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SAGA Extension: Checkpoint and Recovery API (CPR)

Status of This Document

This document provides information to the grid community, proposing a standard for an extension to the Simple API for Grid Applications (SAGA). As such it depends upon the SAGA Core API Specification [2], on the GridCPR Use Case document [1]and the GridCPR architecture document [3]. 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

FIXME: real citations!

This document specifies the an Checkpoint and Recovery (CPR) API extension to the Simple API for Grid Applications (SAGA), a high level, application-oriented API for grid application development. This CPR API is motivated by a number of use cases collected by the GridCPR Working Group in GFD.92 ("Use Cases for Grid Checkpoint and Recovery"). Scope and semantics of the SAGA CPR API extension is motivated by the GridCPR architecture document GFD.93 ("An Architecture for Grid Checkpoint and Recovery (GridCPR) Services and a GridCPR Application Programming Interface").

Contents

1 Introduction

This document specifies an API for the initiation and management of application checkpointing and recovery operations.

1.1 Notational Conventions

In structure, notation and conventions, this documents follows those of the SAGA Core API specification [2], 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 hooks to interface to various security models. In that respect, the SAGA CPR extension covered in this document does not differ from trhe SAGA Core API specification [2], and the Security Considerations from that document apply.

2 SAGA CPR API

2.1 Introduction

This document specifies an API for the initiation and management of application checkpointing and recovery operations. The scope and semantics of this API are motivated by the GridCPR architecture document [3]. Its capabilities fall in the following categories:

A – checkpoint and recovery operations

- **A.1** – specification of application checkpointing capabilities and policies
- **A.2** – issuing notification of checkpointing requests
- **A.3** – receiving notification of checkpointing requests
- **A.4** – issuing notification of recovery requstes
- **A.5** – receiving notification of recovery requstes

B – management of checkpoints

- **B.1** – description of checkpoints and checkpoint meta data
- **B.2** – location and movement of checkpoints
- **B.3** – security, consistency and lifetime management of checkpoints

The capabilites referenced under **A** are, at least partly, already included in the SAGA Core Job API, so it seems sensible to define the remaining capabilies in **A** also as part of the SAGA Core Job API. This document does that by specifying an additional interface (checkpointable) which can optinally be implemented by the `saga::job` class.

The capabilities listed under **B** are closely related to the management of files and logical files, which, in the SAGA Core API, share the abstraction of an hierachical `name_space`. It seems sensible to define the CPR checkpoint management capabilities in the same framework. This document does that by defining a checkpoint namespace, with the classes `cpr_dir` and `cpr_entry`.

2.1.1 Checkpoint URLs

The checkpoint URLs are those URLs which identify `cpr_entry` and `cpr_dir` instances (and thus *not* the URLs pointing to the physical locations of the individual checkpoint files). As this document expects the underlying middleware to adhere to the CPR Architecture described in [**?**], we recommend the usage

of the scheme `gridcpr://` – but that is really up to the implementation, as the required semantics can very likely also be provided by systems which do not follow [**?**].

2.2 Specification

```
package saga.cpr
{
  class cpr_job_description : implements   saga::job_description
                 // from job_description saga::attributes
                 // from job_description saga::object
                 // from object          saga::error_handler
  {
    // Attributes:
    //
    //   name:  CPRPolicy
    //   desc:  checkpoint policy
    //   type:  Enum
    //   mode:  ReadWrite
    //   value: ''
    //   notes: - the attribute can have the values:
    //            - External: checkpoints are triggered by an
    //                        external application
    //            - Internal: checkpoints are triggered by the
    //                        job internally.
    //          - an application with 'Timed' CPR policy can
    //            still create internally and externally
    //            triggered checkpoints.
    //
    //   name:  CPRFrequency
    //   desc:  checkpoint frequency for 'Timed' CPR policy
    //   type:  Int
    //   mode:  ReadWrite
    //   value: '86400'
    //   notes: - specifies the number of seconds between two
    //            consecutive timed checkpoints.
    //          - Defaults to one checkpoint per day.
    //          - The value is ignored if CPR policy is not
    //            set to 'Timed'
    //
    //   name:  CPRSequence
    //   desc:  sequence of checkpoint types
    //   type:  String
```

```
//   mode:  ReadWrite
//   value: ''
//   notes: - the attribute is a sequence of the letters
//            - 'F': Full checkpoint
//            - 'I': Incremental checkpoint
//              (diff to last Full checkpoint)
//            - 'i': Incremental checkpoint
//              (diff to last checkpoint)
//          - the sequence is repeated infinitely
//          - Incremental checkpoints are always relative
//            to some preceding checkpoint.  That implies
//            that the first checkpoint is *always* a
//            full checkpoint.
//          - Examples:
//            - "F"   : allways do full checkpoints
//            - "FIFI": alternate full and incremental
//                      Checkpoints
//            - "i"   : always do incremental checkpoint,
//                      using the previous (incremental)
//                      CP as base.  First CP will be
//                      full.
//          - This attribute is informational, to optimize
//            the checkpoint management.  The application
//            and backend need to ensure that this
//            sequence is actually applied. To
//            simplify that, the SAGA CPR implementation
//            SHOULD put the attributes value into the
//            application's environment, as
//            'SAGA_CPR_SEQUENCE'.
//          - If application and backend do not actually
//            apply this sequence, it MUST NOT imply
//            invalid checkpoints.
//          - SAGA CPR implementation MAY be able to
//            enforce this sequence.
//
//   name:  CPRTimeToLive
//   desc:  lifetime for checkpoint files
//   type:  Int
//   mode:  ReadWrite
//   value: '2500000'
//   notes: - specifies the number of seconds
//            checkpoints are guaranteed to be valid
//          - Defaults 2.500.000 seconds (ca 29 days)
//          - the value can be changed for each individual
//            checkpoint - see the respective cpr_entry
//            attribute with the same name.
```

```
//          - the SAGA CPR implementation SHOULD make sure
//            that no Full checkpoints are deleted for
//            which derived Incremental checkpoints still
//            exist.
//          - for application internal checkpoints, the
//            application itself is responsible to
//            enforce that checkpoint location.  To
//            simplify that, the SAGA CPR implementation
//            SHOULD put the attributes value into the
//            application's environment, as
//            'SAGA_CPR_TIME_TO_LIVE'.
//
//   name:  CPRHistoryLength
//   desc:  number of checkpoints to keep
//   type:  Int
//   mode:  ReadWrite
//   value: '-1'
//   notes: - specifies the number of previous generations
//            of checkpoints to be kept in the system.  If
//            that number is exceeded, the backend MAY
//            delete older checkpoints.
//          - Negative values specify an unlimited number
//            of generations to be kept.
//          - the SAGA CPR implementation MUST make sure
//            that no Full checkpoints are deleted for
//            which derived Incremental checkpoints still
//            exist.
//          - Defaults to -1.
//
//   name:  CPRBaseLocation
//   desc:  cpr_directory to be used for storing
//          checkpoints
//   type:  URL
//   mode:  ReadWrite
//   value: 'any:///#UserID#/#JobID#/'
//   notes: - specifies the cpr_directory to be used when
//            registering the checkpoint files.
//          - if the directory does not exist, it is
//            created, as are its parents.
//          - the '#UserID#' wildcard can be used to
//            specify the value of the UserID attribute
//          - the '#JobID#' wildcard can be used to
//            specify the value of the job's jobid.
//          - for application internal checkpoints, the
//            application itself is responsible to
//            enforce that checkpoint location.  To
```

```
  //            simplify that, the SAGA CPR implementation
  //            SHOULD put the attributes value into the
  //            application's environment, as
  //            'SAGA_CPR_BASE_LOCATION'.
  //
  //   name:  CPRBaseName
  //   desc:  cpr_directory to be used for storing
  //          checkpoints
  //   type:  URL
  //   mode:  ReadWrite
  //   value: '#JobID#.#Generation#.cpr
  //   notes: - specifies the cpr_entry name to be used
  //            when registering the checkpoint files.
  //          - if the entry exists when the checkpoint is
  //            to be created, its content is overwritten!
  //          - The following wildcards are available:
  //            - '#JobID#' : as for CPRBaseLocation
  //            - '#UserID#': as for CPRBaseLocation
  //            - '#Generation#': number of snapshot.
  //          - Generation numbering starts at 0, and MAY be
  //            padded with zeros to a fixed length.
  //
}

class cpr_job_service : implements   saga::job_service
                // from job_service saga::object
                // from job_service saga::async
                // from object      saga::error_handler
{
  create_job           (in  job_description jd_start,
                        in  job_description jd_rec,
                        out job             job);
}

class cpr_job : extends     saga::job,
                implements  saga::steerable
             // from job    saga::task
             // from job    saga::async
             // from job    saga::attribute
             // from task   saga::object
             // from task   saga::monitorable
             // from object saga::error_handler
{
  list_checkpoints  (out array<string> urls);

  // cpr actions
```

```
checkpoint        (in  string        url = "");
recover           (in  string        url = "");
                  // implies run() if New

// manage locality of checkpoints
cpr_stage_out     (in  string        url = "",
                   in  int           id  = -1);
cpr_stage_in      (in  string        url = "",
                   in  int           id  = -1);

get_last_cpr      (out string        url);

// Metrics:
//   name:  Checkpoint
//   desc:  to be fired when an application level
//          checkpoint is requested
//   mode:  ReadWrite
//   unit:  1
//   type:  String
//   value: ''
//   notes: - the metric acts as trigger
//          - the value can optionally be set to
//            an cpr_entry URL to be used for the
//            resulting checkpoint
//
//   name:  Checkpointed
//   desc:  to be fired when application level
//          checkpoint is finished
//   mode:  ReadWrite
//   unit:  1
//   type:  Trigger
//   value: ''
//
//   name:  Recover
//   desc:  to be fired when application level
//          recovery is requested
//   mode:  ReadWrite
//   unit:  1
//   type:  String
//   value: ''
//   notes: - the metric acts as trigger
//          - the value can optionally be set to
//            an cpr_entry URL to be used for the
//            recovery
//
//   name:  Recovered
```

```
  //   desc:  to be fired when application level
  //          recovery is finished
  //   mode:  ReadWrite
  //   unit:  1
  //   type:  Trigger
  //   value: ''
}


class directory : extents             saga::ns_directory
                  implements          saga::attribute
                // from ns::directory  saga::ns_entry
                // from ns_entry       saga::object
                // from ns_entry       saga::async
                // from object         saga::error_handler
{
  enum flags
  {
    None            =    0, // same as in name_space::flags
    Overwrite       =    1, // same as in name_space::flags
    Recursive       =    2, // same as in name_space::flags
    Dereference     =    4, // same as in name_space::flags
    Create          =    8, // same as in name_space::flags
    Excl            =   16, // same as in name_space::flags
    Lock            =   32, // same as in name_space::flags
    CreateParents   =   64, // same as in name_space::flags
    Truncate        =  128,
    Append          =  256,
    Read            =  512,
    Write           = 1024,
    ReadWrite       = 2048,
    Binary          = 4096
  }

  // open flags default to CreateParents and Lock
  // for open on checkpoint files.

  // find checkpoints based on name and meta data
  find         (in    string         name_pattern,
                in    array<string>  meta_pattern = (),
                in    int            flags        = None,
                in    string         spec         = "",
                out   array<string>  urls );

  set_parent   (in  saga_url         checkpoint,
                in  string           url,
```

```
                 in  int              generations = 1)

    get_parent   (in  saga_url        checkpoint,
                  in  int              generations = 1,
                  out string           url);

    create_child (in  saga_url        checkpoint,
                  in  int              flags = None,
                  out cpr_entry        child);

    add_file     (in  saga_url        checkpoint,
                  in  saga::url        file,
                  out int              id);

    remove_file  (in  saga_url        checkpoint,
                  in  int              id)

    update_file  (in  saga_url        checkpoint,
                  in  int              id,
                  in  saga::url        file);

    get_file     (in  int              id,
                  out saga::url        url);

    list_files   (in  saga_url        checkpoint,
                  out array<saga::url> files);

    get_file_num (out int              nfiles);

    stage        (in  saga_url        checkpoint,
                  in  saga::url        target,
                  in  int              id = -1);
  }


  class checkpoint : extends        saga::ns_entry
                     implements     saga::attribute
                  // from ns_entry  saga::object
                  // from ns_entry  saga::async
                  // from object    saga::error_handler
  {
    // get parent checkpoint url
    set_parent   (in  string           url
                  in  int              generations = 1);

    get_parent   (in  int              generations = 1,
```

```
                out string           url);

    create_child (in  int            flags = None,
                  out cpr_entry      child);

    add_file     (in  saga::url      file
                  out int            id);

    remove_file  (in  int            id,
                  out saga::url      file);

    update_file  (in  int            id,
                  in  saga::url      file_new);

    get_file     (in  int            id,
                  out saga::url      url);

    list_files   (out array<saga::url> files);

    get_file_num (out int            nfiles);

    stage        (in  saga::url      target,
                  in  int            id = -1);

    // Attributes:
    //  time
    //  nfiles
    //  ttl
    //  mode   (full, inc 1, inc 2)
    //  parent (url for cpr-entry)
    //  childs (array of cpr-entry urls)
  }
}
```

2.3 Specification Details

2.3.1 The `checkpointable` Interface

As described above, the CPR job extends the SAGA Core Job API. In particular, SAGA jobs will implement the `checkpointable` interface defined here. Otherwise, the `job` class actually stays the same as defined in the original job package in the SAGA Core API. The changes to the SAGA job service are similar small: only the `create_job` method gets overloaded with a version which

accepts an additional job description to be used on job restart (i.e. on recovery). The job description, however, has a number of additional attributes to define the jobs behaviour in the scope of CPR: the default checkpoint policy, the default checkpoint life time, the application specific checkpoint trigger mechanism, etc.**FIXME: add all those**.

The `checkpointable` interface (implemented by `saga::cpr_job`) offers, compared to the normal `saga::job`, several additional methods, such as (`checkpoint()` and `recover()`), and also offers a number of new metrics (`Checkpoint`, `Checkpointed`, `Recover` and `Recovered`). The `cpr_job`'s state model does not change if compared to the `saga::job` state model. Various backends MAY, however, report `'Checkpointing'` or `'Recovering'` or similar as state detail to the `'Running'` state, whenever the job is performing either of the two actions. We always assume that the cpr job continues to utilize compute, network and storage resources while performing CPR operations.

2.3.2 The Checkpoint Name Space – `cpr_dir` and `cpr_entry`

The SAGA CPR API defines a checkpoint (`cpr_entry`) to be a representation of complate application state at a specific point in time. An application (`saga::job`) can consist of multiple processes, and each process may write any number ($0...n$) of checkpoint files; a single `cpr_entry` can thus represent any number of checkpoint files. The individual files are refered to by an integer number (index), and applications can open the them separately for reading and/or writing.

Checkpoints are organized in a SAGA namespace (i.e. `saga::cpr_entry` and `saga::cpr_dir` inherit `saga::ns_entry` and `saga::ns_dir`). An additional relationship between `cpr_entries` is stablished by their order in time: a checkpoint taken directly before another checkpoint is named *parent*, a checkpoint taken directly after another checkpoint is named *child*. The CPR middleware SHOULD be able to identify parent/child relationships automatically – this can, however, be enforced and also changed on API level, by using the `set_parent()`/`remove_parent()` and `set_child()`/`remove_child()` methods. Also, a parent may have more than one child, but a child may have at most one parent. This allows effectively for a tree of checkpoints, which allow applications to rewind to older checkpoints, or to restart with a checkpoint from a different application configuration.

The exact physical location of checkpoint files is, in general, not under application control - it is, however, possible to ensure co-location of the job execution host and checkpoint files (`cpr_stage_in()`, by default fetching the last checkpoint available), It is also possible to enforce the opposite, and to stage out a checkpoint file to ensure its continued availability on node shutdown etc. (`cpr_stage_out()`, also by default refering to the last checkpoint available).

3 Intellectual Property Issues

3.1 Contributors

This document is the result of the joint efforts of several contributors. The authors listed here and on the title page are those committed to taking permanent stewardship for this document. They can be contacted in the future for inquiries about this document.

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