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SAGA API Extension: Advert API

Status of This Document

This document provides information to the grid community, proposing a standard for an extension package to the Simple API for Grid Applications (SAGA). That extension provides access to persistent storage for serialized SAGA objects, and application level meta data (adverts). As SAGA extension, it depends upon the SAGA Core API Specification [1]. This document is supposed to be used as input to the definition of language specific bindings for this API extension, and as reference for implementors of these language bindings. Distribution of this document is unlimited.

Abstract

This document specifies an Advert API extension to the Simple API for Grid Applications (SAGA), a high level, application-oriented API for grid application development. This Advert API is motivated by a number of use cases collected by the OGF SAGA Research Group in GFD.70 [2], and by requirements derived from these use cases, as specified in GFD.71 [3]). It allows to persitently store application specific meta data in a name space hierarchy, along with serialized `saga::object` instances.

[1] editor

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1 Introduction

A significant number of SAGA use cases [2] ask for the possibility to persistently store application level meta data[1]. In difference to data storage in files, these meta data are usually small, and structured as key-value-pairs. The main use case for this API extension is that an application stores some state information, and that these state information are either used by other applications, or by a later running instance of the same application.

For example, an application which allows to stream data (i.e. uses the SAGA Stream API [1]), may store its `saga::stream::service` endpoint URL as an advert, along with information about the protocol to be used, and another application which wants to connect to the first one may obtain the service object, and the protocol information, from the advert service. This allows, amongst others, for simple and environment independent bootstrapping of distributed ensembles of applications. The persistent nature of the advert service also allows applications to cooperate even if their actual application run time does not overlap.

Adverts are defined as an entry in the adverts name space, i.e. as an entry in an `saga::advert_directory`. Similar to `saga::logical_file`, each advert can have meta data attached (i.e. has key-value based attributes). As described above, an `saga::advert` can also store one (serialized) `saga::object` instance. In some sense, that object instance can be considered to be the *content* of the advert, and the attributes can be considered the *meta data* of the advert, usually describing the content. Neither element needs to exist however – even completely empty adverts can be useful in some circumstances, e.g. to simply flag specific conditions.

1.1 Notational Conventions

In structure, notation and conventions, this documents follows those of the SAGA Core API specification [1], unless noted otherwise.

1.2 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

[1]The distinction between data and meta data is usually not very well defined. In this document, we refer to meta data as small pieces of information which are used to manage the overall functionality of the application. They are, usually, not the data which are the object of the the applications core algorithms. In particular, for the purpose of theis document, we consider meta data *not* to be binary data.

hooks to interface to various security models – see the documentation of the `saga::context` class in the SAGA Core API specification [1] 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 SAGA Advert API

2.1 Introduction

Several SAGA use cases [2], and also several current and past SAGA and GAT [**?**] base projects, declared the need for a simple interface to storage of small sets of persisten application data. Further, as distributed applications have an inherent need of coordination [**?**], the state for SAGA object instances is considered to count amongst those information. The advert API extension to SAGA, which is presented and specified in this document, is designed to accommodate those needs.

In its core, the advert package represents a `saga::namespace` derivate which allows to store, search and retrieve `saga::attribute` sets and `saga::object` derivates in its leave nodes. The notion of namespace is repeatedly used throughout the SAGA API [1], as is the notion of attributes. By combining both, the structure of the advert API package should actually be immediately clear. The novel addition to the package is the ability to store SAGA object instances, which should be considering as seriealized representation of the the respective object's state.

The potential use cases of the API package are virtually endless, and as implementation of the API in SAGA and other APIs already exist since a number of years, the paradigm has already been proven to be incredibly useful for the development of distributed applications. An example applications is thus included to (a) demonstrate that usefulness, and (b) illustrate the structure and purpose of the API. The complete application code can be found in section 3.

Interoperability

As SAGA is an API specification, it is generally true that interoperability on backend level can neither be specified, nor enforced, by SAGA. In order to allow, however, to implement interoperable advert service backends, this document *advises* that implementations follow the folllowing conventions:

- advert state information are to be rendered in a reserved attribute namespace, `_SAGA_*`. The following state information SHOULD be supported:

`_SAGA_TTL`	: time in seconds
`_SAGA_CREATED`	: creation time in seconds since epoch
`_SAGA_MODIFIED`	: last modification time in seconds since epoch
`_SAGA_LOCK`	: value `1` if locked, `0` otherwise
`_SAGA_OBJECTTYPE`	: type of attached SAGA object, as per SAGA object enumertion

`_SAGA_OBJECTSTATE` : non-portable object state information

- for each object which gets attached to an advert, the object state is stored in an additional set of attributes. The state attributes for each SAGA object type are specified in appendix A of this document**FIXME: add appendix**. New SAGA extension packages SHOULD define their on object state attributes for advert service serialization, OR the authors SHOULD update the appendix of this document. The additional attribute `_SAGA_OBJECTSTATE`, as defined above, MAY contain additional, implementation specific object state information in serialized form.

  As an example, the object state attributes for a `saga::filesystem::file` instance are defined as

`_SAGA_FILE_FILE_SESSION`	: url, points to a session advert
`_SAGA_FILE_FILE_URL`	: url, points to the physical file
`_SAGA_FILE_FILE_MODE`	: int, flags used on construction
`_SAGA_FILE_FILE_OFFSET`	: int, result of `f.seek (0, CURRENT)`

Example: Master/Slave Application with Advert Registries

Assume a distributed application wants to employ the Master/Slave paradigm. The Master can then, after creating the slave jobs, publish those in a separate advert directory, which thus serves as this master's job registry. Each job advert contains the serialized job instance. Further, the master can publish work items in yet another advert directory, and assign job id's to each work item. That second advert directory this acts as a work item queue. The work item adverts contain (a) a serialized SAGA file instance representing the work data, (b) the id of the job assigned to that work item, and (c) the state of that item (e.g. `'assigned'`). After all work items have been created and assigned, the jobs are `run()`, and can start to pick up work items.

The started slave processes search the work item registry for items assigned to them, by doing a `find()` on the advert directory, with a pattern which specifies `'work_id=<my_id>'`, with `my_id` being their own job id. They then work on each item, marking it as `'accepted'` when starting the work, and as `'completed'` when done.

A separate master process could decide to check the overall progress of the work. To do that, it retrieves all job and work item adverts, and checks the respective status: for the jobs, it retrieves the job instances from the job adverts, and calls `get_state()` on them; for the work items, it checks the `'work_state'` attribute of the work item adverts. If jobs are in a final state, and all work items are completed, the master can safely purge the advert directories.

That example obviously is very simplicistic in respect to scheduling of work items, and also in respect to error recovery, but is nevertheless fully functional. Creating an application with similar functionality without the help of the advert service requires significantly more, and also more complex, operations. In particular, the application is immediately resilient against master failures: once the job and work item registries exist, they are persistent, and can be utilized by any application component with the respective permissions. Further, the communication between the individual application components (i.e. processes) is immediately asynchronous, secure, and persistent (no 'messages' get lost). Also, the registries allow to easily infer the overall state of the distributed application. Finally, the communication via the advert service completely solves the application bootstrapping problem: there is no need for any application component to directly contact any other component. Thus, no component needs to know where any other component is actually being executed. The only shared information are the URLs of the job and work item registries (or, in our code base, the single URL of the directory containing these registries).

2.1.1 Classes

The SAGA Advert API consists of two classes: the `advert::advert` class, which inherits `namespace::entry` and encapsulates the application information to be stored persitently; and the `advert::directory` class, which inherits the `namespace::directory` and represents the directories adverts are organized in. The `advert::advert` class has two additional methods, `store_object()` and `retrieve_object()`, which allow to associate a SAGA object instance with that specific advert. The `advert::directory` has an overloaded `find()` method, which allows to also search object types, and for meta data pattern (i.e. attribute patterns), similar to the find of the SAGA replica package. Additionally, the `advert::flags` enum is inherited from the SAGA namespace package, and extended by the `Truncate` flag which empties both the associated object and the attributes of the advert to be opened.

2.1.2 SAGA Object Serialization

This document is silent about the detais of the object serialization format to be used for storing and retrieving `saga::object` instances in advert entries. That implies that different implementations of the advert service API may not be interoperable, in the sense that objects stored with one implementation may not be retrievable with another implementation. We consider that to be in sync with the other functional SAGA API packages, which also introduce implicit backend dependencies – for example, jobs submitted to one backend can, usually, not be managed by another backend.

We would like to encourage, however, that various language bindings of this API try to exploit existing native object serialization schemas (where they exist) to potentially achieve interoperability, or even to exploit serialization schemes which can cross language boundaries.

It is important to realize that the actual serialization does not need to comprise the complete binary representation of the object instance. In fact, that binary representation may be the least usable version when crossing process and OS boundaries. Instead, only the state of the respective object instance needs to be saved. This specification does not prescribe the set of required state information for the individual SAGA object types, but we again would like to encourage the various language bindings to try to specify that set as concisely as possible. As an example, we consider the folllowing elements to be neccessary and sufficient to serialize a `saga::filesystem::file` instance (C++ rendering):

```
saga::url  url       // the file url
int        flags     // the file open flags
off_t      pos       // the file pointer position
                     //     for I/O operations
```

Using `open()` and `seek()`, the retrieving application instance (i.e. the retrieving SAGA implementation) should be able to re-create a `saga::file` instance which represents the same physical file entity, in the same state.

Implementations of the advert package SHOULD strive to provide support for all SAGA objects types. Language bindings MAY allow to associate other types, such as primitive data types like `int` or `string`, or even complex application level data types such as custom classes, with advert entries. It should be noted though that this will reduce the portability of applications, as it becomes less likely that the respective serializations can be interpreted by (a) other implementations in the same language, and (b) by implementations in other languages.

Again, implementors SHOULD thus follow the guidline that not the binary representation of objects is serialized, but rather the minimal set of information which represents the complete state of the object, as far as the application is concerned.

Note that the `advert.retrieve_object()` method is able to return different object types. It thus uses the same type templatization signature as employed in the SAGA core specifcation, for example for the `task.get_result()` method. Language bindings MAY utilize the same technique for `advert.store_object()`, if the argument's type cannot automatically infered in that language.

2.1.3 Advert Persistency and Lifetime Management

Adverts have, by default, an unspecified lifetime, and can thus in particular survive the application which created the advert. It should be noted that this can, however, lead to garbage, i.e. to an increasing number of entries which are not needed anymore. Similar to stale files in a file system, it is the responsibility of the end user to avoid garbage. To support that, the `get_ttl()` and `set_ttl (int)` methods on the `advert` and `advert_dir` classes can be used to specify a minimal advert lifetime (time to live, TTL) – beyond that time, the advert can be considered as garbage, and MAY be purged out automatically.

If the TTL of an advert is expired, the result of any call accessing that advert is undefined. Implementations MAY be able to open expired adverts, but no guarantees are given on their content. Implementations SHOULD throw an 'IncorrectState' exception for expired adverts.

If no ttl is defined on an advert, it is assumed to never to expire.

2.1.4 Advert URLs

The exact rendering of the advert namespace is up to the respective implementation, and it is thus not specified in this document how valid URLs are formed (i.e. what schemas are supported). Implementations SHOULD, however, strive to support the generic URL schema 'any', as motivated in [1]. Otherwise, the rules specified for file system URLs in [1] SHOULD be followed.

2.2 Specification

```
package saga.adverts
{
  enum flags : extends saga::namespace::flags
  {
    None            =    0,   // from saga::namespace
    Overwrite       =    1,   // from saga::namespace
    Recursive       =    2,   // from saga::namespace
    Dereference     =    4,   // from saga::namespace
    Create          =    8,   // from saga::namespace
    Exclusive       =   16,   // from saga::namespace
    Lock            =   32,   // from saga::namespace
    CreateParents   =   64,   // from saga::namespace
    Truncate        =  128,
```

```
  Read            =  512,   // from saga::namespace
  Write           = 1024,   // from saga::namespace
  ReadWrite       = 1536    // from saga::namespace
}


class advert_directory : extends saga::ns_directory
                         extends saga::attributes
            // 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            session,
                 in  string             url,
                 in  int                flags = Read,
                 out advert_directory   obj);
  DESTRUCTOR    (in  advert_directory   obj);

  // get/set time to live
  get_ttl       (out int                ttl);
  set_ttl       (in  int                ttl);

  // find adverts based on name, object type, and meta data
  find          (in  string             name_pattern,
                 in  array<string>      attr_pattern,
                 in  saga::object::type type  = 0,
                 in  int                flags = Recursive,
                 out array<saga::url>   names );

  // Attributes (extensible):
}


class advert : extends        saga::ns_entry
               extends        saga::attributes
            // from ns_entry  saga::object
            // from ns_entry  saga::async
            // from ns_entry  saga::permissions
            // from object    saga::error_handler
{
  CONSTRUCTOR     (in    session       session,
                   in    string        url,
                   in    int           flags = Read,
                   out   advert        obj);
```

```
    DESTRUCTOR      (in    advert        obj);

    // get/set time to live
    get_ttl         (out   int           ttl);
    set_ttl         (in    int           ttl);

    // attach saga::object instances
    store_object    (in    saga::object  content);
    retrieve_object <type>
                    (out   saga::object  content);

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

2.3 Specification Details

2.4 Enum `flags`

The flags describe the properties of several operations on advert directories and entries. This package inherits the flags from the namespace package, and uses the same ag semantics unless specied otherwise. The `Truncate` flags is added, which is to be used when opening an `advert::entry` instance shall completely empty that entry. The `Truncate` flag does not imply a reset of the creation time, but it causes the entry's time-to-live (TTL) counter to be restarted.

2.4.1 Class `advert::directory`

The `advert::directory` class follows the purpose and semantics of the inherited `saga::namespace::directory` class.

It has two additional method, to query and set the directorie's TTL. If that time is passed (i.e. the directories creation-time plus its TTL is smaller than 'now'), it can be considered to be 'garbage'. It MAY be automatically cleaned out by the backend, if and only if it only contains similarly expired entries. The TLL counter (re)starts on creation time, whenever an advert is being modified, and when calling `set_ttl()`.

Another namespace method, `find()`, is overloaded, and allows to extends the search pattern to (a) the type of objects associated with adverts, and (b) the attributes associated with adverts.

```
- CONSTRUCTOR
  Purpose:  create the object
  Format:   CONSTRUCTOR          (in  session   s,
                                  in  saga::url name,
                                  in  int       flags = Read,
                                  out directory obj)
  Inputs:   s:                    session handle
            name:                 location of directory
            flags:                open mode
  InOuts:   -
  Outputs:  obj:                  the newly created object
  PreCond:  -
  PostCond: - the directory is opened.
            - 'Owner' of directory is the id of the context
              use to perform the operation, if the
              directory gets created.
            - the TTL timer of the object is started on
              Creation, and if the Truncate flag is
              specified.
  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:    - if the 'Truncate' flag is given, the returned
              object MUST NOT have an associated object, and
              MUST have an empty attribute set.
            - the 'Truncate' flag requires that the entry
              exists, or that the 'Create' flag is given,
              too.  Otherwise, a DoesNotExist exception is
              thrown.
            - the 'Create' flag implies 'Write'.


- DESTRUCTOR
```

```
  Purpose:  destroy the object
  Format:   DESTRUCTOR           (in  entry        obj)
  Inputs:   obj:                  the object to destroy
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: - the directory is closed.
  Perms:    -
  Throws:   -
  Notes:    -


- get_ttl
  Purpose:  get the time to life
  Format:   get_ttl               (out  int  ttl);
  Inputs:   ttl:                  time to live in seconds
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: - the instance's ttl timer not restarted.
  Perms:    - Read
  Throws:   NotImplemented
            IncorrectState
            Timeout
            NoSuccess
  Notes:    -


- set_ttl
  Purpose:  set a time to life, and restart the ttl timer.
  Format:   set_ttl              (in  int  ttl);
  Inputs:   ttl:                  time to live in seconds
  InOuts:   -
  Outputs:  -
  PreCond:  -
  PostCond: - the instance's ttl timer is restarted.
            - the instance's ttl is set to ttl.
  Perms:    - Write
  Throws:   NotImplemented
            IncorrectState
            Timeout
            NoSuccess
  Notes:    - A negative tll just restarts the ttl timer,
              but does not actually change the ttl value.
            - A ttl value '0' declares the instance as
              garbage immediately.
```

```
- find
  Purpose:  find adverts 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  saga::object::type type  = 0,
                   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
            type:             filter for adverts with
                              attached saga objects of that
                              type
            flags:            flags defining the operation
                              modus
  InOuts:   -
  Outputs:  names:            array of names matching all
                              criteria
  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 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 supercedes
```

```
    the find_attributes() semantic.  Only entries
    matching all attribute patterns, the name
    space pattern and the object type are returned.
  - the default flags are 'Recursive' (2).
  - expired entries (TTL) SHOULD NOT be returned.
```

2.4.2 Class `advert::advert`

The `advert::advert` class follows the purpose and semantics of the inherited `saga::namespace::entry` class. Two methods allow to manage manage the `saga::object` instance associated with that advert entry. Along the same lines, an overloaded `CONSTRUCTOR` is added which specifies the associated saga::object on creation time. That constructor will only succeed when the `Create` or `Truncate` flag is given, and can succeed.

Advert entry instances do also have a TTL, which follows the same semantics as defined above for the advert directory.

Further, the advert entry implements the `saga::attributes` interface, and can hold an arbitrary set of user define attributes.

```
- CONSTRUCTOR
  Purpose:  create the object
  Format:   CONSTRUCTOR          (in  session   s,
                                  in  saga::url name,
                                  in  int       flags = Read,
                                  out 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:    - semantic as in saga::namespace::entry
              - if the 'Truncate' flag is given, the returned
                object MUST NOT have an associated object, and
                MUST have an empty attribute set.
              - the 'Truncate' flag requires that the entry
                exists, or that the 'Create' flag is given,
                too.  Otherwise, a DoesNotExist exception is
                thrown.
              - the 'Create' flag implies 'Write'.


  - DESTRUCTOR
    Purpose:  destroy the object
    Format:   DESTRUCTOR           (in  entry        obj)
    Inputs:   obj:                  the object to destroy
    InOuts:   -
    Outputs:  -
    PreCond:  -
    PostCond: - the entry is closed.
    Perms:    -
    Throws:   -
    Notes:    - semantic as in saga::namespace::entry


  - get_ttl
    Purpose:  get the time to life
    Format:   get_ttl               (out  int  ttl);
    Inputs:   ttl:                  time to live in seconds
    InOuts:   -
    Outputs:  -
    PreCond:  -
    PostCond: - the instance's ttl timer is not restarted.
    Perms:    - Read
    Throws:   NotImplemented
              IncorrectState
              Timeout
              NoSuccess
```

```
    Notes:    - all notes to advert::directory::get_ttl()
                method apply


  - set_ttl
    Purpose:  set a time to life, and restart the ttl timer.
    Format:   set_ttl               (in  int  ttl);
    Inputs:   ttl:                  time to live in seconds
    InOuts:   -
    Outputs:  -
    PreCond:  -
    PostCond: - the instance's ttl timer is restarted.
              - the instance's ttl is set to ttl.
    Perms:    - Write
    Throws:   NotImplemented
              IncorrectState
              Timeout
              NoSuccess
    Notes:    - all notes to advert::directory::set_ttl()
                method apply


  - store_object
    Purpose:  associate a saga::object instance with the entry
    Format:   store_object          (in  saga::object content);
    Inputs:   content:              saga::object to be
                                    associated with the entry
    InOuts:   -
    Outputs:  -
    PreCond:  -
    PostCond: - the given object instance can be retrieved
                with retrieve_object().
              - any reference to an previously associated
                object is removed.
    Perms:    -
    Throws:   NotImplemented
              IncorrectState
              Timeout
              BadParameter
              NoSuccess
    Notes:    - if the implementation does not suport the
                association of that object type, a
                'BadParameter' exception is thrown.


  - retrieve_object
```

```
Purpose:  retrieve the associated saga::object instance
Format:   retrieve_object       (out saga::object content);
Inputs:   -
InOuts:   -
Outputs:  content:              saga::object associated
                                with the entry
PreCond:  -
PostCond: -
Perms:    -
Throws:   NotImplemented
          IncorrectState
          Timeout
          BadParameter
          NoSuccess
Notes:    - if the implementation cannot de-serialize the
            stored object type, a 'NoSuccess' exception is
            thrown.
          - if the implementation can deserialize the
            stored object type, but cannot deserialize
            that specific instance, an 'IncorrectState'
            exception is thrown.
          - the object stays associated with the entry.
          - each call to this method retrieves a new copy
            of the object.  Depending on the
            implementation, these copies may or may not
            share state.
```

3 Example Code

For a high level description of these examples, see section 2.1.

Master Code - Startup

```
1
2   #define BASE_URL std::string ("any://advert.db.net/my_app")
3   #define JOBNUM   100  // size of worker pool
4   #define WORKNUM  1000 // number of work items
5
6   // the master spawns jobs, and assignes them work items.  These info
7   // are stored in the advert service, waiting for the jobs to pick
8   // them up, and report back.
9   int main ()
10  {
11    // create the job service used to spawn the slaves
12    saga::job::service js ("any://job.service.net");
13
14    // create the job registry in the advert data base
15    saga::advert::advert_dir jobs (BASE_URL + "jobs/",
16                                   saga::advert::Create);
17
18    // keep track of jobs and job_ids
19    saga::task_container tc;
20    std::vector <std::string> job_ids;
21
22    // spawn the slaves
23    for ( int i = 0; i < JOBNUM; i++ )
24    {
25      saga::job::job j = js.create_job (jd);
26
27      // register the slaves in the registry
28      saga::advert a = jobs.open (j.get_jobid (), j,
29                                  saga::advert::Create);
30
31      // keep job and jobid
32      tc.add_task (j);
33      job_ids.push_back (j.get_jobid ());
34    }
35
36    // create the work item registry in the advert data base
37    saga::advert::advert_dir works ("BASE_URL + "works/",
38                                    saga::advert::Create);
39
40    // publish work items, and assign them to the slaves
41    for ( int i = 0; i < WORKNUM; i++ )
42    {
43      // open file representing the work item (pseudo code)
44      saga::filesystem::file f ("any://data.src.net/data/set_[i].dat");
```

```
45
46      // publish it in the work item queue
47      saga::advert a = works.open (f.get_name (), f,
48                                   saga::advert::Create);
49
50      // assign it to a job (pseudo code)
51      a.set_attribute ("worker_id",    job_ids[j % JOBNUM]);
52      a.set_attribute ("worker_state", "assigned");
53    }
54
55    // work items are created and assigned, now we can start the jobs,
56    // so that they can begin to pick up work
57    tc.run ();
58
59    // the master can safely exit here, as all job and work item info
60    // are persistently stored in the advert service
61    return 0;
62  }
```

Client Code Code - Work

```
1   #define BASE_URL std::string ("any://advert.db.net/my_app")
2
3   // the client gets its own job_id, and retrieves all work items
4   // assigned to it.  After completing them, it ticks them off in the
5   // registry, and finishes if no further work is pending.
6   int main ()
7   {
8     // get own job id
9     saga::job::service js;
10    saga::job::job     me = js.get_self  ();
11    std::string        id = me.get_jobid ();
12
13    // retrieve a data items from the work item queue
14    saga::advert::advert_dir works (BASE_URL + "works/");
15
16    std::vector <std::string pattern;
17    pattern.push_back ("worker_id=" + id);        // pseudo code string ops
18    pattern.push_back ("worker_state=assigned");  // only pick new items
19
20    // this worker type can only work on files
21    std::vector <saga::url> items = works.find ("*", pattern,
22                                                saga::object::File);
23
24    while ( ! items.empty () )
25    {
26      // work on the items
27      for ( int i = 0; i < items.size (); i++ )
28      {
```

```
29        // open the work item
30        saga::advert::advert a = works.open (items[i]);
31
32        // signal that we work on that item
33        a.set_attribute ("worker_state", "accepted");
34
35        // do work, on the file which is 'contained' in the advert
36        do_work (a.get_object <saga::filesystem::file> ());
37
38        // signal that item is completed
39        a.set_attribute ("worker_state", "completed");
40      }
41
42      // refresh work item list
43      items = works.find ("*", pattern, saga::object::File);
44    }
45
46    // done - just finish
47    return 0;
48  }
```

Master Code - Check and Finish

```
1   #define BASE_URL std::string ("any://advert.db.net/my_app")
2
3   // another master (yes, we have two) checks the status of jobs and
4   // workers, and cleans up if everything is done.
5   int main ()
6   {
7     bool completed = true;
8
9     // open the work item registry in the advert data base, and get
10    // all work items
11    saga::advert::advert_dir works (BASE_URL + "works/");
12    std::vector <saga::url>  items = works.list ();
13
14    // check item state
15    for ( int i = 0; i < items.size (); i++ )
16    {
17      saga::advert::advert a = works.open (items[i]);
18      std::cout << " item "       << i
19                << " handled by " << a.get_attribute ("worker_id")
20                << " has state "  << a.get_attribute ("work_state")
21                << std::endl;
22
23      // check global state
24      if ( a.get_attribute ("work_state") != "completed" )
25      {
26        completed = false;
```

```
27      }
28    }
29
30
31    // open the job registry in the advert data base, and get all jobs
32    saga::advert::advert_dir jobs (BASE_URL + "jobs/");
33    std::vector <saga::url>  ids = jobs.list ();
34
35    // check item state
36    for ( int i = 0; i < ids.size (); i++ )
37    {
38      saga::advert::advert a = jobs.open (ids[i]);
39      saga::job::job       j = a.get_object <saga::job::job> ();
40
41      std::cout << " job "       << i
42                << " has id "    << ids[i]
43                << " and state " << j.get_attribute ("State")
44                << std::endl;
45
46      // check global state
47      if ( j.get_state != saga::job::Done   ||
48           j.get_state != saga::job::Failed )
49      {
50        completed = false;
51      }
52    }
53
54
55    // if everything is done, we can clean up the advert service dirs.
56    // Otherwise, we just wait for the next run to do so, eventually.
57    if ( completed )
58    {
59      works.remove (saga::advert::Recursive);
60      jobs.remove  (saga::advert::Recursive);
61    }
62
63    return (completed ? 0 : 1);
64  }
```

4 Intellectual Property Issues

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