An example of such a definition is (from the `saga::stream` object):

```
class stream ...
{
  ...

  // Metrics:
  //   name:  stream.read
  //   desc:  fires if a stream gets readable
  //   mode:  ReadOnly
  //   unit:  1
  //   type:  Trigger
  //   value: 1
  //
  //   ...
}
```

These specifications are NORMATIVE, even if described as comments in the SIDL specification! The specified metrics MUST be supported by an implementation, unless noted otherwise in the mode description, as:

```
    //   mode:  ReadOnly, optional
    //   mode:  ReadWrite, optional
```

If a metric MUST be supported, but the SAGA implementation cannot provide that metric, any operation on that metric MUST throw a `NotImplemented` exception, and the resulting error message MUST state `"Metric <name> not not available in this implementation"`.

Implementations MAY add custom metrics, which SHOULD be documented similarly. However, metrics CAN also be added at runtime – that is, for example, required for computational steering of custom applications.

Metric Lifetime

A metric can *appear* and *go away* during the lifetime of an object (again, computational steering provides the obvious use case for this). Any operation on a metric which got removed (*dead metric*) MUST throw an `IncorrectState` exception, with the exceptions described below. Existing class instances of a dead metric MUST stay valid, and expose the same lifetime as any other *live* *metric*. Attributes of a dead metric MUST be readable for the lifetime of the object. The `mode` attribute of such an instance MUST be changed to `Final` by the implementation. Callbacks cannot be registered to a `Final` metric, but can be unregistered. No other changes are allowed on a `Final` metric, neither by the user, nor by the SAGA implementation.

Client Side Authorization

A metric can get fired from a remote party - in fact, that will be the default situation for both monitoring and steering. In order to allow for client side authorization, callbacks get a context as second parameter. That context contains information to be used to authorize the remote party which caused the metric to fire, and the callback to be invoked. Thus, authorization is only available via the callback mechanism. The context information passed to the callback are assumed to be authenticated by the implementation. If no context information is available, a context of type `'Unknown'` is passed, which has no attributes attached.

A callback can evaluate the passed context, and throw an `AuthorizationFailed` exception if the context (i.e. the remote party) is not deemed trustworthy. See callback description above.

```
  - CONSTRUCTOR
    Purpose:  create the object
    Format:   CONSTRUCTOR        (in  string   name
                                  in  string   desc,
                                  in  string   mode,
                                  in  string   unit,
                                  in  string   type,
                                  in  string   value,
                                  out metric   obj);
    Inputs:   name:               name of the metric
              desc:               description of the metric
              mode:               mode of the metric
              unit:               unit of the metric value
              type:               type of the metric
              value:              initial value of the metric
    InOuts:   -
    Outputs:  obj:                the newly created object
    PreCond:  -
    PostCond: - callbacks can be registered on the metric.
    Perms:    -
```

```
  Throws:   NotImplemented
            BadParameter
            Timeout
            NoSuccess
  Notes:    - a metric is not attached to a session, but
              can be used in different sessions.
            - the string arguments given are used to
              initialize the attributes of the metric.
            - the constructor ensures that metrics are
              always initialized completely.  All changes to
              attributes later will always result in an
              equally valid metric.
            - incorrectly formatted 'value' parameter,
              invalid 'mode' and 'type' parameter, and empty
              required parameter (all but 'unit') will cause
              a 'BadParameter' exception.
            - a 'Timeout' or 'NoSuccess' exception indicates
              that the backend could not create that specific
              metric.


- DESTRUCTOR
  Purpose:  destroy the object
  Format:   DESTRUCTOR         (in  metric obj)
  Inputs:   obj:                the object to destroy
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: - all callbacks registered on the metric are
              unregistered.
  Perms:    -
  Throws:   -
  Notes:    - if a callback is active at the time of
              destruction, the destructor MUST block until
              that callback returns.  The callback is not
              activated anew during or after that block.


// manage callbacks on the metric
- add_callback
  Purpose:  add asynchronous notifier callback to watch
            metric changes
  Format:   add_callback       (in  callback cb,
                                out int      cookie);
  Inputs:   cb:                 callback class instance
  InOuts:   -
```

```
  Outputs:  cookie:             handle for this callback,
                                to be used for removal
  PreCond:  - the metric is not 'Final'.
  PostCond: - the callback is invoked on metric changes.
  Perms:    Read
  Throws:   NotImplemented
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - 'IncorrectState' is thrown if the metric is
              'Final'.
            - the 'callback' method on cb will be invoked on
              any change of the metric (not only when its
              value changes)
            - if the 'callback' method returns true, the
              callback is kept registered; if it returns
              false, the callback is called, and is
              un-registered after completion.  If the
              callback throws an exception, it stays
              registered.
            - the cb is passed by reference.
            - the returned cookie uniquely identifies the
              callback, and can be used to remove it.
            - A 'Timeout' or 'NoSuccess' exception is thrown
              if the implementation cannot invoke the
              callback on metric changes.
            - a backend MAY limit the ability to add
              callbacks - the method may hence cause an
              'AuthenticationFailed', 'AuthorizationFailed'
              or 'PermissionDenied' exception to be thrown.


- remove_callback
  Purpose:  remove a callback from a metric
  Format:   remove_callback    (in  int      cookie);
  Inputs:   cookie:             handle identifying the cb to
                                be removed
  InOuts:   -
  Outputs:  -
  PreCond:  - the callback identified by 'cookie' is
              registered for that metric.
  PostCond: - the callback identified by 'cookie' is not
              active, nor invoked ever again.
```

```
    Perms:    Read
    Throws:   NotImplemented
              BadParameter
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
              Timeout
              NoSuccess
    Notes:    - if a callback is active at the time of
                removal, the call MUST block until
                that callback returns.  The callback is not
                activated anew during or after that block.
              - if the callback was removed earlier, or
                was unregistered by returning false, this call
                does nothing.
              - the removal only affects the cb identified
                by 'cookie', even if the same callback was
                registered multiple times.
              - if the cookie was not created by adding a
                callback to this object instance, a
                'BadParameter' is thrown.
              - a 'Timeout' or 'NoSuccess' exception is thrown
                if the backend cannot guarantee that the
                callback gets successfully removed.
              - note that the backend MUST allow the removal of
                the callback, if it did allow its addition -
                hence, no authentication, authorization or
                permission faults are tom be expected.


  - fire
    Purpose:  push a new metric value to the backend
    Format:   fire               (void);
    Inputs:   -
    InOuts:   -
    Outputs:  -
    PreCond:  - the metric is not 'Final'.
              - the metric is 'ReadWrite'
    PostCond: - callbacks registered on the metric are
                invoked.
    Perms:    Write
    Throws:   NotImplemented
              IncorrectState
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
```

```
                  Timeout
                  NoSuccess
      Notes:      - 'IncorrectState' is thrown if the metric is
                    'Final'.
                  - 'PermissionDenied' is thrown if the metric is
                    not 'ReadWrite' -- That also holds for a once
                    writable metric which was flagged 'Final'.
                    To catch race conditions on this exceptions,
                    the application should try/catch the fire().
                  - it is not necessary to change the value of a
                    metric in order to fire it.
                  - 'set_attribute ("value", "...") on a metric
                    does NOT imply a fire.  Hence the value can be
                    changed multiple times, but unless fire() is
                    explicitly called, no consumer will notice.
                  - if the application invoking fire() has
                    callbacks registered on the metric, these
                    callbacks are invoked.
                  - 'AuthenticationFailed', 'AuthorizationFailed'
                    or 'PermissionDenied' may get thrown if the
                    current session is not allowed to fire this
                    metric.
                  - a 'Timeout' or 'NoSuccess' exception signals
                    that the implementation could not communicate
                    the new metric state to the backend.
```

Interface `monitorable`

The monitorable interface is implemented by those SAGA objects which can be monitored, i.e. which have one or more associated metrics. The interface allows introspection of these metrics, and allows to add callbacks to these metrics which get called if these metrics change.

Several methods of this interface reflect similar methods on the metric class – the additional string argument `name` identifies the metric these methods act upon. The semantics of these calls are identical to the specification above.

```
    // introspection
    - list_metrics
      Purpose:  list all metrics associated with the object
      Format:   list_metrics       (out array<string>   names);
      Inputs:   -
```

```
  InOuts:   -
  Outputs:  names:              array of names identifying
                                the metrics associated with
                                the object instance
  PreCond:  -
  PostCond: -
  Perms:    Query
  Throws:   NotImplemented
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - several SAGA objects are required to expose
              certain metrics (e.g. 'task.state').  However,
              in general that assumption cannot be made, as
              implementations might be unable to provide
              metrics.  In particular, listed metrics might
              actually be unavailable.
            - no order is implied on the returned array
            - the returned array is guaranteed to have no
              double entries (names are unique)
            - an 'AuthenticationFailed',
              'AuthorizationFailed' or 'PermissionDenied'
              exception indicates that the current session
              is not allowed to list the available metrics.
            - a 'Timeout' or 'NoSuccess' exception indicates
              that the backend was not able to list the
              available metrics.


- get_metric
  Purpose:  returns a metric instance, identified by name
  Format:   get_metric         (in  string  name,
                                out metric  metric);
  Inputs:   name:               name of the metric to be
                                returned
  InOuts:   -
  Outputs:  metric:             metric instance identified
                                by name
  PreCond:  -
  PostCond: -
  Perms:    Query
  Throws:   NotImplemented
            DoesNotExist
            PermissionDenied
```

```
              AuthorizationFailed
              AuthenticationFailed
              Timeout
              NoSuccess
    Notes:    - multiple calls of this method with the same
                value for name return multiple identical
                instances (copies) of the metric.
              - a 'DoesNotExist' exception indicates that the
                backend does not know the metric with the
                given name.
              - an 'AuthenticationFailed',
                'AuthorizationFailed' or 'PermissionDenied'
                exception indicates that the current session
                is not allowed to obtain the named metric.
              - a 'Timeout' or 'NoSuccess' exception indicates
                that the backend was not able to return the
                named metric.


  // callback handling
  - add_callback
    Purpose:  add a callback to the specified metric
    Format:   add_callback       (in  string      name,
                                  in  callback    cb,
                                  out int         cookie);
    Inputs:   name:               identifies the metric to
                                  which cb
                                  is to be added
              cb:                 reference to callback class
                                  instance to be registered
    InOuts:   -
    Outputs:  cookie:             handle for callback removal
    PreCond:  -
    PostCond: - the callback is registered on the metric.
    Perms:    Read on the metric.
    Throws:   NotImplemented
              DoesNotExist
              IncorrectState
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
              Timeout
              NoSuccess
              NoSuccess
    Notes:    - notes to the add_callback method of the metric
                class apply.
```

```
  - remove_callback
    Purpose:  remove a callback from the specified metric
    Format:   remove_callback    (in  string  name,
                                  in  int     cookie);
    Inputs:   name:               identifies the metric for
                                  which cb is to be removed
              cookie:             identifies the cb to be
                                  removed
    InOuts:   -
    Outputs:  -
    PreCond:  - the callback was registered on the metric.
    PostCond: -
    Perms:    Read on the metric.
    Throws:   NotImplemented
              BadParameter
              DoesNotExist
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
              Timeout
              NoSuccess
    Notes:    - notes to the remove_callback method of the
                metric class apply
```

Interface `steerable`

The steerable interface is implemented by saga objects which can be steered, i.e. which have writable metrics, and which might allow to add new metrics. Steerable objects also implement the monitorable interface.

The method `add_metric()` allows to implement steerable applications. In particular, the `saga::self` object is steerable, and allows to add metrics (see description of `saga::self` in the specification of the SAGA job management).

```
  // metric handling
  - add_metric
    Purpose:  add a metric instance to the application
              instance
    Format:   add_metric         (in  metric  metric,
                                  out bool    success);
```

```
  Inputs:   metric:            metric to be added
  InOuts:   -
  Outputs:  success:           indicates success
  PreCond:  -
  PostCond: - the metric can be accessed from this
              application, and possibly from other
              applications.
  Perms:    Write
  Throws:   NotImplemented
            AlreadyExists
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - a metric is uniquely identified by its name
              attribute - no two metrics with the same name
              can be added.
            - any callbacks already registered on the metric
              stay registered (the state of metric is not
              changed)
            - an object being steerable does not guarantee
              that a metric can in fact be added -- the
              returned boolean indicates if that particular
              metric could be added.
            - an 'AuthenticationFailed',
              'AuthorizationFailed' or 'PermissionDenied'
              exception indicates that the current session
              is not allowed to add metrics to the
              steerable.
            - a 'Timeout' or 'NoSuccess' exception indicates
              that the backend was not able to add the
              metric.
            - if a metric with the same name is already
              known for the object, an 'AlreadyExists'
              exception is thrown.
            - if the steerable instance does not support the
              addition of new metrics, i.e. if only the
              default metrics can be steered, an
              'IncorrectState' exception is thrown.


- remove_metric
  Purpose:  remove a metric instance
  Format:   remove_metric      (in  string  name);
```

```
  Inputs:   name:               identifies the metric to be
                                removed
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: - all callbacks registered on that metric are
              unregistered.
            - the metric is not available anymore.
  Perms:    Write
  Throws:   NotImplemented
            DoesNotExist
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - only previously added metrics can be removed;
              default metrics (saga defined or implementation
              specific) cannot be removed; attempts to do so
              raise a BadParameter exception.
            - an 'AuthenticationFailed',
              'AuthorizationFailed' or 'PermissionDenied'
              exception indicates that the current session
              is not allowed to remove the metrics from the
              steerable.
            - a 'Timeout' or 'NoSuccess' exception indicates
              that the backend was not able to remove the
              metric.
            - if a metric with that name is not known for
              the object, a 'DoesNotExist' exception is
              thrown.
            - if a steerable instance does not support the
              removal of some metric, e.g. if a metric
              needs to be always present, an
              'IncorrectState' exception is thrown.
              For example, the 'state' metric on a steerable
              job cannot be removed.


- fire_metric
  Purpose:  push a new metric value to the backend
  Format:   fire_metric        (int  string  name);
  Inputs:   name:               identifies the metric to be
                                fired
  InOuts:   -
```

```
Outputs:  -
PreCond:  -
PostCond: -
Perms:    Write
Throws:   NotImplemented
          DoesNotExist
          IncorrectState
          PermissionDenied
          AuthorizationFailed
          AuthenticationFailed
          Timeout
          NoSuccess
Notes:    - notes to the fire method of the metric
            class apply
          - fire can be called for metrics which have been
            added with add_metric(), and for predefined
            metrics
          - an 'AuthenticationFailed',
            'AuthorizationFailed' or 'PermissionDenied'
            exception indicates that the current session
            is not allowed to fire the metric.
          - a 'Timeout' or 'NoSuccess' exception indicates
            that the backend was not able to fire the
            metric.
          - if a metric with that name is not known for
            the object, a 'DoesNotExist' exception
            is thrown.
          - an attempt to fire a metric which is
            'ReadOnly' results in an 'IncorrectState'
            exception.
          - an attempt to fire a 'Final' metric results in
            an 'IncorrectState' exception.
```

3.9.3 Examples

Code Example

```
callback example: trace all job state changes:
----------------------------------------------

  // c++ example
  // callback definition
  class trace_cb : public saga::callback
  {
    public:
```

```
      bool cb (saga::monitorable mt,
               saga::metric      m,
               saga::context     c)
      {
        std::cout << "metric " << m.get_attribute ("name")
                  << " fired." << std::endl;
        return true; // stay registered
      }
  }

  // the application
  int main ()
  {
    ...

    // if the callback defined above is added to all known
    // metrics of all saga objects, a continuous trace of state
    // changes of these saga objects will be written to stdout
    trace_cb cb;

    saga::job j = ...

    j.add_callback ("state", cb);

    ...
  }


monitoring example: monitor a write task
----------------------------------------

  // c++ example for task state monitoring
  class write_metric_cb : public saga::callback
  {
    public:
      bool cb (saga::monitorable mt,
               saga::metric      m,
               saga::context     c)
      {
        saga::task t = saga::task (mt);

        std::cout << "bytes written: "
                  << m.get_attribute ("value")
                  << std::endl;
        std::cout << "task state:   "
                  << t.get_state ()
                  << std::endl;

        return true; // keep callback registered
      }
```

```
  };

  int main (int argc, char** argv)
  {
    ssize_t      len = 0;
    saga::buffer buf ("Hello SAGA\n");
    saga::url    url (argv[1]);

    saga::file   f (url);
    saga::task   t = f.write <saga::task::Async> (buf, &len);

    // assume that a file write task has a 'progress' metric
    // indicating the number of bytes already written.  In
    // general, the list of metric names has to be searched
    // for an interesting metric, unless it is a default
    // metric as specified in the SAGA spec.

    // create and add the callback instance
    write_metric_callback cb;
    t.add_callback ("file.write.progress", cb);

    // wait until task is done, and give cb chance to get
    // called a couple of times
    t.wait ();
  }


steering example: steer a remote job
------------------------------------

  // c++ example
  class observer_cb : public saga::metric::callback
  {
    public:
      bool cb (saga::monitorable mt,
               saga::metric      m,
               saga::context     c)
      {
         std::cout << "the new value is"
                   << atoi ( m.get_attribute ("value") )
                   << std::endl;

         return true; // keep callback registered
      }
  };

  // the steering application
  int main (int argc, char** argv)
  {
    saga::job_service js;
```

```

    saga::job j = js.run ("remote.host.net",
                          "my_remote_application");

    // Assume that job has a 'param_1' metric representing
    // an integer parameter for the remote application.
    // In general, one has to list the metrics available on
    // job, with list_metric, and search for an interesting
    // metric.  However, we assume here that we know that
    // metric exists.  So we get that metric, and add an
    // observer callback to it - that causes the asynchronous
    // printout of any changes to the value of that metric.

    // then we get the metric for active steering
    saga::metric m = j.get_metric ("param_1");

    observer_cb cb;
    m.add_callback (cb);

    for ( int i = 0; i < 10; i++ )
    {
      // if param_1 is ReadOnly, set_value() would throw
      // 'ReadOnly' - it would not be usable for
      // steering then.
      m.set_attribute ("value", std::string (i));

      // push the pending change out to the receiver
      m.fire ();

      // callback should get called NOW + 2*latency
      // That means fire REQUESTS the value change, but only
      // the remote job can CHANGE the value - that change
      // needs then reporting back to us.

      // give steered application some time to react
      sleep (1);
    }
  }



steering example: BE a steerable job
------------------------------------

  // c++ example
  //
  // the example shows a job which
  //  - creates a metric to expose a Float steerable
  //    parameter
  //  - on each change of that parameter computes a
```

```
//    new isosurface
//
// callback - on any change of the metric value, e.g. due to
// steering from a remote GUI application, a new iso surface
// is computed
class my_cb : public saga::callback
{
  public:
    // the callback gets called on any steering events, i.e.
    // if some other application steers 'me'.
    bool cb (saga::monitorable mt,
             saga::metric      m,
             saga::context     c)
    {
      // get the new iso-value
      float iso = atof (m.get_attribute ("value"));

      // compute an isosurface with that iso-value
      compute_iso (iso);

      // keep this callback alive, and get called again on
      // the next metric event.
       return true;
    }
 }

int main ()
{
  // create a metric for the iso-value of an isosurfacer
  saga::metric m ("application.isosurfacer.isovalue",
                  "iso-value of the isosurfacer",
                  "ReadWrite",   // is steerable
                  "",            // no unit
                  "Float",       // data type
                  "1.0");        // initial value

  // add the callback which reacts on changes of the
  // metric's value (returned cookie is ignored)
  my_cb cb;
  m.add_callback (cb);

  // get job handle for myself
  saga::self self;

  // add metric to myself
  self.add_metric (m);

  /*
  // the callback could also have been added with:
  self.add_callback ("application.isosurfacer.isovalue", cb);
```

```
    */

    // now others can 'see' the metric, e.g. via
    // job.list_metrics ();

    // compute isosurfaces for the next 10 minutes -
    // the real work is done in the callback, on incoming
    // requests (i.e. steering events).
    sleep (600);

    // on object (self) destruction, metrics and callback
    // objects are destroyed as well
    return (0);
  }



monitoring example: callback for stream connects
------------------------------------------------

  // c++ example
  //
  // callback class which accepts an incoming client
  // connection, and then un-registers itself.  So, it
  // accepts exactly one client, and needs to be re-registered
  // to accept another client.
  class my_cb : public saga::callback
  {
    private:
      // we keep a stream server and a single client stream
      saga::stream_server ss_;
      saga::stream        s_;


    public:
      // constructor initializes these (note that the
      // client stream should not be connected at this
      // point)
      my_cb (saga::stream_server ss,
             saga::stream        s )
      {
        ss_ = ss;
        s_  = s;
      }


      // the callback gets called on any incoming client
      // connection
      bool cb (saga::monitorable mt,
               saga::metric      m,
```

```
                saga::context     c)
        {
          // the stream server got an event triggered, and
          // should be able to create a client socket now.
          s_ = ss_.wait ();

          if ( s_.state == saga::stream::Open )
          {
            // have a client stream, we are done
            // don't call this cb again!
            return (true);
          }

          // no valid client stream obtained: keep this
          // callback alive, and get called again on the
          // next event on ss_
          return true;
        }
      }

      int main ()
      {
        // create a stream server, and an un-connected
        // stream
        saga::stream_server ss;
        saga::stream        s;

        // give both to our callback class, and register that
        // callback with the 'client_connect' metric of the
        // server.  That causes the callback to be invoked on
        // every change of that metric, i.e. on every event
        // that changes that metric, i.e. on every client
        // connect attempt.
        my_cb cb (ss, s);
        ss.add_callback ("client_connect", cb);

        // now we serve incoming clients forever
        while ( true )
        {
          // check if a new client is connected
          // the stream state would then be Open
          if ( s.state == saga::stream::Open )
          {
            // a client got connected!
            // handle open socket
            saga::buffer buf ("You say hello, "
                              "I say good bye!\r\n", 33);
            s.write (buf);

            // and close stream
```

```
          s.close ();

          // the stream is not Open anymore.  We re-add the
          // callback, and hence wait for the next client
          // to connect.
          ss.add_callback ("client_connect", cb);
        }
        else
        {
          // no client yet, idle, or do something useful
          sleep (1);
        }
      }

      // we should never get here
      return (-1);
    }
```

3.10 SAGA Task Model

Operations performed in highly heterogeneous distributed environments may take a long time to complete, and it is thus desirable to have the ability to perform operations in an asynchronous manner. The SAGA task model as described here, provides this ability to all other SAGA classes. As such, the package is orthogonal to the rest of the SAGA API.

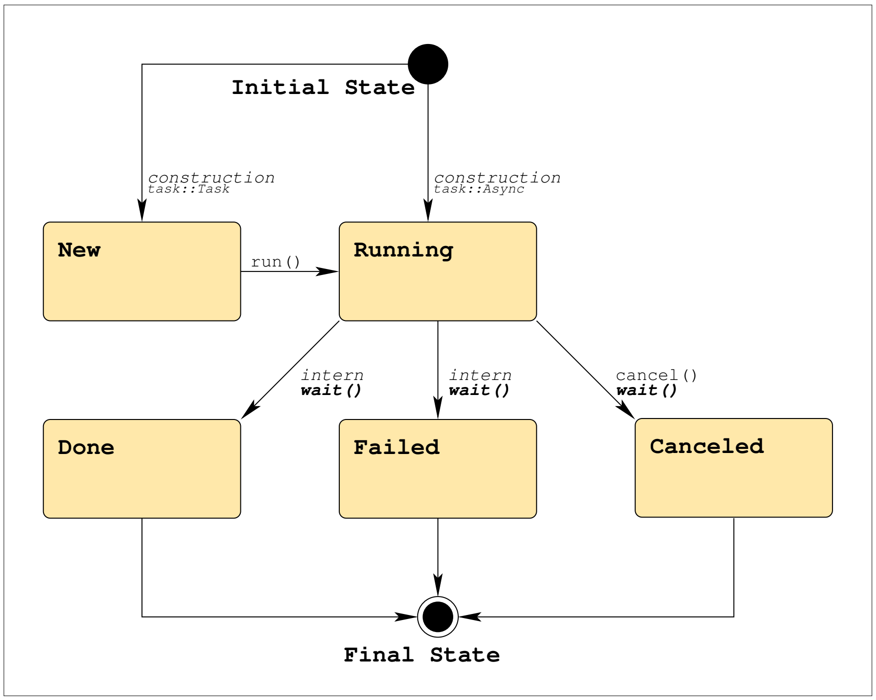

Figure 3: **The SAGA task state model (See figure 1 for a legend).**

In order to understand the SAGA task model it is *not* sufficient to read the specification of the `saga::task` and `saga::task_container` classes below, but it is also imperative to understand how task instances get created. This is actually not covered in the SIDL specification sections in this document, but documented in prose below, with references to Figure 3. Note that the task state model is closely modeled after the BES state model [12], which is in particular relevant to the (similar) job state model as described in Section 4.1.

Tasks versus Jobs

In SAGA, tasks should not be confused with jobs! Jobs represent remotely running applications/executables, which are usually managed by a job manager. Tasks on the other hand represent asynchronous operations. Thus, any asynchronous method call in SAGA results in a task.

Tasks and jobs have, however, several commonalities, the most important one is *state*: both can be newly created (in `New` state), can be currently making progress (in `Running` state), or can be finished in some way (in `Done`, `Failed` or `Canceled` state). Additionally, jobs can be suspended and resumed (they have a `Suspended` state).

Mostly for this reason, and to simplify the management of both tasks and jobs in SAGA, the `saga::job` class inherits the `saga::task` class.

Tasks versus Threads

Tasks and threads are another potential pair to confuse: in many APIs and programming languages, tasks and asynchronous operations are implemented by threading. In SAGA, however, tasks have a semantically richer meaning. In particular, threads always imply that the state management for the asynchronous operation lies within the application hosting the thread. SAGA tasks, however, imply no such restriction.

For example, a SAGA task to copy a remote file could be implemented by using the Globus Reliable File Transfer Service (RFT, [1]): the asynchronous method invocation in SAGA would then start the remote operation on the RFT service. All management of the operation progress is in the service - no threading at all is required on the application side. Even more: the application could finish, and after restart could reconnect to the RFT service, and recreate the task, as the complete state is still available on the RFT service - that is basically impossible with threads. Well, it is also not possible in SAGA right now, but for very different reasons, and it is expected that future versions and extensions of SAGA add this and other options to the notion of tasks.

Implementors of SAGA are warned **not** to rely solely on threading while implementing `saga::task`, but to exploit middleware support for server side asynchronous operations wherever possible.

Task Model Description

The SAGA task model operates as follows:

- A SAGA object is said to *implement the SAGA task model* if, (a) it inherits the `saga::async` interface, and (b) all methods on that object are implemented in three different versions, which are called *synchronous*, *asynchronous*, and *task* version.

- The *synchronous* version of a SAGA call corresponds to the normal method call specified in the SAGA specification. The first `out` parameter specified (if any) is used as return value.

- The *asynchronous* version of a SAGA call has the same signature, but returns a `saga::task` instance. That returned task is in `Running` state and represents the asynchronous operation: it can be queried for state, and can be canceled.

- The *task* version of the SAGA call is very similar to the asynchronous version; the only difference is that the returned task instance is in the `New` state, and must be `run()` to get into the `Running` state.

- For symmetry, a language binding MAY add a second flavour of the synchronous call, which has the same signature as the asynchronous and task version, but the returned task is in a final state (i.e., `run()` *and* `wait()` have been called on that task before returning). [2]

- The first `out` parameter, which is the return value in the synchronous method version, is, in the task and asynchronous version, accessed by calling `task.get_result <return_type> (void);`, which is a templetized member method. That call implies a call to `wait()`. For language bindings where templetized member functions are not available, a language specific mechanism MUST be found, which MAY use type casting.

- Other `out` and all `inout` parameter for asynchronous operations are passed by reference to the initial function call, and MUST NOT be accessed before the corresponding task enters the `Done` state. In all other states, no assumption can be made about the contents of these parameters. They are guaranteed to not be accessed or changed by the implementation when the task enters any final state.

- `in` parameters are passed by value, and are assumed to be constant. They can be accessed and changed again as soon as the task instance is created.

- The original object instance, from which the task was created, can be retrieved from a task by calling `get_object <object_type> (void);`, again a templetized member method, on the task. The same comments as above apply to that templetized method.

[2] Note that state transitions for this type of method call are not shown in the state diagram – the diagram would essentially have 'Done' as an initial and final state.

Asynchronous Object Construction

The task model as described above focuses on asynchronous invocation of object methods. It does not explicitly cover asynchronous object construction or destruction though. That is important, however, as many constructors, such as for example for `saga::file`, imply a remote operation during construction or destruction (here `open()`/`close()`).

How asynchronous constructors and destructors are provided is up to the specific language bindings. Procedural bindings, such as expected for C, SHOULD integrate asynchronous versions for the respective method calls to keep these mechanisms in sync with the task model presented above. Object oriented language bindings MAY either introduce an asynchronous factory pattern, or introduce delayed construction/destruction by explicitly using asynchronous `init()` and `close()`, or MAY introduce some other mechanism which most natively allows to asynchronously create SAGA objects.

Tasks and Error Handling

Errors arising from synchronous method invocations on SAGA objects are, in general, flagged by exceptions, and can be inspected using the `error_handler` interface that all SAGA objects implement. For asynchronous operations, this mechanism would break, as the `error_handler` interface allows in general only inspection of the *last* method call – but the order of execution is undefined for asynchronous operations. Additionally, exceptions from asynchronous operations would be difficult to catch, as they would presumably be thrown outside of an exception protection block.

For this reason, errors on asynchronous operations (i.e. tasks) are handled as follows:

Error Handler: The `saga::task` class implements the `saga::error_handler` interface, which allows inspection of an error thrown by an asynchronous operation. Errors MUST NOT be reported unless the task enters a final state.

Exceptions: The task instance MUST catch all SAGA exceptions and, if possible, all other exceptions thrown by the asynchronous operation. If an exception is caught by the task instance, the task state MUST be changed to `Failed` immediately. Such exceptions are to be re-thrown by the task when the `rethrow()` method is called.

This specification assumes that tasks are, in general, created and maintained in the API implementation, and not in the backend. However, for those cases where task states are maintained in the middleware backend, several methods on `tasks` and `task_containers` MAY throw a `Timeout` or `NoSuccess` exception, if that backend is not available – these exceptions can be directly delivered to the application. It is, however, not allowed to throw an `AuthorizationFailed`, `AuthenticationFailed` or `PermissionDenied` exception, as this specification assumes that the creator of the task can always inspect and control that task – these exceptions MUST be caught, and MUST be made available via `rethrow()`. Later versions of this API MAY change that, for example when they introduce persistent tasks which can survive the lifetime of a SAGA application.

3.10.1 Example Rendering in C++

Below is an example of how the SAGA task model might be rendered in C++ (this example is not normative). Note that template-tags are used here to distinguish the three task-returning method calls.

Code Example

```
// c++ example

// SAGA specification:
//  read        (inout array<byte>            buffer,
//               in    int                    len_in = -1,
//               out   int                    len_out);

// create a saga file
saga::file f (url);

// synchronous version
ssize_t len_out = f.read (size_t   len_in,
                          char   * buffer);


// alternative synchronous version
saga::task t1   = f.read <saga::task::Sync>
                         (size_t    len_in,
                          char    * buffer);

// asynchronous version
saga::task t2   = f.read <saga::task::ASync>
                         (size_t    len_in,
                          char    * buffer);

// task version
saga::task t3   = f.read <saga::task::Task>
                         (size_t    len_in,
                          char    * buffer);

```

```
// t1 is in Done or Failed state
// t2 is in Running state
// t3 is in New state

// get results
ssize_t len_out_1 = t1.get_result <ssize_t> ();
ssize_t len_out_2 = t2.get_result <ssize_t> ();
ssize_t len_out_3 = t3.get_result <ssize_t> ();

// all tasks are in a final state now,
// as get_result() implies a wait().

// obtain the original file object, three
// times the same actually
saga::file f1 = t1.get_object <saga::file> ();
saga::file f2 = t2.get_object <saga::file> ();
saga::file f3 = t3.get_object <saga::file> ();
```

A C language binding of this package might choose to use flags to distinguish between these calls; equivalently the C binding might use different method names, for it is up to the language bindings to define the mechanism that is native – or as close as possible – to the language to distinguish these calls.

For additional notes on resource management and task lifetime, see the introduction Section 2.5.3 of this document.

3.10.2 Specification

```
package saga.task
{
  enum state
  {
    New       =  1,
    Running   =  2,
    Done      =  3,
    Canceled  =  4,
    Failed    =  5
  }


  enum wait_mode
  {
    All       =  0,
```

```
    Any       =  1
  }


  interface async
  {
    // this interface is empty on purpose, and is used only
    // for tagging of SAGA classes which implement the SAGA
    // task model.
  }


  class task : implements   saga::object
               implements   saga::monitorable
            // from object  saga::error_handler
  {
    // no constructor
    DESTRUCTOR       (in  task            obj);

    // state management
    run              (void);
    cancel           (in  float           timeout =  0.0);
    wait             (in  float           timeout = -1.0,
                      out boolean         finished);

    // inspection
    get_state        (out state           state);
    get_result <type> (out type           result);
    get_object <type> (out type           object);

    // error handling
    rethrow          (void);

    // Metric:
    //   name:  task.state
    //   desc:  fires on task state change, and
    //          has the literal value of the task
    //          state enum.
    //   mode:  ReadOnly
    //   unit:  1
    //   type:  Enum
    //   value: 0
  }


  class task_container : implements   saga::object
```

```
                        implements   saga::monitorable
                     // from object  saga::error_handler
  {
    CONSTRUCTOR      (out task_container  obj);
    DESTRUCTOR       (in  task_container  obj);

    // task management
    add               (in  task            t);
    remove            (in  task            t);

    // state management
    run               (void);
    cancel            (in  float           timeout =  0.0);
    wait              (in  wait_mode       mode    =  All,
                       in  float           timeout = -1.0,
                       out task            finished);

    // inspection
    size              (out int             n);
    get_tasks         (out array<task>     tasks);
    get_states        (out array<state>    states);

    // Metric:
    //   name:  task_container.state
    //   desc:  fires on state changes of any task in
    //          the container, and has the value of that
    //          task's object id.
    //   mode:  ReadOnly
    //   unit:  1
    //   type:  String
    //   value: -
  }
}
```

3.10.3 Specification Details

Enum `state`

A task can be in one of several possible states (see Fig. 3):

`New`

This state identifies a newly constructed task instance which has not yet run. This state corresponds to the BES state 'Pending'. This state is initial.

`Running`

The `run()` method has been invoked on the task, either explicitly or implicitly. This state corresponds to the BES state 'Running'. This state is initial.

`Done`

The synchronous or asynchronous operation has finished successfully. It corresponds to the BES state 'Finished'. This state is final.

`Canceled`

The asynchronous operation has been canceled, i.e. `cancel()` has been called on the task instance. It corresponds to the BES state 'Canceled'. This state is final.

`Failed`

The synchronous or asynchronous operation has finished unsuccessfully. It corresponds to the BES state 'Failed'. This state is final.

Enum `wait_mode`

The `wait_mode` enum specifies the condition on which a `wait()` operation on a `saga::task_container` returns:

`All`

`wait()` returns if all tasks in the container reached a final state.

`Any`

`wait()` returns if one or more tasks in the container reached a final state.

Class `task`

Objects of this class represent asynchronous API calls. They are only created by invoking a method on a SAGA object which returns a task object (with `saga::task::ASync` or `saga::task::Task`). But as `saga::job` instances inherit from the task class, jobs are also effectively created as tasks.

If a task gets created, it will share the state of the object it was created from. For more information on state sharing, see Section 2.5.3).

Note that no CONSTRUCTOR is available, as tasks are only created through asynchronous method calls.

```
- DESTRUCTOR
  Purpose:  destroy the object
  Format:   DESTRUCTOR          (in  task obj)
  Inputs:   obj:                 the object to destroy
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: - state is no longer shared with the object
              the task was created from.
            - the task instance is 'Canceled' prior to
              resource deallocation.
  Perms:    -
  Throws:   -
  Notes:    - if the instance was not in a final state
              before, the destructor performs a cancel()
              on the instance, and all notes to cancel()
              apply.


State Management
----------------

- run
  Purpose:  Start the asynchronous operation.
  Format:   run (void);
  Inputs:   -
  InOuts:   -
  Outputs:  -
  PreCond:  - task is in 'New' state.
  PostCond: - task left the 'New' state.
  Perms:    - appropriate permissions for the method
              represented by the task
  Throws:   NotImplemented
            IncorrectState
            Timeout
            NoSuccess
  Notes:    - run can only be called on a task in 'New'
              state.  All other states will cause the
              'IncorrectState' exception to be thrown.
            - a 'Timeout' or 'NoSuccess' exception indicates
              that the backend was not able to start the
```

```
              task.


   - wait
     Purpose:  Wait for the task to finish.
     Format:   wait                 (in  float   timeout,
                                     out boolean done);
     Inputs:   timeout:              seconds to wait
     InOuts:   -
     Outputs:  done:                 indicating if the task
                                     is done running
     PreCond:  - task is not in 'New' state.
     PostCond: - if no timeout occurs, task is in a final
                 state.
     Perms:    -
     Throws:   NotImplemented
               IncorrectState
               Timeout
               NoSuccess
     Notes:    - wait returns success (true) as soon as the
                 task enters a final state
               - if the task is already in a final state, the
                 call returns success (true) immediately.
               - if the task is in 'New' state, an
                 'IncorrectState' exception is thrown.
               - wait returns no success (false) if the task
                 is, even after timeout, not in a final state.
               - a 'Timeout' or 'NoSuccess' exception indicates
                 that the backend was not able to wait for the
                 task.  Note that a 'Timeout' exception does
                 not indicate that the task is not in a final
                 state after the given wait period - that
                 causes an unsuccessful (false) return value.
               - for timeout semantics, see Section 2.


   - cancel
     Purpose:  Cancel the asynchronous operation.
     Format:   cancel               (in  float  timeout = 0.0);
     Inputs:   timeout:              time for freeing resources
     InOuts:   -
     Outputs:  -
     PreCond:  - task is in 'Running' state.
     PostCond: - task is in 'Canceled' state.
     Perms:    -
     Throws:   NotImplemented
```

```
              IncorrectState
              Timeout
              NoSuccess
    Notes:    - for resource deallocation semantics, see
                Section 2.
              - if cancel() fails to cancel the task
                immediately, and tries to continue to cancel
                the task in the background, the task state
                remains 'Running' until the cancel operation
                succeeded.  The state then changes to
                'Canceled'.
              - if the task is in a final state, the call has
                no effect, and, in particular, does NOT change
                the state from 'Done' to 'Canceled', or from
                'Failed' to 'Canceled'.  This is to
                avoid race conditions.
              - if the task is in 'New' state, an
                'IncorrectState' exception is thrown.
              - a 'NoSuccess' exception indicates
                that the backend was not able to initiate the
                cancellation for the task.
              - for timeout semantics, see Section 2.


  Inspection
  ----------

  - get_state
    Purpose:  Get the state of the task.
    Format:   get_state            (out state state);
    Inputs:   -
    InOuts:   -
    Outputs:  state:                state of the task.
    PreCond:  -
    PostCond: -
    Perms:    -
    Throws:   NotImplemented
              Timeout
              NoSuccess
    Notes:    - a 'Timeout' or 'NoSuccess' exception indicates
                that the backend was not able to retrieve the
                task state.


  - get_result
    Purpose:  Get the result of the async operation
```

```
  Format:   get_result <type>    (out type result);
  Inputs:   -
  InOuts:   -
  Outputs:  result:               return value of async
                                  method
  PreCond:  - task is not in New, Failed or Canceled state.
  PostCond: - task is in a final state.
  Perms:    -
  Throws:   NotImplemented
            IncorrectURL
            BadParameter
            AlreadyExists
            DoesNotExist
            IncorrectState
            IncorrectType
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - get_result implies a wait() - all notes to
              wait apply.
            - if the task is in 'Failed' state after wait(), a
              rethrow() is called.  That is why all possible
              exceptions can be thrown by get_result().
            - an IncorrectType exception is thrown when the
              'type' specifier does not match the return type
              of the operation represented by the task
            - the method returns the type and value which
              would be returned by the synchronous version of
              the respective function call.


- get_object
  Purpose:  Get the object from which this task was created
  Format:   get_object <type>    (out type object);
  Inputs:   -
  InOuts:   -
  Outputs:  object:               object this task was
                                  created from
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   NotImplemented
            Timeout
            NoSuccess
```

```
    Notes:    - the method returns a shallow copy of the
                object this task was created from.


  - rethrow
    Purpose:  re-throw any exception a failed task caught.
    Format:   rethrow (void);
    Inputs:   -
    InOuts:   -
    Outputs:  -
    PreCond:  -
    PostCond: -
    Perms:    -
    Throws:   NotImplemented
              IncorrectURL
              BadParameter
              AlreadyExists
              DoesNotExist
              IncorrectState
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
              Timeout
              NoSuccess
    Notes:    - that method does nothing unless the task is in
                'Failed' state, and also MUST NOT throw
                'IncorrectState' if the task is in any other
                state.
              - if in 'Failed' state, the method MUST raise an
                exception which indicates the reason why that
                task entered the 'Failed' state (i.e. it throws
                the exception which caused it to enter the
                'Failed' state.
              - language bindings for languages with no
                support for exceptions MUST change the state
                of the object from which the task was created
                so that a subsequent call to has_error() on
                that object returns true.  A subsequent call to
                get_error() must then return the respective
                exception.
              - rethrow can be called multiple times, always
                throwing the same exception.
```

Class `task_container`

Managing a large number of tasks can be tedious. The `task_container` class is designed to help in these situations, and to effectively handle a large number of asynchronous operations.

For example, when an application uses many tasks, it would be inefficient to invoke the `wait()` method on each of them individually. The `task_container` class provides (amongst other operations) a mechanism to wait for a set of tasks.

Language bindings CAN specify the `task_container` to be, or to inherit from, a native container type, if that allows for the same semantics as described below, and if that helps to 'naturalize' the SAGA Look & Feel for that language.

```
  - CONSTRUCTOR
    Purpose:  create a task_container
    Format:   CONSTRUCTOR          (out task_container tc);
    Inputs:   -
    InOuts:   -
    Outputs:  tc:                   newly created container
    PreCond:  -
    PostCond: -
    Perms:    -
    Throws:   NotImplemented
              Timeout
              NoSuccess
    Notes:    - a 'Timeout' or 'NoSuccess' exception indicates
                that the backend was not able to create a task
                container.


  - DESTRUCTOR
    Purpose:  destroy a task_container
    Format:   DESTRUCTOR           (in task_container tc);
    Inputs:   tc:                   container to destroy
    InOuts:   -
    Outputs:  -
    PreCond:  -
    PostCond: -
    Perms:    -
    Throws:   -
    Notes:    - tasks in the task_container during its
                destruction are not affected by its
                destruction, and, in particular, are not
```

```
              canceled.


   Task Management
   ---------------

   - add
     Purpose:  Add a task to a task_container.
     Format:   add                  (in  task task);
     Inputs:   task:                 task to add to the
                                     task_container
     InOuts:   -
     Outputs:  -
     PreCond:  -
     PostCond: - the task is managed by the task container.
     Perms:    -
     Throws:   NotImplemented
               Timeout
               NoSuccess
     Notes:    - a task can be added only once.  Any attempt
                 to add a task to the container which already
                 is in the container is silently ignored.
               - a 'Timeout' or 'NoSuccess' exception indicates
                 that the backend was not able to add the task
                 to the container.


   - remove
     Purpose:  Remove a task from a task_container.
     Format:   remove               (in  task task);
     Inputs:   task:                 the task to be removed
     InOuts:   -
     Outputs:  -
     PreCond:  - the task is managed by the task container.
     PostCond: - the task is not managed by the task container.
     Perms:    -
     Throws:   NotImplemented
               DoesNotExist
               Timeout
               NoSuccess
     Notes:    - if a task was added more than once, it can be
                 removed only once - see notes to add().
               - if the task is not in the task_container, a
                 'DoesNotExist' exception is thrown.
               - a 'Timeout' or 'NoSuccess' exception indicates
                 that the backend was not able to remove the
```

```
               task from the container.


   State Management
   ----------------

   - run
     Purpose:  Start all asynchronous operations in the
               container.
     Format:   run (void);
     Inputs:   -
     InOuts:   -
     Outputs:  -
     PreCond:  - all tasks in the container are in 'New' state.
     PostCond: - all tasks in the container are in 'Running'
                 state.
     Perms:    - see permissions on task::run()
     Throws:   NotImplemented
               IncorrectState
               DoesNotExist
               Timeout
               NoSuccess
     Notes:    - run() MUST cause an 'IncorrectState' exception
                 if any of the tasks in the container causes
                 that exception on run().
               - a 'Timeout' or 'NoSuccess' exception indicates
                 that the backend was not able to run one or
                 more tasks in the container.
               - if the task_container is empty, an
                 'DoesNotExist' exception is thrown.
               - As the order of execution of the tasks is
                 undefined, no assumption on the individual
                 task states can be made after any
                 exception gets thrown.


   - wait
     Purpose:  Wait for one or more of the tasks to finish.
     Format:   wait                 (in  wait_mode mode = All,
                                     in  float  timeout = -1.0,
                                     out task   done);
     Inputs:   mode:                 wait for All or Any task
               timeout:              seconds to wait
     InOuts:   -
     Outputs:  done:                 finished task
     PreCond:  -
```

```
  PostCond: - if no timeout occurs, All/Any tasks in the
              container are in a final state.
  Perms:    -
  Throws:   NotImplemented
            IncorrectState
            DoesNotExist
            Timeout
            NoSuccess
  Notes:    - if mode is 'All', the wait call returns only
              if all tasks in the container are finished,
              or on timeout, whichever occurs first.
              The output task is then any of the finished
              tasks.
            - if mode is 'Any', the wait call returns on the
              first task which would return on task::wait in
              that timeout period, and returns that task.
            - the default wait mode is 'All' (0).
            - the returned task is removed from the
              container, which allows constructs like
                while ( tc.size () )
                {
                   saga::task t = tc.wait (saga::task::Any) )
                   ...
                }
            - wait() MAY cause an 'IncorrectState' exception
              if any of the tasks in the container causes
              that exception on wait().
            - if the task_container is empty, an
              'DoesNotExist' exception is thrown.
            - a 'Timeout' or 'NoSuccess' exception indicates
              that the backend was not able to wait for one
              or more tasks in the container.
            - As the order of execution of the tasks is
              undefined, no assumption on the individual
              task states can be made after any
              exception gets thrown.
            - for timeout semantics, see Section 2.


- cancel
  Purpose:  Cancel all the asynchronous operations in the
            container.
  Format:   cancel              (in  float  timeout = 0.0);
  Inputs:   timeout:             time for freeing resources
  InOuts:   -
  Outputs:  -
```

```
    PreCond:  -
    PostCond: - if no timeout occurs, all tasks in the
                container are in 'Canceled' state.
    Perms:    -
    Throws:   NotImplemented
              IncorrectState
              DoesNotExist
              Timeout
              NoSuccess
    Notes:    - see semantics of task cancel.
              - cancel() MUST cause an 'IncorrectState'
                exception if any of the tasks in the container
                causes that exception on cancel().
              - a 'Timeout' or 'NoSuccess' exception indicates
                that the backend was not able to run one or
                more tasks in the container.
              - if the task_container is empty, an
                'DoesNotExist' exception is thrown.
              - As the order of execution of the tasks is
                undefined, no assumption on the individual
                task states can be made after any
                exception gets thrown.


  Inspection
  ----------

  - size
    Purpose:  return the number of tasks in the task
              task_container.
    Format:   size                 (out int  n);
    Inputs:   -
    InOuts:   -
    Outputs:  n:                    number of tasks in
                                    task_container
    PreCond:  -
    PostCond: -
    Perms:    -
    Throws:   NotImplemented
              Timeout
              NoSuccess
    Notes:    - a 'Timeout' or 'NoSuccess' exception indicates
                that the backend was not able to list the
                tasks in the container.
```

```
- list_tasks
  Purpose:  List the tasks in the task_container.
  Format:   list_tasks           (out array<task>   tasks);
  Inputs:   -
  InOuts:   -
  Outputs:  tasks:                array of all tasks in
                                  the task_container
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   NotImplemented
            Timeout
            NoSuccess
  Notes:    - a 'Timeout' or 'NoSuccess' exception indicates
              that the backend was not able to list the
              tasks in the container.


- get_task
  Purpose:  Get a single task from the task_container.
  Format:   get_task             (in  string   id,
                                  out task     t);
  Inputs:   id:                   the object id identifying
                                  the task to return
  InOuts:   -
  Outputs:  t:                    the task identified by
                                  id
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   NotImplemented
            DoesNotExist
            Timeout
            NoSuccess
  Notes:    - the returned task is NOT removed from the
              task_container.
            - if the id specifies a task which is not in
              the container, a 'DoesNotExist' exception is
              thrown.
            - a 'Timeout' or 'NoSuccess' exception indicates
              that the backend was not able to list the
              tasks in the container.


- get_tasks
  Purpose:  Get the tasks in the task_container.
```

```
  Format:   get_tasks           (out array<task>   tasks);
  Inputs:   -
  InOuts:   -
  Outputs:  tasks:               array of tasks in
                                 task_container
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   NotImplemented
            Timeout
            NoSuccess
  Notes:    - the returned tasks are NOT removed from the
              task_container.
            - if the task_container is empty, an
              empty list is returned.
            - a 'Timeout' or 'NoSuccess' exception indicates
              that the backend was not able to list the
              tasks in the container.


- get_states
  Purpose:  Get the states of all tasks in the
            task_container.
  Format:   get_states          (out array<state>   states);
  Inputs:   -
  InOuts:   -
  Outputs:  states:              array of states for
                                 tasks in task_container
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   NotImplemented
            Timeout
            NoSuccess
  Notes:    - the returned list is not ordered
            - if the task_container is empty, an
              empty list is returned.
            - a 'Timeout' or 'NoSuccess' exception indicates
              that the backend was not able to obtain the
              states of the tasks in the container.
```

3.10.4 Examples

Code Example

```
// c++ example
saga::directory dir;
saga::job       job;

...

/* create tasks */
saga::task t1 = dir.ls         <saga::task> (result);
saga::task t2 = dir.copy       <saga::task> (source,target);
saga::task t3 = dir.move       <saga::task> (source,target);
saga::task t4 = job.checkpoint <saga::task> ();
saga::task t5 = job.signal     <saga::task> (SIG_USR);

// start tasks
t1.run ();
t2.run ();
t3.run ();
t4.run ();
t5.run ();

// put all tasks into container
saga::task_container tc;

tc.add (t1);
tc.add (t2);
tc.add (t3);
tc.add (t4);
tc.add (t5);

// take one out again
tc.remove (t5);

// wait for all other tasks in container to finish
tc.wait ();

// wait for the last task
t5.wait ();

+-------------------------------------------------------------+

// example for error handling in C++
{
  task.run  ();
  task.wait ();

  if ( task.get_state () == saga::task::Failed )
```

```
  {
    try {
      task.rethrow ();
    }
    catch ( const saga::exception & e )
    {
      std::cout << "task failed: "
                << e.get_message ()
                << std::endl;
    }
  }
}
```

4 SAGA API Specification – API Packages

The Functional SAGA API packages define the functional SAGA API scope, as motivated in the Introduction and in [18].

General Properties of Functional API Classes and Instances

The interfaces, classes and methods defined in this part of the specification are, in general, representing explicit entities and actions of some backend system. As such, all operations on these entities are, in general, subject to authentication and authorization. In order to simplify the specification, the following exceptions are not separately motivated: `AuthenticationFailed`, `AuthorizationFailed`, `PermissionDenied`, `Timeout`, `NoSuccess`. These exceptions have then exactly the semantics as indicated in their description in Section 3.1. Additionally, the conventions for the exceptions `NotImplemented` and `IncorrectURL` apply as described in Section 3.

4.1 SAGA Job Management

Nearly all of the SAGA use cases (except for the GridRPC use cases) had either explicit or implicit requirements for submitting jobs to grid resources, and most needed also to monitor and control these submitted jobs.

This section describes the SAGA API for submitting jobs to a grid resource, either in batch mode, or in an interactive mode. It also describes how to control these submitted jobs (e.g. to `cancel()`, `suspend()`, or `signal()` a running job), and how to retrieve status information for both running and completed jobs.

This API is also intended to incorporate the work of the DRMAA-WG [9]. Much of this specification was taken directly from DRMAA specification [24], with many of the differences arising from an attempt to make the job API consistent with the overall SAGA API Look-&-Feel[3].

The API covers four classes: `saga::job_description`, `saga::job_service`, `saga::job` and `saga::job_self`. The job description class is nothing more than a container for a well defined set of attributes which, using JSDL [15] based keys, defines the job to be started, and its runtime and resource requirements. The job server represents a resource management endpoint which allows the starting and injection of jobs.

The job class itself is central to the API, and represents an application instance running under the management of a resource manager. The `job_self` class `IS-A` job, but additionally implements the steering interface. The purpose of this class is to represent the current SAGA application, which allows for a number of use cases with applications which actively interact with the grid infrastructure, for example to provide steering capabilities, to migrate itself, or to set new job attributes.

The job class inherits the `saga::task` class 3.10, and uses its methods to `run()`, `wait()` for, and to `cancel()` jobs. The inheritance feature also allows for the management of large numbers of jobs in task containers. Additional methods provided by the `saga::job` class relate to the `Suspended` state (which is not available on tasks), and provide access to the job's standard I/O streams, and to more detailed status information. In this specification, the standard I/O streams are specified to have `opaque` types. The SAGA language bindings MUST specify a native type for I/O streams. That type SHOULD be the one used as the file descriptor to the POSIX `read()` call in that language.

[3]We expect that SAGA-API implementations may be implemented using DRMAA, or may produce JSDL documents to be passed to underlying scheduling systems.

4.1.1 Job State Model

The SAGA job state diagram is shown in Figure 4. It is an extension of the `saga::task` state diagram (Figure 3), and extends the state diagram with a `'Suspended'` state, which the job can enter/leave using the `suspend()/resume()` calls.

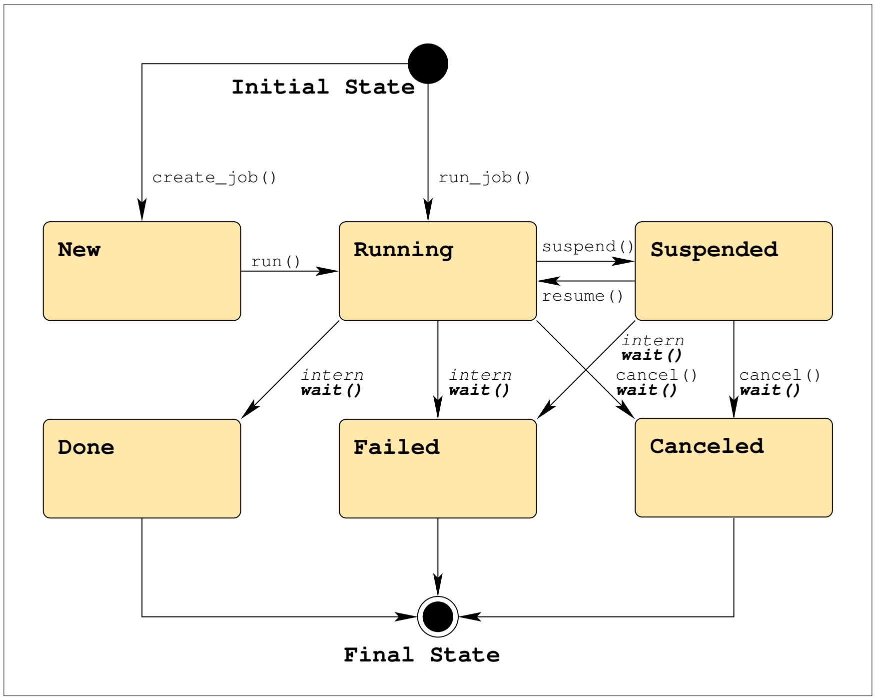

Figure 4: **The SAGA job state model extends the SAGA task state model with a 'Suspended' state, and additional transitions (See Figure 1 for a legend).**

SAGA implementations need to map the native backend state model onto the SAGA state model. The SAGA state model should be simple enough to allow a straight forward mapping in most cases. For some applications, access to the native backend state model is useful. For that reason, an additional metric named `'StateDetail'` allows to query the native job state. That schema follows the current state model of the OGSA-BES specification [12], which also has a simplified top level state model, and allows for additional, backend specific state details.

State details in SAGA SHOULD be formatted as follows:

```
'<model>:<state>'
```

with valid models being "BES", "DRMAA", or other implementation specific models. For example, a state detail for the BES state 'StagingIn' would be rendered as `'BES:StagingIn'`), and would be a substate of `Running`. If no state details are available, the metric is still available, but it has always an empty string value.

4.1.2 Job Description Attributes

SAGA implementations MUST support the `Executable` attribute, as that is the only required attribute for a `job_description`. An implementation MUST document which other attributes are supported, and which are not. In general, a `job_description` containing an unsupported attribute does *not* cause an error on job creation or submission, unless noted otherwise in the attribute description.

Attributes marked as `'not supported by JSDL'` might disappear in future versions of the SAGA API – all other attributes are likely to be kept, at least for backward compatibility. The attribute description additionally mentions if the attributes are supported by DRMAA (see [24]) – that is for information purposes only, and supposed to support implementations on top of DRMAA.

Several metrics on the `saga::job` class (the class implements the `saga::monitorable` interface) reflect attributes from the job description. This redundancy is intentional, and aims at providing information about (a) attributes which may change at runtime, and (b) attributes for jobs for which no job description is available (e.g. `saga::job` instances obtained by calling `get.job()`.

Although JSDL [3] and JSDL SPMD extension [8] based attribute names are used for job description, the API supports no explicit representation of JSDL (i.e. JSDL compliant XML). XML is deemed to be too low level to be included into the SAGA API. Also, the JSDL parameter sweep extension [7] is not used in SAGA at the moment, as bulk job submission, and related the creation of multiple related job descriptions, is performed on application level in SAGA, as described in Section 2.9.

4.1.3 File Transfer Specifications

The syntax of a file transfer directive for the job description is modeled on the LSF syntax (LSF stands for *Load Sharing Facility*, a commercial job scheduler by Platform Computing), and has the general syntax:

```
local_file operator remote_file
```

Both the `local_file` and the `remote_file` can be URLs. If they are not URLs, but full or relative pathnames, then the `local_file` is relative to the host where the submission is executed, and the `remote_file` is evaluated on the execution host of the job.

The operator is one of the following four:

`'>'`	copies the local file to the remote file before the job starts. Overwrites the remote file if it exists.
`'>>'`	copies the local file to the remote file before the job starts. Appends to the remote file if it exists.
`'<'`	copies the remote file to the local file after the job finishes. Overwrites the local file if it exists.
`'<<'`	copies the remote file to the local file after the job finishes. Appends to the local file if it exists.

4.1.4 Command Line Specification

The `run_job()` method of the `saga::job_service` class accepts a string parameter which constitutes a command line to be executed on a remote resource. The parsing of that command lines follows the following rules:

- Elements are delimited by white space, which is either a space or a tab.
- A string surrounded by double quotation marks is interpreted as a single element, regardless of white space contained within. A quoted string can be embedded in an element.
- A double quotation mark preceded by a backslash, `\"`, is interpreted as a literal double quotation mark (`"`).
- Backslashes are interpreted literally, unless they immediately precede a double quotation mark.
- The first element is used as executable name; all other elements are treated as job arguments.

4.1.5 Job Identifiers

The `JobID` is treated as an opaque string in the SAGA API. However, for the sake of interoperability of different SAGA implementations, and for potential extended use of the `JobID` information, the `JobID` SHOULD be implemented as:

```
'[backend url]-[native id]'
```

For example, a job submitted to the host `remote.host.net` via `ssh` (whose daemon runs on port `22`), and having the POSIX PID `1234`, should get the job id:

```
'[ssh://remote.host.net:22/]-[1234]'
```

The implementation MAY free the resources used for the job, and hence MAY invalidate a `JobID`, after a successful wait on the job, or after the application received the job status information, and job status details if available, at least once.

A JobID may be unknown until the job enters the `Running` state, as the backend will often not assign IDs to jobs which are not yet running. In such cases, the value of the `JobID` attribute SHOULD be empty. The job MUST, however, retain its JobID after it enters in a final state.

The job attribute `"ServiceURL"` exposes the URL of the `job::service` instance which spawned the job. Any new `job::service` instance created with that URL SHOULD be able to handle the job's jobid, and in particular SHOULD be able to reconnect to that job. The tuple `JobID, ServiceURL` thus allows to create both the job service and the job instances for any SAGA job.

4.1.6 Specification

```
package saga.job
{
  enum state
  {
    New        =  1,  // same as in saga::task::state
    Running    =  2,  // same as in saga::task::state
    Done       =  3,  // same as in saga::task::state
    Canceled   =  4,  // same as in saga::task::state
    Failed     =  5,  // same as in saga::task::state
    Suspended  =  6
  }


  class job_description : implements   saga::object
                          implements   saga::attributes
                       // from object: saga::error_handler
  {
    CONSTRUCTOR          (out job_description obj);
    DESTRUCTOR           (in  job_description obj);
```

```
// Attributes:
//
//   name:  Executable
//   desc:  command to execute.
//   mode:  ReadWrite
//   type:  String
//   value: ''
//   notes: - this is the only required attribute.
//          - can be a full pathname, a pathname
//            relative to the 'WorkingDirectory' as
//            evaluated on the execution host, or
//            a executable name to be searched in the
//            target host's PATH environment (if
//            available).
//          - available in JSDL, DRMAA
//          - semantics as defined in JSDL
//
//   name:  Arguments
//   desc:  positional parameters for the command.
//   mode:  ReadWrite, optional
//   type:  Vector String
//   value: -
//   notes: - available in JSDL, DRMAA
//            semantics as specified by JSDL
//
//   name:  SPMDVariation
//   desc:  SPMD job type and startup mechanism
//   mode:  ReadWrite, optional
//   type:  String
//   value: -
//   notes: - as defined in the SPMD extension of JSDL
//   notes: - available in JSDL, SPMD extension
//          - semantics as defined in JSDL
//          - the SPMD JSDL extension defines the value
//            to be an URI.  For simplicity, SAGA allows
//            the following strings, which map into the
//            respective URIs: MPI, GridMPI, IntelMPI,
//            LAM-MPI, MPICH1, MPICH2, MPICH-GM, MPICH-MX,
//            MVAPICH, MVAPICH2, OpenMP, POE, PVM, None
//          - the value '' (no value, default) indicates
//            that the application is not a SPMD
//            application.
//          - as JSDL, SAGA allows other arbitrary values.
//            The implementation must clearly document
//            which values are supported.
//
```

```
//   name:  TotalCPUCount
//   desc:  total number of cpus requested for this job
//   mode:  ReadWrite, optional
//   type:  Int
//   value: '1'
//   notes: - available in JSDL, DRMAA
//          - semantics as defined in JSDL
//
//   name:  NumberOfProcesses
//   desc:  total number of processes to be started
//   mode:  ReadWrite, optional
//   type:  Int
//   value: '1'
//   notes: - available in JSDL, SPMD extension
//          - semantics as defined in JSDL
//
//   name:  ProcessesPerHost
//   desc:  number of processes to be started per host
//   mode:  ReadWrite, optional
//   type:  Int
//   value: '1'
//   notes: - available in JSDL, SPMD extension
//          - semantics as defined in JSDL
//
//   name:  ThreadsPerProcess
//   desc:  number of threads to start per process
//   mode:  ReadWrite, optional
//   type:  Int
//   value: '1'
//   notes: - available in JSDL, SPMD extension
//          - semantics as defined in JSDL
//
//   name:  Environment
//   desc:  set of environment variables for the job
//   mode:  ReadWrite, optional
//   type:  Vector String
//   value: -
//   notes: - exported into the job environment
//          - format: 'key=value'
//          - available in JSDL, DRMAA
//          - semantics as specified by JSDL
//
//   name:  WorkingDirectory
//   desc:  working directory for the job
//   mode:  ReadWrite, optional
//   type:  String
```

```
//   value: '.'
//   notes: - gets created if it does not exist
//          - available in JSDL, DRMAA
//          - semantics as specified by JSDL
//
//   name:  Interactive
//   desc:  run the job in interactive mode
//   mode:  ReadWrite, optional
//   type:  Bool
//   value: 'False'
//   notes: - this implies that stdio streams will stay
//            connected to the submitter after job
//            submission, and during job execution.
//          - if an implementation cannot handle
//            interactive jobs, and this attribute is
//            present, and 'True', the job creation MUST
//            throw an 'IncorrectParameter' error with a
//            descriptive error message.
//          - not supported by JSDL, DRMAA
//
//   name:  Input
//   desc:  pathname of the standard input file
//   mode:  ReadWrite, optional
//   type:  String
//   value: -
//   notes: - available in JSDL, DRMAA
//          - semantics as specified by JSDL
//          - will not be used if 'Interactive' is 'True'
//
//   name:  Output
//   desc:  pathname of the standard output file
//   mode:  ReadWrite, optional
//   type:  String
//   value: -
//   notes: - available in JSDL, DRMAA
//          - semantics as specified by JSDL
//          - will not be used if 'Interactive' is 'True'
//
//   name:  Error
//   desc:  pathname of the standard error file
//   mode:  ReadWrite, optional
//   type:  String
//   value: -
//   notes: - available in JSDL, DRMAA
//          - semantics as specified by JSDL
//          - will not be used if 'Interactive' is 'True'
```

```
//
//   name:  FileTransfer
//   desc:  a list of file transfer directives
//   mode:  ReadWrite, optional
//   type:  Vector String
//   value: -
//   notes: - translates into jsdl:DataStaging
//          - used to specify pre- and post-staging
//          - staging is part of the 'Running' state
//          - syntax similar to LSF (see earlier notes)
//          - available in JSDL, DRMAA
//          - semantics as specified in JSDL
//
//   name:  Cleanup
//   desc:  defines if output files get removed after the
//          job finishes
//   mode:  ReadWrite, optional
//   type:  String
//   value: 'Default'
//   notes: - can have the Values 'True', 'False', and
//            'Default'
//          - On 'False', output files MUST be kept
//            after job the finishes
//          - On 'True', output files MUST be deleted
//            after job the finishes
//          - On 'Default', the behavior is defined by
//            the implementation or the backend.
//          - translates into 'DeleteOnTermination' elements
//            in JSDL
//
//   name:  JobStartTime
//   desc:  time at which a job should be scheduled
//   mode:  ReadWrite, optional
//   type:  Int
//   value: -
//   notes: - Could be viewed as a desired job start
//            time, but that is up to the resource
//            manager.
//          - format: number of seconds since epoch
//          - available in DRMAA
//          - not supported by JSDL
//
//   name:  WallTimeLimit
//   desc:  hard limit for the total job runtime.
//   mode:  ReadWrite, optional
//   type:  Int
```

```
//   value: -
//   notes: - intended to provide hints to the scheduler.
//          - available in JSDL, DRMAA
//          - semantics as defined in JSDL
//
//   name:  TotalCPUTime
//   desc:  estimate total number of CPU seconds which
//          the job will require.
//   mode:  ReadWrite, optional
//   type:  Int
//   value: -
//   notes: - intended to provide hints to the scheduler.
//          - available in JSDL, DRMAA
//          - semantics as defined in JSDL
//
//   name:  TotalPhysicalMemory
//   desc:  Estimated amount of memory the job requires
//   mode:  ReadWrite, optional
//   type:  Float
//   value: -
//   notes: - unit is in MegaByte
//          - memory usage of the job is aggregated
//            across all processes of the job
//          - available in JSDL
//          - semantics as defined by JSDL
//
//   name:  CPUArchitecture
//   desc:  compatible processor for job submission
//   mode:  ReadWrite, optional
//   type:  String
//   value: -
//   notes: - allowed values as specified in JSDL
//          - available in JSDL
//          - semantics as defined by JSDL
//
//   name:  OperatingSystemType
//   desc:  compatible operating system for job submission
//   mode:  ReadWrite, optional
//   type:  String
//   value: -
//   notes: - allowed values as specified in JSDL
//          - available in JSDL
//          - semantics as defined by JSDL
//
//   name:  CandidateHosts
//   desc:  list of host names which are to be considered
```

```
    //          by the resource manager as candidate targets
    //   mode:  ReadWrite, optional
    //   type:  Vector String
    //   value: -
    //   notes: - available in JSDL
    //          - semantics as defined by JSDL
    //
    //   name:  Queue
    //   desc:  name of a queue to place the job into
    //   mode:  ReadWrite, optional
    //   type:  String
    //   value: -
    //   notes: - While SAGA itself does not define the
    //            semantics of a "queue", many backend systems
    //            can make use of this attribute.
    //          - not supported by JSDL
    //
    //   name:  JobProject
    //   desc:  name of a account or project name
    //   mode:  ReadWrite, optional
    //   type:  String
    //   value: -
    //   notes: - While SAGA itself does not define the
    //            semantics of an "account" or "project",
    //            many backend systems can make use of
    //            this attribute for the purpose of
    //            accounting.
    //          - available in JSDL
    //          - semantics as defined by JSDL
    //
    //   name:  JobContact
    //   desc:  set of endpoints describing where to report
    //          job state transitions.
    //   mode:  ReadWrite, optional
    //   type:  Vector String
    //   value: -
    //   notes: - format: URI (e.g. fax:+123456789,
    //            sms:+123456789, mailto:joe@doe.net).
    //          - available in DRMAA
    //          - not supported by JSDL
  }


  class job_service : implements   saga::object
                      implements   saga::async
                   // from object  saga::error_handler
```

```
{
  CONSTRUCTOR           (in  session         s,
                         in  url             rm = "",
                         out job_service     obj);
  DESTRUCTOR            (in  job_service     obj);

  create_job            (in  job_description jd,
                         out job             job);
  run_job               (in  string          commandline,
                         in  string          host = "",
                         out job             job,
                         out opaque          stdin,
                         out opaque          stdout,
                         out opaque          stderr);
  list                  (out array<string>   job_ids);
  get_job               (in  string          job_id,
                         out job             job);
  get_self              (out job_self        job);
}


class job : extends      saga::task
            implements   saga::async
            implements   saga::attributes
            implements   saga::permissions
         // from task    saga::object
         // from task    saga::monitorable
         // from object  saga::error_handler
{
  // no CONSTRUCTOR
  DESTRUCTOR            (in  job             obj);

  // job inspection
  get_job_description   (out job_description jd);
  get_stdin             (out opaque          stdin);
  get_stdout            (out opaque          stdout);
  get_stderr            (out opaque          stderr);

  // job management
  suspend               (void);
  resume                (void);
  checkpoint            (void);
  migrate               (in job_description   jd);
  signal                (in int               signum);

  // Attributes:
```

```
//
//   name:  JobID
//   desc:  SAGA representation of the job identifier
//   mode:  ReadOnly
//   type:  String
//   value: -
//   notes: - format: as described earlier
//
//   name:  ServiceURL
//   desc:  URL representation of the job::service instance
//          managing this job
//   mode:  ReadOnly
//   type:  String
//   value: -
//   notes: - can be used for a job::service CONSTRUCTOR.
//
//   name:  ExecutionHosts
//   desc:  list of host names or IP addresses allocated
//          to run this job
//   mode:  ReadOnly, optional
//   type:  Vector String
//   value: -
//   notes: -
//
//   name:  Created
//   desc:  time stamp of the job creation in the
//          resource manager
//   mode:  ReadOnly, optional
//   type:  Time
//   value: -
//   notes: - can be interpreted as submission time
//
//   name:  Started
//   desc:  time stamp indicating when the job started
//          running
//   mode:  ReadOnly, optional
//   type:  Time
//   value: -
//
//   name:  Finished
//   desc:  time stamp indicating when the job completed
//   mode:  ReadOnly, optional
//   type:  Time
//   value: -
//
//   name:  WorkingDirectory
```

```
//   desc:  working directory on the execution host
//   mode:  ReadOnly, optional
//   type:  String
//   value: -
//   notes: - can be used to determine the location of
//            files staged using relative file paths
//
//   name:  ExitCode
//   desc:  process exit code as collected by the wait(2)
//          series of system calls.
//   mode:  ReadOnly, optional
//   type:  Int
//   value: -
//   notes: - exit code is collected from the process
//            which was started from the 'Executable'
//            attribute of the job_description object.
//          - only available in final states, if at all
//
//   name:  Termsig
//   desc:  signal number which caused the job to exit
//   mode:  ReadOnly, optional
//   type:  Int
//   value: -
//   notes: - only available in final states, if at all


// Metrics:
//   name:  job.state
//   desc:  fires on state changes of the job, and has
//          the literal value of the job state enum.
//   mode:  ReadOnly
//   unit:  1
//   type:  Enum
//   value: New
//   notes: - the state metric is inherited from
//            saga::task, but has a different set
//            of possible values
//          - see description of job states above
//
//   name:  job.state_detail
//   desc:  fires as a job changes its state detail
//   mode:  ReadOnly, optional
//   unit:  1
//   type:  String
//   value: -
//
```

```
//   name:  job.signal
//   desc:  fires as a job receives a signal, and has a
//          value indicating the signal number
//   mode:  ReadOnly, optional
//   unit:  1
//   type:  Int
//   value: -
//   notes: - no guarantees are made that any or all
//            signals can be notified by this metric
//
//   name:  job.cpu_time
//   desc:  number of CPU seconds consumed by the job
//   mode:  ReadOnly, optional
//   unit:  seconds
//   type:  Int
//   value: -
//   notes: - aggregated across all processes/threads
//
//   name:  job.memory_use
//   desc:  current aggregate memory usage
//   mode:  ReadOnly, optional
//   unit:  megabyte
//   type:  Float
//   value: 0.0
//   notes: - metric becomes 'Final' after job
//            completion, and then shows the memory
//            high water mark
//
//   name:  job.vmemory_use
//   desc:  current aggregate virtual memory usage
//   mode:  ReadOnly, optional
//   unit:  megabyte
//   type:  Float
//   value: 0.0
//   notes: - metric becomes 'Final' after job
//            completion, and then shows the virtual
//            memory high water mark
//
//   name:  job.performance
//   desc:  current performance
//   mode:  ReadOnly, optional
//   unit:  FLOPS
//   type:  Float
//   value: 0.0
//   notes: - metric becomes 'Final' after job
//            completion, and then shows the performance
```

```
    //            high water mark
  }


  class job_self : extends     saga::job
                   implements  saga::steerable
                // from job    saga::async
                // from job    saga::attributes
                // from job    saga::task
                // from job    saga::object
                // from job    saga::monitorable
                // from job    saga::permissions
                // from job    saga::error_handler
  {
    // no CONSTRUCTOR
    DESTRUCTOR           (in  job_self        obj);
  }
}
```

4.1.7 Specification Details

Enum `state`

The `state` is equivalent to the inherited `saga::task::state`, but adds the `Suspended` state:

`Suspended`
: This state identifies a job instance which has been suspended. This state corresponds to the BES state `'Suspend'`.

Class `job_description`

This object encapsulates all the attributes which define a job to be run. It has no methods of its own, but implements the `saga::attributes` interface in order to provide access to the job properties, which are expressed as JSDL keywords.

The only required attribute in order to perform a valid job submission is the `Executable`. Given the `Executable`, a job can be instantiated in many existing backend systems without any further specification.

There should be significant overlap between the attributes defined within SAGA and within the JSDL specification. This list, however, will not be complete in cases where the JSDL was deemed more complicated than was required for a simple API (e.g. the notion of JSDL profiles), or where an attribute was needed to interact with a scheduler, which was not within the stated scope of the JSDL working group (e.g. `Queue`, which is considered a *site attribute*, and thus not relevant to the pure description of a job).

```
- CONSTRUCTOR
  Purpose:  create the object
  Format:   CONSTRUCTOR       (out job_description obj)
  Inputs:   -
  InOuts:   -
  Outputs:  obj:               the newly created object
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   NotImplemented
            NoSuccess
  Notes:    - a job_description is not associated with a
              session, but can be used for job services
              from different sessions.


- DESTRUCTOR
  Purpose:  destroy the object
  Format:   DESTRUCTOR        (in  job_description obj)
  Inputs:   obj:               the object to destroy
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   -
  Notes:    -
```

Class `job_service`

The `job_service` represents a resource management backend, and as such allows the creation and submision of jobs, and to discover jobs. The job management methods are on the job object itself – this probably implies that implementations need to internally track what resource manager (or `job_service` instance) created the job.

```
- CONSTRUCTOR
  Purpose:  create the object
  Format:   CONSTRUCTOR       (in  session       s,
                               in  url           rm = "",
                               out job_service   obj)
  Inputs:   s:                 session to associate with
                               the object
            rm:                contact url for resource
                               manager
  InOuts:   -
  Outputs:  obj:               the newly created object
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   NotImplemented
            BadParameter
            IncorrectURL
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - 'rm' defaults to an empty string - in that
              case, the implementation must perform a
              resource discovery, or fall back to a fixed
              value, or find a valid  rm contact in any
              other way.  If that is not possible, a
              'BadParameter' exception MUST be thrown, and
              MUST indicate that a rm contact string is
              needed.  The expected behavior MUST be
              documented (i.e. if a default is available).
            - if the rm identified by the rm URL cannot be
              contacted (i.e. does not exist), a
              'BadParameter' exception is thrown.


- DESTRUCTOR
  Purpose:  destroy the object
  Format:   DESTRUCTOR        (in  job_service   obj)
  Inputs:   obj:               the object to destroy
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: - jobs created by that job_service instance
```

```
              are not affected by the destruction, and are
              in particular not canceled.
    Perms:    -
    Throws:   -
    Notes:    -


  - create_job
    Purpose:  create a job instance
    Format:   create_job        (in  job_description jd,
                                 out job             job);
    Inputs:   jd:                description of job to be
                                 submitted
    InOuts:   -
    Outputs:  job:               a job object representing
                                 the submitted job instance
    PreCond:  - jd has an 'Executable' attribute.
    PostCond: - job is in 'New' state
              - jd is deep copied (no state is shared
                after method invocation)
              - 'Owner' of the job is the id of the context
                used for creating the job.
    Perms:    -
    Throws:   NotImplemented
              BadParameter
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
              Timeout
              NoSuccess
    Notes:    - calling run() on the job will submit it to
                the resource, and advance its state.
              - if the job description does not have a valid
                'Executable' attribute, a 'BadParameter'
                exception is thrown.
              - if the job description contains values which
                are outside of the allowed range, or cannot be
                parsed, or are otherwise invalid and not
                usable for creating a job instance, a
                'BadParameter' exception is thrown, which MUST
                indicate which attribute(s) caused this
                exception, and why.


  - run_job
    Purpose:  Run a command synchronously.
```

```
Format:   run_job           (in  string  commandline,
                             in  string  host = "",
                             out job     job,
                             out opaque  stdin,
                             out opaque  stdout,
                             out opaque  stderr);
Inputs:   commandline:       the command and arguments
                             to be run
          host:              hostname to be used by rm for
                             submission
InOuts:   -
Outputs:  stdin:             IO handle for the running
                             job's standard input stream
          stdout:            IO handle for the running
                             job's standard output
          stderr:            IO handle for the running
                             job's standard error
          job:               a job object representing
                             the submitted job instance
PreCond:  -
PostCond: - job is in 'Running', 'Done' or 'Failed' state.
          - 'Owner' of the job is the id of the context
            used for creating the job.
Perms:    -
Throws:   NotImplemented
          BadParameter
          PermissionDenied
          AuthorizationFailed
          AuthenticationFailed
          Timeout
          NoSuccess
Notes:    - This is a convenience routine built on the
            create_job method, and is intended to simplify
            the steps of creating a job_description,
            creating and running the job, and then
            querying the standard I/O streams.
          - the I/O handles have to be passed to the call
            as references, in most languages, as calls
            often allow only one return value (Perl or
            python being notable exceptions).  If these
            parameters are omitted, the job is to be
            started non-interactively, and the output I/O
            streams may be discarded.
          - the job is guaranteed to run on the given
            host, or not at all.
          - the method is exactly equivalent to the
```

```
                 sequence of (1) creation of a job_description
                 with 'Executable' set to the values from the
                 commandline, 'Interactive' set if I/O is
                 requested, 'CandidateHost' set to host; (2)
                 create_job() with that description; (3)
                 calling run() on that job.  This method can
                 throw any of the exceptions which can occur in
                 this sequence, with the semantics defined in
                 the detailed description of the methods used
                 in this sequence.  No other exception are to
                 be expected.
               - if 'host' is an empty string (the default),
                 the implementation MUST choose an arbitrary
                 host for execution.
               - stdin, stdout and stderr are guaranteed to
                 contain/provide the complete standard I/O
                 streams, beginning at the start of the remote
                 process.


    - list
      Purpose:  Get a list of jobs which are currently known by
                the resource manager.
      Format:   list              (out array<string>   job_ids);
      Inputs:   -
      InOuts:   -
      Outputs:  job_ids:           an array of job identifiers
      PreCond:  -
      PostCond: -
      Perms:    Query on jobs identified by the returned ids
      Throws:   NotImplemented
                PermissionDenied
                AuthorizationFailed
                AuthenticationFailed
                Timeout
                NoSuccess
      Notes:    - which jobs are viewable by the calling user
                  context, and how long a resource manager keeps
                  job information, are both implementation
                  dependent.
                - a returned job_id may translate into a job
                  (via get_job()) which is not controllable by
                  the requesting application (e.g. it could
                  cause an 'AuthorizationFailed' exception).
```

```
- get_job
  Purpose:  Given a job identifier, this method returns a
            job object representing this job.
  Format:   get_job             (in  string job_id,
                                 out job    job)
  Inputs:   job_id:              job identifier as returned
                                 by the resource manager
  InOuts:   -
  Outputs:  job:                 a job object representing
                                 the job identified by
                                 job_id
  PreCond:  - job identified by job_id is managed by the
              job_service.
  PostCond: -
  Perms:    Query on the job.
  Throws:   NotImplemented
            BadParameter
            DoesNotExist
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - in general, only a job_service representing the
              resource manager which submitted the job may be
              able to handle the job_id, and to identify the
              job -- however, other job_services may succeed
              as well.
            - if the resource manager can handle the job_id,
              but the referenced job is not alive, a
              'DoesNotExist' exception is thrown.
            - if the resource manager cannot parse the job_id
              at all, a 'BadParameter' exception is thrown.


- get_self
  Purpose:  This method returns a job object representing
            _this_ job, i.e. the calling application.
  Format:   get_self            (out job_self  self)
  Inputs:   -
  InOuts:   -
  Outputs:  self:                a job_self object
                                 representing _this_ job.
  PreCond:  - the application is managed by the job_service.
  PostCond: - job_self is, by definition, in 'Running'
              state.
```

```
Perms:    Query on the job.
Throws:   NotImplemented
          PermissionDenied
          AuthorizationFailed
          AuthenticationFailed
          Timeout
          NoSuccess
Notes:    - in general, only a job_service representing the
            resource manager which started the application
            which now calls get_self() can successfully
            return a job_self instance.  However, other
            job_services may succeed as well.
          - if a job_service cannot handle the calling job
            as a job_self instance, a 'NoSuccess' exception
            is thrown, with a descriptive error message.
```

Class `job`

The `job` provides the manageability interface to a job instance submitted to a resource manager. There are two general types of methods: those for retrieving job state and information, and those for manipulating the job. The methods intended to manipulate jobs cannot make any guarantees about *how* the resource manager will affect an action to be taken. The API implementation is designed to be agnostic of the backend implementation, such that any backend could be implemented to perform an action. For example, the checkpoint routine might cause an application level checkpoint, or might use the services of GridCPR.

Job implements the `saga::attributes` interface. If not noted otherwise, none of these attributes is available before the job is running, and none is guaranteed to have a non-empty value while the job is running or after the job finishes.

Job also implements the monitorable interface, and thus allows monitoring and notification for changes of runtime attributes.

```
- DESTRUCTOR
  Purpose:  destroy the object
  Format:   DESTRUCTOR        (in  job  obj)
  Inputs:   obj:               the object to destroy
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: -
```

```
  Perms:    -
  Throws:   -
  Notes:    - the object destruction does not imply a
              call to cancel() for the job instance.


- get_job_description
  Purpose:  Retrieve the job_description which was used to
            submit this job instance.
  Format:   get_job_description (out job_description jd);
  Inputs:   -
  InOuts:   -
  Outputs:  jd:                 a job_description object
  PreCond:  -
  PostCond: - jd is deep copied (no state is shared
              after method invocation)
  Perms:    Query
  Throws:   NotImplemented
            DoesNotExist
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - There are cases when the job_description is not
              available.  This may include cases when
              the job was not submitted through
              SAGA and get_job() was used to retrieve the
              job, or when this state information has been
              lost (e.g. the client application restarts and
              the particular SAGA implementation did not
              persist the information).  In that case, a
              'DoesNotExist' exception is thrown, with a
              descriptive error message.


- get_stdin
  Purpose:  retrieve input stream for a job.
  Format:   get_stdin          (out opaque stdin)
  Inputs:   -
  InOuts:   -
  Outputs:  stdin:              standard input stream for
                                the job
  PreCond:  - the job is interactive.
  PostCond: - the jobs standard input stream is available
              at stdin.
```

```
  Perms:    Write (application can write to the jobs stdin).
  Throws:   NotImplemented
            BadParameter
            DoesNotExist
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - if the preconditions are met, but the standard
              input stream is not available for some
              reason, a 'DoesNotExist' exception is thrown.
            - the stream MUST be valid until the job reaches
              a final state.  If it is, for some reason,
              disconnected earlier, a language typical error
              message is thrown (e.g. EBADF could be
              returned on writes on that stream in C).
            - if the job is not interactive, e.g. it was
              submitted with the 'Interactive' attribute set
              to 'False', an 'IncorrectState' exception is
              thrown.
            - if the job is not in 'New' state, it is not
              guaranteed that the job did not receive other
              data on its standard input stream before.


- get_stdout
  Purpose:  retrieve output stream of job
  Format:   get_stdout         (out opaque stdout)
  Inputs:   -
  InOuts:   -
  Outputs:  stdout:             standard output stream for
                                the job
  PreCond:  - the job is interactive.
  PostCond: - the jobs standard output stream is available
              from stdout.
  Perms:    Read (application can read the jobs stdout).
  Throws:   NotImplemented
            BadParameter
            DoesNotExist
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
```

```
            NoSuccess
  Notes:    - if the preconditions are met, but the standard
              output stream is not available for some
              reason, a 'DoesNotExist' exception is thrown.
            - the stream MUST be valid until the job reaches
              a final state.  If it is, for some reason,
              disconnected earlier, a language typical error
              message is thrown (e.g. EBADF could be
              returned on reads on that stream in C).
            - if the job is not interactive, e.g. it was
              submitted with the 'Interactive' attribute set
              to 'False', an 'IncorrectState' exception is
              thrown.
            - if the job is not in 'New' state, it is not
              guaranteed that the job did write data on
              its standard output stream before, which are
              then not returned on the returned stream.


- get_stderr
  Purpose:  retrieve error stream of job
  Format:   get_stderr         (out opaque stderr)
  Inputs:   -
  InOuts:   -
  Outputs:  stderr:             standard error stream for
                                the job
  PreCond:  - the job is interactive.
  PostCond: - the jobs standard error stream is available
              from stderr.
  Perms:    Read (application can read the jobs stderr).
  Throws:   NotImplemented
            BadParameter
            DoesNotExist
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - if the preconditions are met, but the standard
              error stream is not available for some
              reason, a 'DoesNotExist' exception is thrown.
            - the stream MUST be valid until the job reaches
              a final state.  If it is, for some reason,
              disconnected earlier, a language typical error
              message is thrown (e.g. EBADF could be
```

```
                 returned on reads on that stream in C).
               - if the job is not interactive, e.g. it was
                 submitted with the 'Interactive' attribute set
                 to 'False', an 'IncorrectState' exception is
                 thrown.
               - if the job is not in 'New' state, it is not
                 guaranteed that the job did write data on
                 its standard error stream before, which are
                 then not returned on the returned stream.


    Job Management Methods:
    -----------------------

    - suspend
      Purpose:  Ask the resource manager to perform a suspend
                operation on the running job.
      Format:   suspend       (void);
      Inputs:   -
      InOuts:   -
      Outputs:  -
      PreCond:  - the job is in 'Running' state.
      PostCond: - the job is in 'Suspended' state.
      Perms:    Exec (job can be controlled).
      Throws:   NotImplemented
                IncorrectState
                PermissionDenied
                AuthorizationFailed
                AuthenticationFailed
                Timeout
                NoSuccess
      Notes:    - if the job is not in 'Running' state, an
                  'IncorrectState' exception is thrown.


    - resume
      Purpose:  Ask the resource manager to perform a resume
                operation on a suspended job.
      Format:   resume             (void);
      Inputs:   -
      InOuts:   -
      Outputs:  -
      PreCond:  - the job is in 'Suspended' state.
      PostCond: - the job is in 'Running' state.
      Perms:    Exec (job can be controlled).
      Throws:   NotImplemented
```

```
                IncorrectState
                PermissionDenied
                AuthorizationFailed
                AuthenticationFailed
                Timeout
                NoSuccess
      Notes:    - if the job is not in 'Suspended' state, an
                  'IncorrectState' exception is thrown.


    - checkpoint
      Purpose:  Ask the resource manager to initiate a checkpoint
                operation on a running job.
      Format:   checkpoint         (void);
      Inputs:   -
      InOuts:   -
      Outputs:  -
      PreCond:  - the job is in 'Running' state.
      PostCond: - the job is in 'Running' state.
                - the job was checkpointed.
      Perms:    Exec (job can be controlled).
      Throws:   NotImplemented
                IncorrectState
                PermissionDenied
                AuthorizationFailed
                AuthenticationFailed
                Timeout
                NoSuccess
      Notes:    - The semantics of checkpoint(), and the actions
                  taken to initiate a checkpoint, are resource
                  manager specific.  In particular, the
                  implementation or backend can trigger either
                  a system level or an application level
                - if the job is not in 'Running' state,
                  an 'IncorrectState' exception is thrown.


    - migrate
      Purpose:  Ask the resource manager to migrate a job.
      Format:   migrate            (in job_description jd);
      Inputs:   jd:                 new job parameters to apply
                                    when the job is migrated
      InOuts:   -
      Outputs:  -
      PreCond:  - the job is in 'Running' or 'Suspended' state.
      PostCond: - the job keeps its state.
```

```
              - jd is deep copied (no state is shared
                after method invocation)
              - the job reflects the attributes specified in
                the job_description.
    Perms:    Exec (job can be controlled).
    Throws:   NotImplemented
              BadParameter
              IncorrectState
              AuthorizationFailed
              AuthenticationFailed
              PermissionDenied
              Timeout
              NoSuccess
    Notes:    - jd might indicate new resource
                requirements, for example.
              - the action of migration might change the job
                identifier within the resource manager.
              - ideally, the submitted job description was
                obtained by get_job_description(), and then
                changed by the application.  This is not a
                requirement though.
              - if the job is not in 'Running' or 'Suspended'
                state, an 'IncorrectState' exception is thrown.
              - the method can call the same exceptions as
                the submit_job() and run() methods, in
                particular in respect to an incorrect
                job_description.


  - signal
    Purpose:  Ask the resource manager to deliver an arbitrary
              signal to a dispatched job.
    Format:   signal               (in int signum);
    Inputs:   signum:               signal number to be
                                    delivered
    InOuts:   -
    Outputs:  -
    PreCond:  - job is in 'Running' or 'Suspended' state.
    PostCond: - the signal was delivered to the job.
    Perms:    Exec (job can be controlled).
    Throws:   NotImplemented
              BadParameter
              IncorrectState
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
```

```
                Timeout
                NoSuccess
      Notes:    - there is no guarantee that the signal number
                  specified is valid for the operating system
                  on the execution host where the job is
                  running, or that the signal can be delivered.
                - if the signal number is not supported by the
                  backend, a 'BadParameter' exception is thrown.
                - if the job is not in 'Running' or 'Suspended'
                  state, an 'IncorrectState' exception is
                  thrown.
```

Class `job_self`

The `job_self` class `IS-A` job which represents the current application (i.e. the very application which owns that `job_self` instance). It can only by created by calling `get_self()` on a job service (that call can fail though).

The motivation to introduce this class is twofold: (1) it allows to actively handle the current application as a grid job (e.g. to migrate it, or to obtain its job description for cloning/spawning); (2) as the class implements the steerable interface, it is possible to add `ReadWrite` metrics to its instance – that way it is possible to expose these metrics to other external applications, which in fact allows to steer the current application.

A drawback of this approach is that, in order to make an application steerable, a `job_service` instance is needed which can in fact return a `job_self` instance, which means there must be a resource manager available which can manage the current application – that however has nothing to do with the concept of remote steering. Future versions of the SAGA API may change that, and may make `job_self` a singleton, independent from the `job_service` behavior. As a result, that class might disappear, and might not be maintained for backward compatibility.

```
    - DESTRUCTOR
      Purpose:  destroy the object
      Format:   DESTRUCTOR        (in  job_self  obj)
      Inputs:   obj:               the object to destroy
      InOuts:   -
      Outputs:  -
      PreCond:  -
      PostCond: -
```

```
Perms:    -
Throws:   -
Notes:    - the object destruction does not imply a
            call to cancel() for the job_self instance.
```

4.1.8 Examples

Code Example

```
Example : simple job submission and polling for finish.

// ----------------------------------------------
// c++ example
std::list <std::string>    transfers;
saga::job_description jobdef;
saga::job_service     js;

transfers.push_back ("infile > infile");
transfers.push_back ("ftp://host.net/path/out << outfile");

jobdef.set_attribute        ("CandidateHost", "hostname");
jobdef.set_attribute        ("Executable",    "job.sh");
jobdef.set_attribute        ("TotalCPUCount", "16");
jobdef.set_vector_attribute ("FileTransfer",  transfers);

saga::job job = js.create_job (jobdef);

job.run ();

while ( 1 )
{
  // get job state
  saga::job::state state = job.get_state ();

  // get list of hosts the job is/where running on
  std::list <std::string> hostlist = job.get_attribute
                                   ("ExecutionHosts");

  if ( saga::job::Running == state )
  {
    std::cout << "Job is running." << std::endl;
  }
  else if ( saga::job::Suspended == state )
  {
    std::cout << "Job is suspended." << std::endl;
  }
  else if ( saga::job::Done == state )
  {
```

```
      std::cout << "Job completed successfully." << std::endl;
      exit (0);
    }
    else if ( saga::job::Canceled == state )
    {
      std::cout << "Job canceled." << std::endl;
      exit (1);
    }
    else
    {
      // state can only be 'Failed'
      assert (saga::job::Failed == state);

      std::string exitcode = job.get_attribute ("ExitCode");

      std::cout << "Job failed with exitcode:"
                << exitcode
                << std::endl;
      exit ( atoi(exitcode) );
    }

    sleep (1); // idle
  }
```

4.2 SAGA Name Spaces

Several SAGA packages share the notion of name spaces and operations on these name spaces. In order to increase consistency in the API, these packages share the same API paradigms. This section describes those paradigms, and these classes which operate on arbitrary hierarchical name spaces, such as used in physical, virtual, and logical file systems, and in information systems.

The API is inspired by the POSIX standard, which defines tools and calls to handle the name space of physical files and directories. The methods listed for the interfaces have POSIX-like syntax and semantics.

While POSIX has an iterative interface to directory listing (i.e. opendir, telldir, seekdir, readdir), the corresponding part of the interface included here deviates significantly from the POSIX version: it has fewer calls, with a different syntax, but identical semantics.

Please note that 'stat'-like API calls are *not* covered here – they are rather meaningless on a name space per se, but belong to the specific implementations, e.g. physical files, which inherit the `namespace` classes.

4.2.1 Definitions

The Grid File System Working Group in OGF has defined a Resource Namespace Service (RNS [20]). The SAGA Core API specification follows the definition of a name space from that document.

Directory: A 'Directory' represents what [20] defines as 'Virtual Directory':

> *"A virtual directory is an RNS entry that is represented as a non-leaf node in the hierarchical name space tree. When rendered by a name space service client, a virtual directory functions similar to that of a standard filesystem directory or registry key. It is considered virtual because it does not have any corresponding representation outside of the name space. A virtual directory, therefore, is purely a name space entity that functions in much the same way as a conventional filesystem directory or registry key by maintaining a list of subentries, which thereby demonstrate a hierarchical relationship. There are no restrictions regarding the layout of the name space tree; both virtual directories and junctions can be nested within nested virtual directories recursively.*
>
> *A virtual directory may be considered analogous to a collection, category, or context – to the extent that these terms are used in most directory, registry, or catalogue contexts. Virtual directories do not have any time or space existence outside of the name space and strictly serve to facilitate hierarchy. Name space hierarchies offer categorization or grouping*

of entries, by presenting the illusion of compartments, which may contain sub-compartments as well as junctions."

Directory Entry: A *directory entry* or *entry* represent what [20] defines as 'Junction'. Note that any type of junction defined there could be used:

> *"A junction is an RNS entry that interconnects a reference to an existing resource into the hierarchical name space. Junctions represent a name-to-resource mapping that is composed of a human oriented index key or 'name' that maps to an endpoint reference. The endpoint reference may refer to any addressable resource, which includes other name space entries, as well as names or unique identifiers to be resolved by other resolution service, as well as definitive target consumable resource. All compliant RNS implementations MUST embody the target information of a name space junction within a valid WS-Addressing [...] Endpoint Reference (EPR)."*

Pathnames: A *pathname* as accepted by this specification MUST be either formatted as URLs or MUST follow the specification of entry names as described in [20], Section 1.2.2.1 "Entry Name Restrictions" (formatting changed):

> *"Entry names are composed of a simple string of human readable characters. Since certain characters serve special purposes both within the name space service and within a number of systems that may use this service, this section describes the mandatory restrictions for all entry names:*
>
> *Names MUST NOT...*
>
> - *Contain any of the following characters:* `/ : ; * ? " < > |`
> - *Contain any non-readable characters, such as the carriage return (ANSI 13) or line feed (ANSI 10) or tab (ANSI 9)*
> - *Be greater than 255 characters in length (Unicode)*
>
> *Names SHOULD...*
>
> - *Accommodate Unicode characters*
> - *Be easily readable by a human user, suggesting less than 32 characters per name*
>
> *Names MAY...*
>
> - *Contain space (ANSI 32) characters*
>
> *Notice these restrictions apply to entry names and are not describing paths. Paths are constructed of one or more entry names separated by the forward slash character (/)".*

Note that, in fact, pathnames as specified above *are* syntactically valid URLs, and this specification is therefore only referring to URLs. Both, SAGA implementations and SAGA usage SHOULD, however, strive for compliance with [20]. An exception is the use of relative pathnames which, in SAGA, can contain wildcards (see below).

All method arguments which are named `name`, `source` or `target` are considered pathnames. These pathnames can always be relative pathnames (i.e. they can be relative to the current working directory (`cwd`) of the object instance the operation is performed upon, e.g. when they start with `'./'` or `'../'`).

Note that relative path elements are not always resolvable during URL construction. Instead, resolution may be delayed until the URL is being used, and further may need to be performed differently on each use of the URL, depending on the context of usage:

```
saga::url u0 ("ftp://localhost/tmp/data/test.txt");
saga::url u1 ("gridftp://localhost/tmp/data/test.txt");
saga::url u2 ("../test.txt");

saga::file f0 (u0);
saga::file f1 (u1);

f0.move (u2);  // resolve u2 relative to u0
f1.move (u2);  // resolve u2 relative to u1
```

Note that the comments from Section 2.11, apply here. In particular, an implementation MAY throw an `IncorrectURL` exception if it is unable to handle a given URL, e.g. because of its scheme.

Current Working Directory (cwd) Every `saga::ns_entry` instance has an associate current working directory (cwd), which forms the implicit base for all operations on relative pathnames. For `saga::ns_directory` instances, that cwd can be changed with the `change_dir` method. Otherwise, cwd only changes if the entry itself is `move()`'d.

Links: *Links* in this specification are considered *symbolic links*, i.e. they can break if the entry they point to is removed. An implementation MAY support links, as not all backends can support links, and others might support links only in specific circumstances (e.g. if entry and link live on the same file system).

The 'Dereference' flag allows methods to operate on the link target instead of the link – only one level of reference is resolved though. The `read_link()` method does also resolve only one link level, and returns a URL pointing to the link target.

At the moment, [20] does not have a notion of symbolic links. However, an RNS 'junction' which is associated with another RNS junction can be regarded as a symbolic link.

Wildcards: The API supports wildcards for a number of calls, as listed below, and thereby follows the POSIX standard [21, 22, 23] for shell wildcards. Available wildcard patterns are:

`*`	: matches any string
`?`	: matches a single character
`[abc]`	: matches any of a set of characters
`[a-z]`	: matches any of a range of characters
`[!abc]`	: matches none of a range of characters
`[!a-z]`	: matches none of a range of characters
`{a,bc}`	: matches any of a set of strings

See the POSIX standard [21, 22, 23] for more details. In the SAGA API, wildcards are allowed in all pathnames where they can be used in the respective shell commands, as:

```
copy   *.txt dir
move   *.txt dir
link   *.txt dir
ls     *.txt
remove *.txt
```

Note that only those methods MUST support wildcards for which this is explicitly specified here. Other methods MUST NOT support wildcards, as this would not be meaningful. Flags MUST be applied to all elements of a wildcard expansion, even if that raises an exception for any reason.

For the use of wildcards, separate calls are provided which accept strings instead of URLs. The reason for this is that RFC 3986 [5], which defines the syntax of URLs, explicitly forbids most POSIX wildcard characters as part of a URL. Also, we feel that wildcards make most sense in relative pathnames (i.e. relative to a working directory). Strings in these separate calls thus MUST be relative paths, and thus MUST only contain URL path elements, whereby the path element MUST NOT start with an `'/'`. Apart from that, the semantics of the wildcard-enabled string method versions of the calls are identical to the semantics of their respective URL counterparts. If the method encounters any error condition on any one of the expanded URLs, an exception is thrown, and the state of the other (valid or invalid) expanded URL targets remains undefined.

Opening and Closing Name Space Entries: If a ns_entry object instance gets created, it is also opened. Hence, the semantics and all notes of the respective open() call also apply to the constructor. The same holds for all classes that inherit ns_entry.

In accordance with Section 2.5.4, the saga::ns_entry class has a close() method, which allows to enforce a timely release of used (local and remote) resources. After a ns_entry instance was closed, all method calls on that instance (apart from the DESTRUCTOR) MUST throw an IncorrectState exception. A destruction of an entry implies the respective close() semantics. The same holds for all classes that inherit ns_entry.

If an entry gets successfully opened without specifying 'Lock' as open flag, its state may get corrupted if some other backend operation removes or moves the opened entity, or changes its state. In that case, any subsequent operation on the object instance can fail unexpectedly. An IncorrectState exception describing the type of state change SHOULD be thrown if such a state change is detected and causes an operation to fail. Otherwise, the normal exception indicating the type of error which occurred SHOULD be thrown. The IncorrectState exception is thus listed on most method calls below, but not individually motivated unless it is also used in any other semantic context.

4.2.2 Specification

```
package saga.namespace
{
  enum flags
  {
    None           =    0,
    Overwrite      =    1,
    Recursive      =    2,
    Dereference    =    4,
    Create         =    8,
    Exclusive      =   16,
    Lock           =   32,
    CreateParents  =   64,
    //                128,    reserved for Truncate
    //                256,    reserved for Append
    Read           =  512,
    Write          = 1024,
    ReadWrite      = 1536  // Read | Write
  }
```

```
class ns_entry : implements   saga::object,
                 implements   saga::async
                 implements   saga::permissions
              // from object  saga::error_handler
{
  CONSTRUCTOR        (in  session        s,
                      in  saga::url      name,
                      in  int            flags   = None,
                      out ns_entry       obj     );
  DESTRUCTOR         (in  ns_entry       obj     );

  // basic properties
  get_url            (out saga::url      url     );
  get_cwd            (out saga::url      cwd     );
  get_name           (out saga::url      name    );

  // navigation/query methods
  is_dir             (out boolean        test    );
  is_entry           (out boolean        test    );
  is_link            (out boolean        test    );
  read_link          (out saga::url      link    );
  get_mtime          (out int            time    );

  // management methods
  copy               (in  saga::url      target,
                      in  int            flags = None);
  link               (in  saga::url      target,
                      in  int            flags = None);
  move               (in  saga::url      target,
                      in  int            flags = None);
  remove             (in  int            flags = None);
  close              (in  float          timeout = 0.0);


  // permissions with flags
  permissions_allow  (in  string         id,
                      in  permission     perm,
                      in  int            flags = None);
  permissions_deny   (in  string         id,
                      in  permission     perm,
                      in  int            flags = None);
}


class ns_directory : extends        saga::ns_entry
```

```
                    // from ns_entry  saga::object
                    // from ns_entry  saga::async
                    // from ns_entry  saga::permissions
                    // from object    saga::error_handler
{
  CONSTRUCTOR        (in  session        s,
                      in  saga::url      name,
                      in  int            flags = None,
                      out ns_directory   obj     );
  DESTRUCTOR         (in  ns_directory   obj     );

  // navigation/query methods
  change_dir         (in  saga::url      dir     );
  list               (in  string         name_pattern = ".",
                      in  int            flags   = None,
                      out array<saga::url> names   );
  find               (in  string         name_pattern,
                      in  int            flags = Recursive,
                      out array<saga::url> names   );
  exists             (in  saga::url      name,
                      out boolean        exists  );
  is_dir             (in  saga::url      name,
                      out boolean        test    );
  is_entry           (in  saga::url      name,
                      out boolean        test    );
  is_link            (in  saga::url      name,
                      out boolean        test    );
  read_link          (in  saga::url      name,
                      out saga::url      link    );
  get_mtime          (in  saga::url      name,
                      out int            time    );

  // manage entries by number
  get_num_entries    (out int            num     );
  get_entry          (in  int            entry,
                      out saga::url      name    );

  // management methods
  copy               (in  saga::url      source,
                      in  saga::url      target,
                      in  int            flags = None);
  link               (in  saga::url      source,
                      in  saga::url      target,
                      in  int            flags = None);
  move               (in  saga::url      source,
                      in  saga::url      target,
```

```
                       in  int            flags = None);
    remove            (in  saga::url      target,
                       in  int            flags = None);
    make_dir          (in  saga::url      target,
                       in  int            flags = None);

    // management methods - wildcard versions
    copy              (in  string         source,
                       in  saga::url      target,
                       in  int            flags = None);
    link              (in  string         source,
                       in  saga::url      target,
                       in  int            flags = None);
    move              (in  string         source,
                       in  saga::url      target,
                       in  int            flags = None);
    remove            (in  string         target,
                       in  int            flags = None);

    // factory methods
    open              (in  saga::url      name,
                       in  int            flags = Read,
                       out ns_entry       entry   );
    open_dir           (in  saga::url     name,
                       in  int            flags = Read,
                       out ns_directory   dir     );


    // permissions with flags
    permissions_allow  (in  saga::url      target,
                       in  string         id,
                       in  int            perm,
                       in  int            flags = None);
    permissions_deny   (in  saga::url      target,
                       in  string         id,
                       in  int            perm,
                       in  int            flags = None);

    // permissions with flags - wildcard versions
    permissions_allow  (in  string         target,
                       in  string         id,
                       in  int            perm,
                       in  int            flags = None);
    permissions_deny   (in  string         target,
                       in  string         id,
                       in  int            perm,
```

```
                          in  int          flags = None);
    }
  }
```

4.2.3 Specification Details

Enum `flags`

The `flags` describe the properties of several operations on namespace entries. Packages which inherit from the namespace package use the same flag semantics unless specified otherwise, but will, in general, add additional flags to some operations.

`None`
: indicates the absence of flags, and thus also implies that the default flags for an operation do not apply, either.

`Overwrite`
: enforces an operation which creates a new namespace entry to continue even if the target entry does already exist – if that flag is not given, an `'AlreadyExists'` exception would result from such an operation.

`Recursive`
: enforces an operation to apply recursively on a directory tree – if that flag is not given, the same operation would only apply to the given directory, and not to its children.

`Dereference`
: enforces an operation to apply not to the entry pointed to by the target name, but to the link target of that entry – if that flag is not given, the same operation would apply to the entry directly, and its link target stays unaffected.

`Create`
: allows a namespace entry to be created while opening it, if it does not already exist – if that flag is not given, the same open operation would cause a `'DoesNotExist'` exception. If the entry exists, the flag is ignored. This flag implies the `'Write'` flag.

`Exclusive`
: implies a modification to the meaning of the `Create` flag: if the entry already exists, the `Create` flag is is no longer silently ignored, but causes an `'AlreadyExists'` exception.

`Lock`

enforces a lock on the name space entry when it is opened. Locks are advisory in SAGA, semantic details for locking are defined in the description of the `open()` call.

`CreateParents`
: An operation which would create a name space entry would normally fail if any path element in the targets name does not yet exist. If this flag is given, such an operation would not fail, but would imply that the missing path elements are created on the fly. This flag implies the `'Create'` flag.

`Read`
: The entry or directory is opened for reading – that does not imply the ability to write to the entry or directory.

`Write`
: The entry or directory is opened for writing – that does not imply the ability to read from the entry or directory.

`ReadWrite`
: The entry or directory is opened for reading and writing.

Class `ns_entry`

`ns_entry` defines methods which serve the inspection of the entry itself, methods which allows to manage the entry (e.g. to copy, move, or remove it), and methods to manipulate the entry's access control lists.

In general, multiple such URLs might be valid to identify an entry:

```
 ftp://ftp.host.net/pub/data/test.txt
http://www.host.net/ftp/data/test.txt
http://www.host.net/ftp/data/./test.txt
http://www.host.net/ftp/data/../data/test.txt
```

Any valid URL can be returned on `get_url()`, but it SHOULD not contain `'..'` or `'.'` as non-leading path components, i.e. SHOULD have a normalized path element. The URL returned on `get_url()` should serve as base for the return values on `get_cwd()` and `get_name()`: In general it should hold that:

```
get_url() == get_cwd() + '/' + get_name()
```

Note that `get_cwd()` behaves like the unix command `'dirname'`.

```
- CONSTRUCTOR
  Purpose:  create the object
  Format:   CONSTRUCTOR          (in  session   s,
                                  in  saga::url name,
                                  in  int       flags = Read,
                                  out ns_entry obj)
  Inputs:   s:                    session handle
            name:                 initial working dir
            flags:                open mode
  InOuts:   -
  Outputs:  obj:                  the newly created object
  PreCond:  -
  PostCond: - the entry is opened.
            - 'Owner' of target is the id of the context
              use to perform the operation, if the entry
              gets created.
  Perms:    Exec  for parent directory.
            Write for parent directory if Create is set.
            Write for name if Write is set.
            Read  for name if Read  is set.
  Throws:   NotImplemented
            IncorrectURL
            BadParameter
            DoesNotExist
            AlreadyExists
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - the default flag set is 'Read'.
            - the constructor performs an open of the
              entry - all notes to the respective open
              call (on namespace_directory) apply.


- DESTRUCTOR
  Purpose:  destroy the object
  Format:   DESTRUCTOR           (in  ns_entry     obj)
  Inputs:   obj:                  the object to destroy
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: - the entry is closed.
  Perms:    -
  Throws:   -
```

```
  Notes:    - if the instance was not closed before, the
              destructor performs a close() on the instance,
              and all notes to close() apply.



Methods for inspecting ns_entry:
--------------------------------

- get_url
  Purpose:  obtain the complete url pointing to the entry
  Format:   get_url            (out  saga::url url);
  Inputs:   -
  InOuts:   -
  Outputs:  url                 url pointing to the entry
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   NotImplemented
            IncorrectState
            Timeout
            NoSuccess
  Notes:    -



- get_cwd
  Purpose:  obtain the current working directory for the
            entry
  Format:   get_cwd            (out saga::url cwd);
  Inputs:   -
  InOuts:   -
  Outputs:  cwd                 current working directory
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   NotImplemented
            IncorrectState
            Timeout
            NoSuccess
  Notes:    -
            - returns the directory part of the url path
              element.
```

```
- get_name
  Purpose:  obtain the name part of the url path element
  Format:   get_name           (out  saga::url name);
  Inputs:   -
  InOuts:   -
  Outputs:  name                last part of path element
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   NotImplemented
            IncorrectState
            Timeout
            NoSuccess
  Notes:    -


- is_dir
  Purpose:  tests the entry for being a directory
  Format:   is_dir             (out boolean test);
  Inputs:   -
  InOuts:   -
  Outputs:  test:               boolean indicating if entry
                                is a directory
  PreCond:  -
  PostCond: -
  Perms:    Query
            Query for parent directory.
  Throws:   NotImplemented
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - returns true if entry is a directory, false
              otherwise
            - similar to 'test -d' as defined by POSIX.


- is_entry
  Purpose:  tests the entry for being an ns_entry
  Format:   is_entry           (out boolean test);
  Inputs:   -
  InOuts:   -
  Outputs:  test:               boolean indicating if entry
```

```
                              is an ns_entry
  PreCond:  -
  PostCond: -
  Perms:    Query
            Query for parent directory.
  Throws:   NotImplemented
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - the method returns false if the entry is a
              link or a directory (although an ns_directory
              IS_A ns_entry, false is returned on a test on
              an ns_directory) - otherwise true is returned.
            - similar to 'test -f' as defined by POSIX.


- is_link
  Purpose:  tests the entry for being a link
  Format:   is_link            (out boolean test);
  Inputs:   -
  InOuts:   -
  Outputs:  test:               boolean indicating if
                                entry is a link
  PreCond:  -
  PostCond: -
  Perms:    Query
            Query for parent directory.
  Throws:   NotImplemented
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - returns true if the entry is a link, false
              otherwise
            - similar to libc's 'readlink' as defined by
              POSIX, but with only one level of redirection
              resolved.


- read_link
  Purpose:  returns the name of the link target
```

```
  Format:   read_link          (out saga::url link);
  Inputs:   -
  InOuts:   -
  Outputs:  link:               resolved name
  PreCond:  -
  PostCond: -
  Perms:    Query
            Query for parent directory.
  Throws:   NotImplemented
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - the returned name MUST be sufficient to
              access the link target entry
            - resolves one link level only
            - if the entry instance this method is called
              upon does not point to a link, an
              'IncorrectState' exception is thrown.
            - similar to libc's 'readlink' as defined by
              POSIX, but with only one level of redirection
              resolved.


- get_mtime
  Purpose:  returns the last modification time
  Format:   get_time           (out int time);
  Inputs:   -
  InOuts:   -
  Outputs:  time:               time of last modification
  PreCond:  -
  PostCond: -
  Perms:    Query
            Query for parent directory.
  Throws:   NotImplemented
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - the returned number represents the time of
              last modification in seconds since epoch
              (01.01.1970)
```

```
              - similar to the 'st_mtimespec' element of the
                stat strucure used in the POSIX stat() call.


    Methods for managing the name space entry:
    -------------------------------------------


    - copy
      Purpose:  copy the entry to another part of the name space
      Format:   copy               (in  saga::url target,
                                    in  int       flags = None);
      Inputs:   target:             name to copy to
                flags:              flags defining the operation
                                    modus
      InOuts:   -
      Outputs:  -
      PreCond:  -
      PostCond: - an identical copy exists at target.
                - 'Owner' of target is the id of the context
                  use to perform the operation, if target gets
                  created.
      Perms:    Query
                Exec  for parent directory.
                Query for target.
                Query for target's parent directory.
                Exec  for target's parent directory.
                Write for target
                      if  target does exist.
                Write for target's parent directory
                      if  target does not exist.
      Throws:   NotImplemented
                IncorrectURL
                BadParameter
                DoesNotExist
                AlreadyExists
                IncorrectState
                PermissionDenied
                AuthorizationFailed
                AuthenticationFailed
                Timeout
                NoSuccess
      Notes:    - if the target is a directory, the source entry
                  is copied into that directory
                - a 'BadParameter' exception is thrown if the
                  source is a directory and the 'Recursive' flag
                  is not set.
```

```
                - a 'BadParameter' exception is thrown if the
                  source is not a directory and the 'Recursive'
                  flag is set.
                - if the target lies in a non-existing part of
                  the name space, a 'DoesNotExist' exception is
                  thrown, unless the 'CreateParents' flag is
                  given - then that part of the name space must
                  be created.
                - if the target already exists, it will be
                  overwritten if the 'Overwrite' flag is set,
                  otherwise it is an 'AlreadyExists' exception.
                - if a directory is to be copied recursively,
                  but the target exists and is not a directory,
                  and not a link to a directory, an
                  'AlreadyExists' exception is thrown even if
                  the 'Overwrite' flag is set.
                - if the instance points at an symbolic link,
                  the source is deeply dereferenced before copy.
                  If derefencing is impossible (e.g. on a broken
                  link), an 'IncorrectState' exception is thrown.
                - other flags are not allowed, and cause a
                  'BadParameter' exception.
                - the default flags are 'None' (0).
                - similar to 'cp' as defined by POSIX.


  - link
    Purpose:  create a symbolic link from the target entry to
              the source entry ( this entry) so that any reference
              to the target refers to the source entry
    Format:   link               (in  saga::url target,
                                  in  int       flags = None);
    Inputs:   target:             name to link to
              flags:              flags defining the operation
                                  modus
    InOuts:   -
    Outputs:  -
    PreCond:  -
    PostCond: - a symbolic link to the entry exists at target.
              - 'Owner' of target is the id of the context
                use to perform the operation if target gets
                created.
    Perms:    Query
              Exec  for parent directory.
              Query for target.
              Query for target's parent directory.
```

```
            Exec  for target's parent directory.
            Write for target
                  if  target does exist.
            Write for target's parent directory
                  if  target does not exist.
  Throws:   NotImplemented
            IncorrectURL
            BadParameter
            DoesNotExist
            AlreadyExists
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - if the target is a directory, the source entry
              is linked into that directory
            - if the source is a directory, and the
              'Recursive' flag is set, the source directory
              is recursively linked to the target (which must
              be a directory as well - otherwise a
              'BadParameter' exception is thrown).  The
              method then behaves similar to lndir.  If the
              'Recursive' flag is not set, the source entry
              itself is linked.
            - a 'BadParameter' exception is thrown if the
              source is not a directory and the 'Recursive'
              flag is set.
            - if the target lies in a non-existing part of
              the name space, a 'DoesNotExist' exception is
              thrown, unless the 'CreateParents' flag is
              given - then that part of the name space must
              be created.
            - if the target already exists, it will be
              overwritten if the 'Overwrite' flag is set,
              otherwise it is an 'AlreadyExists' exception.
            - if a directory is to be moved, but the target
              exists and is not a directory, and not a link
              to a directory, an 'AlreadyExists' exception
              is thrown even if the 'Overwrite' flag is set.
            - if the instance points at an symbolic link,
              the source is not dereferenced before linking,
              unless the 'Dereference' flag is given.  If
              derefencing is impossible (e.g. on a broken
              link), an 'IncorrectState' exception is thrown.
```

```
                - other flags are not allowed, and cause a
                  'BadParameter' exception.
                - the default flags are 'None' (0).
                - similar to 'ln' as defined by POSIX.


    - move
      Purpose:  rename source to target, or move source to
                target if target is a directory.
      Format:   move               (in  saga::url target,
                                    in  int       flags = None);
      Inputs:   target:             name to move to
                flags:              flags defining the operation
                                    modus
      InOuts:   -
      Outputs:  -
      PreCond:  -
      PostCond: - the entry exists at the target url.
                - no entry exists at the original url.
                - the object instance is not closed.
                - 'Owner' of target is the id of the context
                  use to perform the operation, if target gets
                  created.
      Perms:    Query
                Write
                Exec  for parent directory.
                Write for parent directory.
                Query for target.
                Exec  for target's parent directory.
                Write for target
                      if  target does exist.
                Write for target's parent directory
                      if  target does not exist.
      Throws:   NotImplemented
                IncorrectURL
                BadParameter
                DoesNotExist
                AlreadyExists
                IncorrectState
                PermissionDenied
                AuthorizationFailed
                AuthenticationFailed
                Timeout
                NoSuccess
      Notes:    - if the target is a directory, the source entry
                  is moved into that directory.
```

```
                - a 'BadParameter' exception is thrown if the
                  source is a directory and the 'Recursive' flag
                  is not set.
                - a 'BadParameter' exception is thrown if the
                  source is not a directory and the 'Recursive'
                  flag is set.
                - if the target lies in a non-existing part of
                  the name space, a 'DoesNotExist' exception is
                  thrown, unless the 'CreateParents' flag is
                  given - then that part of the name space MUST
                  be created.
                - if the target already exists, it will be
                  overwritten if the 'Overwrite' flag is set,
                  otherwise it is an 'AlreadyExists' exception.
                - if the instance points at an symbolic link,
                  the source is not dereferenced before moving,
                  unless the 'Dereference' flag is given.
                  If derefencing is impossible (e.g. on a broken
                  link), an 'IncorrectState' exception is thrown.
                - other flags are not allowed, and cause a
                  'BadParameter' exception.
                - the default flags are 'None' (0).
                - similar to 'mv' as defined by POSIX.


  - remove
    Purpose:  removes this entry, and closes it
    Format:   remove             (in  int  flags = None);
    Inputs:   target:             entry to be removed
    InOuts:   -
    Outputs:  -
    PreCond:  -
    PostCond: - the original entry is closed and removed.
    Perms:    Query
              Write
              Exec  for parent directory.
              Write for parent directory.
    Throws:   NotImplemented
              BadParameter
              IncorrectState
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
              Timeout
              NoSuccess
    Notes:    - a 'BadParameter' exception is thrown if the
```

```
                    entry is a non-empty directory and the
                    'Recursive' flag is not set.
                  - if the 'Recursive' flag is defined, the target
                    is recursively removed if it is a directory;
                    otherwise this flag is ignored.
                  - if the 'Dereference' flag is specified, the
                    method applies to the link target of target.
                    The flag causes a 'BadParameter' exception if
                    target is not a link.
                  - a 'BadParameter' exception is thrown if the
                    entry is not a directory and the 'Recursive'
                    flag is set.
                  - other flags are not allowed, and cause a
                    'BadParameter' exception.
                  - the default flags are 'None' (0).
                  - if the instance was not closed before, this
                    call performs a close() on the instance, and
                    all notes to close() apply.
                  - similar to 'rm' as defined by POSIX.


    - close
      Purpose:  closes the object
      Format:   close               (in  float timeout = 0.0);
      Inputs:   timeout              seconds to wait
      InOuts:   -
      Outputs:  -
      PreCond:  -
      PostCond: - the entry instance is closed.
      Perms:    -
      Throws:   NotImplemented
                NoSuccess
      Notes:    - any subsequent method call on the object
                  MUST raise an 'IncorrectState' exception
                  (apart from DESTRUCTOR and close()).
                - close() can be called multiple times, with no
                  side effects.
                - if close() is implicitly called in the
                  DESTRUCTOR, it will never throw an exception.
                - for resource deallocation semantics, see
                  Section 2.
                - for timeout semantics, see Section 2.


    // overload permissions because of namespace specific flags
```

```
- permissions_allow
  Purpose:  enable a permission
  Format:   permissions_allow    (in  string  id,
                                  in  int     perm,
                                  in  int     flags = None);
  Inputs:   id:                   id to set permission for
            perm:                 permission to enable
            flags:                mode of operation
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: - the permissions are enabled.
  Perms:    Owner
  Throws:   NotImplemented
            BadParameter
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - all notes to permissions_allow from the
              saga::permissions interface apply.
            - allowed flags are: 'Recursive', 'Dereference'.
              All other flags cause a 'BadParameter'
              exception.
            - specifying 'Recursive' for a non-directory
              causes a 'BadParameter' exception.


- permissions_deny
  Purpose:  disable a permission flag
  Format:   permissions_deny     (in  string     id,
                                  in  int        perm,
                                  in  int        flags);
  Inputs:   id:                   id to set permission for
            perm:                 permission to disable
            flags:                mode of operation
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: - the permissions are disabled.
  Perms:    Owner
  Throws:   NotImplemented
            BadParameter
            IncorrectState
```

```
                PermissionDenied
                AuthorizationFailed
                AuthenticationFailed
                Timeout
                NoSuccess
      Notes:    - all notes to permissions_deny from the
                  saga::permissions interface apply.
                - allowed flags are: 'Recursive', 'Dereference'.
                  All other flags cause a 'BadParameter'
                  exception.
                - specifying 'Recursive' for a non-directory
                  causes a 'BadParameter' exception.
```

Class ns_directory

ns_directory inherits all navigation and manipulation methods from ns_entry, but adds some more methods to these sets: instead of dir.copy (target) they allow, for example, to do dir.copy (source, target). Other methods added allow to change the cwd of the instance (which changes the values returned by the get_name(), get_cwd() and get_url() inspection methods), and others allow to open new ns_entry and ns_directory instances (open() and open_dir()).

For all methods which have the same name as in the ns_entry class, the descriptions and semantics defined in ns_entry apply, unless noted here otherwise.

```
    - CONSTRUCTOR
      Purpose:  create the object
      Format:   CONSTRUCTOR          (in  session   s,
                                      in  saga::url name,
                                      in  int       flags = Read,
                                      out ns_directory obj)
      Inputs:   name:                 initial working dir
                flags:                open mode
                s:                    session handle for
                                      object creation
      InOuts:   -
      Outputs:  obj:                  the newly created object
      PreCond:  -
      PostCond: - the directory is opened.
                - 'Owner' of target is the id of the context
                  use to perform the operation, if the
```

```
                directory gets created.
  Perms:      Exec  for parent directory.
              Write for parent directory if Create is set.
              Write for name if Write is set.
              Read  for name if Read  is set.
  Throws:     NotImplemented
              IncorrectURL
              BadParameter
              DoesNotExist
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
              Timeout
              NoSuccess
  Notes:      - the semantics of the inherited constructors
                apply
              - the constructor performs an open of the
                entry - all notes to the respective open
                call apply.
              - the default flag set is 'Read'.


- DESTRUCTOR
  Purpose:  destroy the object
  Format:   DESTRUCTOR           (in  ns_directory obj)
  Inputs:   obj:                  the object to destroy
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: - the directory is closed.
  Perms:    -
  Throws:   -
  Notes:    - the semantics of the inherited destructors
              apply


Methods for navigation in the name space hierarchy:
---------------------------------------------------

- change_dir
  Purpose:  change the working directory
  Format:   change_dir         (in  saga::url  dir);
  Inputs:   dir:                directory to change to
  InOuts:   -
  Outputs:  -
  PreCond:  -
```

```
  PostCond: - dir is the directory the instance represents.
  Perms:    Exec for dir.
  Throws:   NotImplemented
            IncorrectURL
            BadParameter
            DoesNotExist
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - if 'dir' can be parsed as URL, but contains an
              invalid directory name, a 'BadParameter'
              exception is thrown.
            - if 'dir' does not exist, a 'DoesNotExist'
              exception is thrown.
            - similar to the 'cd' command in the POSIX
              shell.


- list
  Purpose:  list entries in this directory
  Format:   list               (in  string name_pattern = ".",
                                in  int    flags        = None
                                out array<saga::url> names);
  Inputs:   flags:              flags defining the operation
                                modus
            name_pattern:       name or pattern to list
  InOuts:   -
  Outputs:  names:              array of names matching the
                                name_pattern
  PreCond:  -
  PostCond: -
  Perms:    Query for entries specified by name_pattern.
            Exec  for parent directories of these entries.
            Query for parent directories of these entries.
            Read  for directories specified by name_pattern.
            Exec  for directories specified by name_pattern.
            Exec  for parent directories of these directories.
            Query for parent directories of these directories.
  Throws:   NotImplemented
            IncorrectURL
            BadParameter
            IncorrectState
            PermissionDenied
```

```
                AuthorizationFailed
                AuthenticationFailed
                Timeout
                NoSuccess
      Notes:    - if name_pattern is not given (i.e. is an empty
                  string), all entries in the current working
                  directory are listed.
                - if name_pattern is given and points to a
                  directory, the contents of that directory
                  are listed.
                - the name_pattern follows the standard POSIX
                  shell wildcard specification, as described
                  above.
                - list does not follow symbolically linked
                  directories, unless the 'Dereference' flag
                  is specified - otherwise list lists symbolic
                  link entries with a matching name.
                - if the 'DeReference' flag is set, list
                  returns the name of link targets, not of the
                  link entry itself.
                - the default flags are 'None' (0).
                - other flags are not allowed, and cause a
                  'BadParameter' exception.
                - if the name_pattern cannot be parsed, a
                  'BadParameter' exception with a descriptive
                  error message is thrown.
                - if the name_pattern does not match any entry,
                  an empty list is returned, but no exception is
                  raised.
                - similar to 'ls' as defined by POSIX.


    - find
      Purpose:  find entries in the current directory and below
      Format:   find              (in  string  name_pattern,
                                   in  int     flags = Recursive,
                                   out array<saga::url> names);
      Inputs:   name_pattern:      pattern for names of
                                   entries to be found
                flags:             flags defining the operation
                                   modus
      InOuts:   -
      Outputs:  names:             array of names matching the
                                   name_pattern
      PreCond:  -
      PostCond: -
```

```
    Perms:    Read  for cwd.
              Query for entries specified by name_pattern.
              Exec  for parent directories of these entries.
              Query for parent directories of these entries.
              Read  for directories specified by name_pattern.
              Exec  for directories specified by name_pattern.
              Exec  for parent directories of these directories.
              Query for parent directories of these directories.
    Throws:   NotImplemented
              BadParameter
              IncorrectState
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
              Timeout
              NoSuccess
    Notes:    - find operates recursively below the current
                working directory if the 'Recursive' flag is
                specified (default)
              - find does not follow symbolically linked
                directories, unless the 'Dereference' flag
                is specified - otherwise find lists symbolic
                link entries with a matching name.
              - the default flags are 'Recursive' (1).
              - other flags are not allowed, and cause a
                'BadParameter' exception.
              - the name_pattern follows the standard POSIX
                shell wildcard specification, as described
                above.
              - the matching entries returned are path names
                relative to cwd.
              - similar to 'find' as defined by POSIX, but
                limited to the -name option.


  - exists
    Purpose:  returns true if entry exists, false otherwise
    Format:   exists             (in  saga::url name,
                                  out boolean  exists);
    Inputs:   name:               name to be tested for
                                  existence
    InOuts:   -
    Outputs:  exists:             boolean indicating existence
                                  of name
    PreCond:  -
    PostCond: -
```

```
    Perms:    Query for name.
              Exec  for name's parent directory.
              Read  for name's parent directory.
    Throws:   NotImplemented
              IncorrectURL
              BadParameter
              IncorrectState
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
              Timeout
              NoSuccess
    Notes:    - if 'name' can be parsed as URL, but contains
                an invalid entry name, an 'BadParameter'
                exception is thrown.
              - note that no exception is thrown if the entry
                does not exist - the method just returns
                'false' in this case.
              - similar to 'test -e' as defined by POSIX.


  - is_dir
    Purpose:  tests name for being a directory
    Format:   is_dir             (in  saga::url name,
                                  out boolean test);
    Inputs:   name:               name to be tested
    InOuts:   -
    Outputs:  test:               boolean indicating if name
                                  is a directory
    PreCond:  -
    PostCond: -
    Perms:    Query for name.
              Exec  for name's parent directory.
              Read  for name's parent directory.
    Throws:   NotImplemented
              IncorrectURL
              BadParameter
              DoesNotExist
              IncorrectState
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
              Timeout
              NoSuccess
    Notes:    - returns true if the instance represents
                a directory entry, false otherwise
```

```
                - all notes to the ns_entry::is_dir() method
                  apply.
                - if 'name' can be parsed as URL, but contains
                  an invalid entry name, an 'BadParameter'
                  exception is thrown.
                - if 'name' is a valid entry name but the entry
                  does not exist, a 'DoesNotExist' exception is
                  thrown.
                - similar to 'test -d' as defined by POSIX.


    - is_entry
      Purpose:  tests name for being an ns_entry
      Format:   is_entry           (in  saga::url name,
                                    out boolean   test);
      Inputs:   name:               name to be tested
      InOuts:   -
      Outputs:  test:               boolean indicating if name
                                    is a non-directory entry
      PreCond:  -
      PostCond: -
      Perms:    Query for name.
                Exec  for name's parent directory.
                Read  for name's parent directory.
      Throws:   NotImplemented
                IncorrectURL
                BadParameter
                DoesNotExist
                IncorrectState
                PermissionDenied
                AuthorizationFailed
                AuthenticationFailed
                Timeout
                NoSuccess
      Notes:    - all notes to the ns_entry::is_entry() method
                  apply.
                - if 'name' can be parsed as URL, but contains
                  an invalid entry name, a 'BadParameter'
                  exception is thrown.
                - if 'name' is a valid entry name but the entry
                  does not exist, a 'DoesNotExist' exception is
                  thrown.
                - similar to 'test -f' as defined by POSIX.


    - is_link
```

```
  Purpose:  tests name for being a symbolic link
  Format:   is_link            (in  saga::url name,
                                out boolean   test);
  Inputs:   name:               name to be tested
  InOuts:   -
  Outputs:  test:               boolean indicating if name
                                is a link
  PreCond:  -
  PostCond: -
  Perms:    Query for name.
            Exec  for name's parent directory.
            Read  for name's parent directory.
  Throws:   NotImplemented
            IncorrectURL
            BadParameter
            IncorrectState
            DoesNotExist
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - all notes to the ns_entry::is_link() method
              apply.
            - if 'name' can be parsed as URL, but contains
              an invalid entry name, a 'BadParameter'
              exception is thrown.
            - if 'name' is a valid entry name but the entry
              does not exist, a 'DoesNotExist' exception is
              thrown.
            - similar to 'test -L' as defined by POSIX.


- read_link
  Purpose:  returns the name of the link target
  Format:   read_link          (in  saga::url name,
                                out saga::url link);
  Inputs:   name:               name to be resolved
  InOuts:   -
  Outputs:  link:               resolved name
  PreCond:  -
  PostCond: -
  Perms:    Query for name.
            Exec  for name's parent directory.
            Read  for name's parent directory.
  Throws:   NotImplemented
```

```
              IncorrectURL
              BadParameter
              DoesNotExist
              IncorrectState
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
              Timeout
              NoSuccess
    Notes:    - all notes to ns_entry::read_link() apply
              - if 'name' can be parsed as URL, but contains
                an invalid entry name, a 'BadParameter'
                exception is thrown.
              - if 'name' does not exist, a 'DoesNotExist'
                exception is thrown.


  - get_mtime
    Purpose:  returns the last modification time
    Format:   get_time           (in  saga::url name,
                                  out int time);
    Inputs:   name:               name to be checked
    InOuts:   -
    Outputs:  time:               time of last modification
    PreCond:  -
    PostCond: -
    Perms:    Query for name.
              Query for name's parent directory.
    Throws:   NotImplemented
              IncorrectURL
              BadParameter
              DoesNotExist
              IncorrectState
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
              Timeout
              NoSuccess
    Notes:    - all notes to ns_entry::get_mtime() apply.
              - if 'name' can be parsed as URL, but contains
                an invalid entry name, a 'BadParameter'
                exception is thrown.
              - if 'name' does not exist, a 'DoesNotExist'
                exception is thrown.
```

```
Iterate over large directories:
-------------------------------

- get_num_entries
  Purpose:  gives the number of entries in the directory
  Format:   get_num_entries    (out int   num);
  Inputs:   -
  InOuts:   -
  Outputs:  num:                number of entries in the
                                directory
  PreCond:  -
  PostCond: -
  Perms:    Query for cwd.
            Exec  for cwd.
            Read  for cwd.
  Throws:   NotImplemented
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - at the time of using the result of this call,
              the actual number of entries may already have
              changed (no locking is implied)
            - vaguely similar to 'opendir'/'readdir' (2) as
              defined by POSIX.


- get_entry
  Purpose:  gives the name of an entry in the directory
            based upon the enumeration defined by
            get_num_entries
  Format:   get_entry          (in  int       entry,
                                out saga::url name);
  Inputs:   entry:              index of entry to get
  InOuts:   -
  Outputs:  name:               name of entry at index
  PreCond:  -
  PostCond: -
  Perms:    Query for cwd.
            Exec  for cwd.
            Read  for cwd.
  Throws:   NotImplemented
            IncorrectState
```

```
              DoesNotExist
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
              Timeout
              NoSuccess
    Notes:    - '0' is the first entry
              - there is no sort order implied by the
                enumeration, however an underlying
                implementation MAY choose to sort the entries
              - subsequent calls to get_entry and/or
                get_num_entries may return inconsistent data,
                i.e. no locking or state tracking is implied.
                In particular, an index may be invalid - a
                'DoesNotExist' exception is then thrown (not a
                'BadParameter' exception).
              - vaguely similar to 'opendir'/'readdir' (2) as
                defined by POSIX.


  Management of name space entries:
  ---------------------------------


  - copy
    Purpose:  copy the entry to another part of the name space
    Format:   copy              (in  saga::url  source,
                                 in  saga::url  target,
                                 in  int     flags = None);
    Inputs:   source:            name to copy
              target:            name to copy to
              flags:             flags defining the operation
                                 modus
    InOuts:   -
    Outputs:  -
    PreCond:  -
    PostCond: - an identical copy of source exists at target.
              - 'Owner' of target is the id of the context
                used to perform the operation if target gets
                created.
    Perms:    Query for source.
              Exec  for source's parent directory.
              Query for target.
              Query for target's parent directory.
              Exec  for target's parent directory.
              Write for target
                    if  target does exist.
```

```
                Write for target's parent directory
                      if  target does not exist.
      Throws:   NotImplemented
                IncorrectURL
                BadParameter
                AlreadyExists
                DoesNotExist
                IncorrectState
                PermissionDenied
                AuthorizationFailed
                AuthenticationFailed
                Timeout
                NoSuccess
      Notes:    - all notes to the ns_entry::copy() method
                  apply.
                - the default flags are 'None' (0).
                - if 'source' or 'target' can be parsed as URL,
                  but contain an invalid entry name, a
                  'BadParameter' exception is thrown.
                - if 'source' or 'target' are valid entry names
                  but the entry does not exist, a 'DoesNotExist'
                  exception is thrown.


    - link
      Purpose:  create a symbolic link from the target entry to
                the source entry so that any reference to the
                target refers to the source entry
      Format:   link              (in  saga::url  source,
                                   in  saga::url  target,
                                   in  int     flags = None);
      Inputs:   source:            name to link
                target:            name to link to
                flags:             flags defining the operation
                                   modus
      InOuts:   -
      Outputs:  -
      PreCond:  -
      PostCond: - a symbolic link to source exists at target.
                - 'Owner' of target is the id of the context
                  used to perform the operation if target gets
                  created.
      Perms:    Query for source.
                Exec  for source's parent directory.
                Query for target.
                Query for target's parent directory.
```

```
            Exec  for target's parent directory.
            Write for target
                  if  target does exist.
            Write for target's parent directory
                  if  target does not exist.
  Throws:   NotImplemented
            IncorrectURL
            BadParameter
            AlreadyExists
            DoesNotExist
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - all notes to the ns_entry::link() method
              apply.
            - the default flags are 'None' (0).
            - other flags are not allowed on this method,
              and cause a 'BadParameter' exception.
            - if 'source' can be parsed as URL, but contains
              an invalid entry name, a 'BadParameter'
              exception is thrown.
            - if 'source' is a valid entry name but the entry
              does not exist, a 'DoesNotExist' exception is
              thrown.


- move
  Purpose:  rename source to target, or move source to
            target if target is a directory.
  Format:   move               (in  saga::url  source,
                                in  saga::url  target,
                                in  int     flags = None);
  Inputs:   source:             name to move
            target:             name to move to
            flags:              flags defining the operation
                                modus
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: - the entry exists at the target url.
            - no entry exists at the original url.
            - the object instance is not closed.
            - 'Owner' of target is the id of the context
```

```
                   used to perform the operation if target gets
                   created.
      Perms:     Query for source.
                 Write for source.
                 Exec  for source's parent directory.
                 Write for source's parent directory.
                 Query for target.
                 Exec  for target's parent directory.
                 Write for target
                       if  target does exist.
                 Write for target's parent directory
                       if  target does not exist.
      Throws:    NotImplemented
                 IncorrectURL
                 BadParameter
                 AlreadyExists
                 DoesNotExist
                 IncorrectState
                 PermissionDenied
                 AuthorizationFailed
                 AuthenticationFailed
                 Timeout
                 NoSuccess
      Notes:     - all notes to the ns_entry::move() method
                   apply.
-                - if the 'Recursive' flag is defined, the source
-                  is recursively copied if it is a directory;
-                  otherwise this flag is ignored.
-                - if the 'Dereference' flag is specified, the
-                  method applies to the link target of source.
-                  The flag causes a 'BadParameter' exception if
-                  source is not a link.
-                - if the the target already exists, the
-                  'Overwrite' flag must be specified, otherwise
-                  an 'AlreadyExists' exception is thrown.
                 - the default flags are 'None' (0).
                 - other flags are not allowed on this method,
                   and cause a 'BadParameter' exception.
                 - if 'source' can be parsed as URL, but contains
                   an invalid entry name, a 'BadParameter'
                   exception is thrown.
                 - if 'source' is a valid entry name but the entry
                   does not exist, a 'DoesNotExist' exception is
                   thrown.
                 - moving any parent or the current directory
                   (e.g.  '.', '..' etc.) is not allowed, and
```

```
              throws a 'BadParameter' exception


  - remove
    Purpose:  removes the entry
    Format:   remove            (in  saga::url  target,
                                 in  int     flags = None);
    Inputs:   target:            entry to be removed
    InOuts:   -
    Outputs:  -
    PreCond:  -
    PostCond: - target is removed.
              - target is closed if it refers to the cwd.
    Perms:    Query for target.
              Write for target.
              Exec  for target's parent directory.
              Write for target's parent directory.
    Throws:   NotImplemented
              IncorrectURL
              BadParameter
              AlreadyExists
              DoesNotExist
              IncorrectState
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
              Timeout
              NoSuccess
    Notes:    - all notes to the ns_entry::remove() method
                apply.
              - the default flags are 'None' (0).
              - other flags are not allowed on this method,
                and cause a 'BadParameter' exception.
              - if 'target' can be parsed as URL, but contains
                an invalid entry name, a 'BadParameter'
                exception is thrown.
              - if 'target' is a valid entry name but the entry
                does not exist, a 'DoesNotExist' exception is
                thrown.
              - if the instance was not closed before, this
                call performs a close() on the instance, and
                all notes to close() apply.
              - removing any parent or the current directory
                (e.g.  '.', '..' etc.) is not allowed, and
                throws a 'BadParameter' exception
```

```
- make_dir
  Purpose:  creates a new directory
  Format:   make_dir           (in  saga::url  target,
                                in  int     flags = None);
  Inputs:   target:             directory to create
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: - 'Owner' of target is the id of the context
              used to perform the operation if target gets
              created.
  Perms:    Exec  for target's parent directory.
            Write for target's parent directory.
            Write for target if Write is set.
            Read  for target if Read  is set.
  Throws:   NotImplemented
            IncorrectURL
            BadParameter
            AlreadyExists
            DoesNotExist
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - if the parent directory or directories do not
              exist, the 'CreateParents' flag must be set
              or a 'DoesNotExist' exception is thrown.
              If set, the parent directories are created as
              well.
            - an 'AlreadyExists' exception is thrown if the
              directory already exists and the 'Exclusive'
              flag is given.
            - the default flags are 'None' (0).
            - other flags are not allowed on this method,
              and cause a 'BadParameter' exception.
            - if 'target' can be parsed as URL, but contains
              an invalid entry name, a 'BadParameter'
              exception is thrown.
            - similar to 'mkdir' (2) as defined by POSIX.


- open_dir
  Purpose:  creates a new ns_directory instance
```

```
Format:   open_dir           (in  saga::url name,
                              in  int       flags = Read,
                              out ns_directory dir);
Inputs:   name:               directory to open
          flags:              flags defining the operation
                              modus
InOuts:   -
Outputs:  dir:                opened directory instance
PreCond:  -
PostCond: - the session of the returned instance is that of
            the calling instance.
          - 'Owner' of name is the id of the context
            used to perform the operation if name gets
            created.
          - the namespace directory is created if it
            does not yet exist, and the Create is set.
Perms:    Exec  for name's parent directory.
          Write for name's parent directory if Create is set.
          Write for name if Write is set.
          Read  for name if Read  is set.
Throws:   NotImplemented
          IncorrectURL
          BadParameter
          AlreadyExists
          DoesNotExist
          IncorrectState
          PermissionDenied
          AuthorizationFailed
          AuthenticationFailed
          Timeout
          NoSuccess
Notes:    - the cwd of the new dir object instance is set
            to 'name'
          - a 'DoesNotExist' exception is thrown if 'name'
            does not exist and the 'Create' flag is not
            given.
          - a 'AlreadyExist' exception is thrown if 'name'
            does exist and the 'Create' flag and the
           'Exclusive' flag are given.
          - no exception is thrown if 'name' does exist and
            the 'Create' flag is given, and the 'Exclusive'
            flag is not given.
          - if the 'Create' flag is given, all notes to the
            ns_directory::make_dir() method apply.
          - the default flag set is 'Read'.
          - the flags 'Overwrite', 'Recursive' and
```

```
                 'Dereference' are not allowed on this method,
                 and cause a 'BadParameter' exception.
               - 'name' is always deeply dereferenced, however,
                 the cwd is still set to 'name', and not to the
                 value of the link target.
               - parent directories are created on the fly if
                 the 'CreateParents' and 'Create' flag are both
                 given, if they don't exist.
               - if 'name' can be parsed as URL, but contains
                 an invalid directory name, a 'BadParameter'
                 exception is thrown.


  - open
    Purpose:  creates a new ns_entry instance
    Format:   open               (in  saga::url name,
                                  in  int       flags = Read,
                                  out ns_entry  entry);
    Inputs:   name:               entry
              flags:              flags defining the operation
                                  modus
    InOuts:   -
    Outputs:  entry:              opened entry instance
    PreCond:  -
    PostCond: - the session of the returned instance is that
                of the calling instance.
              - 'Owner' of name is the id of the context
                used to perform the operation if name gets
                created.
              - the namespace entry is created if it does not
                yet exist, and the CREATE flag is specified.
    Perms:    Exec  for name's parent directory.
              Write for name's parent directory if Create is set.
              Write for name if Write is set.
              Read  for name if Read  is set.
    Throws:   NotImplemented
              IncorrectURL
              BadParameter
              AlreadyExists
              DoesNotExist
              IncorrectState
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
              Timeout
              NoSuccess
```

```
  Notes:    - a 'BadParameter' exception is thrown if 'name'
              is an invalid entry name.
            - a 'DoesNotExist' exception is thrown if 'name'
              does not exist, and the 'Create' flag is not
              given.
            - a 'AlreadyExists' exception is thrown if 'name'
              does exist, and the 'Create' and 'Exclusive'
              flags are given.
            - 'name' is always deeply dereferenced, the cwd,
              however, is not changed to the link targets
              cwd.
            - parent directories are created on the fly if
              the 'CreateParents' and 'Create' flag are both
              given, if they don't exist.
            - the entry is locked on open if the 'Lock' flag
              is given.  If the entry is already in a locked
              state, the open will fail and a descriptive
              error will be issued.  If a entry is opened in
              locked mode, any other open on that entry MUST
              fail with a 'NoSuccess' exception if the 'Lock'
              flag is given.  Note that a entry can be opened
              in unlocked mode, and then in locked mode,
              without an error getting raised.  The
              application programmer must take precautions
              to avoid such situations.  The lock will get
              removed on destruction of the entry object, and
              also on close.  If an implementation does not
              support locking, a descriptive 'BadParameter'
              exception MUST get thrown if the 'Lock' flag
              is given.  Read-locks and Write-locks are not
              distinguished.
            - the default flag set is 'Read'.
            - the flags 'Recursive' and 'Dereference' are
              not allowed on this method, and cause a
              'BadParameter' exception.
            - similar to 'open' (2) as defined by POSIX.


Management of name space entries - wildcard versions:
-----------------------------------------------------


- copy
  Purpose:  copy the entry to another part of the name space
  Format:   copy              (in  string     source,
                               in  saga::url  target,
                               in  int        flags = None);
```

```
  Notes:    - the syntax and semantics of this call is
              identical to its URL based counterpart.
            - the 'source' string can contain wildcards, as
              described above.
            - on error conditions on any of the expanded
              list of source entries, the respective error
              described in the URL version of the method is
              thrown - the state of the operations on the
              other elements of the expanded entry list is
              undefined.
            - if source expands to multiple entries, then the
              target URL MUST specify a directory -
              otherwise a 'BadParameter' exception is thrown.


- link
  Purpose:  create a symbolic link from the target entry to
            the source entry so that any reference to the
            target refers to the source entry
  Format:   link               (in  string     source,
                                in  saga::url  target,
                                in  int        flags = None);
  Notes:    - the syntax and semantics of this call is
              identical to its URL based counterpart.
            - the 'source' string can contain wildcards, as
              described above.
            - on error conditions on any of the expanded
              list of source entries, the respective error
              described in the URL version of the method is
              thrown - the state of the operations on the
              other elements of the expanded entry list is
              undefined.
            - if source expands to multiple entries, then the
              target URL MUST specify a directory -
              otherwise a 'BadParameter' exception is thrown.

- move
  Purpose:  moves sources to a target directory.
  Format:   move               (in  string     source,
                                in  saga::url  target,
                                in  int        flags = None);
  Notes:    - the syntax and semantics of this call is
              identical to its URL based counterpart.
            - the 'source' string can contain wildcards, as
              described above.
            - on error conditions on any of the expanded
```

```
                list of source entries, the respective error
                described in the URL version of the method is
                thrown - the state of the operations on the
                other elements of the expanded entry list is
                undefined.
              - if source expands to multiple entries, then the
                target URL MUST specify a directory -
                otherwise a 'BadParameter' exception is thrown.

  - remove
    Purpose:  removes entries
    Format:   remove             (in  string  target,
                                  in  int     flags = None);
    Notes:    - the syntax and semantics of this call is
                identical to its URL based counterpart.
              - the 'target' string can contain wildcards, as
                described above.
              - on error conditions on any of the expanded
                list of target entries, the respective error
                described in the URL version of the method is
                thrown - the state of the operations on the
                other elements of the expanded entry list is
                undefined.


  // overload permissions because of namespace specific flags

  - permissions_allow
    Purpose:  enable a permission
    Format:   permissions_allow    (in  saga::url target,
                                    in  string    id,
                                    in  int       perm,
                                    in  int       flags = None);
    Inputs:   target:               entry to set permissions for
              id:                   id to set permission for
              perm:                 permission to enable
              flags:                mode of operation
    InOuts:   -
    Outputs:  -
    PreCond:  -
    PostCond: - the permissions are enabled.
    Perms:    Owner of target
    Throws:   NotImplemented
              IncorrectURL
              BadParameter
              IncorrectState
```

```
                PermissionDenied
                AuthorizationFailed
                AuthenticationFailed
                Timeout
                NoSuccess
      Notes:    - all notes to permissions_allow from the
                  saga::permissions interface apply.
                - allowed flags are: 'Recursive', 'Dereference'.
                  All other flags cause a 'BadParameter'
                  exception.
                - specifying 'Recursive' for a non-directory
                  causes a 'BadParameter' exception.


    - permissions_deny
      Purpose:  disable a permission flag
      Format:   permissions_deny     (in  saga::url target,
                                      in  string    id,
                                      in  int       perm,
                                      in  int       flags = None);
      Inputs:   target:               entry to set permissions for
                id:                   id to set permission for
                perm:                 permission to disable
                flags:                mode of operation
      InOuts:   -
      Outputs:  -
      PreCond:  -
      PostCond: - the permissions are disabled.
      Perms:    Owner of target
      Throws:   NotImplemented
                IncorrectURL
                BadParameter
                IncorrectState
                PermissionDenied
                AuthorizationFailed
                AuthenticationFailed
                Timeout
                NoSuccess
      Notes:    - all notes to permissions_deny from the
                  saga::permissions interface apply.
                - allowed flags are: 'Recursive', 'Dereference'.
                  All other flags cause a 'BadParameter'
                  exception.
                - specifying 'Recursive' for a non-directory
                  causes a 'BadParameter' exception.
```

```
// permissions calls - wildcard versions

- permissions_allow
  Purpose:  enable a permission
  Format:   permissions_allow    (in  string  target,
                                  in  string  id,
                                  in  int     perm,
                                  in  int     flags = None);
  Notes:    - the syntax and semantics of this call is
              identical to its URL based counterpart.
            - the 'source' string can contain wildcards, as
              described above.
            - on error conditions on any of the expanded
              list of source entries, the respective error
              described in the URL version of the method is
              thrown - the state of the operations on the
              other elements of the expanded entry list is
              undefined.


- permissions_deny
  Purpose:  disable a permission flag
  Format:   permissions_deny     (in  string  target,
                                  in  string  id,
                                  in  int     perm,
                                  in  int     flags = None);
  Notes:    - the syntax and semantics of this call is
              identical to its URL based counterpart.
            - the 'source' string can contain wildcards, as
              described above.
            - on error conditions on any of the expanded
              list of source entries, the respective error
              described in the URL version of the method is
              thrown - the state of the operations on the
              other elements of the expanded entry list is
              undefined.
```

4.2.4 Examples:

Code Example

```
More examples are given in the File and Logical_File packages.

Example: provide recursive directory listing for a given
```

```
        directory

Note:   - check for '.' and '..' recursion are left as an
          exercise to the reader.
        - string operations and printf statements are
          obviously simplified.

+-------------------------------------------------------------+
 // c++ example
 std::string indent (int indent)
 {
   std::string s = "  ";

   for (int i = 0; i < indent; i++, s += "  ");

   return (s);
 }

 void list_dir (saga::url url,
                int       indent = 0)
 {
   try
   {
     // create directory and iterate over entries
     saga::ns_dir dir (url);

     printf ("\n%s ---> %s\n", indent (indent), url.get_url ());

     for ( int i = 0; i < dir.get_num_entries (); i++ )
     {
       char   type = '?';
       string info = "";

       // get name of next entry
       saga::url name = dir.get_entry (i);

       // get type and other info
       if ( dir.is_link (name) )
       {
         // check where link points to
         if (dir.exists(dir.read_link (name))){info=" ---> ";}
         else                                 {info=" -|-> ";}
         info += dir.read_link (name);
         type  = 'l';
       }
       else if (dir.is_entry(name)){ type = 'f';             }
       else if (dir.is_dir  (name)){ type = 'd'; info = "/";}

       printf ("%s > %3d - %s - %s%s\n",
               indent (indent), i + 1,
```

```
                type, name.get_cstr (), info);

        // recursion on directories
        if ( dir.is_dir (name) )
        {
          list_dir (name, indent++);
        }
      }

      printf ("\n%s <--- %s\n", indent (indent), url.get_url ());
    }

    // catch all errors - see elsewhere for better examples
    // of error handling in SAGA
    catch ( const saga::exception & e )
    {
      std::cerr << "Oops! SAGA exception: "
                << e.get_message ()
                << std::endl;
    }

    return;
  }
```

4.3 SAGA File Management

The ability to access the contents of files regardless of their location is central to many of the SAGA use cases. This section addresses the most common operations detailed in these use cases.

It is important to note that interactions with files as opaque entities (i.e. as entries in file name spaces) are covered by the `namespace` package. The classes presented here supplement the `namespace` package with operations for the reading and writing of the *contents* of files. For all methods, the descriptions and notes of the equivalent methods in the `namespace` package apply if available, unless noted here otherwise.

The described classes are syntactically and semantically POSIX oriented [21, 22, 23]. Executing large numbers of simple POSIX-like remote data access operations is, however, prone to latency related performance problems. To allow for efficient implementations, the presented API borrows ideas from GridFTP and other specifications which are widely used for remote data access. These extensions should be seen as just that: optimizations. Implementations of this package MUST implement the POSIX-like `read()`, `write()` and `seek()` methods, and MAY implement the additional optimized methods (a 'NotImplemented' exception MUST be thrown if these are not implemented). The optimizations included here are:

Scattered I/O Scattered I/O operations are already defined by POSIX, as `readv()` and `writev()`. Essentially, these methods represent **v** ector versions of the standard POSIX `read()/write()` methods; the arguments are, basically, vectors of instructions to execute, and buffers to operate upon. In other words, `readv()` and `writev()` can be regarded as specialized bulk methods, which cluster multiple I/O operations into a single operation. Advantage of such an approach are that it is easy to implement, is very close to the original POSIX I/O in semantics, and in some cases even very fast. Disadvantages are that for many small I/O operations (a common occurrence in SAGA use cases), the description of the I/O operations can be larger than the sent, returned or received data.

Pattern-Based I/O (FALLS) One approach to address the bandwidth limitation of scattered I/O is to describe the required I/O operations at a more abstract level. Regularly repeating patterns of binary data can be described by the so-called 'Family of Line Segments' (FALLS) [14]. The pattern-based I/O routines in SAGA use such descriptions to reduce the bandwidth limitation of scattered I/O. The advantage of such an approach is that it targets very common data access patterns (at least those very commonly found in SAGA use cases). The disadvantages are that FALLS is a paradigm not widely known or used, and that FALLS is by definition, limited to regular patterns of data, and hence is inefficient for more randomized data access.

FALLS (FAmiLy of Line Segments) were originally introduced for transformations in parallel computing. There is also a parallel filesystem which uses FALLS to describe the file layout. They can be used to describe regular subsets of arrays with a very compact syntax.

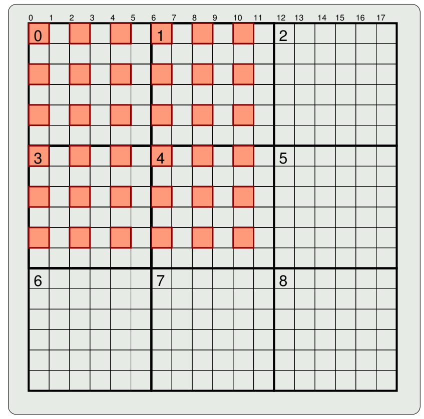

Figure 5: **The highlighted elements are defined by** `"(0,17,36,6,(0,0,2,6))"`.

FALLS pattern are formed as 5-tuples: `"(from,to,stride,rep,(pat))"`. The `from` element defines the starting offset for the first pattern unit, `to` defines the finishing offset of the first pattern unit, `stride` defines the distance between consecutive pattern units (begin to begin), and `rep` defines the number of repetitions of the pattern units. The optional 5th element `pat` allows the definition of nested patterns, where the internal pattern defines the unit the outer pattern is applied to (by default that is one byte). As an example: the following FALLS describe the highlighted elements of the matrix in Fig 5: `"(0,17,36,6,(0,0,2,6))"`: the inner pattern describes a pattern unit of one byte length (from 0 to 0), with a distance of 2 to the next application, and 6 repetitions. These are the 6 bytes per line which are marked. The outer pattern defines the repeated application of the inner pattern, starting at 0, ending at 17 (end of line), distance of 36 (to begin of next but one line), and repetition of 6.

Extended I/O GridFTP (which was designed for a similar target domain) introduced an additional remote I/O paradigm, that of Extended I/O operations.

In essence, the Extended I/O paradigm allows the formulation of I/O requests using custom strings, which are not interpreted on the client but on the server side; these can be expanded to arbitrarily complex sets of I/O operations. The type of I/O request encoded in the string is called `mode`. A server may support one or many of these extended I/O modes. Whereas the approach is very flexible and powerful and has proven its usability in GridFTP, a disadvantage is that it requires very specific infrastructure to function, i.e. it requires a remote server instance which can interpret opaque client requests. Additionally, no client side checks or optimizations on the I/O requests are possible. Also, the application programmer needs to estimate the size of the data to be returned in advance, which in some cases is very difficult.

The three described operations have, if compared to each other, increasing semantic flexibility, and are increasingly powerful for specific use cases. However, they are also increasingly difficult to implement and support in a generic fashion. It is up to the SAGA implementation and the specific use cases, to determine the level of I/O abstraction that serves the application best and that can be best supported in the target environment.

4.3.1 Specification

```
package saga.file
{
  enum flags
  {
    None           =    0, // same as in namespace::flags
    Overwrite      =    1, // same as in namespace::flags
    Recursive      =    2, // same as in namespace::flags
    Dereference    =    4, // same as in namespace::flags
    Create         =    8, // same as in namespace::flags
    Exclusive      =   16, // same as in namespace::flags
    Lock           =   32, // same as in namespace::flags
    CreateParents  =   64, // same as in namespace::flags
    Truncate       =  128,
    Append         =  256,
    Read           =  512, // same as in namespace::flags
    Write          = 1024, // same as in namespace::flags
    ReadWrite      = 1536, // same as in namespace::flags
    Binary         = 2048
  }


  enum seek_mode
  {
    Start      =   1,
    Current    =   2,
    End        =   3
  }


  class iovec : extends saga::buffer
             // from buffer saga::object
```

```
          // from object saga::error_handler
  {
    CONSTRUCTOR (in array<byte>         data   = "",
                 in    int              size   = 0,
                 in    int              offset = 0,
                 in    int              len_in = size,
                 out   buffer           obj);

    set_offset  (in    int              offset);
    get_offset  (out   int              offset);

    set_len_in  (in    int              len_in);
    get_len_in  (out   int              len_in);

    get_len_out (out   int              len_out);
  }

  class file : extends        saga::ns_entry,
            // from ns_entry  saga::object
            // from ns_entry  saga::async
            // from ns_entry  saga::permissions
            // from object    saga::error_handler
  {
    CONSTRUCTOR (in    session          s,
                 in    saga::url        name,
                 in    int              flags = Read,
                 out   file             obj      );
    DESTRUCTOR  (in    file             obj      );

    // inspection
    get_size    (out   int              size     );

    // POSIX-like I/O
    read        (inout buffer           buf,
                 in    int              len_in = -1,
                 out   int              len_out  );
    write       (in    buffer           buf,
                 in    int              len_in = -1,
                 out   int              len_out  );
    seek        (in    int              offset,
                 in    seek_mode        whence,
                 out   int              position );

    // scattered I/O
    read_v      (inout array<iovec>     iovecs  );
    write_v     (inout array<iovec>     iovecs  );
```

```
    // pattern-based I/O
    size_p      (in    string            pattern,
                 out   int               size     );
    read_p      (in    string            pattern,
                 inout buffer            buf,
                 out   int               len_out  );
    write_p     (in    string            pattern,
                 in    buffer            buf,
                 out   int               len_out  );

    // extended I/O
    modes_e     (out   array<string>     emodes   );
    size_e      (in    string            emode,
                 in    string            spec,
                 out   int               size     );
    read_e      (in    string            emode,
                 in    string            spec,
                 inout buffer            buf,
                 out   int               len_out  );
    write_e     (in    string            emode,
                 in    string            spec,
                 in    buffer            buf,
                 out   int               len_out  );
  }


  class directory : extends            saga::ns_directory
                 // from ns_directory  saga::ns_entry
                 // from ns_entry      saga::object
                 // from ns_entry      saga::async
                 // from ns_entry      saga::permissions
                 // from object        saga::error_handler
  {
    CONSTRUCTOR (in    session           s,
                 in    saga::url         name,
                 in    int               flags = Read,
                 out   directory         obj      );
    DESTRUCTOR  (in    directory         obj      );

    // inspection methods
    get_size    (in    saga::url         name,
                 in    int               flags = None,
                 out   int               size     );
    is_file     (in    saga::url         name,
                 in    int               flags = None,
```

```
                 out   boolean           test     );

      // factory-like methods
      open_dir    (in    saga::url         name,
                   in    int               flags = Read,
                   out   directory         dir      );

      open        (in    saga::url         name,
                   in    int               flags = Read,
                   out   file              file     );
    }
  }
```

4.3.2 Specification Details

Enum `flags`

The `flags` enum is inherited from the `namespace` package. A number of file specific flags are added to it. All added flags are used for the opening of `file` and `directory` instances, and are not applicable to the operations inherited from the `namespace` package.

`Truncate`
: Upon opening, the file is truncated to length `0`, i.e. a following `read()` operation will never find any data in the file. That flag does not apply to directories.

`Append`
: Upon opening, the file pointer is set to the end of the file, i.e. a following `write()` operation will extend the size of the file. That flag does not apply to directories.

Class `iovec`

The `iovec` class inherits the `saga::buffer` class, and three additional state attributes: `offset`, `len_in` and `len_out` (with the latter one being read-only). With that addition, the new class can be used very much the same way as the `iovec` structure defined by POSIX for `readv/writev`, with the buffer `len_in` being interpreted as the POSIX `iov_len`, i.e. the number of bytes to read/write.

If `len_in` is not specified, that length is set to the size of the buffer. It is a `BadParameter` error if `len_in` is specified to be larger than size, for application managed buffers (see Section 3.4 for details on buffer memory management). Before an `iovec` instance is used, it's `len_in` MUST be set to a non-zero value; otherwise it's use will cause a `BadParameter` exception.

After a `read_v()` or `write_v()` operations completes, `len_out` will report the number of bytes read. Before completion, the SAGA implementation MUST report `len_out` to be `-1`.

```
- CONSTRUCTOR
  Purpose:  create an iovec instance
  Format:   CONSTRUCTOR     (in  array<byte> data   = "",
                             in  int         size   = -1,
                             in  int         offset = 0,
                             in  int         len_in = size,
                             out iovec       obj);
  Inputs:   type:                data to be used
            size:                size of data to be used
            offset               offset for I/O operation
            len_in:              number of bytes to read
                                 or write on read_v/write_v
  InOuts:   -
  Outputs:  buffer:              the newly created iovec
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   BadParameter
            NoSuccess
  Notes:    - all notes from the buffer CONSTRUCTOR apply.
            - if len_in is larger than size, and size is
              not given as -1, a 'BadParameter' exception
              is thrown.

- DESTRUCTOR
  Purpose:  destroy an iovec instance
  Format:   DESTRUCTOR          (in  iovec obj);
  Inputs:   obj:                 the iovec to destroy
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   -
  Notes:    - all notes from the buffer DESTRUCTOR apply.
```

```
- set_offset
  Purpose:  set offset
  Format:   set_offset           (in  int   offset);
  Inputs:   offset:               value for offset
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   BadParameter
  Notes:    - if offset is smaller that zero, a
              'BadParameter' exception is thrown.

- get_offset
  Purpose:  retrieve the current value for offset
  Format:   get_offset           (out int   offset);
  Inputs:   -
  InOuts:   -
  Outputs:  offset:               value of offset
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   -
  Notes:    -

- set_len_in
  Purpose:  set len_in
  Format:   set_len_in           (in  int   len_in);
  Inputs:   len_in:               value for len_in
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   BadParameter
  Notes:    - if len_in is larger than size, and size is
              not set to -1, a 'BadParameter' exception
              is thrown.

- get_len_in
  Purpose:  retrieve the current value for len_in
  Format:   get_len_in           (out int   len_in);
  Inputs:   -
  InOuts:   -
  Outputs:  len_in:               value of len_in
  PreCond:  -
```

```
      PostCond: -
      Perms:    -
      Throws:   -
      Notes:    -

    - get_len_out
      Purpose:  retrieve the value for len_out
      Format:   get_len_out          (out int   len_out);
      Inputs:   -
      InOuts:   -
      Outputs:  len_out:              value of len_out
      PreCond:  -
      PostCond: -
      Perms:    -
      Throws:   -
      Notes:    - len_out reports the number of bytes read
                  or written in a completed read_w or write_w
                  operation.
                - before completion of the operation, the
                  returned value is -1.
                - for implementation managed memory, the
                  value of len_out is always the same as
                  for size.
```

Class `file`

This class represents an open file descriptor for read/write operations on a physical file. Its concept is similar to the file descriptor returned by the `open (2)` call in POSIX.

In language bindings where this is appropriate, several methods can return error codes indicating failure, instead of always raising an exception. These error codes are, as described in Section 3.1, defined as POSIX `errno` values. These codes SHOULD be used in identical situations as described in POSIX. The calls which can use return error codes are documented.

A file instance has specific state, which in general consists of the file's URL, the mode with which the file was opened or created, and the position of the file pointer used for I/O. Note that a `move()` operation keeps the file instance and the file pointer state, but the other state information (URL and open mode) may change under `move()`.

```
- CONSTRUCTOR
  Purpose:  create the obj
  Format:   CONSTRUCTOR        (in  session   s,
                                in  saga::url name,
                                in  int       flags = Read,
                                out file      obj)
  Inputs:   s:                  session to associate the
                                object with
            name:               location of file
            flags:              mode for opening
  InOuts:   -
  Outputs:  obj:                the newly created object
  PreCond:  -
  PostCond: - the file is opened.
            - 'Owner' of target is the id of the context
              use to perform the operation, if the file
              gets created.
  Perms:    Exec  for parent directory.
            Write for parent directory if Create is set.
            Write for name if Write is set.
            Read  for name if Read  is set.
  Throws:   NotImplemented
            IncorrectURL
            BadParameter
            AlreadyExists
            DoesNotExist
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - all notes from the directory::open() method
              apply.
            - the default flags are 'Read' (512).


- DESTRUCTOR
  Purpose:  destroy the object
  Format:   DESTRUCTOR         (in  file      obj)
  Inputs:   obj:                the object to destroy
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: - the file is closed.
  Perms:    -
  Throws:   -
```

```
  Notes:    - the semantics of the inherited destructors
              apply


additional inspection methods:
------------------------------

- get_size
  Purpose:  returns the number of bytes in the file
  Format:   get_size           (out int     size);
  Inputs:   -
  InOuts:   -
  Outputs:  size:               number of bytes in the file
  PreCond:  -
  PostCond: -
  Perms:    Query
  Throws:   NotImplemented
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - similar to the 'st_size' field from 'stat' (2)
              as defined by POSIX


POSIX-like I/O methods:
-----------------------

- read
  Purpose:  reads up to len_in bytes from the file into
            the buffer.
  Format:   read               (inout buffer      buf,
                                in    int         len_in = -1,
                                out   int         len_out);
  Inputs:   len_in:             number of bytes to be read
  InOuts:   buf:                buffer to read data into
  Outputs:  len_out:            number of bytes successfully
                                read
  PreCond:  -
  PostCond: - the data from the file are available in the
              buffer.
  Perms:    Read
  Throws:   NotImplemented
            BadParameter
```

```
              IncorrectState
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
              Timeout
              NoSuccess
    Notes:    - the actual number of bytes read into buffer
                is returned in len_out.  It is not an error
                to read less bytes than requested, or in fact
                zero bytes, e.g. at the end of the file.
              - errors are indicated by returning negative
                values for len_out, which correspond to
                negatives of the respective POSIX ERRNO error
                code.
              - the file pointer is positioned at the end of
                the byte area successfully read during this
                call.
              - the given buffer must be large enough to
                store up to len_in bytes, or managed by the
                implementation - otherwise a 'BadParameter'
                exception is thrown.
              - the notes about memory management from the
                buffer class apply.
              - if the file was opened in write-only mode (i.e.
                no 'Read' or 'ReadWrite' flag was given), this
                method throws an 'PermissionDenied' exception.
              - if len_in is smaller than 0, or not given,
                the buffer size is used for len_in.
                If that is also not available, a
                'BadParameter' exception is thrown.
              - similar to read (2) as specified by POSIX


  - write
    Purpose:  writes up to len_in bytes from buffer into
              the file at the current file position.
    Format:   write              (in  buffer      buf,
                                  in  int         len_in = -1,
                                  out int         len_out);
    Inputs:   len_in:             number of bytes to write
              buf:                buffer to write data from
    InOuts:   -
    Outputs:  len_out:            number of bytes successfully
                                  written
    PreCond:  -
    PostCond: - the buffer data are written to the file.
```

```
    Perms:    Write
    Throws:   NotImplemented
              BadParameter
              IncorrectState
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
              Timeout
              NoSuccess
    Notes:    - errors are indicated by returning negative
                values for len_out, which correspond to
                negatives of the respective POSIX ERRNO error
                code.
              - the file pointer is positioned at the end
                of the byte area written during this call.
              - if the file was opened in read-only mode (i.e.
                no 'Write' or 'ReadWrite' flag was given), this
                method throws an 'PermissionDenied' exception.
              - the given buffer must hold enough data to
                write - otherwise, only the available data
                will be written, and and len_out will be set
                to the number of bytes written.
              - the notes about memory management from the
                buffer class apply.
              - if len_in is smaller than 0, or not given,
                the buffer size is used for len_in.
                If that is also not available, a
                'BadParameter' exception is thrown.
              - if data are written beyond the current end of
                file, the intermediate gap is filled with '\0'
                bytes.
              - similar to write (2) as specified by POSIX


  - seek
    Purpose:  reposition the file pointer
    Format:   seek              (in  int        offset,
                                 in  seek_mode  whence,
                                 out int        position);
    Inputs:   offset:            offset in bytes to move
                                 pointer
              whence:            offset is relative to
                                 'whence'
    InOuts:   -
    Outputs:  position:          position of pointer after
                                 seek
```

```
  PreCond:  -
  PostCond: - the file pointer is moved to the new position.
            - following read() or write() operations use
              that position.
  Perms:    Read or Write.
  Throws:   NotImplemented
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - seek repositions the file pointer for
              subsequent read, write and seek calls.
            - initially (after open), the file pointer is
              positioned at the beginning of the file,
              unless the 'Append' flag was given - then
              the initial position is the end of the file.
            - the repositioning is done relative to the
              position given in 'Whence', so relative to
              the 'Begin' or 'End' of the file, or to the
              'Current' position.
            - errors are indicated by returning negative
              values for len_out, which correspond to
              negatives of the respective POSIX ERRNO error
              code.
            - the file pointer can be positioned after the
              end of the file without extending it.
            - the given offset can be positive, negative, or
              zero.
            - note that a subsequent read at or behind the end
              of file returns no data.
            - similar to lseek (2) as specified by POSIX.


Scattered I/O methods:
----------------------

- read_v
  Purpose:  gather/scatter read
  Format:   read_v             (inout array<iovec> iovecs);
  Inputs:   -
  InOuts:   iovecs:             array of iovec structs
                                defining start (offset) and
                                length (len_in) of each
                                individual read, the buffer
```

```
                               to read into, and integer
                               to store result into
                               (len_out).
     Outputs:  -
     PreCond:  -
     PostCond: - data from the file are available in the
                 iovec buffers.
     Perms:    Read
     Throws:   NotImplemented
               BadParameter
               IncorrectState
               PermissionDenied
               AuthorizationFailed
               AuthenticationFailed
               Timeout
               NoSuccess
     Notes:    - the behavior of each individual read is as
                 in the normal read method, and all notes from
                 the read() method apply.
               - an exception MUST be thrown if any of the
                 individual reads detects a condition which
                 would raise an exception for the normal
                 read() method.
               - the notes about memory management from the
                 buffer class apply.
               - if for any of the given iovecs no len_in is
                 given, then the buffer's (size - offset) is
                 used as len_in.  If that is also not available,
                 a 'BadParameter' exception is thrown.
               - if for any of the given iovecs, the of
                 (offset + len_in) is larger than size,
                 a 'BadParameter' exception is thrown.
               - if the file was opened WriteOnly, a
                 'PermissionDenied' exception is thrown.
               - similar to readv (2) as specified by POSIX


   - write_v
     Purpose:  gather/scatter write
     Format:   write_v            (inout  array<iovec> iovecs);
     Inputs:   -
     InOuts:   iovecs:             array of iovec structs
                                   defining start (offset) and
                                   length (len_in) of each
                                   individual write, and
                                   buffers containing the data
```

```
                                  to write (len_out)
    Outputs:  -
    PreCond:  -
    PostCond: - the iovec buffer data are written to the file.
    Perms:    Write
    Throws:   NotImplemented
              IncorrectState
              BadParameter
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
              Timeout
              NoSuccess
    Notes:    - the behavior of each individual write is as
                in the normal write method.
              - an exception MUST be thrown if any of the
                individual writes detects a condition which
                would raise an exception for the normal write
                method.
              - the notes about memory management from the
                buffer class apply.
              - if for any of the given iovecs no len_in is
                given, then the buffer's (size - offset) is
                used as len_in.  If that is also not available,
                a 'BadParameter' exception is thrown.
              - if for any of the given iovecs, the of
                (offset + len_in) is larger than size,
                a 'BadParameter' exception is thrown.
              - if the file was opened ReadOnly, a
                'PermissionDenied' exception is thrown.
              - similar to writev (2) as specified by POSIX


  Pattern-based I/O methods:
  --------------------------

  - size_p
    Purpose:  determine the storage size required for a
              pattern I/O operation
    Format:   size_p            (in  string  pattern,
                                  out int     size);
    Inputs:   pattern:            pattern to determine size for
    InOuts:   -
    Outputs:  size:               size required for I/O
                                  operation with that pattern
    PreCond:  -
```

```
    PostCond: -
    Perms:    -
    Throws:   NotImplemented
              BadParameter
              IncorrectState
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
              Timeout
              NoSuccess
    Notes:    - the method does, in general, not perform a
                remote operation, but is intended to help
                the application programmer to correctly handle
                pattern-based I/O and associated buffer sizes.
              - if the pattern cannot be parsed or interpreted,
                a 'BadParameter' exception is thrown.


  - read_p
    Purpose:  pattern-based read
    Format:   read_p            (in    string      pattern,
                                 inout buffer      buf,
                                 out   int         len_out);
    Inputs:   pattern:           pattern specification for
                                 read operation
    InOuts:   buf:               buffer to store read data
                                 into
    Outputs:  len_out:           number of successfully read
                                 bytes
    PreCond:  -
    PostCond: - data from the file are available in the
                buffers.
    Perms:    Read
    Throws:   NotImplemented
              BadParameter
              IncorrectState
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
              Timeout
              NoSuccess
    Notes:    - if the pattern cannot be parsed or interpreted,
                a 'BadParameter' exception is thrown.
              - all notes for the read() method apply for the
                individual reads resulting from the
                interpretation of the pattern.
```

```
                - an exception MUST be thrown if any of the
                  individual writes detects a condition which
                  would raise an exception for the normal write
                  method.


    - write_p
      Purpose:  pattern-based read
      Format:   write_p            (in    string      pattern,
                                    in    buffer      buf,
                                    out   int         len_out);
      Inputs:   pattern:            pattern specification for
                                    write operation
                buf:                buffer to be written
      InOuts:   -
      Outputs:  len_out:            number of bytes successfully
                                    written
      PreCond:  -
      PostCond: - the buffer data are written to the file.
      Perms:    Write
      Throws:   NotImplemented
                BadParameter
                IncorrectState
                PermissionDenied
                AuthorizationFailed
                AuthenticationFailed
                Timeout
                NoSuccess
      Notes:    - if the pattern cannot be parsed or interpreted,
                  a 'BadParameter' exception is thrown.
                - all notes for the write() method apply for the
                  individual writes resulting from the
                  interpretation of the pattern.
                - an exception MUST be thrown if any of the
                  individual writes detects a condition which
                  would raise an exception for the normal write
                  method.


    Extended I/O methods:
    ---------------------

    - modes_e
      Purpose:  list the extended modes available in this
                implementation, and/or on server side
      Format:   modes_e            (out array<string> emodes);
```

```
  Inputs:   -
  InOuts:   -
  Outputs:  emodes:             list of modes available for
                                extended I/O
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   NotImplemented
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - the method does, in general, not perform a
              remote operation, but is intended to help
              the application programmer to determine what
              extended I/O methods are supported by the
              implementation.


- size_e
  Purpose:  determine the storage size required for an
            extended I/O operation
  Format:   size_e             (in  string  emode,
                               (in  string  spec,
                                out int     size);
  Inputs:   emode:              extended mode to use
            spec:               specification to determine
                                size for
  InOuts:   -
  Outputs:  size:               size required for I/O
                                operation with that
                                emode/spec
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   NotImplemented
            BadParameter
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - the method does, in general, not perform a
```

```
                remote operation, but is intended to help
                the application programmer to correctly handle
                extended I/O and associated buffer sizes.
              - if the specification cannot be parsed or
                interpreted, a 'BadParameter' exception is
                thrown.


  - read_e
    Purpose:  extended read
    Format:   read_e            (in    string      emode,
                                 in    string      spec,
                                 inout buffer      buf,
                                 out   int         len_out);
    Inputs:   emode:             extended mode to use
              spec:              specification of read
                                 operation
    InOuts:   buf:               buffer to store read data
                                 into
    Outputs:  len_out:           number of successfully read
                                 bytes
    PreCond:  -
    PostCond: - data from the file are available in the
                buffers.
    Perms:    Read
    Throws:   NotImplemented
              BadParameter
              IncorrectState
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
              Timeout
              NoSuccess
    Notes:    - if the emode is not supported, a 'BadParameter'
                exception is thrown.
              - if the spec cannot be parsed or interpreted,
                a 'BadParameter' exception is thrown.
              - all notes from the read() method apply to the
                individual reads resulting from the
                interpretation of the emode and spec.
              - an exception MUST be thrown if any of the
                individual writes detects a condition which
                would raise an exception for the normal write
                method.
```

```
  - write_e
    Purpose:  extended write
    Format:   write_e            (in    string      emode,
                                  in    string      spec,
                                  in    buffer      buf,
                                  out   int         len_out);
    Inputs:   emode:              extended mode to use
              spec:               specification of write
                                  operation
              buf:                buffer to store read data
                                  into
    InOuts:   -
    Outputs:  len_out:            number of bytes successfully
                                  written
    PreCond:  -
    PostCond: - the buffer data are written to the file.
    Perms:    Write
    Throws:   NotImplemented
              BadParameter
              IncorrectState
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
              Timeout
              NoSuccess
    Notes:    - if the emode is not supported, a 'BadParameter'
                exception is thrown.
              - if the spec cannot be parsed or interpreted,
                a 'BadParameter' exception is thrown.
              - all notes from the write() method apply to the
                individual writes resulting from the
                interpretation of the 'emode' and 'spec'.
              - an exception MUST be thrown if any of the
                individual writes detects a condition which
                would raise an exception for the normal write
                method.
```

Class `directory`

```
  - CONSTRUCTOR
    Purpose:  open the directory
    Format:   CONSTRUCTOR        (in  session    s,
```

```
                             in  saga::url  name,
                             in  int        flags = Read,
                             out directory  obj)
  Inputs:   s:               session to associate the
                             object with
            name:            location of directory
            flags:           mode for opening
  InOuts:   -
  Outputs:  obj:             the newly created object
  PreCond:  -
  PostCond: - the directory is opened.
            - 'Owner' of target is the id of the context
              use to perform the operation, if the
              directory gets created.
  Perms:    Exec  for parent directory.
            Write for parent directory if Create is set.
            Write for name if Write is set.
            Read  for name if Read  is set.
  Throws:   NotImplemented
            IncorrectURL
            BadParameter
            AlreadyExists
            DoesNotExist
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - the default flags are 'Read' (512).
            - the semantics of the inherited constructors
              apply


- DESTRUCTOR
  Purpose:  destroy the directory object
  Format:   DESTRUCTOR        (in  directory obj)
  Inputs:   obj:               the object to destroy
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: - the directory is closed.
  Perms:    -
  Throws:   -
  Notes:    - the semantics of the inherited destructors
              apply.
```

```
inspection methods:
-------------------

- get_size
  Purpose:  returns the number of bytes in the file
  Format:   get_size           (in  saga::url name,
                                in  int       flags = None,
                                out int       size);
  Inputs:   name:               name of file to inspect
            flags:              mode for operation
  InOuts:   -
  Outputs:  size:               number of bytes in the file
  PreCond:  -
  PostCond: -
  Perms:    Query
  Throws:   NotImplemented
            IncorrectURL
            BadParameter
            DoesNotExist
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - if 'name' can be parsed as URL, but contains
              an invalid entry name, a 'BadParameter'
              exception is thrown.
            - if the entry 'name' points to does not exist,
              a 'DoesNotExist' exception is thrown.
            - if the 'name' points to a link and the
              'Dereference' flag is set, the size is
              returned for the link target.  If that target
              does not exist, a 'DoesNotExist' exception is
              thrown.
            - implementations MAY report directory sizes by
              accumulating the content sizes recursively.
              If that is not implemented, a 'BadParameter'
              exception with descriptive error message is
              thrown.
            - the default flags are 'None' (0).
            - other flags are not allowed on this method,
              and cause a 'BadParameter' exception.
            - similar to the 'st_size' field from 'stat' (2)
              as defined by POSIX
```

```
- is_file
  Alias:    for is_entry in saga::ns_directory


Factory-like methods for creating objects:
------------------------------------------

- open_dir
  Purpose:  creates a directory object
  Format:   open_dir           (in  saga::url name,
                                in  int       flags = Read,
                                out directory dir)
  Inputs:   name:               name of directory to open
            flags:              flags defining operation
                                modus
  InOuts:   -
  Outputs:  dir:                opened directory instance
  PreCond:  -
  PostCond: - the session of the returned instance is that of
              the calling instance.
            - 'Owner' of name is the id of the context
              used to perform the operation if name gets
              created.
  Perms:    Exec  for name's parent directory.
            Write for name's parent directory if Create is set.
            Write for name if Write is set.
            Read  for name if Read  is set.
  Throws:   NotImplemented
            IncorrectURL
            BadParameter
            AlreadyExists
            DoesNotExist
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - all notes from the ns_directory::open_dir()
              method apply.
            - default flags are 'Read' (512).


- open
  Purpose:  creates a new file instance
```

```
Format:   open               (in  saga::url name,
                              in  int       flags = Read,
                              out file      file);
Inputs:   name:               file to be opened
          flags:              flags defining operation
                              modus
InOuts:   -
Outputs:  file:               opened file instance
PreCond:  -
PostCond: - the session of the returned instance is that of
            the calling instance.
          - 'Owner' of name is the id of the context
            used to perform the operation if name gets
            created.
Perms:    Exec  for name's parent directory.
          Write for name's parent directory if Create is set.
          Write for name if Write is set.
          Read  for name if Read  is set.
Throws:   NotImplemented
          IncorrectURL
          BadParameter
          AlreadyExists
          DoesNotExist
          IncorrectState
          PermissionDenied
          AuthorizationFailed
          AuthenticationFailed
          Timeout
          NoSuccess
Notes:    - all notes from the ns_directory::open() method
            apply.
          - the file is truncated to length 0 on the open
            operation if the 'Trunc' flag is given.
          - the file is in opened in append mode if the
            'Append' flag is given (a seek(0, End) is
            performed after the open).  If the 'Append'
            flag is not given, the file pointer is
            initially placed at the beginning of the file
            (a seek(0,Start) is performed after the open).
          - the 'Binary' flag is to be silently ignored on
            systems which do not support it.
          - at least one of the flags 'Read', 'Write' or
            'ReadWrite' must be given, otherwise a
            'BadParameter' exception is thrown.
          - the flag set 'Read | Write' is equivalent to
            the flag 'ReadWrite'.
```

```
- default flags are 'Read' (512).
```

4.3.3 Examples

Example: open a file. If its size is greater than 10, then read the first 10 bytes into a string, and print it.

Code Example

```
// c++ example
void head (saga::url url)
{
  try {
    // get type and other info
    saga::file f (url);

    off_t size = f.get_size ();

    if ( size > 10 )
    {
      char   buf[11];

      ssize_t len_out = f.read (saga::buffer (buf));

      if ( 10 == len_out )
      {
        std::cout << "head: "
                  << buffer.get_data ()
                  << std::endl;
      }
    }
  }

  // catch any possible error - see elsewhere for better
  // examples of error handling in SAGA
  catch ( const saga::exception & e )
  {
    std::cerr << "Oops! SAGA error: "
              << e.get_message ()
              << std::endl;
  }

  return;
}
```

4.4 SAGA Replica Management

This section of the SAGA API describes the interaction with replica systems. Numerous SAGA use cases required replica management functionality in the API – however, only a small number of operation have been requested. The methods described here are hence limited to the creation and maintainance of logical files, replicas, and to search on logical file meta data.

The `saga::logical_file` class implements the `saga::attributes` interface. It is important to realize that this is intended to reflect the ability of replica systems to associate meta data with logical files. The SAGA attribute model (string based key/value pairs) can, with all probability, only give a crude representation of meta data models used in real world replica systems – however, the definition of a more abstract and comprehensive data model for replica meta data was felt to be outside the scope of a SAGA API definition. Implementations are expected to map the native data model to key/value pairs as well as possible, and MUST document that mapping process (and in particular the supported keys) carefully.

Please note that the interactions with logical files as opaque entities (as entries in logical file name spaces) are covered by the `namespace` package. The interfaces presented here supplement the `namespace` package with operations for operating on entries in replica catalogues.

It is up to the used backend to ensure that multiple replica locations registered on a logical file are indeed identical copies – the SAGA API does not imply any specific consistency model. The SAGA implementation MUST document the consistency model used.

4.4.1 Definitions

Logical File: A *logical file* represents merely an entry in a name space which has (a) an associated set of registered (physical) replicas of that file, and (b) an associated set of meta data describing that logical file. Both sets can be empty. To access the *content* of a logical file, a `saga::file` needs to be created with one of the registered replica locations.

Replica: A *replica* (or *physical file*) is a file which is registered on a logical file. In general, all replicas registered on the same logical file are identical. Often, one of these replicas is deemed to be a master copy (often it is the first replica registered, and/or the only one which can be changed) – that distinction is, however, not visible in the SAGA API.

Logical Directory: A *logical directory* represents a directory entry in the name space of logical files. Several replica system implementations have the notion of *container* s, which, for our purposes, represent directories which can have, just as logical files, associated sets of meta data. In the presented API, logical directories and containers are the same.

Note that the `Truncate`, `Append` and `Binary` flags have no meaning on logical files. The respective enum values for these flags for `saga::files` have been reserved though, for (a) future use, and (b) consistency with the `saga::file` flag values.

The `find()` method of the `saga::logical_directory` class represents a combination of (a) the `find()` method from the `saga::ns_directory` class, and (b) the `find_attributes()` method from the `saga::attributes` interface. The method accepts patterns for meta data matches (`attr_pattern`) and a single pattern for file name matches (`name_pattern`), and returns a list of logical file names which match all `attr_pattern` and the `name_pattern` (`AND` semantics). The `attr_pattern` are formatted as defined for `find_attribute()` of the `saga::attributes` interface. The `name_pattern` are formatted as defined for the `find()` method of the `saga::ns_directory` class. In general, the allowed patterns are the same as defined as wildcards in the description of the SAGA `namespace` package.

4.4.2 Specification

```
package saga.logical_file
{
  enum flags
  {
    None           =    0, // same as in namespace::flags
    Overwrite      =    1, // same as in namespace::flags
    Recursive      =    2, // same as in namespace::flags
    Dereference    =    4, // same as in namespace::flags
    Create         =    8, // same as in namespace::flags
    Exclusive      =   16, // same as in namespace::flags
    Lock           =   32, // same as in namespace::flags
    CreateParents  =   64, // same as in namespace::flags
    //                128,    reserved for Truncate
    //                256,    reserved for Append
    Read           =  512, // same as in namespace::flags
    Write          = 1024, // same as in namespace::flags
    ReadWrite      = 1536, // same as in namespace::flags
    //               2048     reserved for Binary
```

```
}


class logical_file : extends        saga::ns_entry
                     implements     saga::attributes
                  // from ns_entry  saga::object
                  // from ns_entry  saga::async
                  // from object    saga::error_handler
{
  CONSTRUCTOR     (in  session             s,
                   in  saga::url           name,
                   in  int                 flags = Read,
                   out logical_file        obj);
  DESTRUCTOR      (in  logical_file        obj);


  // manage the set of associated replicas
  add_location    (in  saga::url           name);
  remove_location (in  saga::url           name);
  update_location (in  saga::url           name_old,
                   in  saga::url           name_new);
  list_locations  (out array<saga::url>    names);

  // create a new physical replica
  replicate       (in  saga::url           name,
                   in  int                 flags = None);

  // Attributes (extensible):
  //
  // no attributes pre-defined
}


class logical_directory : extends            saga::ns_directory
                          implements         saga::attributes
                       // from ns_directory  saga::ns_entry
                       // from ns_entry      saga::object
                       // from ns_entry      saga::async
                       // from object        saga::error_handler
{

  CONSTRUCTOR     (in  session             s,
                   in  saga::url           name,
                   in  int                 flags = Read,
                   out logical_directory   obj);
  DESTRUCTOR      (in  logical_directory   obj);
```

```
      // inspection methods
      is_file         (in  saga::url           name,
                       out boolean             test);

      // open methods
      open_dir        (in  saga::url           name,
                       in  int                 flags = Read,
                       out logical_directory   dir);

      open            (in  saga::url           name,
                       in  int                 flags = Read,
                       out logical_file        file);

      // find logical files based on name and meta data
      find            (in  string              name_pattern,
                       in  array<string>       attr_pattern,
                       in  int                 flags = Recursive,
                       out array<saga::url>    names   );
    }
  }
```

4.4.3 Specification Details

Enum `flags`

The `flags` enum is inherited from the `namespace` package. No additional flags are added.

Class `logical_file`

This class provides the means to handle the contents of logical files. These contents consists of strings representing locations of physical files (replicas) associated with the logical file.

```
    - CONSTRUCTOR
      Purpose:  create the object
      Format:   CONSTRUCTOR      (in session    s,
                                  in  saga::url name,
```

```
                              in  int       flags = Read,
                              out logical_file  obj)
  Inputs:   s:                session to associate with
                              the object
            name:             location of file
            flags:            mode for opening
  InOuts:   -
  Outputs:  obj:              the newly created object
  PreCond:  -
  PostCond: - the logical_file is opened.
            - 'Owner' of target is the id of the context
              use to perform the operation, if the
              logical_file gets created.
  Perms:    Exec  for parent directory.
            Write for parent directory if Create is set.
            Write for name if Write is set.
            Read  for name if Read  is set.
  Throws:   NotImplemented
            IncorrectURL
            BadParameter
            AlreadyExists
            DoesNotExist
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - the semantics of the inherited constructors
              and of the logical_directory::open() method
              apply.
            - the default flags are 'Read' (512).


- DESTRUCTOR
  Purpose:  destroy the object
  Format:   DESTRUCTOR       (in  logical_file   obj)
  Inputs:   obj:              the object to destroy
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: - the logical_file is closed.
  Perms:    -
  Throws:   -
  Notes:    - the semantics of the inherited destructors
              apply.
```

```
  manage the set of associated replicas:
  --------------------------------------

- add_location
  Purpose:  add a replica location to the replica set
  Format:   add_location     (in  saga::url name);
  Inputs:   name:             location to add to set
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: - name is in the list of replica locations for
              the logical file.
  Perms:    Write
  Throws:   NotImplemented
            IncorrectURL
            BadParameter
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - this methods adds a given replica location
              (name) to the set of locations associated with
              the logical file.
            - the implementation MAY choose to interpret the
              replica locations associated with the logical
              file.  It MAY return an 'IncorrectURL' error
              indicating an invalid location if it is unable
              or unwilling to handle that specific locations
              scheme.  The implementation documentation MUST
              specify how valid replica locations are formed.
            - if 'name' can be parsed as URL, but contains
              an invalid entry name, a 'BadParameter'
              exception is thrown.
            - if the replica is already in the set, this
              method does nothing, and in particular MUST
              NOT raise an 'AlreadyExists' exception
            - if the logical file was opened ReadOnly, a
              'PermissionDenied' exception is thrown.


- remove_location
  Purpose:  remove a replica location from the replica set
  Format:   remove_location  (in  saga::url name);
```

```
  Inputs:   name:            replica to remove from set
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: - name is not anymore in list of replica
              locations for the logical file.
  Perms:    Write
  Throws:   NotImplemented
            IncorrectURL
            BadParameter
            DoesNotExist
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - this method removes a given replica location
              from the set of replicas associated with the
              logical file.
            - the implementation MAY choose to interpret the
              replica locations associated with the logical
              file.  It MAY return an 'IncorrectURL' error
              indicating an invalid location if it is unable
              or unwilling to handle that specific locations
              scheme.  The implementation documentation MUST
              specify how valid replica locations are formed.
            - if 'name' can be parsed as URL, but contains
              an invalid entry name, a 'BadParameter'
              exception is thrown.
            - if the location is not in the set of
              replicas, a 'DoesNotExist' exception is
              thrown.
            - if the set of locations is empty after this
              operation, the logical file object is still
              a valid object (see replicate() method
              description).
            - if the logical file was opened ReadOnly, a
              'PermissionDenied' exception is thrown.


- update_location
  Purpose:  change a replica location in replica set
  Format:   update_location  (in saga::url name_old,
                              in saga::url name_new);
  Inputs:   name_old         replica to be updated
```

```
          name_new          update of replica
InOuts:   -
Outputs:  -
PreCond:  -
PostCond: - name_old is not anymore in list of replica
            locations for the logical file.
          - name_new is in the list of replica locations
            for the logical file.
Perms:    Read
          Write
Throws:   NotImplemented
          IncorrectURL
          BadParameter
          AlreadyExists
          DoesNotExist
          IncorrectState
          PermissionDenied
          AuthorizationFailed
          AuthenticationFailed
          Timeout
          NoSuccess
Notes:    - this method removes a given replica location
            from the set of locations associated with the
            logical file, and adds a new location.
          - the implementation MAY choose to interpret the
            replica locations associated with the logical
            file.  It MAY return an 'IncorrectURL' error
            indicating an invalid location if it is unable
            or unwilling to handle that specific locations
            scheme.  The implementation documentation MUST
            specify how valid replica locations are formed.
          - if 'name' can be parsed as URL, but contains
            an invalid entry name, a 'BadParameter'
            exception is thrown.
          - if the old replica location is not in the
            set of locations, a 'DoesNotExist' exception
            is thrown.
          - if the new replica location is already in the
            set of locations, an 'AlreadyExists' exception
            is thrown.
          - if the logical file was opened ReadOnly, an
            'PermissionDenied' exception is thrown.
          - if the logical file was opened WriteOnly, an
            'PermissionDenied' exception is thrown.
```

```
- list_locations
  Purpose:  list the locations in the location set
  Format:   list_locations   (out array<saga::url> names);
  Inputs:   -
  InOuts:   -
  Outputs:  names:            array of locations in set
  PreCond:  -
  PostCond: -
  Perms:    Read
  Throws:   NotImplemented
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - this method returns an array of urls
              containing the complete set of locations
              associated with the logical file.
            - an empty array returned is not an error -
              the logical file object is still a valid
              object (see replicate() method description).
            - if the logical file was opened WriteOnly, an
              'PermissionDenied' exception is thrown.


- replicate
  Purpose:  replicate a file from any of the known
            replica locations to a new location, and, on
            success, add the new replica location to the
            set of associated replicas
  Format:   replicate        (in  saga::url name,
                              in  int       flags = None);
  Inputs:   name:             location to replicate to
            flags:            flags defining the operation
                              modus
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: - an identical copy of one of the available
              replicas exists at name.
            - name is in the list of replica locations
              for the logical file.
  Perms:    Read
            Write
  Throws:   NotImplemented
```

```
                IncorrectURL
                BadParameter
                AlreadyExists
                DoesNotExist
                IncorrectState
                PermissionDenied
                AuthorizationFailed
                AuthenticationFailed
                Timeout
                NoSuccess
      Notes:    - the method implies a two step operation:
                  1) create a new and complete replica at the
                     given location, which then represents
                     a new replica location.
                  2) perform an add_location() for the new
                     replica location.
                - all notes to the saga::ns_entry::copy() and
                  saga::logical_file::add_location methods
                  apply.
                - the method is not required to be atomic, but:
                  the implementation MUST be either
                  successful in both steps, or throw an
                  exception indicating if both methods failed,
                  or if one of the methods succeeded.
                - a replicate call on an instance with empty
                  location set raises an 'IncorrectState'
                  exception, with an descriptive error message.
                - the default flags are 'None' (0).  The
                  interpretation of flags is as described for
                  the ns_entry::copy() method.
                - The 'Recursive' flag is not allowed, and
                  causes a 'BadParameter' exception.
                - if the logical file was opened ReadOnly, an
                  'PermissionDenied' exception is thrown.
                - if the logical file was opened WriteOnly, an
                  'PermissionDenied' exception is thrown.
```

Class `logical_directory`

This class represents a container for logical files in a logical file name space. It allows traversal of the catalog's name space, and the manipulation and creation (open) of logical files in that name space.

```
Constructor / Destructor:
-------------------------

- CONSTRUCTOR
  Purpose:  create the object
  Format:   CONSTRUCTOR      (in  session       s,
                              in  saga::url     name,
                              in  int           flags = Read,
                              out logical_directory
                                                obj)
  Inputs:   s:                session to associate with
                              the object
            name:             location of directory
            flags:            mode for opening
  InOuts:   -
  Outputs:  obj:              the newly created object
  PreCond:  -
  PostCond: - the logical_directory is opened.
            - 'Owner' of target is the id of the context
              use to perform the operation, if the
              logical_directory gets created.
  Perms:    Exec  for parent directory.
            Write for parent directory if Create is set.
            Write for name if Write is set.
            Read  for name if Read  is set.
  Throws:   NotImplemented
            IncorrectURL
            BadParameter
            AlreadyExists
            DoesNotExist
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - the semantics of the inherited constructors
              and of the logical_directory::open_dir()
              method apply.
            - the default flags are 'Read' (512).


- DESTRUCTOR
  Purpose:  destroy the object
  Format:   DESTRUCTOR        (in  logical_directory obj)
```

```
    Inputs:   obj:                the object to destroy
    InOuts:   -
    Outputs:  -
    PreCond:  -
    PostCond: - the logical_directory is closed.
    Perms:    -
    Throws:   -
    Notes:    - the semantics of the inherited destructors
                apply.


  - is_file
    Alias:    for is_entry of saga::ns_directory


  - open_dir
    Purpose:  creates a new logical_directory instance
    Format:   open_dir         (in  saga::url name,
                                in  int       flags = Read,
                                out logical_directory dir);
    Inputs:   name:             name of directory to open
              flags:            flags defining operation
                                modus
    InOuts:   -
    Outputs:  dir:              opened directory instance
    PreCond:  -
    PostCond: - the session of the returned instance is that of
                the calling instance.
              - 'Owner' of name is the id of the context
                used to perform the operation if name gets
                created.
    Perms:    Exec  for name's parent directory.
              Write for name's parent directory if Create is set.
              Write for name if Write is set.
              Read  for name if Read  is set.
    Throws:   NotImplemented
              IncorrectURL
              BadParameter
              AlreadyExists
              DoesNotExist
              IncorrectState
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
              Timeout
              NoSuccess
```

```
  Notes:    - all notes from the ns_directory::open_dir()
              method apply.
            - default flags are 'Read' (512).


- open
  Purpose:  creates a new logical_file instance
  Format:   open             (in  saga::url    name,
                               in  int          flags = Read,
                               out logical_file file);
  Inputs:   name:              file to be opened
            flags:             flags defining operation
                               modus
  InOuts:   -
  Outputs:  file:              opened file instance
  PreCond:  -
  PostCond: - the session of the returned instance is that of
              the calling instance.
            - 'Owner' of name is the id of the context
              used to perform the operation if name gets
              created.
  Perms:    Exec  for name's parent directory.
            Write for name's parent directory if Create is set.
            Write for name if Write is set.
            Read  for name if Read  is set.
  Throws:   NotImplemented
            IncorrectURL
            BadParameter
            AlreadyExists
            DoesNotExist
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - all notes from the ns_directory::open() method
              apply.
            - the flag set 'Read | Write' is equivalent to
              the flag 'ReadWrite'.
            - default flags are 'Read' (512).


- find
  Purpose:  find entries in the current directory and below,
            with matching names and matching meta data
```

```
Format:   find            (in  string          name_pattern,
                           in  array<string>   attr_pattern,
                           in  int             flags = Recursive,
                           out array<saga::url> names);
Inputs:   name_pattern:    pattern for names of
                           entries to be found
          attr_pattern:    pattern for meta data
                           key/values of entries to be
                           found
          flags:           flags defining the operation
                           modus
InOuts:   -
Outputs:  names:           array of names matching both
                           pattern
PreCond:  -
PostCond: -
Perms:    Read  for cwd.
          Query for entries specified by name_pattern.
          Exec  for parent directories of these entries.
          Query for parent directories of these entries.
          Read  for directories specified by name_pattern.
          Exec  for directories specified by name_pattern.
          Exec  for parent directories of these directories.
          Query for parent directories of these directories.
Throws:   NotImplemented
          BadParameter
          IncorrectState
          PermissionDenied
          AuthorizationFailed
          AuthenticationFailed
          Timeout
          NoSuccess
Notes:    - the description of find() in the Introduction
            to this section applies.
          - the semantics for both the find_attributes()
            method in the saga::attributes interface and
            for the find() method in the
            saga::ns_directory class apply.  On
            conflicts, the find() semantic supersedes
            the find_attributes() semantic.  Only entries
            matching all attribute patterns and the name
            space pattern are returned.
          - the default flags are 'Recursive' (2).
```

4.4.4 Examples

Code Example

```
// c++ example
int main ()
{
  saga::logical_file lf ("lfn://remote.catalog.net/tmp/file1");

  lf.replicate ("gsiftp://localhost//tmp/file.rep");
  saga::file f ("gsiftp://localhost//tmp/file.rep");

  std::cout << "size of local replica: "
            << f.get_size ()
            << std::endl;

  return (0);
}
```

4.5 SAGA Streams

A number of use cases involve launching remotely located components in order to create distributed applications. These use cases require simple remote socket connections to be established between these components and their control interfaces.

The target of the streams API is to establish the simplest possible authenticated socket connection with hooks to support application level authorization. The stream API has the following characteristics

1. It is not performance oriented: If performance is required, then it is better to program directly against the APIs of existing performance oriented protocols like GridFTP or XIO. The API design should allow, however, for high performance implementations.
2. It is focused on TCP/IP socket connections. There has been no attempt to generalize this to arbitrary streaming interfaces (although it does not prevent such things as connectionless protocols from being supported).
3. It does not attempt to create a programming paradigm that diverges very far from baseline BSD sockets, Winsock, or Java Sockets.

This API greatly reduces the complexity of establishing authenticated socket connections in order to communicate with remotely located components. It however, provides very limited functionality and is thus suitable for applications that do not have very sophisticated requirements (as per 80-20 rule). It is envisaged that as applications become progressively more sophisticated, they will gradually move to more sophisticated, native APIs in order to support those needs.

Several SAGA use cases require a more abstract communication API, which exchanges opaque messages instead of byte streams. That behavior can be modeled on top of this stream API, but future versions of the SAGA API may introduce higher level communication APIs.

4.5.1 Endpoint URLs

The SAGA stream API uses URLs to specify connection endpoints. These URLs are supposed to allow SAGA implementations to be interoperable. For example, the URL

```
tcp://remote.host.net:1234/
```

is supposed to signal that a standard `tcp` connection can be established with host `remote.host.net` on port `1234`. No matter what the specified URL scheme is, the SAGA stream API implementation MUST have the same semantics on API level, i.e. behave like a reliable byte-oriented data stream.

4.5.2 Endpoint Permissions

The SAGA API allows for application level authorization of stream communications: an application is able to set permissions on `saga::stream_server` and `saga::stream` instances. These permissions control what remote party can perform what action on those streams, e.g. control what remote parties are able to connect to an endpoint, or to write to them etc.

Not all implementations will be able to fully implement that security model – the implementation MUST carefully document which permissions are supported, and which are not.

4.5.3 Specification

```
package saga.stream
{
  enum state
  {
    New         =  1
    Open        =  2,
    Closed      =  3,
    Dropped     =  4,
    Error       =  5
  }

  enum activity
  {
    Read        =  1,
    Write       =  2,
    Exception   =  4
  }


  class stream_server  : implements   saga::object
                         implements   saga::async
                         implements   saga::monitorable
                         implements   saga::permissions
```

```
                    // from object  saga::error_handler
{
  CONSTRUCTOR       (in    session         s,
                     in    saga::url       url,
                     out   stream_server   obj);
  DESTRUCTOR        (in    stream_server   obj);

  get_url           (out   saga::url       url);

  serve             (in    float           timeout = -1.0,
                     out   stream          stream);

  connect           (in    float           timeout = -1.0,
                     out   stream          stream);

  close             (in    float           timeout = 0.0);

  // Metrics:
  //   name:  stream_server.client_connect
  //   desc:  fires if a client connects
  //   mode:  ReadOnly
  //   unit:  1
  //   type:  Trigger
  //   value: 1
}


class stream : extends      saga::object
               implements   saga::async
               implements   saga::attributes
               implements   saga::monitorable
            // from object  saga::error_handler
{
  // constructor / destructor
  CONSTRUCTOR  (in    session          s,
                in    saga::url        url = "",
                out   stream           obj);
  DESTRUCTOR   (in    stream           obj);

  // inspection methods
  get_url      (out   saga::url        url);
  get_context  (out   context          ctx);

  // management methods
  connect      (in    float            timeout = -1.0);
  wait         (in    int              what,
```

```
               in    float           timeout = -1.0,
               out   int             cause);
    close     (in    float           timeout = 0.0);

    // I/O methods
    read      (inout buffer          buf,
               in    int             len_in = -1,
               out   int             len_out);
    write     (in    buffer          buf,
               in    int             len_in = -1,
               out   int             len_out);

    // Attributes:
    //
    //   name:  BufSize
    //   desc:  determines the size of the send buffer,
    //          in bytes
    //   mode:  ReadWrite, optional
    //   type:  Int
    //   value: system dependent
    //   notes: - the implementation MUST document the
    //            default value, and its meaning (e.g. on what
    //            layer that buffer is maintained, or if it
    //            disables zero copy).
    //
    //   name:  Timeout
    //   desc:  determines the amount of idle time
    //          before dropping the line, in seconds
    //   mode:  ReadWrite, optional
    //   type:  Int
    //   value: system dependent
    //   notes: - the implementation MUST document the
    //            default value
    //          - if this attribute is supported, the
    //            connection MUST be closed by the
    //            implementation if for that many seconds
    //            nothing has been read from or written to
    //            the stream.
    //
    //   name:  Blocking
    //   desc:  determines if read/writes are blocking
    //          or not
    //   mode:  ReadWrite, optional
    //   type:  Bool
    //   value: True
    //   notes: - if the attribute is not supported, the
```

```
//            implementation MUST be blocking
//          - if the attribute is set to 'True', a read or
//            write operation MAY return immediately if
//            no data can be read or written - that does
//            not constitute an error (see EAGAIN in
//            POSIX).
//
//   name:  Compression
//   desc:  determines if data are compressed
//          before/after transfer
//   mode:  ReadWrite, optional
//   type:  Bool
//   value: schema dependent
//   notes: - the implementation MUST document the
//            default values for the available schemas
//
//   name:  Nodelay
//   desc:  determines if packets are sent
//          immediately, i.e. without delay
//   mode:  ReadWrite, optional
//   type:  Bool
//   value: True
//   notes: - similar to the TCP_NODELAY option
//
//   name:  Reliable
//   desc:  determines if all sent data MUST arrive
//   mode:  ReadWrite, optional
//   type:  Bool
//   value: True
//   notes: - if the attribute is not supported, the
//            implementation MUST be reliable


// Metrics:
//   name:  stream.state
//   desc:  fires if the state of the stream changes,
//          and has the value of the new state
//          enum
//   mode:  ReadOnly
//   unit:  1
//   type:  Enum
//   value: New
//
//   name:  stream.read
//   desc:  fires if a stream gets readable
//   mode:  ReadOnly
```

```
      //   unit:  1
      //   type:  Trigger
      //   value: 1
      //   notes: - a stream is considered readable if a
      //            subsequent read() can successfully read
      //            1 or more bytes of data.
      //
      //   name:  stream.write
      //   desc:  fires if a stream gets writable
      //   mode:  ReadOnly
      //   unit:  1
      //   type:  Trigger
      //   value: 1
      //   notes: - a stream is considered writable if a
      //            subsequent write() can successfully write
      //            1 or more bytes of data.
      //
      //   name:  stream.exception
      //   desc:  fires if a stream has an error condition
      //   mode:  ReadOnly
      //   unit:  1
      //   type:  Trigger
      //   value: 1
      //   notes: -
      //
      //   name:  stream.dropped
      //   desc:  fires if the stream gets dropped by the
      //          remote party
      //   mode:  ReadOnly
      //   unit:  1
      //   type:  Trigger
      //   value: 1
    }
  }
```

4.5.4 Specification Details

Enum `state`

A SAGA stream can be in several states – the complete state diagram is shown in Figure 64.5.4. The stream states are:

`New`

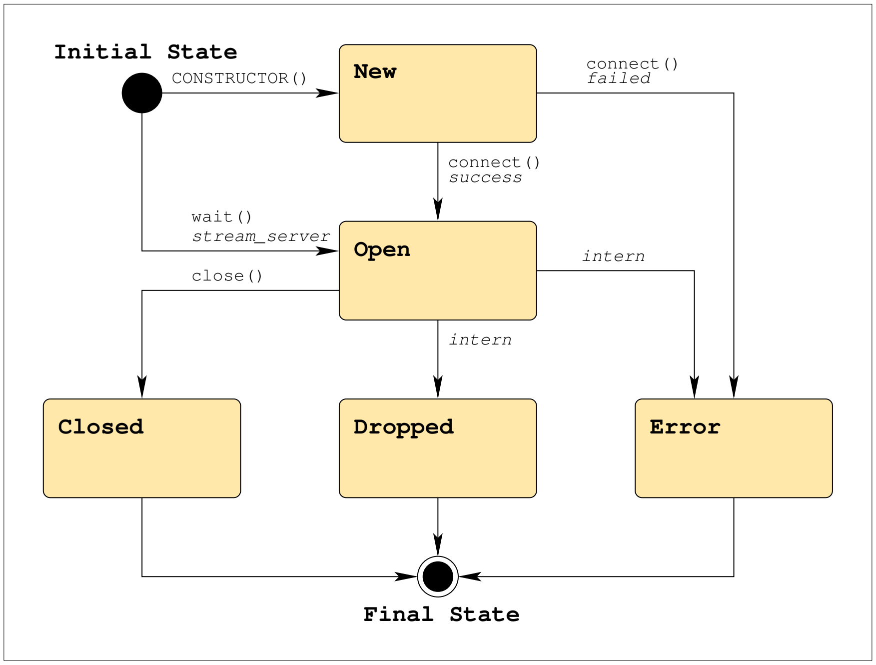

Figure 6: The SAGA stream state model (See Figure 1 for a legend).

A newly constructed stream enters the initial `New` state. It is not connected yet, and no I/O operations can be performed on it. `connect()` must be called to advance the state to `Open` (on success) or `Error` (on failure).

`Open`

The stream is connected to the remote endpoint, and I/O operations can be called. If any error occurs on the stream, it will move into the `Error` state. If the remote party closes the connection, the stream will move into the `Dropped` state. If `close()` is called on the stream, the stream will enter the `Closed` state.

`Closed`

The `close()` method was called on the stream – I/O is no longer possible. This is a final state.

`Dropped`

The remote party closed the connection – I/O is no longer possible. This is a final state.

`Error`

An error occurred on the stream – I/O is no longer possible. This is a final state. The exact reason for reaching this state MUST be available through the `error_handler` interface.

All method calls, apart from the `DESTRUCTOR`, will cause an `IncorrectState` exception if the stream is in a final state.

Enum `activity_type`

The SAGA stream API allows for event driven communication. A stream can flag activities, i.e. `Read`, `Write` and `Exception`, and the application can react on these activities. It is possible to poll for these events (using `wait()` with a potential timeout), or to get asynchronous notification of these events, by using the respective metrics.

`Read`

Data are available on the stream, and a subsequent `read()` will succeed.

`Write`

The stream is accepting data, and a subsequent `write()` will succeed.

`Exception`

An error occurred on the stream, and a following I/O operation may fail.

Class `stream_server`

The `stream_server` object represents a connection endpoint. If it represents aconnection endpoint managed by the application, it establishes a listening/server object that waits for client connections. If it represents a remote connection point, calling `connect()` on it will create a client `stream` instance connected to that remote endpoint.

The `stream_server` can thus *only* be used as a factory for client sockets. It doesn't support any read/write I/O.

```
  - CONSTRUCTOR
    Purpose:  create a new stream_server object
    Format:   CONSTRUCTOR          (in  session   s,
                                    in  saga::url url = "",
                                    out stream_server obj);
```

```
  Inputs:   s:                   session to be used for
                                 object creation
            url:                 channel name or url,
                                 defines the source side
                                 binding for the stream
  InOuts:   -
  Outputs:  obj:                 new stream_server object
  PreCond:  -
  PostCond: - stream_server can wait for incoming
              connections.
            - 'Owner' of name is the id of the context
              used to create the stream_server.
            - the stream_server has 'Exec', 'Query', 'Read'
              and 'Write' permissions for '*'.
  Perms:    -
  Throws:   NotImplemented
            IncorrectURL
            BadParameter
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - if the given url is an empty string (the
              default), the implementation will choose an
              appropriate default value.
            - the implementation MUST ensure that the given
              URL is usable, and a later call to 'serve'
              will not fail because of the information given
              by the URL - otherwise, a 'BadParameter'
              exception MUST be thrown.


- DESTRUCTOR
  Purpose:  Destructor for stream_server object.
  Format:   DESTRUCTOR          (in stream_server obj)
  Inputs:   obj:                 object to be destroyed
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: - the stream_server is closed.
  Perms:    -
  Throws:   -
  Notes:    - if the instance was not closed before, the
              destructor performs a close() on the instance,
              and all notes to close() apply.
```

```
// inspection
- get_url
  Purpose:  get URL to be used to connect to this server
  Format:   get_url              (out saga::url url);
  Inputs:   -
  InOuts:   -
  Outputs:  url:                  the URL of the connection.
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   NotImplemented
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - returns a URL which can be passed to
              the stream constructor to create a connection
              to this stream_server.


// stream management
- serve
  Purpose:  wait for incoming client connections
  Format:   serve                (in  float   timeout,
                                  out stream  client);
  Inputs:   timeout:              number of seconds to wait
                                  for a client
  InOuts:   -
  Outputs:  client:               new Connected stream object
  PreCond:  -
  PostCond: - the returned client is in 'Open' state.
            - the session of the returned client is that of
              the stream_server.
  Perms:    - Exec.
            - Exec for the connecting remote party.
  Throws:   NotImplemented
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            NoSuccess
            Timeout
  Notes:    - if successful, it returns a new stream object
```

```
                that is connected to the client.
              - if no client connects within the specified
                timeout, a 'Timeout' exception is thrown.
              - if connection setup failed (not on timeout!),
                the returned client is in the 'Error' state.
                Its error_handler interface should give
                detailed information about the reason.
              - for timeout semantics, see Section 2.


  - connect
    Purpose:  Establishes a connection to the remote
              connection endpoint represented by this instance
    Format:   connect              (in float timeout = -1.0);
    Inputs:   timeout:              connection timeout
    InOuts:   -
    Outputs:  -
    PreCond:  -
    PostCond: - the returned stream is in 'Open' state.
    Perms:    Exec
    Throws:   NotImplemented
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
              Timeout
              NoSuccess
    Notes:    - on failure, the stream state is changed to
                'Error'
              - this call is equivalent to creating a
                stream instance with the URL used to
                create this stream_server instance, and
                calling connect() on that stream.
              - if the stream instance is not in 'New' state,
                an 'IncorrectState' exception is thrown.
              - for timeout semantics, see Section 2.


  - close
    Purpose:  closes a stream server
    Format:   close                (in float timeout)
    Inputs:   timeout               seconds to wait
    InOuts:   -
    Outputs:  -
    PreCond:  -
    PostCond: - no clients are accepted anymore.
              - no callbacks registered for the
```

```
                'ClientConnect' metric are invoked.
      Perms:    -
      Throws:   NotImplemented
                NoSuccess
      Notes:    - any subsequent method call on the object
                  MUST raise an 'IncorrectState' exception
                  (apart from DESTRUCTOR and close()).
                - if close() is implicitly called in the
                  DESTRUCTOR, it will never throw an exception.
                - close() can be called multiple times, with no
                  side effects.
                - for resource deallocation semantics, see
                  Section 2.
                - for timeout semantics, see Section 2.
```

Class `stream`

This is the object that encapsulates all client stream objects.

```
    Constructor / Destructor:
    -------------------------

    - CONSTRUCTOR
      Purpose:  Constructor, initializes a client stream,
                for later connection to a server.
      Format:   CONSTRUCTOR          (in  session    s,
                                      in  saga::url  url,
                                      out stream  obj);
      Inputs:   s:                    saga session handle
                url:                  server location as URL
      InOuts:   -
      Outputs:  obj:                  new, unconnected stream
                                      instance
      PreCond:  -
      PostCond: - the state of the socket is 'New'.
      Perms:    - Query for the stream_server represented by
                  url.
      Throws:   NotImplemented
                IncorrectURL
                BadParameter
                PermissionDenied
```

```
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - server location and possibly protocol are
              described by the input URL - see description
              above.
            - the 'url' can be empty (which is the default).
              A stream so constructed is only to be used
              as parameter to an asynchronous
              stream_server::serve() call.  For such a
              stream, a later call to connect() will fail.
            - the implementation MUST ensure that the
              information given in the URL are usable -
              otherwise a 'BadParameter' exception MUST be
              thrown.
            - the socket is only connected after the
              connect() method is called.


- DESTRUCTOR
  Purpose:  destroy a stream object
  Format:   DESTRUCTOR           (in stream obj)
  Inputs:   obj:                  stream to destroy
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: - the socket is closed.
  Perms:    -
  Throws:   -
  Notes:    - if the instance was not closed before, the
              destructor performs a close() on the instance,
              and all notes to close() apply.


Inspection methods:
-------------------

- get_url
  Purpose:  get URL used for creating the stream
  Format:   get_url               (out saga::url url);
  Inputs:   -
  InOuts:   -
  Outputs:  url:                  the URL of the connection.
  PreCond:  -
  PostCond: -
```

```
  Perms:    -
  Throws:   NotImplemented
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - returns a URL which can be passed to a
              stream constructor to create another
              connection to the same stream_server.
            - the returned url may be empty, indicating that
              this instance has been created with an empty
              url as parameter to the stream CONSTRUCTOR().


- get_context
  Purpose:  return remote authorization info
  Format:   get_context           (out context ctx);
  Inputs:   -
  InOuts:   -
  Outputs:  ctx:                   remote context
  PreCond:  - the stream is, or has been, in the 'Open'
              state.
  PostCond: - the returned context is deep copied, and does
              not share state with any other object.
  Perms:    -
  Throws:   NotImplemented
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - the context returned contains the security
              information from the REMOTE party, and can be
              used for authorization.
            - if the stream is in a final state, but has
              been in 'Open' state before, the returned
              context represents the remote party the stream
              has been connected to while it was in 'Open'
              state.
            - if the stream is not in 'Open' state, and is
              not in a final state after having been in
              'Open' state, an 'IncorrectState' exception is
              thrown.
```

```
                - if no security information are available, the
                  returned context has the type 'Unknown' and no
                  attributes are attached.
                - the returned context MUST be authenticated, or
                  must be of type 'Unknown' as described above.


    Management methods:
    -------------------

    - connect
      Purpose:  Establishes a connection to the target defined
                during the construction of the stream.
      Format:   connect             (in float timeout = -1.0);
      Inputs:   timeout:             connection timeout
      InOuts:   -
      Outputs:  -
      PreCond:  - the stream is in 'New' state.
      PostCond: - the stream is in 'Open' state.
      Perms:    Exec for the stream_server represented by the
                url used for creating this stream instance.
      Throws:   NotImplemented
                IncorrectState
                PermissionDenied
                AuthorizationFailed
                AuthenticationFailed
                Timeout
                NoSuccess
      Notes:    - on failure, the stream state is changed to
                  'Error'
                - this call is equivalent to creating a
                  stream_server instance with the URL used ot
                  create this stream instance, and calling
                  connect() on that stream_server.
                - if the stream instance is not in 'New' state,
                  an 'IncorrectState' exception is thrown.
                - for timeout semantics, see Section 2.


    - close
      Purpose:  closes an active connection
      Format:   close               (in float timeout)
      Inputs:   timeout              seconds to wait
      InOuts:   -
      Outputs:  -
      PreCond:  -
```

```
  PostCond: - stream is in 'Closed' state
  Perms:    -
  Throws:   NotImplemented
            IncorrectState
            NoSuccess
  Notes:    - any subsequent method call on the object
              MUST raise an 'IncorrectState' exception
              (apart from DESTRUCTOR and close()).
            - if close() is implicitly called in the
              DESTRUCTOR, it will never throw an exception.
            - close() can be called multiple times, with no
              side effects.
            - for resource deallocation semantics, see
              Section 2.
            - for timeout semantics, see Section 2.


Stream I/O methods:
-------------------


- read
  Purpose:  Read a data buffer from stream.
  Format:   read                 (inout buffer      buf,
                                  in    int         len_in = -1,
                                  out   int         len_out);
  Inputs:   len_in:               Maximum number of bytes
                                  that can be copied into
                                  the buffer.
  InOuts:   buf:                  buffer to store read data
                                  into
  Outputs:  len_out:              number of bytes read, if
                                  successful.
  PreCond:  - the stream is in 'Open' state.
  PostCond: - data from the stream are available in the
              buffer.
  Perms:    Read for the stream_server represented by the
            url used for creating this stream instance.
  Throws:   NotImplemented
            BadParameter
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - if the stream is blocking, the call waits
```

```
                  until data become available.
                - if the stream is non-blocking, the call
                  returns immediately, even if no data are
                  available -- that is not an error condition.
                - the actually number of bytes read into buffer
                  is returned in len_out.  It is not an error
                  to read less bytes than requested, or in fact
                  zero bytes.
                - errors are indicated by returning negative
                  values for len_out, which correspond to
                  negatives of the respective ERRNO error code
                - the given buffer must be large enough to
                  store up to len_in bytes, or managed by the
                  implementation - otherwise a 'BadParameter'
                  exception is thrown.
                - the notes about memory management from the
                  buffer class apply.
                - if len_in is smaller than 0, or not given,
                  the buffer size is used for len_in.
                  If that is also not available, a
                  'BadParameter' exception is thrown.
                - if the stream is not in 'Open' state, an
                  'IncorrectState' exception is thrown.
                - similar to read (2) as specified by POSIX


    - write
      Purpose:  Write a data buffer to stream.
      Format:   write               (in  buffer        buf,
                                     in  int           len_in = -1,
                                     out int           len_out);
      Inputs:   len_in:              number of bytes of data in
                                     the buffer
                buffer:              buffer containing data
                                     that will be sent out via
                                     socket
      InOuts:   -
      Outputs:  len_out:             bytes written if successful
      PreCond:  - the stream is in 'Open' state.
      PostCond: - the buffer data are written to the stream.
      Perms:    Write for the stream_server represented by the
                url used for creating this stream instance.
      Throws:   NotImplemented
                BadParameter
                IncorrectState
                PermissionDenied
```

```
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - if the stream is blocking, the call waits
              until the data can be written.
            - if the stream is non-blocking, the call
              returns immediately, even if no data are
              written -- that is not an error condition.
            - it is not an error to write less than len_in
              bytes.
            - errors are indicated by returning negative
              values for len_out, which correspond to
              negatives of the respective ERRNO error code
            - the given buffer must be large enough to
              store up to len_in bytes, or managed by the
              implementation - otherwise a 'BadParameter'
              exception is thrown.
            - the notes about memory management from the
              buffer class apply.
            - if len_in is smaller than 0, or not given,
              the buffer size is used for len_in.
              If that is also not available, a
              'BadParameter' exception is thrown.
            - if the stream is not in 'Open' state, an
              'IncorrectState' exception is thrown.
            - similar to write (2) as specified by POSIX


- wait
  Purpose:  check if stream is ready for reading/writing, or
            if it has entered an error state.
  Format:   wait                 (in  int      what,
                                  in  float    timeout,
                                  out int      cause);
  Inputs:   what:                 activity types to wait for
            timeout:              number of seconds to wait
  InOuts:   -
  Outputs:  cause:                activity type causing the
                                  call to return
  PreCond:  - the stream is in 'Open' state.
  PostCond: - the stream can be read from, or written to, or
              it is in 'Error' state.
  Perms:    -
  Throws:   NotImplemented
            IncorrectState
```

```
                PermissionDenied
                AuthorizationFailed
                AuthenticationFailed
                NoSuccess
      Notes:    - wait will only check on the conditions
                  specified by 'what'
                - 'what' is an integer representing
                   OR'ed 'Read', 'Write', or 'Exception' flags.
                - 'cause' describes the availability of the
                  socket (e.g. OR'ed 'Read', 'Write', or
                  'Exception')
                - for timeout semantics, see Section 2.
                - if the stream is not in 'Open' state, an
                  'IncorrectState' exception is thrown.
```

4.5.5 Examples

Code Example

```
Sample SSL/Secure Client:
-------------------------


  Opens a stream connection using native security: the
  context is passed in implicitly via the default SAGA
  session's contexts.

  // C++/JAVA Style
     ssize_t recvlen;
     saga::buffer b;
     saga::stream s ("localhost:5000");

     s.connect ();
     s.write   (saga::buffer ("Hello World!"));

     // blocking read, read up to 128 bytes
     recvlen = s.read (b, 128);


  /* C Style */
     ssize_t recvlen;

     SAGA_stream sock  = SAGA_Stream_open ("localhost:5000");
     SAGA_buffer b_in  = SAGA_Buffer_create ("Hello World");
     SAGA_buffer b_out = SAGA_Buffer_create ("Hello World");

     SAGA_Stream_connect (sock);
     SAGA_Stream_write   (sock, b_in);
```

```
      /* blocking read, read up to 128 bytes */
      recvlen = SAGA_Stream_read (sock, b_ou, 128);


    c  Fortran Style */
       INTEGER   err,SAGAStrRead,SAGAStrWrite,err
       INTEGER*8 SAGAStrOpen,streamhandle
       CHARACTER buffer(128)
       SAGAStrOpen("localhost:5000",streamhandle)
       call SAGAStrConnect(streamhandle)
       err = SAGAStrWrite(streamhandle,"localhost:5000",12)
       err = SAGAStrRead(streamhandle,buffer,128)


Sample Secure Server:
---------------------

  Once a connection is made, the server can use information
  about the authenticated client to make an authorization
  decision

   // c++ example
     saga::stream_server server ("tcp://localhost/5000");

     saga::stream client;

     // now wait for a connection
     while ( saga::stream::Open != client.get_state () )
     {
       // wait forever for connection
       client = server.serve ();

       // get remote security details
       saga::context ctx = client.get_context ();

       // check if context type is X509, and if DN is the
       // authorized one
       if ( ctx.type ()              == "X509"       &&
            ctx.get_attribute ("DN") == some_auth_dn )
       {
         // allowed - keep open and leave loop
         client.write (saga::buffer ("Hello!"));
       }
       else
       {
         client.close (); // not allowed
       }
     }
```

```
      // start activity on client socket...


Example for async stream server
-------------------------------

  // c++ example
  class my_cb : public saga::callback
  {
    privat:
      saga::stream_server ss;
      saga::stream        s;

    public:

      my_cb (saga::stream_server ss_,
             saga::stream        s_)
      {
        ss = ss_;
        s   = s_;
      }

      bool cb (saga::monitorable mt,
               saga::metric      m,
               saga::context     c)
      {
        s = ss.serve ();
        return (false); // want to be called only once
      }
   }

   int main ()
   {
     saga::stream_server ss;
     saga::stream        s;

     my_cb cb (ss, s);

     ss.add_callback ("client_connect", cb);

     while ( true )
     {
       if ( s.state != saga::stream::Open )
       {
         // no client, yet
         sleep (1);
       }
       else
       {
         // handle open socket
```

```
          s.write ("Hello Client\r\n", 14);
          s.close ();

          // restart listening
          ss.add_callback ("client_connect", cb);
        }
      }

      return (-1); // unreachable
    }
```

4.6 SAGA Remote Procedure Call

GridRPC is one of the few high level APIs that have been specified by the GGF [19]. Thus including the GridRPC specification in the SAGA API benefits both SAGA and the GridRPC effort: SAGA becomes more complete and provides a better coverage of its use cases with a single Look-&-Feel, whilst GridRPC gets embedded into a set of other tools of similar scope, which opens it to a potentially wider user community, and ensures its further development.

Semantically, the methods defined in the GridRPC specification, as described in GFD.52 [19], map exactly with the RPC package of the SAGA API as described here. In essence, the GridRPC API has been imported into the SAGA RPC package, and has been equipped with the Look-&-Feel, error conventions, task model, etc. of the SAGA API.

The rpc class constructor initializes the remote function handle. This process may involve connection setup, service discovery, etc. The rpc class further offers one method 'call', which invokes the remote procedure, and returns the respective return data and values. The asynchronous call versions described in the GridRPC specification are realized by the SAGA task model, and are not represented as separate calls here.

In the constructor, the remote procedure to be invoked is specified by a URL, with the syntax:

```
gridrpc://server.net:1234/my_function
```

with the elements responding to:

`gridrpc`	–	scheme	–	identifying a grid rpc operation
`server.net`	–	server	–	server host serving the rpc call
`1234`	–	port	–	contact point for the server
`my_function`	–	name	–	name of the remote method to invoke

All elements can be empty, which allows the implementation to fall back to a default remote method to invoke.

The argument and return value handling is very basic, and reflects the traditional scheme for remote procedure calls, that is, an array of structures acts as variable parameter vector. For each element of the vector, the `parameter` struct describes its data `buffer`, the `size` of that buffer, and its input/output `mode`.

The `mode` value has to be initialized for each `parameter`, and `size` and `buffer` values have to be initialized for each `In` and `InOut` struct. For `Out` parameters, `size` may have the value `0` in which case the `buffer` must be un-allocated, and is to be created (e.g. allocated) by the SAGA implementation upon arrival of the result data, with a size sufficient to hold all result data. The `size` value is to be set by the implementation to the allocated buffer size. SAGA language bindings MUST prescribe the responsibilities for releasing the allocated buffer, according to usual procedures in the respective languages.

When an `Out` or `InOut` struct uses a pre-allocated buffer, any data exceeding the buffer size are discarded. The application is responsible for specifying correct buffer sizes for pre-allocated buffers; otherwise the behavior is undefined.

This argument handling scheme allows efficient (copy-free) passing of parameters. The parameter vector must be passed by reference because it is specified as `inout` in SIDL. (See also Section 2.2.)

4.6.1 RPC Permissions

The SAGA API allows for application level authorization of RPC calls an application is able to set permissions on `saga::rpc` instances. Not all implementations will be able to fully implement that security model – the implementation MUST carefully document which permissions are supported, and which are not.

4.6.2 Specification

```
package saga.rpc
{
  enum io_mode
  {
    In    = 1,          // input  parameter
    Out   = 2,          // output parameter
    InOut = 3           // input and output parameter
  }

  class parameter : extends saga::buffer
              // from buffer saga::object
              // from object saga::error_handler
  {
    CONSTRUCTOR (in    array<byte>       data = "",
                 in    int               size = -1,
                 in    io_mode           mode = In,
                 out   buffer            obj);

    set_io_mode (in    io_mode           mode);
```

```
    get_io_mode (out   io_mode          mode);
  }

  class rpc : implements   saga::object
              implements   saga::async
              implements   saga::permissions
           // from object  saga::error_handler
  {
    CONSTRUCTOR (in    session          s,
                 in    saga::url        url = "",
                 out   rpc              obj         );
    DESTRUCTOR  (in    rpc              obj         );

    // rpc method invocation
    call        (inout array<parameter>  parameters   );

    // handle management
    close       (in    float            timeout = 0.0);
  }
}
```

4.6.3 Specification Details

Enum `io_mode`

The `io_mode` enum specifies the modus of the `rpc::parameter` instances:

`In`
: The parameter is an input parameter: its initial value will be evaluated, and its data buffer will not be changed during the invocation of `call()`.

`Out`
: The parameter is an output parameter: its initial value will not be evaluated, and its data buffer will likely be changed during the invocation of `call()`.

`InOut`
: The parameter is input and output parameter: its initial value will not evaluated, *and* its data buffer will likely be changed during the invocation of `call()`.

Class `parameter`

The `parameter` class inherits the `saga::buffer` class, and adds one additional state attribute: `io_mode`, which is read-only. With that addition, the new class can conveniently be used to define input, inout and output parameters for RPC calls.

```
- CONSTRUCTOR
  Purpose:  create an parameter instance
  Format:   CONSTRUCTOR          (in  array<byte> data = "",
                                  in  int         size = -1,
                                  in  io_mode     mode = In,
                                  out parameter       obj);
  Inputs:   type:                 data to be used
            size:                 size of data to be used
            io_mode:              type of parameter
  InOuts:   -
  Outputs:  parameter:            the newly created parameter
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   NotImplemented
            BadParameter
            NoSuccess
  Notes:    - all notes from the buffer CONSTRUCTOR apply.


- DESTRUCTOR
  Purpose:  destroy an parameter instance
  Format:   DESTRUCTOR           (in  parameter obj);
  Inputs:   obj:                  the parameter to destroy
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: -
  Perms:    -
  Throws:   -
  Notes:    - all notes from the buffer DESTRUCTOR apply.


- set_io_mode
  Purpose:  set io_mode
  Format:   set_io_mode          (in  io_mode mode);
  Inputs:   mode:                 value for io mode
```

```
    InOuts:   -
    Outputs:  -
    PreCond:  -
    PostCond: -
    Perms:    -
    Throws:   -
    Notes:    -

  - get_io_mode
    Purpose:  retrieve the current value for io mode
    Format:   get_io_mode          (out io_mode mode);
    Inputs:   -
    InOuts:   -
    Outputs:  mode:                 value of io mode
    PreCond:  -
    PostCond: -
    Perms:    -
    Throws:   -
    Notes:    -
```

Class `rpc`

This class represents a remote function handle, which can be called (repeatedly), and returns the result of the respective remote procedure invocation.

```
  - CONSTRUCTOR
    Purpose:  initializes a remote function handle
    Format:   CONSTRUCTOR  (in  session   s,
                            in  saga::url url = "",
                            out rpc       obj);
    Inputs:   s:            saga session to use
              url:          remote method to
                            initialize
    InOuts:   -
    Outputs:  obj           the newly created object
    PreCond:  -
    PostCond: - the instance is open.
    Perms:    Query
    Throws:   NotImplemented
              IncorrectURL
              BadParameter
              DoesNotExist
```

```
              PermissionDenied
              AuthorizationFailed
              AuthenticationFailed
              Timeout
              NoSuccess
    Notes:    - if url is not given, or is empty (the
                default), the implementation will choose an
                appropriate default value.
              - according to the GridRPC specification, the
                constructor may or may not contact the RPC
                server; absence of an exception does not imply
                that following RPC calls will succeed, or that
                a remote function handle is in fact available.
              - the following mapping MUST be applied from
                GridRPC errors to SAGA exceptions:
                GRPC_SERVER_NOT_FOUND   : BadParameter
                GRPC_FUNCTION_NOT_FOUND : DoesNotExist
                GRPC_RPC_REFUSED        : AuthorizationFailed
                GRPC_OTHER_ERROR_CODE   : NoSuccess
              - non-GridRPC based implementations SHOULD ensure
                upon object construction that the remote handle
                is available, for consistency with the
                semantics on other SAGA object constructors.

  - DESTRUCTOR
    Purpose:  destroy the object
    Format:   DESTRUCTOR           (in  rpc  obj)
    Inputs:   obj:                  the object to destroy
    InOuts:   -
    Outputs:  -
    PreCond:  -
    PostCond: - the instance is closed.
    Perms:    -
    Throws:   -
    Notes:    - if the instance was not closed before, the
                destructor performs a close() on the instance,
                and all notes to close() apply.


  - call
    Purpose:  call the remote procedure
    Format:   call         (inout array<parameter> param);
    Inputs:   -
    In/Out:   param:        argument/result values for call
    InOuts:   -
    Outputs:  -
```

```
  PreCond:  - the instance is open.
  PostCond: - the instance is available for another call()
              invocation, even if the present call did not
              yet finish, in the asynchronous case.
  Perms:    Exec
  Throws:   NotImplemented
            IncorrectURL
            BadParameter
            DoesNotExist
            IncorrectState
            PermissionDenied
            AuthorizationFailed
            AuthenticationFailed
            Timeout
            NoSuccess
  Notes:    - according to the GridRPC specification, the
              RPC server might not be contacted before
              invoking call(). For this reason, all notes to
              the object constructor apply to the call()
              method as well.
            - if an implementation finds inconsistent
              information in the parameter vector, a
              'BadParameter' exception is thrown.
            - arbitrary backend failures (e.g. semantic
              failures in the provided parameter stack, or
              any errors occurring during the execution of
              the remote procedure) MUST be mapped to a
              'NoSuccess' exception, with a descriptive
              error message.  That way, error semantics of
              the SAGA implementation and of the RPC
              function implementation are strictly
              distinguished.
            - the notes about memory management from the
              buffer class apply.


- close
  Purpose:  closes the rpc handle instance
  Format:   close              (in  float timeout = 0.0);
  Inputs:   timeout             seconds to wait
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: - the instance is closed.
  Perms:    -
  Throws:   NotImplemented
```

```
                NoSuccess
     Notes:     - any subsequent method call on the object
                  MUST raise an 'IncorrectState' exception
                  (apart from DESTRUCTOR and close()).
                - if close() is implicitly called in the
                  DESTRUCTOR, it will never throw an exception.
                - close() can be called multiple times, with no
                  side effects.
                - for resource deallocation semantics, see
                  Section 2.
                - for timeout semantics, see Section 2.
```

4.6.4 Examples

Code Example

```
// c++ example
// call a remote matrix multiplication A = A * B
try
{
  rpc rpc ("gridrpc://rpc.matrix.net/matrix-mult");

  std::vector <saga::rpc::parameter> params (2);

  params[0].set_data (A); // ptr to matrix A
  params[0].set_io_mode (saga::rpc::InOut);

  params[1].set_data (B); // ptr to matrix B
  params[1].set_io_mode (saga::rpc::In);

  rpc.call (params);

  // A now contains the result
}
catch ( const saga::exception & e)
{
  std::err << "SAGA error: "
           << e.get_message ()
           << std::endl;
}

+---------------------------------------------------------+

// c++ example
// call a remote matrix multiplication C = A * B
try
{
```

```
    rpc rpc ("gridrpc://rpc.matrix.net//matrix-mult-2");

    std::vector <saga::rpc::parameter> params (3);

    params[0].set_data (NULL); // buffer will be created
    params[0].set_io_mode (saga::rpc::Out);

    params[1].set_data (A); // ptr to matrix A
    params[1].set_io_mode (saga::rpc::In);

    params[2].set_data (B); // ptr to matrix B
    params[2].set_io_mode (saga::rpc::In);

    rpc.call (params);

    // params[0].get_data () now contains the result
  }
  catch ( const saga::exception & e)
  {
    std::err << "SAGA error: "
              << e.get_message ()
              << std::endl;
  }

  +-------------------------------------------------------------+

  // c++ example
  // asynchronous version of A = A * B
  try
  {
    rpc rpc ("gridrpc://rpc.matrix.net/matrix-mult");

    std::vector <saga::rpc::parameter> params (2);

    params[0].set_data (A); // ptr to matrix A
    params[0].set_io_mode (saga::rpc::InOut);

    params[1].set_data (B); // ptr to matrix B
    params[1].set_io_mode (saga::rpc::In);

    saga::task t = rpc.call <saga::task::ASync> (params);

    // do something else

    t.wait ();
    // A now contains the result
  }
  catch ( const saga::exception & e)
  {
    std::err << "SAGA error: "
```

```
           << e.get_message ()
           << std::endl;
}

+-------------------------------------------------------------+

// c++ example
// parameter sweep example from
// http://ninf.apgrid.org/documents/ng4-manual/examples.html
//
// Monte Carlo computation of PI
//
try
{
  saga::url     uri[NUM_HOSTS]; // initialize...
  long times, count[NUM_HOSTS], sum;

  std::vector <saga::rpc> servers;

  // create the rpc handles for all URIs
  for ( int i = 0; i < NUM_HOSTS; ++i )
  {
    servers.push_back (saga::rpc (uri[i]));
  }

  // create persistent storage for tasks and parameter structs
  saga::task_container tc;
  std::vector <std::vector <saga:parameter> > params;

  // fill parameter structs and start async rpc calls
  for ( int i = 0; i < NUM_HOSTS; ++i )
  {
    std::vector <saga::rpc::parameter> param (3);

    param[0].set_data (i); // use as random seed
    param[0].set_io_mode (saga::rpc::In);

    param[1].set_data (times);
    param[1].set_io_mode (saga::rpc::In);

    param[2].set_data (count[i]);
    param[2].set_io_mode (saga::rpc::Out);

    // start the async calls
    saga::task t = servers[i].call <saga::task::Async> (param);

    // save the task;
    tc.add (t[i]);

    // save the parameter structs
```

```
      params.push_back (param);
    }

    // wait for all async calls to finish
    tc.wait (saga::task::All);

    // compute and print pi
    for ( int i = 0; i < NUM_HOSTS; ++i )
    {
      sum += count[i];
    }

    std::out << "PI = "
             << 4.0 * ( sum / ((double) times * NUM_HOSTS))
             << std::endl;
  }
  catch ( const saga::exception & e)
  {
    std::err << "SAGA error: "
             << e.get_message ()
             << std::endl;
  }
```

5 Intellectual Property Issues

5.1 Contributors

This document is the result of the joint efforts of many contributors. The authors listed here and on the title page are those taking responsibility for the content of the document, and all errors. The editors (underlined) are committed to taking permanent stewardship for this document and can be contacted in the future for inquiries.

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5.2 Intellectual Property Statement

5.3 Disclaimer

5.4 Full Copyright Notice

Appendix

A SAGA Code Examples

This appendix shows a couple of SAGA examples in different languages. As stated in the introduction, these examples are not normative – language bindings are outside the scope of this document. This appendix is rather supposed to illustrate how the authors imagine the use of the API in various languages.

We hope that the examples illustrate that the API stays SIMPLE in various language incarnations, as was the major design intent for the _S_ AGA API.

Code Example

```

Example 1 (C++): Object State:
==============================

  // This example illustrates the expected life
  // times of object states.  State is shared in
  // these cases, as only shallow copies occur.

  int main (void)
  {
    { // task scope
      saga::task t;

      { // file scope
        saga::file f;

        { // session scope
          saga::session s;

          { // context scope
            saga::context c (saga::context::UserPass);

            s.add_context (c);
            f (s, saga::url ("file:////tmp/data.bin"));
            t = f.copy <saga::task::Task>
                  (saga::url ("file:////tmp/data.bak"));

          } // leave context scope
            // session keeps context state

        } // leave session scope
          // file keeps session state

      } // file scope
        // task keeps file state

      t.run ();
```

```
      // task runs, and uses state of file, session,
      // and context.
      t.wait ();

    } // task scope
      // task    releases file state
      // file    releases session state
      // session releases context state

    return (0);
  }


+--------------------------------------------------------------+

Example 2: Files:
=================

  open a file. if its size is > 10, then read the first 10
  bytes into a string, print it, end return it.

  --------------------------------------------------------------
  Example 2a: C++
  --------------------------------------------------------------
  // c++ example
  void head (const saga::url url)
  {
    try {
      // get type and other info
      saga::file f (url);

      off_t size = f.get_size ();

      if ( size > 10 )
      {
        char   buf[11];

        ssize_t len_out = f.read (saga::buffer (buf));

        if ( 10 == len_out )
        {
          std::cout << "head: "
                    << buffer.get_data ()
                    << std::endl;
        }
      }
    }

    catch ( const saga::exception & e )
    {
```

```
      std::cerr << "Oops! SAGA error: "
                << e.get_message ()
                << std::endl;
    }

    return;
  }
  -------------------------------------------------------------
  -------------------------------------------------------------
  Example 2b: C
  -------------
    void head (const SAGA_URL url)
    {
      SAGA_File my_file = SAGA_File_create (url);

      if ( NULL == my_file )
      {
        fprintf (stderr, "Could not create SAGA_File "
                         "for %s: %s\n",
                 SAGA_URL_get_url (url),
                 SAGA_Session_get_error (theSession));
        return (NULL);
      }

      off_t size = SAGA_File_get_size (my_file);

      if ( size < 0 )
      {
        fprintf (stderr, "Could not determine file size "
                         "for %s: %s\n",
                 SAGA_URL_get_url (url),
                 SAGA_Session_get_error (theSession));
        return (NULL);
      }
      else if ( size >= 10 )
      {
        SAGA_buffer b = SAGA_Buffer_create ();
        size_t buflen;

        ssize_t ret = SAGA_File_read (my_file, b, 10);

        if ( ret < 0 )
        {
          fprintf (stderr, "Could not read file %s: %s\n",
                   SAGA_URL_get_url (url),
                   SAGA_Session_get_error (theSession));
        }
        else if ( ret < 10 )
        {
          fprintf (stderr, "head: short read: %d\n", ret);
```

```
        }
        else
        {
          printf ("head: '%s'\n", SAGA_Buffer_get_data (b));
        }
      }
      else
      {
        fprintf (stderr, "head: file %s is too short: %d\n",
                 file, size);
      }

      return;
    }

  -------------------------------------------------------------
  Example 2c: Java
  ----------------

  import org.ogf.saga.URI;
  import org.ogf.saga.buffer.Buffer;
  import org.ogf.saga.buffer.BufferFactory;
  import org.ogf.saga.file.File;
  import org.ogf.saga.file.FileFactory;
  import org.ogf.saga.namespace.Flags;
  import org.ogf.saga.session.Session;

  public class Example {
    // open a file. if its size is >= 10, then read the first
    // 10 bytes into a string, print it, end return it.
    public String head(Session session, URI uri)
    {
      try
      {
        File f = FileFactory.createFile(session, uri, Flags.READ);
        long size = f.getSize();

        if (10 <= size) {
          Buffer    buffer = BufferFactory.createBuffer(10);
          int       res    = f.read(10, buffer);

          if (10 == res) {
            System.out.println("head: " + buffer);
          } else {
            System.err.println("head: read is short! " + res);
          }
          return new String(buffer.getData());
        } else {
          System.err.println("file is too small: " + size);
        }
```

```
    } catch (Exception e) {
      // catch any possible error - see elsewhere for better
      // examples of error handling in SAGA
      System.err.println ("Oops! " + e);
    }

    return null;
  }
}
--------------------------------------------------------------
Example 2d: Perl ('normal' error handling)
------------------------------------------

  sub head ($)
  {
    my $url     = shift;
    my $my_file = new saga::file (url)
            or die ("can't create file for $url: $!\n");

    my $size    = my_file->get_size ();

    if ( $size > 10 )
    {
      my $buffer = new saga::buffer (10)l
      my $ret    = my_file->read ($buffer)
            or die ("can't read from file $url: $!\n");

      if ( $ret == 10 )
      {
        print "head: ", $buffer->get_data (), "\n";
      }
      else
      {
        printf STDERR "head: short read: %d\n" ($buffer);
      }
    }
    else
    {
      print STDERR "file $url is too short: $size\n";
    }

    return;
  }

--------------------------------------------------------------
Example 2e: Perl (exceptions)
-----------------------------
  sub head ($)
  {
    my $url     = shift;
```

```
      eval
      {
        my $my_file = new saga::file (url);
        my $size    = my_file->get_size ();

        if ( $size > 10 )
        {
          my $buffer = new saga::buffer (10)l
          my $ret    = my_file->read ($buffer);

          if ( $ret == 10 )
          {
            print "head: ", $buffer->get_data (), "\n";
          }
          else
          {
            printf "head: short read: %d \n", length ($buffer);
          }
        }
        else
        {
          print "file $url is too short: $size\n";
        }
      }

      if ( $@ =~ /^saga/i )
      {
        print "catched saga error: $@\n" if $@;
      }

      return;
    }

  --------------------------------------------------------------
  Example 2f: Fortran 90
  ----------------------

  C Fortran 90 example
     SUBROUTINE HEAD(session, url, buffer)

     INTEGER      :: session, url, file, size, buflen
     CHARACTER*10 :: buffer

     CALL SAGA_FILE_CREATE(session, url, file)
     CALL SAGA_FILE_GET_SIZE(file, size)

     IF size .GT. 10 THEN

       CALL SAGA_FILE_READ(file, 10, buffer, buflen)
```

```

        IF buflen .EQ. 10 THEN
          WRITE(5, *) 'head: ', buffer
        ELSE
          WRITE(5, *) 'head: short read: ', buflen
        ENDIF
      ELSE
        WRITE(5, *) 'file is too short'
      ENDIF

      END

  --------------------------------------------------------------
  Example 2g: Python
  ------------------
  # Python example
  def head (session,url):

    try:
      my_file = saga.file(session,url)
      size = my_file.get_size()

      if (size > 10):
        my_buffer = saga.buffer (10)
        ret = my_file.read (my_buffer)
        if (ret == 10):
          print "head: ", my_buffer.get_data ()
        else
          print "head: short read: ", ret
      else
        print "head: file is too short: ", size

    # catch any possible error - see elsewhere for better
    # examples of error handling in SAGA
    except saga.Exception, e:
      print "Oops! SAGA error: ", e.get_message ()
```

B Changelog

This appendix lists the errata changes which have been applied to the originally published SAGA Core API specification. As most changes are not breaking backward compatibility, the version number of this document has not been changed, and remains 1.0.

Errata to SAGA Core API Version 1.0

- The `context` c'tor does not call `set_defaults()` anymore. In fact, the method `set_defaults()` is gone, and its functionality is now performed on `session.add_context()` – the original context is left untouched (as it is specified that `add_context()` performs a deep copy on the context to be added). **This is the only change which breakes backward compatibility.**
- Typos, spelling and grammar have been fixed in several places. These fixes are not listed individually.
- The biggest change is that saga exceptions are now recursive objects, i.e. they can provide a list of lower level exceptions. That change is backward compatible, and is introduced mainly for the sake of late binding implementations. At the same time, the stricly prescribed exception precedence has been relaxed, and can be changed by the implementation. The `NotImplemented` exception now has lowest precedence. This change is also backward compatible.
- It has been clarified what Look-&-Feel classes MUST be implemented, and when `NotImplemented` exceptions MAY be thrown.
- The `read_v()` method now throws `BadParameter` when "out of bounds": when no `len_in` is specified, the buffer size is used instead as `len_in`. If, in this case, `offset > 0`, a `BadParameter` exception is thrown.
- `write_v` method now throws `BadParameter` when "out of bounds": when no `len_in` is specified, the buffer size is used instead as `len_in`. If, in this case, `offset > 0`, a `BadParameter` exception is thrown.
- The default flag for file `open()` is now `Read`.
- The `Create` flag now implies `Write`.
- The `CreateParents` flag now implies `Create`.
- Callbacks now can remove conditions to be called again, i.e. shut down the metric, read more than one message, etc. Implementations MUST be able to handle this.
- The URL behaviour for relative path elements, and their time of expansion, has been clarified.
- `task.get_result()` now calls `rethrow()` if the task is in `Failed` state.

- The url.get_xxxx() methods return an empty string on undefined or unknown values, or -1 for get_port().
- JobProject and WallTimeLimit have been added to the job_description attributes.
- The run() postcondition is now 'left New state' instead of 'is in Running state', to avoid races with jobs entering a final state immediately.
- The url class was added to the list of Look-&-Feel packages/classes in paragraph 6 on page 17.
- The behaviour of get_link() has been clarifies: it resolves only one level.
- The namespace package got Read and Write flags, as they are needed for directories.
- URL escaping has been clarified, and a get_escaped() method has been added, to enforce character escaping.
- close() is not throwing IncorrectState anymore.
- object.clone() does not copy the object id anymore, but assigns a new, unique one.
- On page 225, the notes of NSDirectory.copy (source, target, flags) have been fixed.
- The RPC c'tor signature has been fixed (parameter name).
- The signature for task_container.wait () has been fixed (default timeout value was missing).
- The url class was added to the class diagram, and the iovec and parameter classes have been moved into their respective packages.
- The size parameter in the rpc c'tor has been fixed.
- Exception has been removed from object::type enum.
- A saga::job now provides the ServiceURL attribute which allows the re-creation of the job::service instance which handles the job.
- A url::translate() variant with explicit session parameter has been added.
- session.list_contexts() now returns deep copies of session contexts, not shallow copies.

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