GFD-R-P.xxx
Category: Recommendation
GLUE Working Group

https://redmine.ogf.org/projects/glue-wg/

Authors:
Alessandro Paolini°, EGI Foundation
Baptiste Grenier°, EGI Foundation
Enol Fernandez°, EGI Foundation
Paolo Andreetto°, INFN-PADOVA
Marco Verlato°, INFN-PADOVA
Stephen Burke, RAL
Shiraz Memon*, FZJ
JP Navarro*, ANL

*co-chairs
°editor

Jul 13th, 2018

GLUE Specification v 2.1

Status of This Document

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Replaces

This document obsoletes GFD-R-P-147.

Abstract

The GLUE specification is an information model for Grid entities described using the natural language and UML Class Diagrams. As a conceptual model, it is designed to be independent from the concrete data models adopted for its implementation. This document defines the GLUE 2.1 model by extending the GLUE 2.0 model to include Cloud resources and services. Rendering to concrete data models such XML Schema, LDAP Schema and SQL are provided in a separate document.

Contents

1. Introduction

In this document, we present a conceptual information model for Grid and Cloud entities described using natural language and enriched with a graphical representation using UML Class Diagrams. As a conceptual model, it is designed to be independent from the concrete data models adopted for its implementation. Rendering to concrete data models such XML Schema, LDAP Schema, JSON schema and SQL are provided in a separate document. From the semantic viewpoint, the concrete data models SHOULD represent the same concepts and relationships of the conceptual information model; nevertheless they MAY contain simplifications targeted at improving query performance or other aspects of interest.

This information model is based on the experience of several modelling approaches being used in current production Grid infrastructures (e.g., GLUE Schema 1.x [GLUE-1.X], GLUE Schema 2.0 [GLUE-2.0], NorduGrid schema [NG-SCHEMA], Naregi model [NAREGI-SCHEMA]). The main supporting use cases are collected in the use cases document [GLUE-USECASES].

The mapping to concrete data models will be published in separate documents. Profile documents SHOULD appear to define how to generate and use the information in production scenarios or how to integrate the GLUE specification along with clarifications, refinements, interpretations and amplifications to promote interoperability (e.g., a profile MAY decide that an attribute which is optional in the conceptual model, is considered mandatory in a certain Grid infrastructure; or that optional attributes are never published).

2. Change-log

The following table provides a list of changes from the past GLUE editions

Release	Change description
1.0	**Initial release**
2.0	**Major re-design to other information models**
2.1	**Addition of Accelerators and Cloud Computing objects**

3. 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 (see http://www.ietf.org/rfc/rfc2119.txt). All class names are written using `this font`.

4. General Statements

The Information Model and its renderings MUST treat strings, both entity and attribute names and their values, as being case-sensitive. Each GLUE entity MUST have an ID attribute (an exception is made for the `Extension` class) which is needed for identification or for access to the attributes of the related entity over time and across different information sources. As a general guideline, ID's SHOULD be persistent at least for a day when assigned to an entity. The ID MUST NOT be interpreted by the user or the system as having any meaning other than an identifier. In particular, there is no relationship between an ID and a network endpoint. Every ID MUST be a valid URI. The usage of URN (Uniform Resource Name, a subset of Uniform Resource Identifier or URI) is RECOMMENDED. The motivations for choosing URI’s reside in the fact that Grid services are evolving towards Web-based technologies, therefore it is meaningful to adopt the same identification system.

As regards units of measure, multiples of bytes MUST refer to the SI (*Le **S**ystème **I**nternational d'Unités*) prefix (http://en.wikipedia.org/wiki/SI_prefix), therefore GB is 10^9 Bytes and not 2^{30} Bytes (the latter are GibiBytes).

In Appendix A, we provide guidelines for place-holder values that MUST be used when the attributes have no good default value or when the attribute cannot be measured for some reason.

As regards extensibility, two main approaches are introduced to extend the information associated to the existing classes: the OtherInfo attribute and the `Extension` class. The OtherInfo attribute is present in the `Entity` class, therefore it is inherited by all GLUE classes. Its type is string and its multiplicity is *. This SHOULD be used for associating a flat list of tags to a certain class instance. The `Extension` class is associated to the `Entity` class (and therefore also to all the derived classes) and enables to link key/value pairs to any GLUE class instance. This SHOULD be used when there is the need for advertising more structured information, for instance an attribute not present in the model with a related value.

Both solutions are proposed because they have a different impact in the implementations: the OtherInfo approach is easier to query, nevertheless it MAY require parsing in case of concatenation of different chunks of information (e.g., attribute name and attribute value). The `Extension` class offers a two-dimensional construct, but nevertheless it is more complex to query.

The extensibility regarding the addition of new classes and associations is not supported at the conceptual level. We RECOMMEND to create specializations of the conceptual model and to implement them by extending the concrete data models. Such extensions MUST NOT be considered part of the GLUE specification, but nevertheless we RECOMMEND submitting them to the GLUE WG for consideration in future revisions of the specification.

5. Template

In order to enrich the UML Class Diagrams with additional information, a table for each UML class is provided. This descriptive table is composed of three parts.

The first part refers to the whole entity and presents the entity name, the entity from which it inherits and the description of what the entity represents.

The second part refers to the properties of the class; for each of them, the following characteristics are described: the attribute name, the data type, the multiplicity concerning how many values are allowed (* means zero or more), the unit of measurement and a description. For easy of reading, the properties that are inherited from a parent class are also listed. As regards the multiplicity, the value of zero means that it is allowed to refrain from publishing a value for the related attribute even though this MAY be measured.

The third part refers to the associations (association, composition, aggregation or association class) that the class MAY hold with other classes. For each association, the associated class reference is described in terms of the associated end class and key attribute, the multiplicity (i.e., the number of instances of the associated class that are allowed) and a description. The inherited associations are also reported in the "inherited association end" if they are not redefined in the "association end". The template structure is the following:

Entity	Inherits from	Description

Inherited Attribute	Type	Mult.	Unit	Description
Attribute	Type	Mult.	Unit	Description
Association End		Mult.	Description	
Inherited Association End		Mult.	Description	

6. Conceptual Model of the Main Entities

This section introduces the main entities of the GLUE information model. They capture the core concepts relevant in a Grid environment. The main entities SHOULD be used to derive specialized information models. In Figure 1, the classes and the related relationships are presented in the form of a UML Class Diagram.

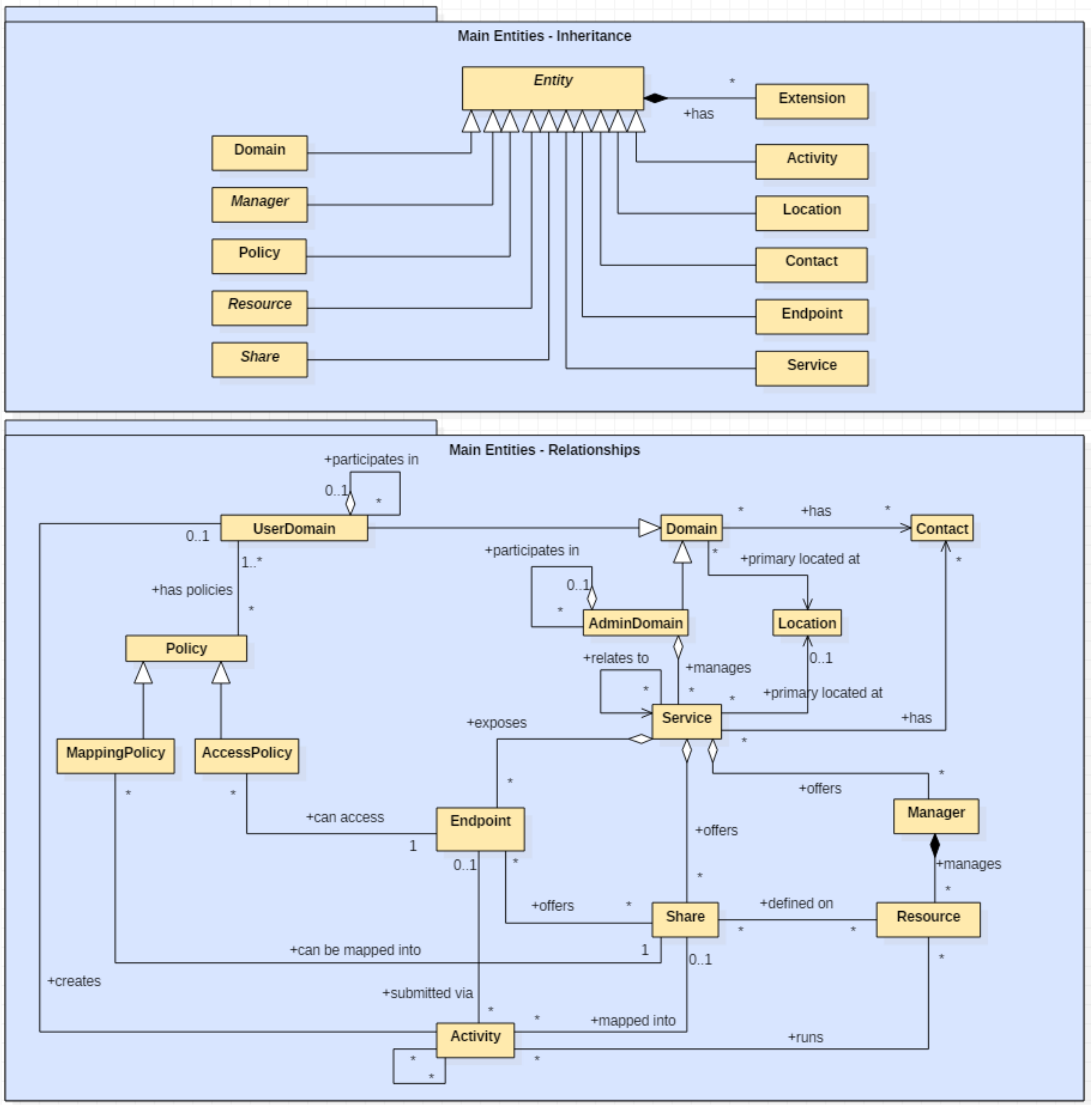


Figure 1 Entities and relationships for the Main Entities conceptual model

6.1. Entity

The `Entity` class is the root entity from which all the GLUE classes inherit (an exception is made for the `Extension` class). The specialized classes will inherit both the associations and the attributes of `Extension` class. The attributes CreationTime and Validity are metadata related to the generation and life of the information. The Name attribute allows a human-readable name to be provided for any object, usable for e.g. monitoring or diagnostic displays. The Name SHOULD NOT have any semantic interpretation.

Entity	Inherits from	Description
Entity <<abstract>>		Abstract root concept from which all the other concepts are derived (except the `Extension` class); it has metadata about information creation

				and validity plus a key-value pair extension mechanism.
Attribute	**Type**	**Mult.**	**Unit**	**Description**
CreationTime	DateTime_t	0..1		Timestamp describing when the entity instance was generated.
Validity	UInt64	0..1	s	The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed, the information SHOULD NOT be considered relevant.
ID [key]	URI	1		A global unique ID.
Name	String	0..1		A human-readable name.
OtherInfo	String	*		Placeholder to publish information that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pairs are all examples of valid syntax.
Association End		**Mult.**	**Description**	
Extension.Key		*	The entity MAY be associated to zero or more key-value pairs.	

6.2. Extension

The `Extension` class provides a general mechanism to add key/value pairs to GLUE classes when suitable specific attributes are not present. The creation time and validity of each `Extension` instance are those of the extended class instance.

Entity	Inherits from			Description
Extension				A key/value pair enabling the association of extra information not captured by the model with an Entity instance.
Attribute	**Type**	**Mult.**	**Unit**	**Description**
LocalID	LocalID_t	1		An identifier unique within the class instance to which it is associated
Key	String	1		An identifier local to the container class instance; typically an attribute name not present in the model. This identifier is not required to be unique; several instances of this class MAY hold the same value for this attribute.
Value	String	1		A value for the attribute named by the Key.
Association End		**Mult.**	**Description**	
Entity		1	The key/value pair is associated to an Entity instance.	

6.3. Location

The `Location` class is introduced to model geographical locations where a certain `Domain` or `Service` are placed. The aim is to provide a simple way to express geographical information, and it is not intended to be used in complex geographical information systems. Due to different requirements, the granularity is not strictly defined and is left to the information producers depending on their needs. Hence the extent of a geographical location can vary from an exact position to a region spanning several different countries, not necessarily adjacent. The accuracy of the latitude and longitude attributes should be defined in an interoperability profile defined by projects adopting this specification.

Entity	Inherits from			Description
Location	Entity			A geographical region where the granularity MAY vary from an exact position to a region spanning several different countries, not necessarily adjacent.
Inherited Attribute	**Type**	**Mult.**	**Unit**	**Description**
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed,*

				the information SHOULD NOT be considered relevant
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	**Type**	**Mult.**	**Unit**	**Description**
Address	String	0..1		Street address (free format).
Place	String	0..1		Name of town/city.
Country	String	0..1		Name of country.
PostCode	String	0..1		Postal code.
Latitude	Real32	0..1	degree	The position of a place north or south of the equator measured from -90° to +90° with positive values going north and negative values going south.
Longitude	Real32	0..1	degree	The position of a place east or west of the primary meridian (located in Greenwich, UK) measured from -180° to +180° with positive values going east and negative values going west (the value -180° is excluded from the range).
Association End		**Mult.**	**Description**	
Service.ID		*	The location is related to zero or more services.	
Domain.ID <<abstract>>		*	The location is related to zero or more domains.	
Inherited Association End		**Mult.**	**Description**	
Extension.Key		*	The entity MAY be associated to zero or more key-value pairs.	
ComputingService.ID		*	The location is related to zero or more computing services.	
CloudComputingService.ID		*	The location is related to zero or more cloud computing services	
StorageService.ID		*	The location is related to zero or more storage services.	
AdminDomain.ID		*	The location is related to zero or more admin domains.	
UserDomain.ID		*	The location is related to zero or more user domains.	

6.4. Contact

The `Contact` class is introduced to represent contact information for different groups or expert roles responsible for aspects of the operation of services and domains (e.g., user support, security or sysadmin). The various types of contact are identified by the Type attribute. In case of time-dependent contact information (e.g., due to work on shifts), the instances of this entity should represent only the currently active contact information.

The contact information SHOULD be encoded as a URI. There are several specifications recommending how to embed contacts into a URI. The following specifications SHOULD be used:

- telephone and fax: http://www.ietf.org/rfc/rfc2806.txt
- email: http://www.ietf.org/rfc/rfc2368.txt
- irc: http://www.w3.org/Addressing/draft-mirashi-url-irc-01.txt

Entity	**Inherits from**			**Description**
Contact	Entity			Information enabling the establishment of communication with a person or group of persons related to a Domain.
Inherited Attribute	**Type**	**Mult.**	**Unit**	**Description**
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed,* *the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*

OtherInfo	*String*	*		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	Type	Mult.	Unit	Description
Detail	URI	1		URI embedding the contact information. The syntax of the URI depends on the nature of the communication channel.
Type	ContactType_t	1		Type of contact.
Association End		Mult.		Description
Service.ID		*		The contact is related to zero or more services
Domain.ID	<<abstract>>	*		The contact is related to zero or more domains
Inherited Association End		Mult.		Description
Extension.Key		*		The entity MAY be associated to zero or more key-value pairs
ComputingService.ID		*		The contact is related to zero or more computing services
CloudComputingService.ID		*		The contact is related to zero or more cloud computing services
StorageService.ID		*		The contact is related to zero or more storage services
AdminDomain.ID		*		The contact is related to zero or more admin domains
UserDomain.ID		*		The contact is related to zero or more user domains

6.5. Domain

The Domain class is introduced to model and identify groups of actors that MAY play roles in a Grid system. It is an abstract entity that MUST NOT be instantiated; it SHOULD be used in order to derive specialized entities.

Entity	Inherits from			Description
Domain <<abstract>>	Entity			A collection of actors that MAY be assigned with roles and privileges associated with Entities via Policies. A Domain MAY have relationships to other domains.
Inherited Attribute	Type	Mult.	Unit	Description
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed, the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	*		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	Type	Mult.	Unit	Description
Description	String	0..1		A description of the domain (free format).
WWW	URL	*		A URL identifying a web page with more information about the domain.
Association End		Mult.	Description	
Contact.ID		*	A domain MAY be contacted via zero or more contacts.	
Location.ID		0..1	A domain is primarily located at one location.	
Association End		Mult.	Description	
Extension.Key		*	The entity MAY be associated to zero or more key-value pairs.	

6.5.1. AdminDomain

The AdminDomain class is introduced to model a collection of actors that manage a number of services. An AdminDomain MAY be associated to both Contact and Location class instances in order to provide contact information and geographical location respectively. An AdminDomain

MAY be composed by other `AdminDomains` in a hierarchical structure. This structure MAY represent a "participates in" association.

Entity	Inherits from			Description
AdminDomain	Domain			A collection of actors that MAY be assigned administrative roles and privileges over services via policies. An AdminDomain manages services that MAY be geographically distributed, but nevertheless a primary location should be identified.
Inherited Attribute	Type	Mult.	Unit	Description
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed,* *the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Description	*String*	*0..1*		*A description of the domain*
WWW	*URI*	***		*The URL identifying a web page with more information about the domain*
Attribute	Type	Mult.	Unit	Description
Distributed	ExtendedBoolean_t	0..1		True if the services managed by the AdminDomain are considered geographically distributed by the administrators themselves.
Owner	String	*		Identification of a person or legal entity which pays for the services and resources (no particular format is defined).
Association End		Mult.	Description	
Service.ID		*	An AdminDomain manages zero or more Services.	
AdminDomain.ID		*	An AdminDomain aggregates zero or more AdminDomains.	
AdminDomain.ID		0..1	An AdminDomain participates in another AdminDomain.	
Inherited Association End		Mult.	Description	
Extension.Key		*	The entity MAY be extended via key-value pairs.	
ComputingService.ID		*	An AdminDomain manages zero or more Computing Services.	
CloudComputingService.ID		*	An AdminDomain manages zero or more Cloud Computing Services	
StorageService.ID		*	An AdminDomain manages zero or more Storage Services.	
Contact.ID		*	A domain MAY be contacted via zero or more contacts.	
Location.ID		0..1	A domain is primary located at one location.	

6.5.2. UserDomain

The `UserDomain` class SHOULD be used to capture the concept of a Virtual Organization (VO). By VO, we mean a set of individuals and/or institutions having direct access to computers, software, data, and other resources for collaborative problem-solving or other purposes. Resources utilized by a VO are expected to be accessible via network endpoints and constrained by defined utilization targets called shares. The VO MAY exhibit its internal structure in terms of groups of individuals, each of them constituting a `UserDomain`. `UserDomains` MAY be hierarchically structured. The "participates in" association MAY represent this structure.

Entity	Inherits from	Description
UserDomain	Domain	A collection of actors that MAY be assigned with user roles and privileges to services or shares via policies.

Inherited Attribute	Type	Mult.	Unit	Description
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed, the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Description	*String*	*0..1*		*A description of the domain*
WWW	*URI*	***		*The URL identifying a web page with more information about the domain*
Attribute	**Type**	**Mult.**	**Unit**	**Description**
Level	UInt32	0..1		The number of hops to reach the root for hierarchically organized domains described by the “composed by” association (0 is for the root).
UserManager	URI	*		An Endpoint ID for the endpoint of a service managing the association of users with the domain, and related attributes such as groups or roles.
Member	String	*		An identifier for a user in this user domain.

Association End	Mult.	Description
Policy.ID <<abstract>>	*	A User Domain has associated zero or more policies.
UserDomain.ID	*	A User Domain aggregates zero or more User Domains.
UserDomain.ID	0..1	An User Domain participates in another User Domain.
Inherited Association End	**Mult.**	**Description**
Extension.Key	*	The entity MAY be extended via key-value pairs.
Contact.ID	*	The domain MAY be contacted via zero or more contacts.
Location.ID	0..1	A domain is primary located at one location.
AccessPolicy.ID	*	A User Domain has associated zero or more access policies.
MappingPolicy.ID	*	A User Domain has associated zero or more mapping policies.

As regards the UserManager attribute, it is RECOMMENDED that its value is an Endpoint ID enabling discovery of the related `Service` class instance and associated attributes. An example of a User Manager would be an endpoint for a VOMS (Virtual Organization Membership Service, http://en.wikipedia.org/wiki/VOMS) server.

6.6. Service

One of the main goals of the GLUE information model is to enable the discovery of the Grid capabilities available in a certain infrastructure. Based on the use cases and modeling experience, a number of concepts were identified as general building blocks: `Endpoint`, `Share`, `Manager`, `Resource`. The `Service` class enables the unique identification of instances of these concepts participating in the provision of some unified capability. The `Service` class SHOULD be also used to characterize this overall capability.

Entity	Inherits from	Description
Service	Entity	An abstracted, logical view of actual software components that participate in the creation of an entity providing one or more functionalities useful in a Grid environment. A service exposes zero or more Endpoints having well-defined interfaces, zero or more Shares and zero or more Managers and the related

				Resources. The Service is autonomous and denotes a weak aggregation among Endpoints, the underlying Managers and the related Resources, and the defined Shares. The Service enables the identification of this whole set of entities providing the functionality with a persistent name.
Inherited Attribute	Type	Mult.	Unit	Description
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed,* *the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	Type	Mult.	Unit	Description
Capability	Capability_t	*		The provided capabilities according to the Open Grid Service Architecture (OGSA) architecture [OGF-GFD80] (this is the union of all values assigned to the Capability attribute of the Endpoints which form part of this service).
Type	ServiceType_t	1		The type of service according to a namespace-based classification (the namespace MAY be related to a middleware name, an organization or other concepts; org.ogf.glue.* is reserved for Types defined by the OGF GLUE Working Group).
QualityLevel	QualityLevel_t	1		The maturity of the Service in terms of the quality of the underlying software components; the value corresponds to the highest QualityLevel among the available Endpoints.
StatusInfo	URL	*		A URL specifying a web page providing additional information, for example monitoring of the underlying services.
Complexity	String	0..1		A human-readable summary description of the complexity in terms of the number of endpoint types, shares and resources. The syntax should be: endpointType=X, share=Y, resource=Z.
Association End		Mult.	Description	
Endpoint.ID		*	A service exposes zero or more endpoints.	
Share.ID	<<abstract>>	*	A service offers zero or more shares.	
Manager.ID	<<abstract>>	*	A service offers zero or more managers.	
Contact.ID		*	A service has zero or more contacts.	
Location.ID		0..1	A service is primary located at a location.	
Service.ID		*	A service is related to zero or more services.	
Inherited Association End		Mult.	Description	
Extension.Key		*	The entity MAY be extended via key-value pairs.	

A simple `Service` aggregates an `Endpoint`, no `Share`, no `Manager` and no `Resource` (e.g., a metadata catalogue service). In the context of a `Service` class, the same `Resource` MAY be exposed via multiple `Endpoints` based on the defined `Shares`. For instance, in the area of storage systems, two `Endpoints` implementing SRMv1 [SRMV1] and SRMv2.2 [SRMV2] interfaces respectively MAY expose the same `Resource` via different `Endpoints` offering different interface versions; in the area of computing systems, the CREAM [cream] and GRAM [GRAM] `Endpoints` MAY expose the `Resources` locally managed by the same `Manager` (typically a batch system). `Endpoints, Shares,Managers` and `Resources` MUST belong to precisely one Service.

6.7. Endpoint

The `Endpoint` class models a network location that can be contacted to access certain functionalities based on a well-defined interface. The defined attributes refer to aspects such as the network location, the exposed interface name and version, the details of the implementation, the functional state and the scheduled downtime.

Entity	Inherits from			Description
Endpoint	Entity			A network location having a well-defined interface and exposing specific service functionalities.
Inherited Attribute	**Type**	**Mult.**	**Unit**	**Description**
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed,* *the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	**Type**	**Mult.**	**Unit**	
URL	URL	1		Network location of an endpoint,which enables a specific component of the Service to be contacted.
Capability	Capability_t	*		The provided capability according to the OGSA architecture classification.
Technology	EndpointTechnology_t	0..1		The technology used to implement the endpoint interface.
InterfaceName	InterfaceName_t	1		The identification name of the primary protocol supported by the endpoint interface.
InterfaceVersion	String	0..*		The version of the primary interface protocol (free format).
InterfaceExtension	URI	*		The identification of an extension to the interface protocol supported by the Endpoint.
WSDL	URL	*		The URL of a WSDL document describing the offered interface (this applies only to Web Services endpoints).
SupportedProfile	URI	*		A URI identifying a supported profile for the Endpoint interface.
Semantics	URL	*		The URI of a document providing a human-readable description of the semantics of the Endpoint functionalities (e.g. a software manual).
Implementor	String	0..1		The name of the main organization implementing this software component (free format, but the chosen names SHOULD be clearly identifiable with the organisation).
ImplementationName	String	0..1		The name of the implementation (as defined by the Implementor).

ImplementationVersion	String	0..1		The version of the implementation (the syntax is defined by the Implementor, but MAY be: major.minor.patch).
QualityLevel	QualityLevel_t	1		The maturity of the endpoint in terms of the quality of the software components which implement it.
HealthState	EndpointHealthState_t	1		A state representing the current health of the Endpoint in terms of its ability to properly deliver the expected functionality.
HealthStateInfo	String	0..1		A human-readable explanation of the HealthState of the Endpoint (free format).
ServingState	ServingState_t	1		A state specifying whether the Endpoint is currently accepting new requests, and whether it is currently servicing requests which have already been accepted.
StartTime	DateTime_t	0..1		The timestamp of the start time of the service underlying the Endpoint.
Authentication	*EndpointAuthentication_t*	*0..1*		*Name of the authentication method supported by the endpoint.*
IssuerCA	DN_t	0..1		The Distinguished Name of the Certification Authority issuing the host/service certificate presented by the Endpoint.
TrustedCA	DN_t	*		The Distinguished Name of a trusted Certification Authority (CA); i.e., certificates issued by the CA are accepted by the authentication process. Alternatively this may identify a standard bundle of accepted CAs, e.g. those accredited by the IGTF. Note that this does not imply that such certificates will be authorized to use the Endpoint.
DowntimeAnnounce	DateTime_t	0..1		The timestamp for an announcement of the next scheduled downtime.
DowntimfeStart	DateTime_t	0..1		A timestamp describing when the next downtime is scheduled to start.
DowntimeEnd	DateTime_t	0..1		A timestamp describing when the next downtime is scheduled to end.
DowntimeInfo	String	0..1		A human-readable description of the next scheduled downtime (free format).
Association End		**Mult.**	**Description**	
Service.ID		1	An endpoint is part of a Service.	
Share.ID	<<abstract>>	*	An endpoint MAY pass activities to zero or more Shares.	
AccessPolicy.ID		*	An endpoint has associated zero or more AccessPolicies.	
Activity.ID		*	An endpoint has accepted and is managing zero or more Activities.	
Inherited Association End		**Mult.**	**Description**	
Extension.Key		*	The entity MAY be extended via key-value pairs.	

For Grid services requiring a richer set of attributes for the `Endpoint`, specific models MAY be derived by specializing from the `Endpoint` class and adding new properties or relationships. The current proposal contains the `ComputingEndpoint` specialization (see Section 8.2) and the `StorageEndpoint` specialization (see Section 9.4).

The network location of an endpoint MUST be encoded in a URI. When available, standard schemes for the encoding SHOULD be used (e.g., as used for the Java Messaging Service http://www.ietf.org/internet-drafts/draft-merrick-jms-uri-03.txt).

Concerning the SupportedProfile attribute, if there is no recommended URI for the identification of a certain profile, then the following options SHALL be considered: (1) use the main URL of the document specifying the profile, or (2) use the target namespace URI (in case of an XML Schema representation of the profile).

6.8. Share

The `Share` class is an abstract entity that MUST NOT be instantiated; it SHOULD be used in order to derive specialized entities. At this level, it is introduced to capture the concept of a utilization target, that is a constrained usage of service functionalities or resources that MAY be created based on aspects such as identify or UserDomain membership, usage information or resource characteristics.

Entity	Inherits from			Description
Share <<abstract>>	Entity			A utilization target for a set of Resources managed by a local Manager and offered via related Endpoints. The share is defined by configuration parameters and characterized by status information.
Inherited Attribute	**Type**	**Mult.**	**Unit**	**Description**
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed, the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	**Type**	**Mult.**	**Unit**	**Description**
Description	String	0..1		A human-readable description of this share (free format).
Association End		**Mult.**		**Description**
Endpoint.ID		*		A share is consumed via one or more endpoints.
Resource.ID	<<abstract>>	*		A share is defined on one or more resources.
Service.ID		1		A share participates in a service.
Activity.ID		*		A share is consumed by zero or more activities.
MappingPolicy.ID		*		A share has zero or more mapping policies.
Inherited Association End		**Mult.**		**Description**
Extension.Key		*		The entity MAY be extended via key-value pairs.

6.9. Manager

The `Manager` class is an abstract entity that MUST NOT be instantiated; it SHOULD be used in order to derive specialized entities. At this level, it is introduced to capture the characteristics of a local software layer (not directly exposed via an Endpoint) which has control of the underlying resources. The functionalities of a manager layer that need to be accessible by remote users are typically abstracted by a middleware component via a standard interface, and are modeled by the concept of `Endpoint.` Examples of managers are: for computing resources, batch systems such as OpenPBS or LSF; for storage resources, GPFS or HPSS.

Entity	Inherits from			Description
Manager <<abstract>>	Entity			A software component locally managing one or more resources. It MAY also describe aggregated information about the managed resources.
Inherited Attribute	**Type**	**Mult.**	**Unit**	**Description**
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed, the information SHOULD NOT be considered relevant*

ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	**Type**	**Mult.**	**Unit**	
ProductName	String	1		The name of the software product which implements the Manager functionality. The attribute is free format, but SHOULD correspond to the standard name by which the product is generally known.
ProductVersion	String	0..1		The version of the software product which implements the Manager functionality. The attribute is free format, but SHOULD correspond to the primary version as defined by the software provider.
Association End		**Mult.**		**Description**
Service.ID		1		A manager participates in a service.
Resource.ID	<<abstract>>	1..*		A manager manages zero or more resources.
Inherited Association End		**Mult.**		**Description**
Extension.Key		*		The entity MAY be extended via key-value pairs.

6.10. Resource

The `Resource` class is an abstract entity that MUST NOT be instantiated; it SHOULD be used in order to derive specialized entities. It is introduced to identify and model hardware entities providing capabilities which are exposed via `Endpoints`. Examples are execution environments for computational activities or data stores for data.

Entity	Inherits from			Description
Resource <<abstract>>	Entity			An entity providing a capability or capacity, managed by a local software component (Manager), part of a logical Service, reachable via one or more Endpoints and having one or more Shares defined on it. A Resource MAY refer to a specified category of hardware, with summary information on the available resources in that category.
Inherited Attribute	**Type**	**Mult.**	**Unit**	**Description**
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed, the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	**Type**	**Mult.**	**Unit**	**Description**
No extra properties are defined in the specialized entity				
Association End		**Mult.**		**Description**
Manager.ID	<<abstract>>	1		A resource is managed by a manager.
Share.ID	<<abstract>>	*		A resource provides capacity in terms of shares.
Activity.ID		*		A resource runs zero or more activities.
Inherited Association End		**Mult.**		**Description**
Extension.Key		*		The entity MAY be extended via key-value pairs.

6.11. Activity

The `Activity` class models units of work which are submitted to `Services` via `Endpoints`. Grid jobs, i.e. Computing Activities in GLUE, are example of `Activities` for a Computing Service. An interesting type of relationship for jobs derives from their propagation through several `Services`. For instance, a broker `Service` submits a Grid job to a selected execution `Service;` upon completion the execution `Service` submits a logging record to an accounting `Service`. Each of these `Services` may have associated an instance of a Grid `Activity` related to the lifecycle of the job within the service. All instances refer to the same conceptual job submitted by the user.

Entity	Inherits from			Description
Activity	Entity			An Activity is a unit of work managed by a Service and submitted via an Endpoint; when accepted by the Endpoint, than it MAY be mapped to a Share and MAY be executed by a local Manager via one or more Resources. An Activity MAY have relationships to other Activities being managed by different Services, in which case it shares a common context.
Inherited Attribute	Type	Mult.	Unit	Description
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed, the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	Type	Mult.	Unit	Description
No extra properties are defined in the specialized entity				
Association End		Mult.	Description	
UserDomain.ID		0..1	An activity is managed by a user domain.	
Endpoint.ID		0..1	An activity is submitted to an endpoint.	
Share.ID <<abstract>>		0..1	An activity is mapped into a share.	
Resource.ID <<abstract>>		0..1	An activity is executed in a resource.	
Activity.ID		*	An activity is related to zero or more activities.	
Inherited Association End		Mult.	Description	
Extension.Key		*	The entity MAY be extended via key-value pairs.	

6.12. Policy

The `Policy` class is an abstract entity that MUST NOT be instantiated; it SHOULD be used in order to derive specialized entities. This class is introduced to model statements, rules or assertions that define the correct or expected behavior of entities. Two specializations are introduced: `AccessPolicy` related to `Endpoints` and `MappingPolicy` related to `Shares`.

For a given entity to which policies are associated (i.e., `Endpoint` and `AccessPolicy`, `Share` and `MappingPolicy`), several instances of the `Policy` class MAY be defined. This is allowed in order to enable the advertisement of policies using different schemes. We RECOMMEND that only one instance per policy scheme is associated to the same entity instance. The evaluation algorithm for the rules SHOULD be defined by the policy scheme.

If an entity instance is associated to different `Policy` instances, each of them based on a different scheme, then the evaluation process SHOULD consider each set of policies independently. This means that the evaluation SHOULD rely on a certain policy scheme which is selected and understood by the consumer, and not by composing policies expressed using different schemes.

In this document, we provide the definition for a "basic" scheme (see Appendix B.37). Such a scheme is designed to be simple and is inspired by real world scenarios in current production Grid systems. The Rule attribute implicitly contains a reference to the associated User Domains; therefore, in the concrete data model mapping, we RECOMMEND to not represent the association between User Domain and Access Policy or Mapping Policy explicitly since it is already captured by the Rule.

More complex schemes MAY be defined in profile documents describing the usage of the schema in particular Grid infrastructures.

The published `Policies` do not represent a contract, and hence the associated `Service` is not bound to honour the decisions implied by the published rules. In addition the published rules may be expressed at a coarse granularity, which may be modified internally by more finely-grained rules which are not published. However, the published rules SHOULD match the decisions which will be made in practice in a substantial majority of cases.

Entity	Inherits from			Description
Policy <<abstract>>	Entity			Statements, rules or assertions that specify the correct or expected behavior of an entity.
Inherited Attribute	**Type**	**Mult.**	**Unit**	**Description**
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed, the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	**Type**	**Mult.**	**Unit**	**Description**
Scheme	PolicyScheme_t	1		The scheme used to define the syntax and semantics of the policy Rules.
Rule	String	1..*		A policy rule (for the basic policy scheme, the syntax is provided in the Appendix).
Association End		**Mult.**	**Description**	
UserDomain.ID		1..*	A policy is related to a user domain.	
Inherited Association End		**Mult.**	**Description**	
Extension.Key		*	The entity MAY be extended via key-value pairs.	

6.12.1. AccessPolicy

The `AccessPolicy` class is a specialization of the `Policy` class. This entity MAY be used to express authorization rules, e.g. which `UserDomains` MAY access a certain service `Endpoint`. The granularity of these policies SHOULD be coarse-grained and suitable for pre-selection of services. The actual decision on the service side is performed by an authorization component that MAY contain a finer-grained set of policy rules that in some case MAY contradict the published coarse-grained policy rules. The default policy is assumed to be to deny access, hence `Endpoints` for which there are no matching Rules SHOULD NOT be selected for possible use.

Examples of actors involved in this entity are `UserDomains` representing VOs or groups.

Entity	Inherits from			Description
AccessPolicy	Policy			Statements, rules or assertions that provide coarse-granularity information about the authorization of access by groups of actors to an Endpoint.
Inherited Attribute	**Type**	**Mult**	**Unit**	**Description**
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*

Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed, the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Scheme	*PolicyScheme_t*	*1*		*Scheme adopted to define the policy rules*
Rule	*PolicyRule_t*	*1..**		*A policy rule (for the basic policy scheme, syntax is provide in the Appendix)*
Attribute	Type	Mult.	Unit	Description
No extra properties are defined in the specialized entity.				
Association End		Mult.	Description	
Endpoint.ID		1	An access policy is related to an endpoint.	
Inherited Association End		Mult.	Description	
Extension.Key		*	The entity MAY be extended via key-value pairs.	
UserDomain.ID		1..*	An access policy is related to a user domain.	

6.12.2. MappingPolicy

The `MappingPolicy` class is a specialization of the `Policy` class. This entity MAY be used to express which `UserDomains` MAY consume a certain share of resources. The granularity of these policies SHOULD be coarse-grained and suitable for pre-selection of services. The actual decision on the service side is performed by an authorization component that MAY contain a finer-grained set of policy rules that in some case MAY contradict the published coarse-grained policy rules.

Conceptually, the union of all the `MappingPolicy` rules should match the corresponding `AccessPolicy` rules, i.e. any authorised `UserDomain` will be mapped to at least one `Share.` However, publication of `Shares` is OPTIONAL, and hence there MAY be no `Share` with a matching `MappingPolicy` rule. In this case a consumer SHOULD NOT make any assumption about the properties of the `Share` to which it will be mapped. Conversely, the published `MappingPolicy` rules MAY not have a corresponding `AccessPolicy`, in which case the implication is that there is some unpublished access method enabling access to the associated Share.

When evaluating the mapping to a certain `Share` using the algorithm implied by the policy scheme, if multiple solutions are available then the consumer SHOULD NOT make any assumption about which `Share` will be assigned to its `Activity,` and if it requires a specific `Share` it SHOULD request that `Share` explicitly.

Entity	Inherits from			Description
MappingPolicy	Policy			Statements, rules or assertions that provide coarse-granularity information about the mapping of User Domain requests to a Share.
Inherited Attribute	Type	Mult	Unit	Description
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed, the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*

OtherInfo	*String*	*		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Scheme	*PolicyScheme_t*	*1*		*Scheme adopted to define the policy rules*
Rule	*PolicyRule_t*	*1..**		*A policy rule (for the basic policy scheme, syntax is provide in the Appendix)*
Attribute	Type	Mult.	Unit	Description
No extra properties are defined in the specialized entity.				
Association End		Mult.	Description	
Share.ID	<<abstract>>	1	A mapping policy is related to a share.	
Inherited Association End		Mult.	Description	
Extension.Key		*	The entity MAY be extended via key-value pairs.	
UserDomain.ID		1..*	An access policy is related to a user domain.	

7. Conceptual Model of the Computing Service

The conceptual model of the Computing Service is based on the main entities and uses specializations of the `Service`, `Endpoint`, `Share`, `Manager`, `Resource`, and `Activity` entities. Further computing related concepts such as `Application Environment`, `Application Handle` and `Benchmark` are introduced.

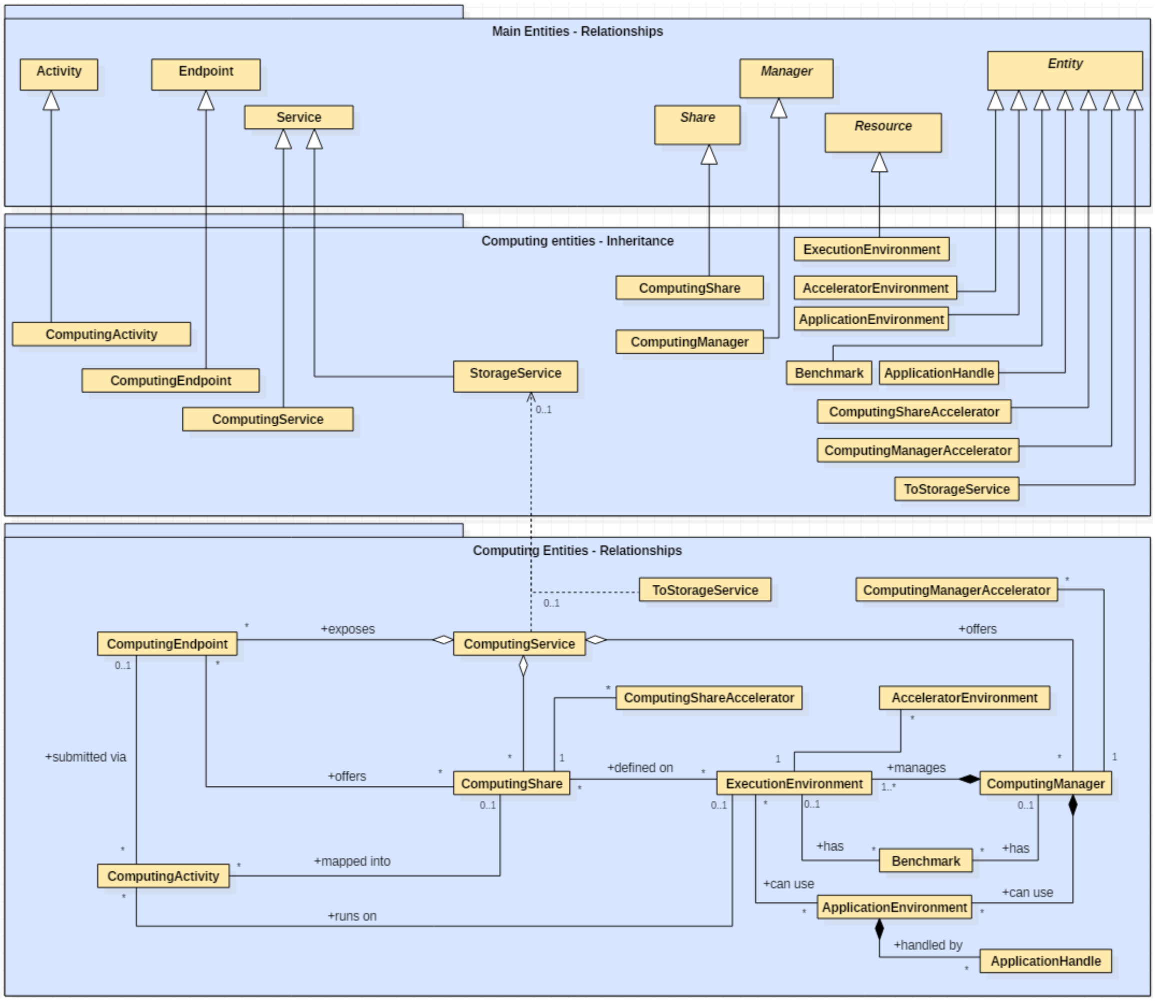


Figure 2 Entities and relationships for the Computing Service conceptual model

In this section, we extensively use the concepts of physical CPU, logical CPU and slot defined as follows:

- a physical CPU is defined by a socket on a motherboard, i.e. there is one physical CPU per socket (e.g., a multi-core CPU counts as one physical CPU);
- a logical CPU corresponds to a CPU as visible by the operating system running either on a real or virtual machine (e.g. a four-core CPU counts as four logical CPUs);
- a slot is a portion of executable time in a logical CPU offered by an execution environment instance which MAY be occupied by a job:
    - typically there is one slot per logical CPU, but a logical CPU MAY be shared among multiple slots;
    - jobs MAY occupy several slots at the same time (e.g., MPI jobs); a multi-slot job is counted as one `Activity`.

Throughout the specification, we also use the concept of storage extent to mean the capabilities and management of the various media that exist to store data and allow data retrieval.

7.1. ComputingService

The `ComputingService` class is a specialization of the `Service` class for a service offering computational capacity. The `ComputingService` entity is the main logical unit, and aggregation point for several entities together modeling a computing capability in a Grid system. A `ComputingService` is capable of executing `ComputingActivities` on its associated resources. The resources behind the `ComputingService` are described via the `ComputingManager`, `ExecutionEnvironment`, `ApplicationEnvironment`, `ApplicationHandle` and `Benchmark` entities. The governing policies and status of the resources are given by the `ComputingShare` elements. The `ComputingActivities` of a `ComputingService` are submitted and controlled via a `ComputingEndpoint`.

Entity	Inherits from			Description
ComputingService	Service			An abstracted, logical view of software and hardware components that participate in the creation of a computational capacity in a Grid environment. A Computing Service exposes zero or more Computing Endpoints having well-defined interfaces, zero or more Computing Shares and zero or more Computing Managers and the related Execution Environments. The computing service is autonomous and denotes a weak aggregation among Computing Endpoints, the underlying Computing Managers and related Execution Environments, and the defined Computing Shares. The Computing Service enables the identification of the whole set of entities providing the computing functionality with a persistent name.
Inherited Attribute	**Type**	**Mult**	**Unit**	**Description**
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed, the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	*		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Capability	*Capability_t*	*		*The provided capability according to the Open Grid Service Architecture (OGSA) architecture [OGF-GFD80]*

				(this is the union of all values assigned to the capability attribute of the endpoints part of this service)
Type	*ServiceType_t*	*1*		*The type of service according to a namespace-based classification (the namespace MAY be related to a middleware name, an organization or other concepts; org.ogf.glue is reserved for the OGF GLUE Working Group)*
QualityLevel	*QualityLevel_t*	*1*		*Maturity of the service in terms of quality of the software components*
StatusInfo	*URI*	***		*Web page providing additional information like monitoring aspects*
Complexity	*String*	*0..1*		*Human-readable summary description of the complexity in terms of the number of endpoint types, shares and resources. The syntax should be: endpointType=X, share=Y, resource=Z.*
Attribute	**Type**	**Mult**	**Unit**	**Description**
TotalJobs	UInt32	0..1	job	The total number of Grid jobs currently known to the system (the sum of RunningJobs, WaitingJobs, StagingJobs, SuspendedJobs and PreLRMSWaitingJobs); this value SHOULD not include jobs submitted locally rather than via the Grid.
RunningJobs	UInt32	0..1	job	The number of Grid jobs which are currently running in an Execution Environment.
WaitingJobs	UInt32	0..1	job	The number of Grid jobs which are currently waiting to start execution. Usually these will be queued in the underlying Computing Manager (i.e., a Local Resource Managment System or LRMS).
StagingJobs	UInt32	0..1	job	The number of Grid jobs which are currently either staging files in before starting execution, or staging files out after finishing execution.
SuspendedJobs	UInt32	0..1	job	The number of Grid jobs which have started their execution, but are currently suspended (e.g., having been preempted by another job).
PreLRMSWaitingJobs	UInt32	0..1	job	The number of Grid jobs which are currently managed by the Grid software layer waiting to be passed to the underlying Computing Manager (LRMS), and hence are not yet candidates to start execution.
Association End		**Mult.**	**Description**	
ComputingEndpoint.ID [redefines Endpoint.ID]		*	A computing service exposes zero or more computing endpoints.	
ComputingShare.ID [redefines Share.ID]		*	A computing service offers zero or more computing shares.	
ComputingManager.ID [redefines Manager.ID]		*	A computing service offers zero or more computing managers.	
StorageService.ID				
Inherited Association End		**Mult.**	**Description**	
Extension.Key		*	The entity MAY be extended via key-value pairs.	
Contact.ID		*	A computing service has zero or more contacts.	
Location.ID		0..1	A computing service is primarily located at a location.	
Service.ID		*	A computing service is related to zero or more services.	

A simple `Computing Service` is formed by a `Computing Endpoint` exposing an interface for job submission and control. In the case of a single `Computing Manager` whose `Execution Environments` are exposed by multiple `Computing Endpoints`, the `Computing Manager`, `Execution Environments` and `Computing Endpoints` MUST be considered as part of the same `Computing Service`. In the case of a single `Computing Endpoint` exposing `Execution Environments` managed by different `Computing Managers`, then the `Computing Endpoint`, the `Execution Environments` and the related `Computing Managers` MUST be considered as part of the same `Computing Service`.

The `Computing Service` always aggregates `Computing Endpoints`, `Computing Shares`, `Computing Managers` and `Execution Environments` forming a connected set. In other words, `Endpoint` A exposing `Execution Environment` A of `Manager` A via `Share` A and

Endpoint B exposing Execution Environment B of Manager B via Share B form two different Computing Services. On the other hand, Endpoint A exposing Execution Environment A of Manager A via Share A and Endpoint B exposing Execution Environment A of Manager A via Share B form a single Computing Service.

7.2. ComputingEndpoint

The ComputingEndpoint is a specialization of the Endpoint class for a service possessing computational capability. The class represents an endpoint which is used to create, control and monitor computational activities. The computational-specific information concerns service load related parameters, staging capabilities and supported types of job description. This class provides attributes that MAY be used to publish summary information about jobs submitted via a particular Endpoint. Such attributes are optional and may not always be measurable (e.g., in the case of a stateless Endpoint which does not keep information about the jobs submitted through it).

Entity	Inherits from			Description
ComputingEndpoint	Endpoint			A network Endpoint for creating, monitoring, and controlling computational Activities called jobs. It MAY also be used to expose complementary capabilities (e.g., resource reservation or proxy manipulation).
Inherited Attribute	Type	Mult	Unit	Description
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed, the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
URL	*URI*	*1*		*Network location of the endpoint to contact the related service*
Capability	*Capability_t*	***		*The provided capability according to the OGSA architecture*
Technology	*EndpointTechnology_t*	*0..1*		*Technology used to implement the endpoint*
InterfaceName	*InterfaceName_t*	*1*		*Identification of the interface*
InterfaceVersion	*String*	*0..**		*Version of the interface*
InterfaceExtension	*URI*	***		*Identification of an extension to the interface*
WSDL	*URI*	***		*URL of the WSDL document describing the offered interface (applies to Web Services endpoint)*
SupportedProfile	*URI*	***		*URI identifying a supported profile*
Semantics	*URI*	***		*URI of a document providing a human-readable description of the semantics of the endpoint functionalities*
Implementor	*String*	*0..1*		*Main organization implementing this software component*
ImplementationName	*String*	*0..1*		*Name of the implementation*
ImplementationVersion	*String*	*0..1*		*Version of the implementation (e.g., major version.minor version.patch version)*
QualityLevel	*QualityLevel_t*	*1*		*Maturity of the endpoint in terms of quality of the software components*
HealthState	*EndpointHealthState_t*	*1*		*A state representing the health of the endpoint in terms of its capability of properly delivering the functionalities*
HealthStateInfo	*String*	*0..1*		*Textual explanation of the state endpoint*

ServingState	*ServingState_t*	*1*		*A state specifying if the endpoint is accepting new requests and if it is serving the already accepted requests*
StartTime	*DateTime_t*	*0..1*		*The timestamp for the start time of the endpoint*
Authentication	*EndpointAuthentication_t*	*0..1*		*Name of the authentication method supported by the endpoint.*
IssuerCA	*DN_t*	*0..1*		*Distinguished name of Certification Authority issuing the certificate for the endpoint*
TrustedCA	*DN_t*	*		*Distinguished name of the trusted Certification Authority (CA), i.e., certificates issued by the CA are accepted for the authentication process*
DowntimeAnnounce	*DateTime_t*	*0..1*		*The timestamp for the announcement of the next scheduled downtime*
DowntimeStart	*DateTime_t*	*0..1*		*The starting timestamp of the next scheduled downtime*
DowntimeEnd	*DateTime_t*	*0..1*		*The ending timestamp of the next scheduled downtime*
DowntimeInfo	*String*	*0..1*		*Description of the next scheduled downtime*
Attribute	Type	Mult.	Unit	Description
Staging	Staging_t	0..1		Supported file staging functionalities, if any.
JobDescription	JobDescription_t	*		Supported type of job description language.
TotalJobs	UInt32	0..1	Job	The total number of Grid jobs currently known to the system (the sum of RunningJobs, WaitingJobs, StagingJobs, SuspendedJobs and PreLRMSWaitingJobs); this value SHOULD not include jobs submitted locally rather than via the Grid.
RunningJobs	UInt32	0..1	job	The number of Grid jobs which are currently running in an Execution Environment.
WaitingJobs	UInt32	0..1	job	The number of Grid jobs which are currently waiting to start execution. Usually these will be queued in the underlying Computing Manager (i.e., a Local Resource Managment System or LRMS).
StagingJobs	UInt32	0..1	job	The number of Grid jobs which are currently either staging files in before starting execution, or staging files out after finishing execution.
SuspendedJobs	UInt32	0..1	job	The number of Grid jobs which have started their execution, but are currently suspended (e.g., having been preempted by another job).
PreLRMSWaitingJobs	UInt32	0..1	job	The number of Grid jobs which are currently managed by the Grid software layer waiting to be passed to the underlying Computing Manager (LRMS), and hence are not yet candidates to start execution.
Association End		Mult.	Description	
ComputingService.ID [redefines Service.ID]		1	A computing endpoint is part of a Computing Service.	
ComputingShare.ID [redefines Share.ID]		*	A computing endpoint MAY pass activities to zero or more computing shares.	
ComputingActivity.ID [redefines Activity.ID]		*	An endpoint has accepted and is managing zero or more Activities.	
Inherited Association End		Mult.	Description	
Extension.Key		*	The entity MAY be extended via key-value pairs.	
AccessPolicy.ID		*	A computing endpoint has assocated zero or more AccessPolicies.	

7.3. ComputingShare

The ComputingShare class is the specialization of the main Share class for computational services. A Computing Share is a high-level concept introduced to model a utilization target for a set of Execution Environments defined by a set of configuration parameters and characterized by status information. A ComputingShare carries information about "policies" (limits) defined over all or a subset of resources and describes their dynamic status (load).

In clusters managed by a batch system (LRMS), the simplest way to set up a Computing Share is to configure a batch queue. Nevertheless, the same Computing Share may be implemented using different batch system configuration strategies. In complex batch systems, a batch queue may be configured with different sets of policies for different sets of users. This implies that each set of users obtains a different utilization target. Such a scenario MAY be represented by different Computing Shares. In general, given a number of shares to be set up, it is possible to adopt different configuration strategies in the underlying system. Regardless of the selected approach, the external behaviour does not change. The main goal of the Computing Share concept is to abstract from such implementation choices and to represent the externally observable behaviour.

The introduction of the Computing Share concept also supports the modelling of heterogeneity within a `ComputingService` by being able to have associations to different Execution Environments.

Entity	Inherits from			Description
ComputingShare	Share			A utilization target for a set of Execution Environments, defined by a set of configuration parameters and characterized by status information.
Inherited Attribute	Type	Mult	Unit	Description
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed, the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Description	*String*	*0..1*		*Description of this share*
Attribute	Type	Mult.	Unit	Description
MappingQueue	String	0..1		The name of a queue available in the underlying Computing Manager (i.e., LRMS) where jobs related to this share are submitted. Different Shares MAY be mapped into the same queue; it is not foreseen that a single share MAY be mapped into many different queues.
MaxWallTime	UInt64	0..1	s	The maximum obtainable wall clock time limit that MAY be granted to a single-slot job upon user request (un-normalized value, see below).
MaxMultiSlotWallTime	UInt64	0..1	s	The maximum obtainable wall clock time limit that MAY be granted to a multi-slot job upon user request; this value is measured from the start of the first slot up to the release of the last slot. (un-normalized value, see below).
MinWallTime	UInt64	0..1	s	The minimum wall clock time per slot for a job (un-normalized value, see below); if a job requests a lower time, then it MAY be rejected; if a job requests at least this value, but runs for a shorter time, then it might be accounted for this value.
DefaultWallTime	UInt64	0..1	s	The default wall clock time limit per slot assigned to a job by the Computing Manager (LRMS) if no limit is requested in the job submission description (un-

				normalized value, see below). Once this time is expired the job MAY be killed or removed from the queue.
MaxCPUTime	UInt64	0..1	s	The maximum obtainable CPU time limit that MAY be granted to the job upon user request per slot (un-normalized value, see below)
MaxTotalCPUTime	UInt64	0..1	s	The maximum obtainable CPU time limit that MAY be granted to the job upon user request across all assigned slots; this attribute is a limit on the sum of the CPU time used in all the slots occupied by a multi-slot job (un-normalized value, see below).
MinCPUTime	UInt64	0..1	s	The minimum CPU time per slot for a job (un-normalized value, see below); if a job requests a lower time, than it MAY be rejected; if a job requests at least this value, but uses the CPU for a shorter time, then it might be accounted for this value.
DefaultCPUTime	UInt64	0..1	s	The default CPU time limit per slot assigned to each job by the Computing Manager (LRMS) if no limit is requested in the job submission description (un-normalized value, see below).
MaxTotalJobs	UInt32	0..1	job	The maximum allowed number of jobs in this Share.
MaxRunningJobs	UInt32	0..1	job	The maximum allowed number of jobs in the running state in this Share.
MaxWaitingJobs	UInt32	0..1	job	The maximum allowed number of jobs in the waiting state in this Share.
MaxPreLRMSWaitingJobs	UInt32	0..1	job	The maximum allowed number of jobs that are in the Grid layer waiting to be passed to the underlying computing manager (i.e., LRMS) for this Share.
MaxUserRunningJobs	UInt32	0..1	job	The maximum allowed number of jobs in the running state per Grid user in this Share.
MaxSlotsPerJob	UInt32	0..1	slot	The maximum number of slots which could be allocated to a single job in this Share (defined to be 1 for a Computing Manager accepting only single-slot jobs).
MaxStageInStreams	UInt32	0..1	stream	The maximum number of streams available to stage files in.
MaxStageOutStreams	UInt32	0..1	stream	The maximum number of streams available to stage files out.
SchedulingPolicy	SchedulingPolicy_t	0..1		The type of scheduling policy used for the Share.
MaxMainMemory	UInt64	0..1	MB	The maximum physical RAM that a job is allowed to use; if the limit is hit, then the LRMS MAY kill the job.
GuaranteedMainMemory	UInt64	0..1	MB	The amount of physical RAM that a job is guaranteed to have available for its use.
MaxVirtualMemory	UInt64	0..1	MB	The maximum total memory size (RAM plus swap) that a job is allowed to use; if the limit is hit, then the LRMS MAY kill the job.
GuaranteedVirtualMemory	UInt64	0..1	MB	The total amount of memory (RAM plus swap) that a job is guaranteed to have available for its use.
MaxDiskSpace	UInt64	0..1	GB	The maximum disk space that a job is allowed use in the working area; if the limit is hit, then the LRMS MAY kill the job.
DefaultStorageService	URI	0..1		The ID of the default Storage Service to be used to store files by jobs in the case that no destination Storage Service is explicitly chosen.
Preemption	ExtendedBoolean_t	0..1		True if the Computing Manager (i.e., LRMS) enables pre-emption of jobs; a pre-empted

				job is supposed to be automatically resumed, but may be suspended for an indefinite period.
ServingState	ServingState_t	1		A state specifying whether the Share is open to accept new requests, and if it is open to offer the already present requests for execution.
TotalJobs	UInt32	0..1	job	The total number of jobs in any state (the sum of RunningJobs, WaitingJobs, StagingJobs, SuspendedJobs and PreLRMSWaitingJobs). Note that this number includes the locally submitted jobs.
RunningJobs	UInt32	0..1	job	The number of jobs which are currently running in an Execution Environment, submitted via any type of interface (local and Grid).
LocalRunningJobs	UInt32	0..1	job	The number of running jobs submitted via a local (non-GRID) interface.
WaitingJobs	UInt32	0..1	job	The number of jobs which are currently waiting to start execution, submitted via any type of interface (local and Grid). Usually these will be queued in the underlying Computing Manager (i.e., a Local Resource Managment System or LRMS).
LocalWaitingJobs	UInt32	0..1	job	The number of jobs which are currently waiting to start execution, submitted via a local (non-Grid) interface. Usually these will be queued in the underlying Computing Manager (i.e., a Local Resource Managment System or LRMS).
SuspendedJobs	UInt32	0..1	job	The number of jobs, submitted via any type of interface (local and Grid), which have started their execution, but are currently suspended (e.g., having been preempted by another job).
LocalSuspendedJobs	UInt32	0..1	job	The number of jobs, submitted via a local (non-Grid) interface, which have started their execution, but are currently suspended (e.g., having been preempted by another job).
StagingJobs	UInt32	0..1	job	The number of Grid jobs which are currently either staging files in before starting execution, or staging files out after finishing execution.
PreLRMSWaitingJobs	UInt32	0..1	job	The number of Grid jobs which are currently managed by the Grid software layer waiting to be passed to the underlying Computing Manager (LRMS), and hence are not yet candidates to start execution.
EstimatedAverageWaitingTime	UInt64	0..1	s	An estimate of the average time a job will wait after submission until it starts to execute. The value SHOULD be reported as 0 if there are free slots and a new job will start immediately, even if it takes some finite time for a job to be started.
EstimatedWorstWaitingTime	UInt64	0..1	s	An estimate of the worst-case time a job could wait after submission until it starts to execute. This would generally be based on an assumption that all existing jobs run to their maximum allowed time limits.
FreeSlots	UInt32	0..1	slot	The number of slots which are currently unoccupied by jobs and are free for new jobs in this Share to start immediately.
FreeSlotsWithDuration	String	0..1	slot:s	The number of free slots with their time limits. Syntax: ns[:t] [ns:t]*, where the pair ns:t means that there are *ns* free slots for the duration of *t* (expressed in seconds); the time limit information is optional.

UsedSlots	UInt32	0..1	slot	The number of slots currently occupied by running jobs.
RequestedSlots	UInt32	0..1	slot	The number of slots which are needed to execute all currently waiting and staging jobs.
ReservationPolicy	ReservationPolicy_t	0..1		The type of policy used for advance reservation, if any.
Tag	String	*		A UserDomain-defined tag for this Share (the values SHOULD use a namespace based on the UserDomain name to avoid collision).
Association End		**Mult.**	**Description**	
ComputingEndpoint.ID [redefines Endpoint.ID]		*	A computing share MAY be consumed via one or more computing endpoints.	
ExecutionEnvironment.ID [redefines Resource.ID]		*	A computing share is defined on one or more computing resources.	
ComputingService.ID [redefines Service.ID]		1	A computing share participates in a computing service.	
ComputingActivity.ID [redefines Activity.ID]		*	A computing share is being consumed by zero or more computing activities.	
ComputingShareAccelerator.ID		*	A computing share provides about the usage level of several accelerator devices.	
Inherited Association End		**Mult.**	**Description**	
Extension.Key		*	The entity MAY be extended via key-value pairs.	
MappingPolicy.ID		*	A share has zero or more mapping policies.	

As regards CPU Time and Wallclock Time related properties, there is a need to have a way to normalize them depending on the computing capacity of the Execution Environment. The approach proposed in GLUE is to add two attributes in the Execution Environment (see Section 7.8) which refer to the scaling factor to be used to compute the CPU/Wallclock time limit that a job will get if it will be assigned to such an Execution Environment via a certain Share. It is important that a job SHOULD always get at least the advertised CPU/Wallclock time. This means that the reference Execution Environment for the normalization should be always the fastest (most powerful) among those available in the entire Computing Service. For this Execution Environment, the scaling factor MUST be equal to 1. The CPU/Wallclock time values published by a Share therefore refer to the time limit that the job will get when mapped to this Execution Environment. For the other Execution Environments, the time should be adjusted according to the published scaling factors.

7.4. ComputingShareAccelerator

The ComputingShareAccelerator class contains all the information about the usage level of the accelerator device bound to the computing share.

Entity	Inherits from			Description
ComputingShareAccelerator	Entity			The usage level of the accelerator devices for a given computing share
Inherited Attribute	**Type**	**Mult.**	**Unit**	**Description**
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed,* *the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	*		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	**Type**	**Mult.**	**Unit**	**Description**
Type	*AccType_t*	1		The accelerator architecture type.

FreeSlots	*UInt32*	0..1		The number of accelerator cards slots which are currently unoccupied by jobs and are free for new jobs in this Share to start immediately
UsedSlots	*UInt32*	0..1		The number of accelerator cards slots currently occupied by running jobs.
MaxSlotsPerJob	*UInt32*	0..1		The maximum number of accelerator slots which could be allocated to a single job in this Share
Association End		Mult.	Description	
ComputingShare. ID		1	A set of accelerator information is related to a computing share.	
Inherited Association End		Mult.	Description	
Extension.Key		*	The entity MAY be extended via key-value pairs.	

7.5. ComputingManager

The ComputingManager class is a specialization of the Manager class for the computational capability. The ComputingManager is responsible for the local control of resources, and this layer is not exposed directly to external clients. The operating system might be the simplest case of a Computing Manager, but the ComputingManager is often realized by means of a Local Resource Management (LRMS) "batch" system. A Computing Service will usually only have one Computing Manager, but MAY have more. The class provides aggregated information on controlled resources, and also describes local storage extents accessible to jobs.

Entity	Inherits from			Description
ComputingManager	Manager			A software component locally managing one or more Execution Environments. It MAY also describe aggregated information about the managed resources. The computing manager is also known as a Local Resource Management System (LRMS).
Inherited Attribute	Type	Mult	Unit	Description
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed, the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
ProductName	*String*	*1*		*Name of the software product adopted as manager*
ProductVersion	*String*	*0..1*		*Version of the software product adopted as manager*
Attribute	Type	Mult.	Unit	Description
Reservation	ExtendedBoolean_t	0..1		True if the Computing Manager (i.e, LRMS) supports advance reservation of resources.
BulkSubmission	ExtendedBoolean_t	0..1		True if the computing manager (i.e, LRMS) supports bulk submission of multiple jobs.
TotalPhysicalCPUs	UInt32	0..1	Ph.CPU	The total number of physical CPUs accessible via any of the available Endpoints and managed by this Computing Manager (there is one physical CPU per socket). This value SHOULD represent the total installed capacity, i.e. including resources which are temporarily unavailable.

TotalLogicalCPUs	UInt32	0..1	Log.CPU	The total number of logical CPUs accessible via any of the available Endpoints and managed by this Computing Manager (a logical CPU corresponds to a CPU visible to the operating system). This value SHOULD represent the total installed capacity, i.e. including resources which are temporarily unavailable.
TotalSlots	UInt32	0..1	slot	The total number of slots managed by this Computing Manager which are currently available to run jobs.
SlotsUsedByLocalJobs	UInt32	0..1	slot	The number of slots currently occupied by jobs submitted via a local (non-Grid) interface.
SlotsUsedByGridJobs	UInt32	0..1	slot	The number of slots currently occupied by jobs submitted via a Grid interface.
Homogeneous	ExtendedBoolean_t	0..1		True if this Computing Manager manages only one type of Execution Environment.
NetworkInfo	NetworkInfo_t	*		The type of internal network connection available among the managed Execution Environment instances. If many values are published then the various types of network MAY be available only within subsets of the Execution Environment instances; the Execution Environment properties SHOULD publish this information.
LogicalCPUDistribution	String	0..1		A classification of the managed Execution Environment instances aggregated by the number of logical CPUs. Syntax: X*1*:Y*1*, …, X*n*:Y*n,* where I is the i-*th* group of Execution Environments with the same number of logical CPUs, X*i* is the number of logical CPUs in each Execution Environment instance and Y*i* is the number of Execution Environment instances.
WorkingAreaShared	ExtendedBoolean_t	0..1		True if the working area (see below) is shared across different Execution Environment instances (i.e., cluster nodes), typically via an NFS mount; this attribute applies to single-slot jobs.
WorkingAreaGuaranteed	ExtendedBoolean_t	0..1		True if the job is guaranteed the full extent of the WorkingAreaTotal; this attribute applies to single-slot jobs.
WorkingAreaTotal	UInt64	0..1	GB	Total size of the working area (see below) available to all single-slot Grid jobs, either as a shared area across all the Execution Environments (WorkingAreaShared is true) or local to each Execution Environment (WorkingAreaShared is false). If the Computing Manager supports individual quotas per job/user, this is not advertised. In the case of a non-shared working area with a different local space allocation on each node, the advertised total size SHOULD be the minimum available across all the Execution Environment instances.
WorkingAreaFree	UInt64	0..1	GB	The amount of free space currently available in the working area (see below), available to all single-slot Grid jobs either as a shared area across all the Execution Environments (WorkingAreaShared is true) or local to each Execution Environment (WorkingAreaShared is false). If the computing manager supports

				individual quotas per job/user, this is not advertised. In the case of a non-shared and non-guaranteed working area, this attribute SHOULD represent the minimum free working area currently available in any Execution Environment instance. In the case of a non-shared and guaranteed working area, the free size SHOULD equal the total size.
WorkingAreaLifeTime	UInt64	0..1	s	The minimum guaranteed lifetime of the files created by single-slot Grid jobs in the working area (see below); the lifetime is related to the end time of the job. After the expiration of this lifetime, the files are not guaranteed to exist.
WorkingAreaMultiSlotTotal	UInt64	0..1	GB	The total size of the working area (see below) available to all the multi-slot Grid jobs shared across all the Execution Environments. If the Computing Manager supports individual quotas per job/user, this is not advertised.
WorkingAreaMultiSlotFree	UInt64	0..1	GB	The amount of free space currently available in the working area (see below) available to all multi-slot Grid jobs shared across all the Execution Environments. If the Computing Manager supports individual quotas per job/user, this is not advertised. This attribute SHOULD represent the minimum free working area currently available in any Execution Environment instance.
WorkingAreaMultiSlotLifeTime	UInt64	0..1	s	The minimum guaranteed lifetime of the files created by multi-slot Grid jobs in the working area (see below); the lifetime is related to the end time of the job. After the expiration of the lifetime, the files are not guaranteed to exist.
CacheTotal	UInt64	0..1	GB	If local caching of input files is supported, this attribute represents the total size of a shared storage area where frequently accessed data MAY be stored for rapid access by subsequent Grid jobs; in this area, files are kept after job completion for a certain amount of time, depending on the caching algorithm.
CacheFree	UInt64	0..1	GB	If local caching of input files is supported, this attribute represents the free space in a shared storage area where frequently accessed data MAY be stored for rapid access by subsequent Grid jobs. In the computation of the free size, files which are not claimed by any job MAY be considered as deleted.
TmpDir	String	0..1		The absolute path of a temporary directory local to an Execution Environment instance (i.e., a worker node). This directory MUST be available to programs using the normal file access primitives (open/read/write/close). Any files in the directory MAY be deleted as soon as the job which created them finishes.
ScratchDir	String	0..1		The absolute path of a shared directory available for application data. Typically this is a POSIX accessible transient disk space shared between the Execution Environment instances, e.g. via an NFS mount. It MAY be used by MPI applications or to store intermediate files

				that need further processing by local jobs or as a staging area, especially if the Execution Environment instances have no internet connectivity. Any files in the directory MAY be deleted as soon as the job which created them finishes.
ApplicationDir	String	0..1		The path of a directory available for installation of persistent application software and data. Typically this will be a POSIX accessible disk space, e.g. an NFS mount, with a long-term allocation of space to supported User Domains. The detailed usage of such a space SHOULD be described in a profile document for a specific Grid infrastructure.

Association End	Mult.	Description
ComputingService.ID [redefines Service.ID]	1	A computing manager participates in a computing service.
ExecutionEnvironment.ID [redefines Resource.ID]	1..*	A computing manager manages one or more execution environments.
ApplicationEnvironment.ID	*	A computing manager MAY use zero or more application environments.
ComputingManagerAccelerator.ID	*	A computing manager MAY display information about the usage level of the accelerator devices installed in the cluster.
Benchmark.ID	*	A computing manager has zero or more associated benchmarks.
Inherited Association End	**Mult.**	**Description**
Extension.Key	*	The entity MAY be extended via key-value pairs.

As regards the WorkingArea-related attributes and single-slot jobs, four scenarios should be considered. Both scenarios and the related attribute values are presented in Table 1.

Table 1 Working Area and Single-slot jobs scenarios

Working Area	Shared	Guaranteed
One working area shared across all the Execution Environments and shared among simultaneous jobs.	true	false
One working area shared across all the Execution Environments with a guaranteed quota for each job.	true	true
A working area local to each Execution Environment, but shared among all the jobs which run simultaneously in those Execution Environments.	false	false
A working area local to each Execution Environment and dedicated to each job.	false	true

In case there is a dedicated working area for multi-slot jobs, this SHOULD be represented by the WorkingAreaMultiSlot* attributes. In case there is no dedicated working area for multi-slot jobs, i.e., there is a common working area for both single-slot and multi-slot jobs, we RECOMMEND to publish only the attributes related to the working area for single-slot jobs.

7.6. ComputingManagerAccelerator

The ComputingManagerAccelerator contains information about the accelerator device handled by the computing manager.

Entity	Inherits from			Description
ComputingManagerAccelerator	Entity			The information about the accelerator device handled by the computing manager.
Inherited Attribute	**Type**	**Mult.**	**Unit**	**Description**
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed, the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	**Type**	**Mult.**	**Unit**	**Description**
Type	*AccType_t*	1		The accelerator architecture type.
TotalNumbers	*UInt32*	0..1		The total number of physical Accelerator cards accessible via any of the available Endpoints and managed by this Computing Manager. This value SHOULD represent the total installed capacity, i.e. including resources which are temporarily unavailable.
TotalSlots	*UInt32*	0..1		The total number of Accelerator slots managed by this Computing Manager which are currently available to run jobs.
UsedSlots	*UInt32*	0..1		The total number of slots currently occupied by jobs.
Association End		**Mult.**		**Description**
ComputingManager.ID		1		A set of accelerator information is related to a computing manager.
Inherited Association End		**Mult.**		**Description**
Extension.Key		*		The entity MAY be extended via key-value pairs.

7.7. Benchmark

The `Benchmark` class characterizes the relative performance of the computing resource by providing the result of a specific benchmark suite executed on the computing resource underlying the Computing Service. The `Benchmark` class provides the both the type and the value of the benchmark.

Entity	Inherits from			Description
Benchmark	Entity			Benchmark information either about an Execution Environment providing computing capacity or about a CloudComputingInstanceType providing cloud computing capacity
Inherited Attribute	**Type**	**Mult.**	**Unit**	**Description**
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed, the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*

Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	**Type**	**Mult.**	**Unit**	**Description**
Type	Benchmark_t	1		The type of benchmark.
Value	Real32	1		The benchmark value.
Association End		**Mult.**	**Description**	
ExecutionEnvironment.ID		0..1	A benchmark MAY be related to an execution environment.	
ComputingManager. ID		0..1	A benchmark MAY be related to a computing resource.	
CloudComputingInstanceType.ID		0..1	A benchmark MAY be related to a cloud computing instance type.	
CloudComputingManager.ID		0..1	A benchmark MAY be related to a cloud computing resource.	
Inherited Association End		**Mult.**	**Description**	
Extension.Key		*	The entity MAY be extended via key-value pairs.	

7.8. ExecutionEnvironment

The `ExecutionEnvironment` class describes the hardware and operating system environment in which a job will run. It represents a set of homogeneous Worker Nodes, so if a computing system contains nodes with significantly different properties there MAY be several `ExecutionEnvironment` instances. This implies that it should be possible to request a specific environment when a job is submitted. The `ExecutionEnvironment` MAY refer to virtual rather than physical machines.

As well as attributes describing a typical node, the class gives summary information about the size and usage of the set of nodes which possess those properties. However, there is no way to relate these to the information in other entities, e.g. it is not possible to know which jobs in a given `ComputingShare` are running on which `ExecutionEnvironment`.

Entity	Inherits from			Description
ExecutionEnvironment	Resource			A type of environment available to and requestable by a Grid job when submitted to a ComputingService via a Computing Endpoint; the type of environment is described in terms of hardware, operating system and network characteristics. Information about the total/available/used instances of this type of execution environment are also included.
Inherited Attribute	**Type**	**Mult.**	**Unit**	**Description**
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed, the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	**Type**	**Mult.**	**Unit**	**Description**
Platform	Platform_t	1		The platform architecture of this Execution Environment.
VirtualMachine	ExtendedBoolean_t	0..1		True if the Execution Environment is hosted within a virtual machine; in this case, the values of the other attributes are related to the virtualized environment and not to the hosting environment.
TotalInstances	UInt32	0..1		The total number of Execution Environment instances. This SHOULD reflect the total installed

				capacity, i.e. including resources which are temporarily unavailable.
UsedInstances	UInt32	0..1		The number of Execution Environment instances which are considered to be fully used; an instance is used when, according to the policies of the Computing Manager (i.e., LRMS), it cannot accept new jobs because it already runs the maximum number of allowed jobs.
UnavailableInstances	UInt32	0..1		The number of Execution Environment instances which are currently unavailable, e.g. because of failures or maintenance.
PhysicalCPUs	UInt32	0..1		The number of physical CPUs in one ExecutionEnvironment instance, i.e. the number of sockets per Worker Node.
LogicalCPUs	UInt32	0..1		The number of logical CPUs in one Execution Environment instance, i.e. typically the number of cores per Worker Node.
CPUMultiplicity	CPUMultiplicity_t	0..1		Condensed information about the multiplicity of both physical CPUs and cores available in an execution environment instance..
CPUVendor	String	0..1		The name of the physical CPU vendor. Free format, but it SHOULD correspond to the name by which the vendor is generally known.
CPUModel	String	0..1		The name of the physical CPU model, as defined by the vendor.
CPUVersion	String	0..1		The specific version of the Physical CPU model, as defined by the vendor.
CPUClockSpeed	UInt32	0..1	MHz	The nominal clock speed of the physical CPU.
CPUTimeScalingFactor	Real32	0..1		The factor used by the Computing Manager (i.e., LRMS) to scale the CPU time limit (the CPU Time is divided by the CPUTimeScalingFactor); for the reference execution environment, this attribute is equal to 1. See the description of the ComputingShare for further information.
WallTimeScalingFactor	Real32	0..1		The factor used by the Computing Manager (i.e., LRMS) to scale the Wallclock time limit (the Wallclock Time is divided by the WallTimeScalingFactor). See the description of the ComputingShare for further information.
ConnectivityOut	ExtendedBoolean_t	1		True if direct outbound network connectivity is available from a running job, even if limited, e.g. by firewall rules.
NetworkInfo	NetworkInfo_t	*		The type of internal network connection available among the Execution Environment instances.

Association End	Mult.	Description
ComputingManager.ID [redefines Manager.ID]	1	An execution environment is managed by a computing manager.
ComputingShare.ID [redefines Share.ID]	*	An execution environment provides capacity in terms of computing shares.
ComputingActivity.ID [redefines Activity.ID]	*	An execution environment runs zero or more computing activities.
AcceleratorEnvironment.ID	*	An execution environment MAY contains zero or more accelerator environments.
ApplicationEnvironment.ID	*	An execution environment offers zero or more application environments.
Benchmark.ID	*	An execution environment has zero or more associated benchmarks.

Inherited Association End	Mult.	Description
Extension.Key	*	The entity MAY be extended via key-value pairs.

Each Execution Environment instance is under the control of a Computing Manager (i.e., LRMS). An Execution Environment MAY be realized in several ways. Examples are a physical computing node, or a virtual machine image that MAY be requestable by a job (different virtual machine images MAY coexist on the same physical node).

7.9. AcceleratorEnvironment

The AcceleratorEnvironment is an entity used to describe an homogeneous set of accelerator processors. This entity is associated with one or more execution environments.

Entity	Inherits from			Description
AcceleratorEnvironment	Entity			Description of the accelerator device
Inherited Attribute	**Type**	**Mult.**	**Unit**	**Description**
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed,* *the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	**Type**	**Mult.**	**Unit**	**Description**
Type	*AccType_t*	1		The type of Accelerator.
Numbers	UInt32	1		The number of physical Accelerators in one ExecutionEnvironment instance, i.e. the number of accelerator cards per Worker Node.
Vendor	String	0..1		The name of the physical Accelerator vendor. Free format, but it SHOULD correspond to the name by which the vendor is generally known.
Model	String	0..1		The name of the physical Accelerator model, as defined by the vendor.
Version	String	0..1		The specific version of the Physical Accelerator model, as defined by the vendor.
ClockSpeed	UInt32	0..1	MHz	The nominal clock speed of the physical Accelerator.
Memory	UInt32	0..1	MB	The nominal memory size of the physical Accelerator
ComputeCapability	String	*		Compute Capability is a reference, an ID or tag, representing the set of features supported by an accelerator device, as declared by the vendor
Association End		**Mult.**	**Description**	
ExecutionEnvironment.ID		1	An accelerator environment is associated with one execution environments.	
Inherited Association End		**Mult.**	**Description**	
Extension.Key		*	The entity MAY be extended via key-value pairs.	

7.10. ApplicationEnvironment

The `ApplicationEnvironment` class describes the software environment in which a job will run, i.e. what pre-installed software will be available to it. Each Application is identified by a name (the AppName attribute); these names are not defined within the schema, but SHOULD be assigned in a way which allows applications to be uniquely identified. In some deployment scenarios, the definition of namespace-based AppNames or guidelines for the generation of unique application names MAY be specified, and application repository services relying on those application names MAY be provided. This aspect is considered out of scope for the GLUE schema specification, but MAY be included in a profile document for a specific production Grid.

The Application Environment can be used to describe installed application software or special environment setups in terms of a simple tag string. In this case, the AppName attribute should be used to publish this tag; other attributes are optional.

The properties of installed software may vary substantially, but the attributes of the class cover the most common cases, in particular for licensed software. If necessary, additional information MAY be added using the `OtherInfo` attribute and the `Extension` class.

Entity	Inherits from			Description
ApplicationEnvironment	Entity			A description of installed application software or software environment characteristics available within one or more Execution Environments.
Inherited Attribute	Type	Mult.	Unit	Description
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed,* *the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	*		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	Type	Mult.	Unit	Description
AppName	String	1		The name of the application or environment.
AppVersion	String	0..1		The version of the application or environment, as defined by the supplier.
Repository	URL	0..1		The URL of a service which offers a name service and/or a repository for this application environment. Application environments can be categorized under namespaces maintained by application repositories.
State	AppEnvState_t	0..1		The current installation state of the application.
RemovalDate	DateTime_t	0..1		The date and time after which the application MAY be removed.
License	License_t	0..1		The type of license under which the application is usable.
Description	String	0..1		A human-readable description of this application or environment.
BestBenchmark	Benchmark_t	*		The type of benchmark which best identifies the sensitivity of this application to the performance of the Execution Environment, which can be compared with the rating published via the Benchmark class.
ParallelSupport	ParallelSupport_t	0..1		The type of supported parallel execution framework.
MaxSlots	UInt32	0..1	slot	The maximum number of concurrent slots that may be used to run jobs using the application.
MaxJobs	UInt32	0..1	job	The maximum number of concurrent jobs that may use the application.
MaxUserSeats	UInt32	0..1	user seat	The maximum number of concurrent user seats (i.e. distinct users) that may use the application.
FreeSlots	UInt32	0..1	slot	The number of slots currently available to run jobs using the application.
FreeJobs	UInt32	0..1	slot	The number of jobs that could immediately start their execution using the application.
FreeUserSeats	UInt32	0..1	user seat	The current number of free seats for additional users to use the application.
Association End		Mult.	Description	
ExecutionEnvironment.ID		*	An application environment MAY be used in zero or more execution environments.	
ComputingManager.ID		1	An application environment is part of a computing manager.	
ApplicationHandle.ID		*	An application environment MAY be handled via zero or more application handles.	
Inherited Association End		Mult.	Description	
Extension.Key		*	The entity MAY be extended via key-value pairs.	

7.11. ApplicationHandle

The ApplicationHandle class is an extension to ApplicationEnvironment for applications which need to be set up in some way before they can be used. For each supported setup method a string MAY be specified, the interpretation of which is specific to the method - in the simplest case this could just be a setup script to execute. A single Application MAY support multiple setup methods.

Entity	Inherits from			Description
ApplicationHandle	Entity			The description of a technique for bootstrapping and/or accessing an application environment.
Inherited Attribute	Type	Mult.	Unit	Description
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed, the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	Type	Mult.	Unit	Description
Type	ApplicationHandle_t	1		The type of method used to set up this application environment.
Value	String	1		A string which defines how to set up this application in the context of the setup method specified by the Type.
Association End		Mult.	Description	
ApplicationEnvironment.ID		1	An application handle MAY be used for one application environment.	
Inherited Association End		Mult.	Description	
Extension.Key		*	The entity MAY be extended via key-value pairs.	

7.12. ComputingActivity

The ComputingActivity class represents a single (but possibly multi-processor) job. The attributes give the job properties and state as seen by the local batch system, together with some Grid-level information.

Entity	Inherits from			Description
ComputingActivity	Activity			An Activity managed by an OGSA execution capability service (the Computing Activity is traditionally called a job).
Inherited Attribute	*Type*	*Mult*	*Unit*	*Description*
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed, the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated*

				tags, (name, value) pair are all examples of valid syntax

Attribute	Type	Mult.	Unit	Description
Type	ComputingActivityType_t	0..1		The type of this Computing Activity.
IDFromEndpoint	URI	0..1		The job ID as assigned by the Computing Endpoint.
LocalIDFromManager	String	0..1		The local ID of the job as assigned by the Computing Manager (i.e., LRMS).
JobDescription	JobDescription_t	0..1		The job description language used to specify the job request.
State	ComputingActivityState_t	1..*		The state of the job; different state models are allowed; a state for each model is allowed provided that it has a different namespace prefix (see data type definition)
RestartState	ComputingActivityState_t	0..*		The state from which a failed job MAY restart upon a client request; different state models are allowed; a state for each model is allowed provided that it has a different namespace prefix (see data type definition)
ExitCode	Int32	0..1		The exit code as returned by the main executable code or script of the job.
ComputingManagerExitCode	String	0..1		The exit code provided by the Computing Manager (i.e., LRMS).
Error	String	*		Error messages as provided by the software components involved in the management of the job.
WaitingPosition	UInt32	0..1		For a waiting job being queued in the Computing Manager (i.e., LRMS), the position of the job in the queue.
UserDomain	String	0..1		The User Domain specified by the job owner in the job submission request. The owner MAY belong to several User Domains, but typically decides which one to choose when submitting a job.
Owner	String	1		The Grid identity of the job's owner; in the case that anonymity is required, the reserved value CONFIDENTIAL should be advertised.
LocalOwner	String	0..1		The local user name to which the job's owner is mapped for the execution of this job.
RequestedTotalWallTime	UInt64	0..1	s	The total wall clock time requested by the job; for multi-slot jobs, it represents the sum of wall clock times needed for each required slot.
RequestedTotalCPUTime	UInt64	0..1	s	The total CPU time requested by the job; for multi-slot jobs, it represents the sum of CPU times needed for each required slot.
RequestedSlots	UInt32	0..1	slot	The number of slots requested for this job.
RequestedApplicationEnvironment	String	*		A serialization of the AppName and Version of the requested Application Environments (the serialization syntax is delegated to the implementation).
StdIn	String	0..1		The name of the file which is used as the standard input of the job.
StdOut	String	0..1		The name of the file which contains the standard output of the job.

StdErr	String	0..1		The name of the file which contains the standard error of the job.
LogDir	String	0..1		The name of the directory which contains the logs related to the job and generated by the Grid layer (usually the directory is private to the job).
ExecutionNode	String	*		A hostname associated to the Execution Environment instance (i.e., worker node) running the job; multi-node jobs are described by several instances of this attribute.
Queue	String	0..1		The name of the Computing Manager (i.e, LRMS) queue in which this job was queued before execution.
UsedTotalWallTime	UInt64	0..1	s	The total wall clock time consumed so far by the job. In case of multi-slot jobs, this value refers to the sum of the wall clock time consumed in each slot.
UsedTotalCPUTime	UInt64	0..1	s	The total CPU time consumed so far by the job. In case of multi-slot jobs, this value refers to the sum of the CPU time consumed in each slot.
UsedMainMemory	UInt64	0..1	MB	The physical RAM currently used by the job.
SubmissionTime	DateTime_t	0..1		The time when the job was submitted to the Computing Endpoint.
ComputingManagerSubmissionTime	DateTime_t	0..1		The time when the job was submitted to the Computing Manager (i.e., LRMS) by the Grid layer.
StartTime	DateTime_t	0..1		The time when the job entered the Computing Manager (i.e., LRMS) running state.
ComputingManagerEndTime	DateTime_t	0..1		The time when the job entered its final Computing Manager (i.e., LRMS) state.
EndTime	DateTime_t	0..1		The time when the job entered its final state as recorded by the Grid layer.
WorkingAreaEraseTime	DateTime_t	0..1		A working area is an allocated storage extent that holds the home directories of the Grid jobs; this attribute specifies the time when the dedicated working area of this job will be removed.
ProxyExpirationTime	DateTime_t	0..1		The expiration time of the Grid proxy currently associated with the job; in case of a proxy with attribute certificates having different expiration times, then this value represent the minimum expiration time among all the values.
SubmissionHost	String	0..1		The name of the host from which the job was submitted.
SubmissionClientName	String	0..1		The name of the software client which was used to submit the job.
OtherMessages	String	*		Optional job messages provided by either the Grid Layer or the Computing Manager (i.e., LRMS).
Association End		**Mult.**	**Description**	
ComputingEndpoint.ID [redefines Endpoint.ID]		0..1	A computing activity is submitted to a computing endpoint.	
ComputingShare.ID [redefines Share.ID]		0..1	A computing activity is mapped into a computing share.	
ExecutionEnvironment.ID [redefines Resource.ID]		0..1	A computing activity is executed in an execution environment.	
Inherited Association End		**Mult.**	**Description**	

Extension.Key	*	The entity MAY be extended via key-value pairs.
UserDomain.ID	0..1	An activity is managed by a user domain.
Activity.ID	*	An activity is related to zero or more activities.

In this specification, the Computing Activity may refer to simple jobs, or to elements of collections or workflows. The description of the relationships between jobs which are part of a collection or workflow may be considered in future revisions of the specification.

As regards the State attribute and the related ComputingActivityState_t type, we note that currently there is no commonly accepted state model for Grid jobs. Each production Grid middleware defines and is using its own state model. As regards the standardization process, the OGSA-BES specification defines a simple state model. The middleware providers have started to define their own extensions to the BES state model, but they differ and do not enable interoperability. Given the current scenario, we RECOMMEND to use namespaces in state model values, so that every middleware provider MAY publish the Computing Activity State according to its definition. We expect that an extension to the core BES state model common to all the middleware providers and suitable for production scenarios may be defined by a profiling activity of the BES/ JSDL/GLUE specifications.

7.13. ToStorageService

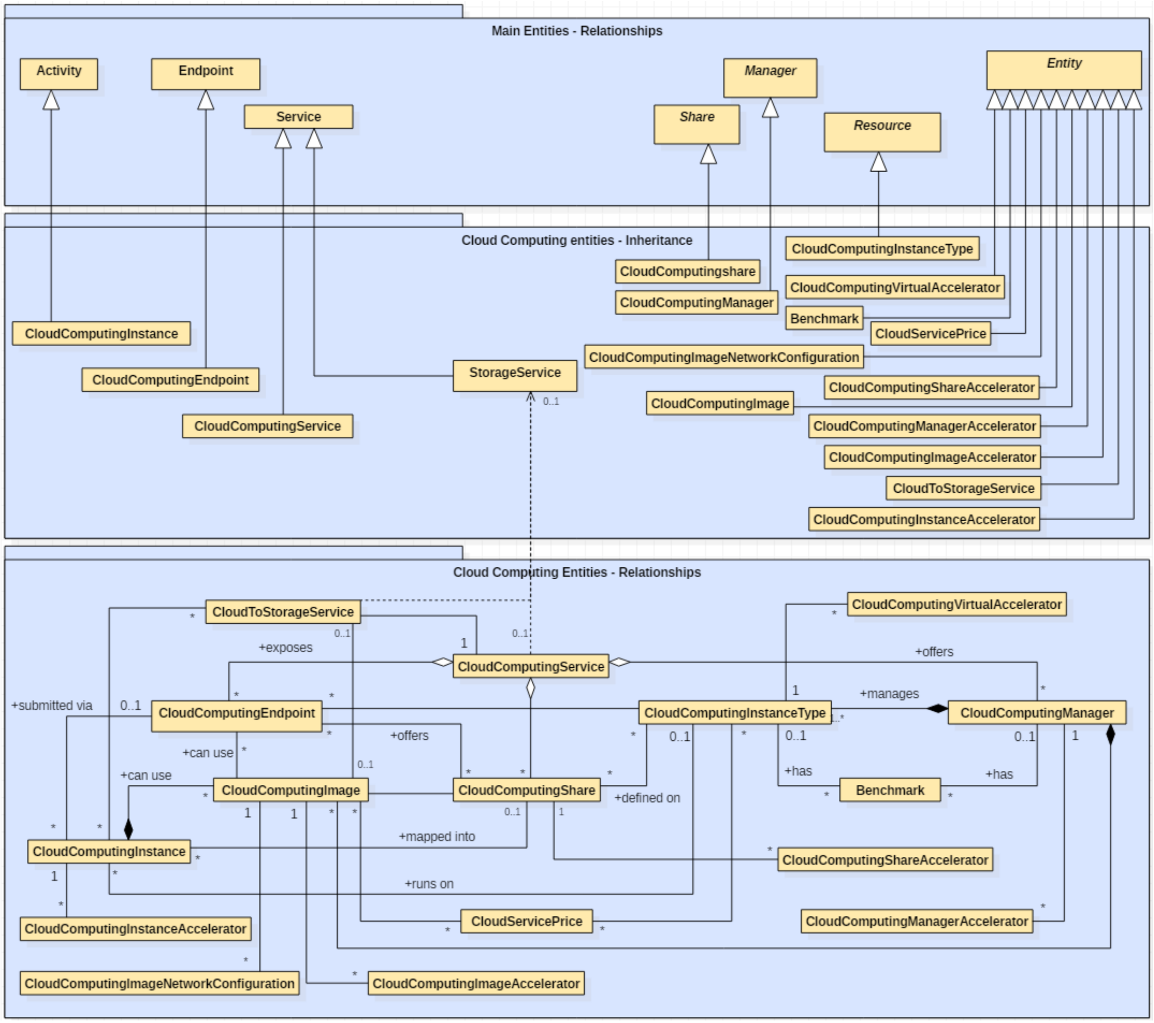
The `ToStorageService` class represents the case where a filesystem from a Storage Service is available to jobs running on a Computing Service via POSIX access, e.g. as an NFS mount. Each `ToStorageService` instance represents a single mount point. It is assumed that such mounts are available on all nodes (i.e. all Execution Environments) in the Computing Service.

Entity	Inherits from			Description
ToStorageService	Entity			The description of POSIX access via a file system technology enabling jobs running in the Computing Service to access an associated Storage Service.
Inherited Attribute	*Type*	*Mult*	*Unit*	*Description*
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed,* *the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	Type	Mult.	Unit	Description
LocalPath	String	1		The local path within the Computing Service which makes it possible to access files in the associated Storage Service (this is typically an NFS mount point).
RemotePath	String	1		The remote path in the Storage Service which is associated to the local path in the Computing Service (this is typically an NFS exported directory).
Association End		Mult.	Description	
ComputingService.ID		1	Is associated to a computing service.	
StorageService.ID		1	Is associated to a storage service.	

Inherited Association End	Mult.	Description
Extension.Key	*	The entity MAY be extended via key-value pairs.

8. Conceptual Model of the Cloud Computing Service

The conceptual model of the Cloud Infrastructure as a Service is based on the main entities and uses specializations of the `Service`, `Endpoint`, `Share`, `Manager` and `Resource`. Further cloud computing related concepts such as `Computing Image`, `Service Price` and `Benchmark` are introduced.



Main Entities - Relationships
Activity
Endpoint
Service
Manager
Share
Resource
Entity
Cloud Computing entities - Inheritance
CloudComputingInstanceType
CloudComputingshare
CloudComputingVirtualAccelerator
CloudComputingManager
Benchmark
CloudServicePrice
CloudComputingInstance
CloudComputingImageNetworkConfiguration
CloudComputingEndpoint
StorageService
0..1
CloudComputingShareAccelerator
CloudComputingImage
CloudComputingService
CloudComputingManagerAccelerator
CloudComputingImageAccelerator
CloudToStorageService
CloudComputingInstanceAccelerator
Cloud Computing Entities - Relationships
CloudToStorageService
CloudComputingVirtualAccelerator
+exposes
+offers
CloudComputingService
+submitted via
CloudComputingEndpoint
+manages
CloudComputingInstanceType
CloudComputingManager
+offers
+can use
+can use
+has
+has
CloudComputingImage
CloudComputingShare
Benchmark
+defined on
+mapped into
CloudComputingInstance
CloudComputingShareAccelerator
+runs on
CloudComputingInstanceAccelerator
CloudServicePrice
CloudComputingManagerAccelerator
CloudComputingImageNetworkConfiguration
CloudComputingImageAccelerator

Figure 3 Entities and relationships for the Cloud Compute Service conceptual model.

In this section, we extensively use the concepts of Virtual Machine (VM), Virtual Machine status (halted, pending, running, suspended), Virtual Accelerator and Cloud Middleware, these are defined as follows:

- A Virtual Machine (instance) is a compute environment that runs a software configuration (for example operating system, an application server, and applications) from a given Virtual Machine image. Every VM is a fully functioning virtual computer which can be accessed via the network. The VM has a given set of virtual CPU, RAM and disk resources. The VM has usually one or more virtual network interfaces, to which are assigned public or private IPs.

- A Virtual Machine is in Running state when the VM is actively consuming system resources in terms of RAM, CPU, disk and network. Some of the physical resources may be shared with other VMs or reserved for private VM usage.
- A Virtual Machine is in Suspended state when the VM is not running, but it still has resources reserved on the system. A VM in suspended state usually consumes only disk space for the OS, and optionally additional disk space for RAM snapshot.
- A Virtual Machine is in Pending state when the VM is in the process of gathering resources from the system (ex. acquiring VM OS disk, CPU resources, initializing system). Machines in Pending state uses system resources but are not yet available for users to access.
- A Virtual Machine is in Halted state when the VM has uses no resources in the system, but its template and configuration is still stored into the system (so the machine may be started again, but with a clean configuration).
- A Virtual Machine can be equipped with one or more Virtual Accelerators. A Virtual Accelerator is defined as any kind of computing device that is provided by the virtualization capability of the system to the Virtual Machine.
- A Cloud Middleware is a piece of computer software that leverages on virtualization capabilities to provide Virtual Machines on-demand to final users. The Cloud Middleware may provide not only virtual servers (namely Infrastructure as a Service feature), but also storage (Storage as a Service) and other rich services (Platform as a Service, etc…).

Throughout the specification, we also use the concept of Cloud Storage extent to mean the capabilities and management of the various media that exist to store data and allow data retrieval.

In the model, the Cloud service price is represented via separated `CloudServicePrice` entities associated to single accounted resources (eg. CPU, Memory, Disk, Network IN/OUT, Software Licensing). Each resource price is calculated on consumption or fixed fee basis and targeted to a give user base (eg. commercial, no-profit organizations, research). The total price for a `CloudComputingInstance` can be obtained by adding all the price elements from the associated `CloudComputingImage` and `CloudComputingInstanceType`.

A Cloud Computing service relates directly to a Cloud Infrastructure-as-a-Service (IaaS) system, which allows the user to run on-demand Virtual Appliances for computing purposes. For different Cloud computing services such as Platform-as-a-Service and Software-as-a-Service, the generic Grid platform computing model (GLUE2 Computing entities), bed in Chapter 7, may be a better fit.

8.1. CloudComputingService

The `CloudComputingService` class is a specialization of the `Service` class for a service offering Cloud Infrastructure as a Service computational capacity. The `CloudComputingService` entity is the main logical unit, and aggregation point for several entities together modeling a computing infrastructure capability in a Cloud system. A `CloudComputingService` is capable of executing `CloudComputingInstance` on its associated resources. The resources behind the `CloudComputingService` are described via the `CloudComputingManager`, `CloudComputingInstanceType`, `CloudComputingImage` and `Benchmark` entities. The governing policies and status of the resources are given by the `CloudComputingShare` elements. The `CloudComputingInstance` of a `CloudComputingService` are submitted and controlled via a `CloudComputingEndpoint`.

Entity	Inerits from	Description
CloudComputingService	Service	An abstracted, logical view of software and hardware components that participate in the creation of a computational capacity in a Cloud environment, in form of Cloud Virtual Machines instances. A Cloud Computing Service exposes zero or more Cloud Computing Endpoints having well-defined interfaces, zero or more Cloud Computing Shares and zero or more Cloud Computing Managers.

		The computing service is autonomous and denotes a weak aggregation among Computing Endpoints, the underlying Computing Managers and the defined Computing Shares. The Computing Service enables the identification of the whole set of entities providing the computing functionality with a persistent name.		
Inherited Attribute	Type	Mult	Unit	Description
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed, the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Capability	*Capability_t*	***		*The provided capability according to the Open Grid Service Architecture (OGSA) architecture [OGF-GFD80] (this is the union of all values assigned to the capability attribute of the endpoints part of this service)*
Type	*ServiceType_t*	*1*		*The type of service according to a namespace-based classification. Examples are org.openstack or org.opennebula*
QualityLevel	*QualityLevel_t*	*1*		*Maturity of the service in terms of quality of the software components*
StatusInfo	*URI*	***		*Web page providing additional information like monitoring aspects*
Complexity	*String*	*0..1*		*Human-readable summary description of the complexity in terms of the number of endpoint types, shares and resources. The syntax should be: endpointType=X, share=Y, resource=Z.*
Attribute	Type	Mult	Unit	Desciption
TotalVM	UInt32	0..1		Total number of VM known to the system (the sum of RunningVM, PendingVM, SuspendedVM and HaltedVM)
RunningVM	UInt32	0..1		The number of VM in Running state (VMs actively consuming the system resources)
PendingVM	UInt32	0..1		The number of VM in Pending state (VM in preparation to be running on the system)
SuspendedVM	UInt32	0..1		The number of VM in Suspended state (VMs not running but with reserved resources on the system)
HaltedVM	UInt32	0..1		The number of VM in Halted state (VMs not running on the system with no resources reserved)
AUP	URI	0..1		Link to the service Acceptable User Policy (AUP) or Terms and Conditions for the usage of the service. This shall be in URL format.
Association End	Mult.			Description
CloudComputingEndpoint.ID	*			A CloudComputingService is associated with zero or more endpoints (interfaces)
CloudComputingShare.ID	*			A CloudComputingService offers zero or more computing shares.
CloudComputingManager.ID	*			A CloudComputingService offers zero or more computing manager.
Inherited Association End	Mult.			Description
Extension.Key	*			The entity MAY be extended via key-value pairs.
Contact.ID	*			A Cloud computing service has zero or more contacts.
Location.ID	0..1			A Cloud computing service is primarily located at a location.
Service.ID	*			A Cloud computing service is related to zero or more services.

A simple `CloudComputingService` is formed by a `CloudComputingEndpoint` exposing an interface for VM instantiation and control. The `CloudComputingService` always aggregates `CloudComputingEndpoints`, `CloudComputingShares`, `CloudComputingManagers`, `CloudComputingImage` and `CloudComputingInstanceType` forming a connected set. In other words, `Endpoint` A exposing `InstanceType` A and `Image` A served by `Manager` A via `Share` A and `Endpoint` B exposing `InstanceType` B and `Image` B served by `Manager` B via `Share` B form two different `Computing Services`. On the other hand, `Endpoint` A exposing `InstanceType` A and `Image` A served by `Manager` A via `Share` A and `Endpoint` B exposing `InstanceType` A and `Image` A served by `Manager` A via `Share` B form a single `Computing Service`.

8.2. CloudComputingEndpoint

The `CloudComputingEndpoint` is a specialization of the `Endpoint` class for a service possessing cloud Infrastructure-as-a-Service capability. The class represents an endpoint which is used to create, control and monitor Cloud computing activities. The specific information concerns service status and interface capabilities. This class provides attributes that MAY be used to publish summary information about VM instantiated via a particular Endpoint. Such attributes are optional and may not always be measurable (e.g., in the case of a stateless Endpoint which does not keep information about the VM instantiated through it).

Entity	Inherits from			Description
CloudComputingEndpoint	Endpoint			A network Endpoint for creating, monitoring, and controlling computational Cloud Activities called Virtual Machines instances. It MAY also be used to expose complementary capabilities (e.g., resource reservation, attached block storage, VM image manipulation).
Inherited Attribute	**Type**	**Mult**	**Unit**	**Description**
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed, the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
URL	*URI*	*1*		*Network location of the endpoint to contact the related service*
Capability	*Capability_t*	***		*The provided capability according to the OGSA architecture*
Technology	*EndpointTechnology_t*	*0..1*		*Technology used to implement the endpoint*
InterfaceName	*InterfaceName_t*	*1*		*Identification of the interface*
InterfaceVersion	*String*	*0..**		*Version of the interface*
InterfaceExtension	*URI*	***		*Identification of an extension to the interface*
WSDL	*URI*	***		*URL of the WSDL document describing the offered interface (applies to Web Services endpoint)*
SupportedProfile	*URI*	***		*URI identifying a supported profile*
Semantics	*URI*	***		*URI of a document providing a human-readable description of the semantics of the endpoint functionalities*

Implementor	*String*	*0..1*		*Main organization implementing this software component*
ImplementationName	*String*	*0..1*		*Name of the implementation*
ImplementationVersion	*String*	*0..1*		*Version of the implementation (e.g., major version.minor version.patch version)*
QualityLevel	*QualityLevel_t*	*1*		*Maturity of the endpoint in terms of quality of the software components*
HealthState	*EndpointHealthState_t*	*1*		*A state representing the health of the endpoint in terms of its capability of properly delivering the functionalities*
HealthStateInfo	*String*	*0..1*		*Textual explanation of the state endpoint*
ServingState	*ServingState_t*	*1*		*A state specifying if the endpoint is accepting new requests and if it is serving the already accepted requests*
StartTime	*DateTime_t*	*0..1*		*The timestamp for the start time of the endpoint*
Authentication	*EndpointAuthentication_t*	*0..1*		*Name of the authentication method supported by the endpoint.*
IssuerCA	*DN_t*	*0..1*		*Distinguished name of Certification Authority issuing the certificate for the endpoint*
TrustedCA	*DN_t*	***		*Distinguished name of the trusted Certification Authority (CA), i.e., certificates issued by the CA are accepted for the authentication process*
DowntimeAnnounce	*DateTime_t*	*0..1*		*The timestamp for the announcement of the next scheduled downtime*
DowntimeStart	*DateTime_t*	*0..1*		*The starting timestamp of the next scheduled downtime*
DowntimeEnd	*DateTime_t*	*0..1*		*The ending timestamp of the next scheduled downtime*
DowntimeInfo	*String*	*0..1*		*Description of the next scheduled downtime*

Association End	Mult.	Description
CloudComputingService.ID [redefines Service.ID]	1	A Cloud endpoint is part of a Cloud Computing Service.
CloudComputingShare.ID [redefines Share.ID]	*	A Cloud endpoint MAY pass activities to zero or more Cloud computing shares.
CloudComputingInstance.ID [redefines Activity.ID]	*	An Cloud endpoint has accepted and is managing zero or more Cloud Activities.

Inherited Association End	Mult.	Description
Extension.Key	*	The entity MAY be extended via key-value pairs.
AccessPolicy.ID	*	A computing endpoint has assocated zero or more AccessPolicies.

8.3. CloudComputingShare

The `CloudComputingShare` class is the specialization of the main `Share` class for cloud Infrastructure-as-a-Service. A `CloudComputingShare` is a high-level concept introduced to model a utilization target for a pool of resources, sometimes referred as Zones or Sites, defined by a homogeneous set of configuration parameters and characterized by single status information. A `CloudComputingShare` carries information about "policies" (limits) defined over all or a subset of resources and describes their dynamic status (load).

The `CloudComputingShare` stores also a set of `CloudComputingImage` and `CloudComputingInstanceType`, which are used to define respectively the virtual OS and the virtual hardware resources of the `CloudComputingInstance` running on the share. Such virtual OS and hardware resources are provided by the Share with a given Service Level Agreement (SLA). In case of the same `CloudComputingInstanceType` and `CloudComputingImage` are offered under different SLAs, multiple `CloudComputingShare`s shall be created, one for each SLA.

Entity	Inherits from	Description

CloudComputingShare	Share			A utilization target for a set of Cloud Computing Instance Types and Cloud Computing Images, defined by a set of homogeneous configuration parameters and characterized by single status information.
Inherited Attribute	**Type**	**Mult**	**Unit**	**Description**
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed, the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Description	*String*	*0..1*		*Description of this share*
Attribute	**Type**	**Mult.**	**Unit**	**Description**
TotalVM	UInt32	0..1		Total number of VM known to this computing share (the sum of RunningVM, PendingVM, SuspendedVM, HaltedVM)
RunningVM	UInt32	0..1		The number of VM running into this computing share
PendingVM	UInt32	0..1		The number of VM in Pending state (VM in preparation to be running on the system)
SuspendedVM	UInt32	0..1		The number of VM in suspended state (VMs not running but with reserved resources on this computing share)
HaltedVM	UInt32	0..1		The number of VM in Halted state (VMs not running on the system with no resources reserved on this computing share)
MaxVM	UInt32	0..1		The maximum number of VM instances that can run on this share
InstanceMaxCPU	UInt32	0..1		The maximum number of Virtual CPU who can be assigned to a single VM for the VM in this share. With virtual CPU it is intended the CPU seen by the VM OS, not the physical host CPU assigned to the VM.
InstanceMaxRAM	UInt32	0..1	MB	The maximum value (in MB) of virtual RAM memory who can be assigned to a single VM for the VM in this share. With virtual RAM memory it is intended the amount of RAM seen by the VM OS, not the physical RAM dedicated to the VM
NetworkInfo	NetworkInfo_t	*		The type of internal network connection available among the managed Hosts. If many values are published then the various types of network MAY be available only within subsets of the Hosts; the Hosts properties SHOULD publish this information.
DefaultNetworkType	NetworkType_t	0..1		The default network type that will be setup for an instance (e.g. public, private, private_only…)
PublicNetworkName	String	0..1		The name of the public network if any.
SLA	String	0..1		Service Level Agreement for the VMs under this share. This can be an URL to the SLA document or a keyword representing the SLA itself (eg. 99.99% availability, best effort, etc…)
ProjectID	String	0..1		The native identifier of the corresponding local project to be used for this share (e.g. used by API users to know what is the project_id for OpenStack)
Association End		**Mult.**	**Description**	
CloudComputingEndpoint.ID [redefines Endpoint.ID]		*	A Cloud computing share MAY be consumed via one or more computing endpoints.	
CloudComputingInstanceType.ID [redefines Resource.ID]		*	A Cloud computing share is defined on one or more computing resources.	

CloudComputingService.ID [redefines Service.ID]	1	A Cloud computing share participates in a computing service.
CloudComputingInstance.ID [redefines Activity.ID]	*	A Cloud computing share is being consumed by zero or more computing activities.
CloudComputingImage.ID	*	A Cloud computing share provides zero or more VM Image templates
CloudToStorageService.ID	*	Link to the storage share used to store instances templates, VM images and/or attached disks
CloudComputingShareAccelerator.ID	*	A Cloud computing share provides zero or more sets of information about the usage level of virtual accelerator devices.
Inherited Association End	**Mult.**	**Description**
Extension.Key	*	The entity MAY be extended via key-value pairs.
MappingPolicy.ID	*	A share has zero or more mapping policies.

8.4. CloudComputingShareAccelerator

The CloudComputingShareAccelerator contains all the information about the usage level of the virtual accelerator device bound to the cloud computing share.

Entity	Inherits from			Description
CloudComputingShareAccelerator	Entity			The usage level of the virtual accelerator device for a given cloud computing share
Inherited Attribute	**Type**	**Mult.**	**Unit**	**Description**
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed, the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	*		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	**Type**	**Mult.**	**Unit**	**Description**
Type	*AccType_t*	1		The virtual accelerator architecture type.
MaxNumber	*UInt32*	0..1		The maximum number of virtual accelerators that can be assigned to a single VM for any VM in this share.
Association End		**Mult.**	**Description**	
CloudComputingShare.ID		1	A set of virtual accelerator information is related to a cloud computing share.	
Inherited Association End		**Mult.**	**Description**	
Extension.Key		*	The entity MAY be extended via key-value pairs.	

8.5. CloudComputingManager

The `CloudComputingManager` class is a specialization of the `Manager` class for the computational capability (Virtual Machines) manager. The `CloudComputingManager` is responsible for the local control of resources. The `CloudComputingManager` layer may be not exposed directly to external clients or to the Virtual Machines themselves.

The Virtual Machine manager, also known as Cloud Middleware, normally uses a hypervisor, a piece of software, firmware or hardware which creates, runs and manages Virtual Machines or possibly containers. A Cloud Computing Service will usually have only one Cloud Computing Manager, but MAY have more. The class provides aggregated information on controlled resources, limits and also describes local storage extents accessible to the Virtual Machines.

Entity	Inherits from	Description

CloudComputingManager	Manager			A software component locally managing one or more Cloud Instance Type virtual environments. It MAY also describe aggregated information about the managed resources. The Cloud Computing Manager is also known as Cloud Middleware.
Inherited Attribute	Type	Mult	Unit	Description
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed, the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
ProductName	*String*	*1*		*Name of the software product adopted as manager*
ProductVersion	*String*	*0..1*		*Version of the software product adopted as manager*
Attribute	Type	Mult.	Unit	Description
HypervisorName	String	0..1		Name of the underlying hypervisor that creates, runs and manages Virtual Machines.
HypervisorVersion	String	0..1		Version of the hypervisor.
TotalCPUs	UInt32	0..1	Ph.CPU	The total number of physical CPUs cores accessible via any of the available Endpoints and managed by this Cloud Compute Manager. This value SHOULD represent the total installed capacity, i.e. including resources which are temporarily unavailable.
TotalRAM	UInt32	0..1	MB	The total amount of RAM accessible via any of the available Endpoints and managed by this Cloud Compute Manager. This value SHOULD represent the total installed capacity, i.e. including resources which are temporarily unavailable.
InstanceMaxCPU	UInt32	0..1		The maximum number of Virtual CPU who can be assigned to a single VM. (with virtual CPU it is intended the CPU cores as seen by the VM OS)
InstanceMinCPU	UInt32	0..1		The minimum number of Virtual CPU who can be assigned to a single VM (with virtual CPU it is intended the CPU cores as seen by the VM OS)
InstanceMaxRAM	UInt32	0..1	MB	The maximum value (in MB) of virtual RAM memory who can be assigned to a single VM (with virtual RAM memory it is intended the amount of RAM seen by the VM OS, not the phisical RAM dedicated to the VM)
InstanceMinRAM	UInt32	0..1	MB	The minimum value (in MB) of virtual RAM memory who can be assigned to a single VM (with virtual RAM memory it is intended the amount of RAM seen by the VM OS, not the phisical RAM dedicated to the VM)

InstanceMaxDedicatedRAM	UInt32	0..1	MB	The maximum value (in MB) of virtual RAM memory who can be dedicated to a VM (i.e. physical host memory, not shared of swapped)
InstanceMinDedicatedRAM	UInt32	0..1	MB	The minimum value (in MB) of virtual RAM memory who can is dedicated to a VM (i.e. physical host memory, not shared of swapped)
NetworkVirtualizationType	NetVirtualizationT_t	*		The type of network virtualization performed by the Cloud Computing Manager to segregate VMs VLANs (ex. none, vSwitch, ebtables, etc…).
CPUVirtualizationType	CPUVirtualizationT_t	*		The type of CPU virtualization (ex. full/paravirtualization/hardware assisted)
VirtualDiskFormat	DiskVirtualizationT_t	*		The format of virtual disk images supported (ex. qcow2, raw, vmdk)
Failover	ExtendedBoolean_t	0..1		Failover is the automatic transition of the VM to a secondary machine or server upon failure of the primary component.
LiveMigration	ExtendedBoolean_t	0..1		If true the Cloud Computing Manager allows to move the virtual machine from one physical host to another without powering down the system
VMBackupRestore	ExtendedBoolean_t	0..1		If true the Cloud Computing Manager allows to backup and restore the virtual machines. This is a static value and does not ensure the availability of the storage for the backup

Association End	Mult.	Description
CloudComputingService.ID [redefines Service.ID]	1	A cloud computing manager participates in a computing service.
CloudComputingInstanceType.ID [redefines Resource.ID]	*	A cloud computing manager manages one or more cloud computing instance type..
CloudComputingImage.ID	*	A cloud computing manager manages one or more cloud computing image
Benchmark.ID	*	A cloud computing manager has zero or more associated benchmarks. This benchmarks are referred to the virtual resources (RAM, CPU, disk, network) provided to the VMs
CloudComputingManagerAccelerator.ID	*	A cloud computing manager controls zero or more virtual accelerator devices.

Inherited Association End	Mult.	Description
Extension.Key	*	The entity MAY be extended via key-value pairs.

8.6. CloudComputingManagerAccelerator

The CloudComputingManagerAccelerator contains all the information about the virtual accelerator device available for a given cloud computing manager.

Entity	Inherits from	Description
CloudComputingManager Accelerator	Entity	The set of information about the virtual accelerator device provided by the cloud computing manager.

Inherited Attribute	Type	Mult.	Unit	Description
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed,* *the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*

OtherInfo	*String*	*		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	Type	Mult.	Unit	Description
Type	*AccType_t*	1		The virtual accelerator architecture type.
TotalNumber	*UInt32*	0..1		The total number of physical Accelerator cards accessible through any of the available Endpoints and managed by this Cloud Compute Manager. This value SHOULD represent the total installed capacity, i.e. including resources which are temporarily unavailable.
MaxNumber	*UInt32*	0..1		The maximum number of virtual accelerators that can be assigned to a single VM
MinNumber	*UInt32*	0..1		The minimum number of virtual accelerators that can be assigned to a single VM
Association End		Mult.	Description	
CloudComputingManager.ID		1	A set of virtual accelerator information is related to a cloud computing share.	
Inherited Association End		Mult.	Description	
Extension.Key		*	The entity MAY be extended via key-value pairs.	

8.7. CloudComputingInstanceType

The `CloudComputingInstanceType` class describes the hardware environment of the VM, i.e. the amount of RAM, CPU, disk and network resources the VM OS will see and manage. The resources provided to the VM are virtual resources, usually shared with other VMs running in the same infrastructure. The performances of the provided resources are specified via the Benchmarks associated to the Instance Type.

Entity	Inherits from			Description
CloudComputingInstanceType	Resource			A type of environment available to the CloudComputingManager for running a VM in a ComputingService via a Computing Endpoint; the type of environment is described in terms of hardware, operating system and network characteristics.
Inherited Attribute	Type	Mult.	Unit	Description
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed, the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	*		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	Type	Mult.	Unit	Description
TemplateID	String	1		Reference to this particular template to be used during instantiation of a VM via the Endpoint.
MarketplaceURL	URI	*		Reference to one or more marketplaces which stores the metadata of this resource template. Reference is the URL of the resource in the marketplace.
Platform	Platform_t	1		The platform architecture provided to the virtual machine (ex. i386, x86_64)
CPU	UInt32	1		Number of virtual cores provided to the virtual machine (this is the number of core the machine OS will see)
RAM	UInt32	1	MB	Virtual RAM memory provided to the virtual machine (this is the total wuantity of RAM the machine OS will see)
Disk	UInt32	0..1	GB	Size of the disk associated to the OS image. If this attribute is omitted, the OS disk size will be the one specified by the CloudComputingImage entity,

				otherwise the CloudComputingImage OS disk will be extended to this value.
EphemeralStorage	UInt32	0..1	GB	Amount of Ephemeral storage associated to the VM. This is temporary storage which is deleted after the VM closure and is represented as a new resource.
NetworkIn	ExtendedBoolean_t	0..1		True if direct inbound network connectivity is available to the OS, even if limited, e.g. by firewall rules.
NetworkOut	ExtendedBoolean_t	0..1		True if direct outbound network connectivity is available to the OS, even if limited, e.g. by firewall rules.
NetworkPortsIn	NetworkConfiguration Port_t	*		The allowed inbound external connectivity ports (if not specified, all ports are allowed)
NetworkPortsOut	NetworkConfiguration Port_t	*		The allowed outbound external connectivity ports (if not specified, all ports are allowed)
NetworkInfo	NetworkInfo_t	*		The type of internal network connection available to the OS.
Association End		**Mult.**	**Description**	
CloudComputingManager.ID [redefines Manager.ID]		1	Cloud Computing Instance Type is managed by a Cloud computing manager.	
CloudComputingShare.ID [redefines Share.ID]		*	Cloud Computing Instance Type is served by a set of computing shares.	
CloudComputingInstance.ID [redefines Activity.ID]		*	Zero or more cloud computing instances runs this Cloud Computing Instance Type.	
CloudComputingEndpoint.ID		*	Cloud Computing Instance Type is available on a set of Cloud Computing Endpoints.	
CloudComputingVirtualAccelerator.ID		*	A cloud computing instance type provides zero or more virtual accelerator devices.	
CloudServicePrice.ID		*	The price metric associated to the resources provided by this template. It contains a different metric for each resource (Computing, Memory, Network IN/OUT)	
Inherited Association End		**Mult.**	**Description**	
Extension.Key		*	The entity MAY be extended via key-value pairs.	

The associated `CloudServicePrice` entities define the price for the entire template or separately for each one of the resources (eg. CPU, Memory, Disk, Network IN/OUT) provided by the infrastructure. Price element associated to the `CloudComputingInstanceType` contributes separately to the final price of the VM, together with the other price elements associated to the `CloudComputingImage`.

8.8. CloudComputingVirtualAccelerator

The `CloudComputingVirtualAccelerator` is an entity used to describe a set of homogeneous virtual accelerator devices. Generally a virtual accelerator device corresponds to physical one installed on the host. A cloud computing instance may be associated with one or more virtual accelerators.

Entity	Inherits from			Description
CloudComputingVirtualAccelerator	Entity			Description of the accelerator device
Inherited Attribute	**Type**	**Mult.**	**Unit**	**Description**
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed,* *the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-*

				separated tags, (name, value) pair are all examples of valid syntax
Attribute	Type	Mult.	Unit	Description
Type	AccType_t	1		The type of virtual accelerator device.
Number	UInt32	1		The number of virtual accelerators provided to the virtual machine (usually this is the number of cards the machine OS will see)
Vendor	String	0..1		The name of the virtual accelerator vendor provided to the virtual machine. Free format, but it SHOULD correspond to the name by which the vendor is generally known.
Model	String	0..1		The name of the virtual accelerator model, as defined by the vendor, provided to the virtual machine
Version	String	0..1		The specific version of the virtual accelerator model, as defined by the vendor, provided to the virtual machine.
ClockSpeed	UInt32	0..1	MHz	The nominal clock speed of the virtual accelerator, provided to the virtual machine.
Memory	UInt32	0..1	MB	The nominal memory size of the virtual accelerator, provided to the virtual machine.
ComputeCapability	String	*		The reference, an ID or tag, representing the set of features supported by a virtual accelerator, as declared by the vendor
VirtualizationType	VirtType_t	0..1		The virtualization mode adopted for creating the virtual accelerator device.
Association End		Mult.	Description	
CloudComputingInstanceType.ID		1	A virtual accelerator is associated with one CloudComputingInstanceType.	
Inherited Association End		Mult.	Description	
Extension.Key		*	The entity MAY be extended via key-value pairs.	

8.9. CloudComputingImage

The `CloudComputingImage` class describes the software environment of the VM, i.e. which OS is booting at VM startup and which pre-installed software is available on it. Each application installed on the OS is identified by a name (the InstalledSoftware attribute); these names are not defined within the schema, but SHOULD be assigned in a way which allows applications to be uniquely identified. In some deployment scenarios, the definition of namespace-based InstalledSoftware or guidelines for the generation of unique application names MAY be specified, and application repository services relying on those application names MAY be provided. This aspect is considered out of scope for the GLUE schema specification, but MAY be included in a profile document for a specific production Clouds.

The `CloudComputingImage` can be used to describe specific OS features, particular OS configuration, installed application software or special environment setups in terms of a simple tag string. In this case, the InstalledSoftware attribute should be used to publish this tag.

The properties of installed software may vary substantially, but the attributes of the class cover the most common cases, in particular for licensed software. If necessary, additional information MAY be added using the `OtherInfo` attribute and the `Extension` class.

The OS template may require a certain amount of resources (CPU, RAM and GPU) to run. These requirements are specified in terms of minimum and recommended requirements, which will lead the user to the proper selection of virtual resources needed by the VM.

Entity	Inherits from	Description
CloudComputingImage	Entity	A description of installed OS and applications or OS environment characteristics and configuration available for VM instantiation.

Inherited Attribute	Type	Mult.	Unit	Description
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed,* *the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	Type	Mult.	Unit	Description
TemplateID	String	1		Reference to this particular template to be used during instantiation of a VM via the Endpoint.
MarketplaceURL	URI	*		Reference to one or more marketplaces which stores the metadata of this instance. Reference is the URL of the resource in the marketplace.
OSPlatform	Platform_t	1		The platform architecture to which the OS belongs (ex. i386, x86_64)
OSFamily	OSFamily_t	1		The general family to which the OS belongs.
OSName	OSName_t	0..1		The specific name of the OS.
OSVersion	String	0..1		The version of the OS, as defined by the vendor.
DiskSize	UInt32	1	GB	Size of the OS disk image in GB.
RecommendedCPU	UInt32	0..1		Number of virtual CPU cores recommended to run the image (this is a recommended value, actual number of cores will depend on the selected CloudComputeInstanceType)
RecommendedRAM	UInt32	0..1	MB	Virtual RAM memory recommended to run the image (this is a recommended value, the actual RAM value will depend on the selected CloudComputeInstanceType)
MinCPU	UInt32	0..1		Minimum number of virtual CPU cores required to run the image (the actual number of cores will depend on the selected CloudComputeInstanceType)
MinRAM	UInt32	0..1	MB	Minimum virtual RAM memory required to run the image (the actual RAM value will depend on the selected CloudComputeInstanceType)
AccessInfo	HostAccessInfo_t	1		Information about user access to the VM. Can be: credentials injected during contextualization, pre-defined username/password, pre-defined RSA key
ContextualizationName	ContextualizationName_t	0..1		Supported contextualization mechanism (if any)
ContextualizationVersion	String	*		Supported contextualization mechanism versions
DefaultUsername	String	0..1		Pre-defined username to access the VM (if AccessInfo specify pre-defined credentials)
DefaultPassword	String	0..1		Pre-defined password (or RSA private key) to access the CM (if AccessInfo specify pre-defined credentials)
InstalledSoftware	String	*		Custom software installed on the instance.
Description	String	0..1		Description of the image.
Version	String	0..1		Version of the image.
Association End		Mult.	Description	

CloudComputingManager.ID [redefines Manager.ID]	1	Cloud Computing Image is managed by a Cloud computing manager.
CloudComputingShare.ID	1..*	An OS template is available to one or more computing shares
CloudComputingInstance.ID	*	An OS template is used by one or more computing activities
CloudComputingEndpoint.ID	*	An OS template is available on a set of Cloud Computing Endpoints.
CloudServicePrice.ID	*	The price metric associated to the resources provided by this template. It contains a different metric for each resource (OS License, Application license, etc…)
CloudToStorageService.ID	0..1	Link to the OS disk location in the storage service.
`CloudComputingImageNetworkTraffic.ID`	*	An image may contain information about multiple NetworkTraffic objects.
Inherited Association End	**Mult.**	**Description**
Extension.Key	*	The entity MAY be extended via key-value pairs.

The price item linked to this entity represent a single price voice of the final bill, usually related to OS or applicantion licensing price. The linked price values need to be added to the prices in the `CloudComputingInstanceType` to determinate the final price associated to an active instance.

The OS disk size specified in the `CloudComputingImage` is the minimum disk size who need to be provided by the `CloudComputingInstanceType` for a VM to be instantiated correctly. If the `CloudComputingInstanceType` has no OS disk size associated, the VM OS disk size will be the one specified by the `CloudComputingImage`, otherwise, the VM OS disk will be enlarged to the size specified by the `CloudComputingInstanceType`.

8.10. CloudComputingImageNetworkConfiguration

The `CloudComputingImageNetworkConfiguration` contains information about expected network usage, related to a single or a set of ports and a network address in CIDR notation of a cloud computing image. There might be zero, one or more objects for each computing image.

Entity	Inherits from			Description
CloudComputingImageNetworkConfiguration	Entity			The set of information about the network configuration of a cloud computing image.
Inherited Attribute	**Type**	**Mult.**	**Unit**	**Description**
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed, the information SHOULD NOT be considered relevant*

ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	Type	Mult.	Unit	Description
Direction	NetworkConfigurationDirection_t	1		Information about traffic direction
Protocol	NetworkConfigurationProtocol_t	1		Information about network protocol
Port	NetworkConfigurationPort_t	1		Information about network port(s)
AddressRange	NetworkConfigurationAddressRange_t	1		Information about network address range
Association End		Mult.		Description
CloudComputingImage.ID		1		A NetworkConfiguration object is related to a cloud computing image.
Inherited Association End		Mult.		Description
Extension.Key		*		The entity MAY be extended via key-value pairs.

8.11. CloudComputingInstance

The `CloudComputingInstance` class represents a single VM (but possibly multi-VM) instance. The attributes give the instance properties and state as seen by the Cloud Computing Manager.

Entity	Inherits from			Description
CloudComputingInstance	Activity			An Activity managed by the Cloud Manager execution capability (the Computing Activity is traditionally called VM).
Inherited Attribute	*Type*	*Mult*	*Unit*	*Description*
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed, the information SHOULD NOT be considered relevant*

ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	**Type**	**Mult.**	**Unit**	**Description**
Type	CloudComputingInstanceType_t	0..1		The type of this Computing Activity.
VMID	URI	1		The VM ID as assigned by the Computing Endpoint.
LocalID	String	0..1		The local ID of the VM as assigned by the Cloud Computing Manager.
State	CloudComputingInstanceState_t	1..*		The state of the VM; different state models are allowed; a state for each model is allowed provided that it has a different namespace prefix (see data type definition)
Error	String	*		Error messages as provided by the software components involved in the management of the job.
Owner	String	0..1		The identity of the VM's owner;.
LocalOwner	String	0..1		The local user name to which the VM's owner is mapped for the execution of this job.
ExecutionNode	String	*		A hostname associated to the Execution Environment instance (i.e., host) running the VM; multi-node VMs are described by several instances of this attribute.
UsedTotalCPUTime	UInt64	0..1	s	The total CPU time consumed so far by the VM. In case of multi-VM, this value refers to the sum of the CPU time consumed in each slot.
UsedMainMemory	UInt64	0..1	MB	The amount of RAM currently used by the VM.
UsedNetworkIn	UInt64	0..1	Kb	The amount of inbound network connectivity consumed so far by the VM. The value is measured in terms of Kb in input to the VM virtual interfaces.
UsedNetworkOut	UInt64	0..1	Kb	The amount of outbound network connectivity consumed so far by the VM. The value is measured in terms of Kb in output to the VM virtual interfaces.
ComputingManagerSubmissionTime	DateTime_t	0..1		The time when the VM instantiation was submitted to the Cloud Middelware by the user.
StartTime	DateTime_t	0..1		The time when the VM entered Running state.
ComputingManagerEndTime	DateTime_t	0..1		The time when the VM destroy request was submitted to the Cloud Middelware by the user.
EndTime	DateTime_t	0..1		The time when the VM entered Halted state.
SubmissionHost	String	0..1		The name of the host from which the VM was submitted.

SubmissionClientName	String	0..1		The name of the software client which was used to submit the VM.
OtherMessages	String	*		Optional job messages provided by either the Cloud Middelware or the Compute Manager.
Association End		Mult.	Description	
CloudComputingEndpoint.ID [redefines Endpoint.ID]		0..1	A Cloud computing activity is submitted to a computing endpoint.	
CloudComputingShare.ID [redefines Share.ID]		0..1	A Cloud computing activity is mapped into a computing share.	
CloudComputingInstanceType.ID [redefines Resource.ID]		0..1	A Cloud computing activity is executed in an execution environment.	
CloudToStorageService		*	Link to the attached disks location in the storage service. The OS disk is included in this list.	
CloudComputingInstanceAccelerator.ID		*	A cloud computing instance shows zero or more information about the usage level of installed virtual accelerator devices.	
Inherited Association End		Mult.	Description	
Extension.Key		*	The entity MAY be extended via key-value pairs.	
UserDomain.ID		0..1	An activity is managed by a user domain.	
Activity.ID		*	An activity is related to zero or more activities.	

In this specification, the Cloud Computing Instance may refer to a VM or to elements of collections or appliances. The description of the relationships between VMs which are part of a collection or appliance may be considered in future revisions of the specification.

8.12. CloudComputingInstanceAccelerator

The `CloudComputingInstanceAccelerator` contains information about the usage level of the virtual accelerator device handled by the cloud computing instance.

Entity	Inherits from			Description
CloudComputingInstance Accelerator	Entity			The usage level of the virtual accelerator device handled by the cloud computing instance.
Inherited Attribute	Type	Mult.	Unit	Description
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed,* *the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	Type	Mult.	Unit	Description
Type	*AccType_t*	1		The virtual accelerator architecture type.
TotalProcessingTime	*UInt64*	0..1	*s*	The total Accelerator time consumed so far by the VM. In case of multi-VM, this value refers to the sum of the Accelerator time consumed in each slot.
Association End		Mult.	Description	
CloudComputingInstance. ID		1	A set of virtual accelerator information is related to a cloud computing instance.	

Inherited Association End	Mult.	Description
Extension.Key	*	The entity MAY be extended via key-value pairs.

8.13. CloudServicePrice

The `CloudServicePrice` entity models the resources price in the cloud environment. This entity represents a single price voice of the final price for the activity. This voice is related to a given consumed resource which is specified in the attributes of the entity.

The price for the given resource is represented by a fixed price or consumption model. The fixed price is independent on the resource usage and can be billed once or multiple times during the life of the Cloud Computing Instance (ex. monthly fixed prices). The consumption price needs to be multiplied by the accounted resource consumption value (present in the Cloud Computing Instance entity) in the given consumption period. Consumption prices must be specified in the same unit as per the unit of the accounted resource.

Different costs models may be applied to different users according to the scope of the Cloud Computing Instance. For example, research usage may have different pricing respect to commercial one. The related scope for the price to apply is described in the entity attributes.

With the information provided by the Scope attribute, this entity MAY be used in alternative to `User Domain` and `Access Policy` entities, to discriminate which category of users have access to the resource. In this view, it MAY be defined by the user community that users category without associated cost entity for the service have no access to it.

Entity	Inherits from			Description
CloudServicePrice	Entity			Price information for a given Cloud service resource.
Inherited Attribute	*Type*	*Mult*	*Unit*	*Description*
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*S*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed, the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	Type	Mult.	Unit	Description
Resource	CloudResourceName_t	1		Name of the resource this price entity refers to. Can be any resource billed (CPU, Memory, Disk, Software Licenses, etc…).
Scope	ResourceScope_t	*		Usage scope required for the price to apply (eg. commercial, no-profit, research, training)
FixFee	Float32	0..1	Euro	Fixed fee to be paid for the service usage (this price is not dependent from the resource usage)
FixFeePeriod	Period_t	0..1		Billing period for the fixed price (ex. once, monthly, yearly, etc.)
ConsumptionFee	Float32	0..1	Euro/period/x	Consumption fee to be paid for the service (this price shall be specified in the same unit as per the accounted resource x)

ConsumptionFeePeriod	Period_t	0..1		Billing period for the per usage price (ex. monthly, yearly, etc.)
Association End		**Mult.**		**Description**
CloudComputingInstanceType.ID		0..*		It MAY be associated to a Computing Instance Type.
CloudComputingImage.ID		0..*		It MAY be associated to a OS template.
StorageService.ID		0..*		It MAY be associated to a Storage service.
Inherited Association End		**Mult.**		**Description**
Extension.Key		*		The entity MAY be extended via key-value pairs.

The entity can be associated to multiple `CloudComputingInstanceType` or `CloudComputingImage` or `StorageService`, but not to different class of entities at the same time.

8.14. CloudToStorageService

The `CloudToStorageService` class represents the case where a virtual disk is created into the Storage Service for VM usage. The disk may be attached to the VM (visible as a disk device by the VM OS) or available via other export protocols (NFS share, iSCSI, etc…).

The attributes of this entity refer to the link of the storage resource into the Storage System and the VM environment.

Entity	Inherits from			Description
CloudToStorageService	Entity			The description of a device access to a Virtual Disk attached to a VM, thus available in the VM as a virtual hardware device.
Inherited Attribute	***Type***	***Mult***	***Unit***	***Description***
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed,* *the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	**Type**	**Mult.**	**Unit**	**Description**
LocationID	String	0..1		Reference to this disk to be used for attaching/detaching it to a VM.
LocalPath	String	1		The link to the local storage into the VM environment (this is typically a link to a local virtual disk device)
RemotePath	String	1		The link to the storage into the remote Storage Service (this is typically a link to a virtual disk image).
Association End		**Mult.**		**Description**
CloudComputingInstance.ID		0..*		It MAY be associated to a cloud computing instance.
CloudComputingImage.ID		0..1		It MAY be associated to a OS template.
CloudComputingService.ID		1		Is associated to a cloud computing service.
StorageService.ID		1		Is associated to a storage service.
Inherited Association End		**Mult.**		**Description**
Extension.Key		*		The entity MAY be extended via key-value pairs.

The entity can be associated to multiple `CloudComputingInstance`, to a `CloudComputingImage` or to both the entities at the same time. The disk may also be temporary un-associated to any Computing entity. This is the case of data which has been detached from all the running VMs but stays available to be attached to new VMs.

9. Conceptual Model of the Storage Service

The conceptual model of the Storage Service is based on the main entities and uses specializations of the `Service`, `Endpoint`, `Share`, `Manager`, `Resource`, and `Activity` entities. Further storage-related concepts such as `Storage Service Capacity`, `Storage Share Capacity` and `Storage Access Protocol` are also introduced.

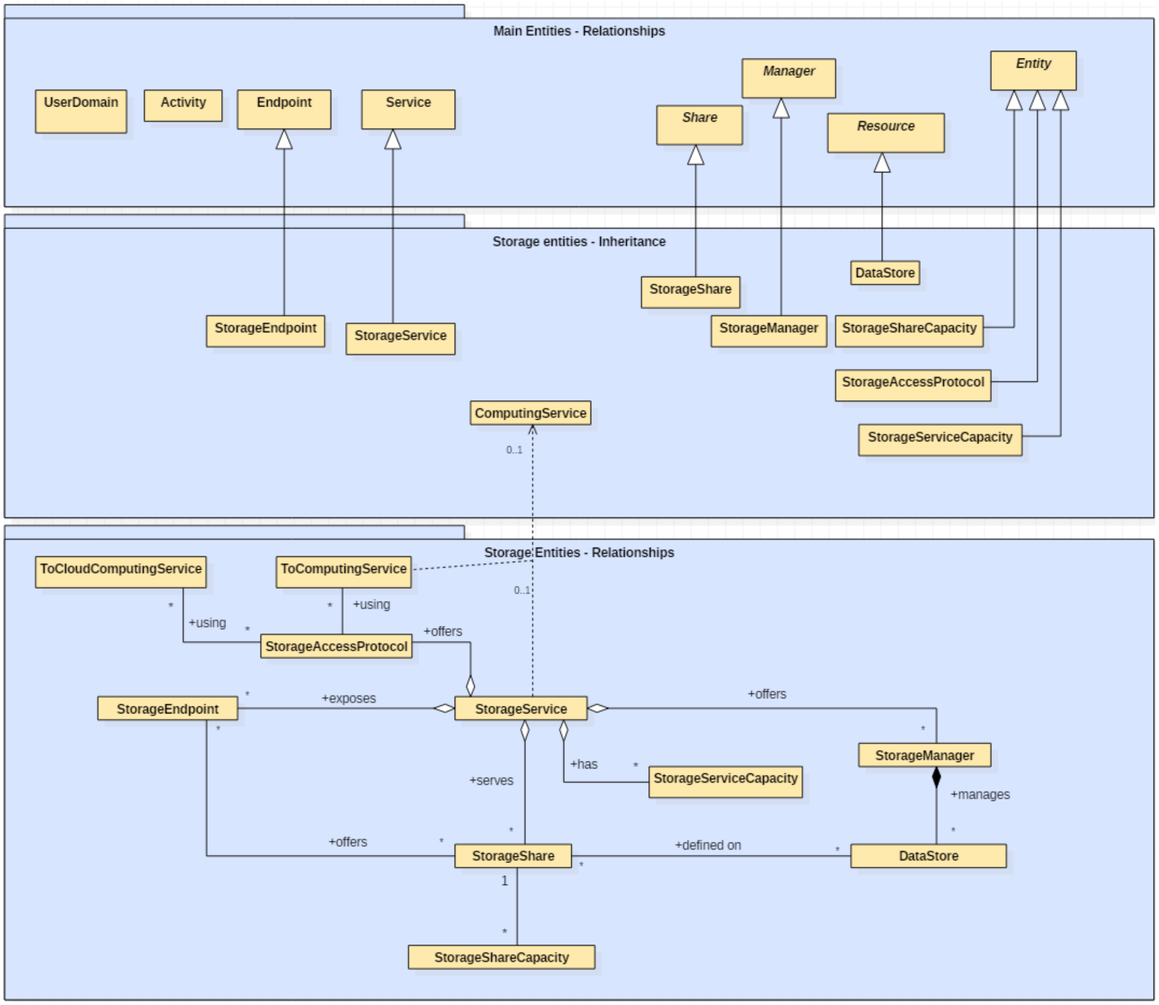


Figure 4 Entities and relationships for the Storage Service conceptual model

As explained in Section , we use the concept of storage extent to mean the capabilities and management of the various media that exist to store data and allow data retrieval.

9.1. StorageService

A `StorageService` represents a storage system, most often hosted by a single site, but possibly distributed over multiple sites. A `StorageService` makes `StorageShares` of given properties available to selected `UserDomains`, typically (not necessarily) through one or more explicitly identified `StorageEndpoints`. Data may be stored in or retrieved from `StorageShares` through one or more StorageAccessProtocols. A StorageShare is a composition of extents from one or more DataStores. StorageShares MAY overlap, i.e. map to the same underlying extent. A DataStore represents a physical device that holds data (e.g. a disk farm or a tape robot). Each DataStore is managed by a StorageManager, an instance of a particular software product identified by the ProductName and ProductVersion. StorageServiceCapacity objects summarize capacity-related information, for which details may be available associated to StorageShares and DataStores.

Entity	Inherits from			Description
StorageService	Service			An abstracted, logical view of software and hardware components that participate in the creation of a storage capability in the environment. A Storage Service exposes zero or more Endpoints having well-defined interfaces, zero or more Storage Shares and zero or more Storage Managers and the related Data Stores. The Storage Service also offers zero or more Storage Access Protocols, and provides summary information about the overall amount of storage by means of the Storage Service Capacity. The Storage Service is autonomous and denotes a weak aggregation among Storage Endpoints, Storage Shares, Storage Managers, Storage Access Protocols and Storage Service Capacities. The Storage Service enables the identification of the entire set of entities providing storage functionality with a persistent name.
Inherited Attribute	Type	Mult	Unit	Description
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed,* *the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	*		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Capability	*Capability_t*	*		*The provided capability according to the Open Grid Service Architecture (OGSA) architecture [OGF-GFD80] (this is the union of all values assigned to the capability attribute of the endpoints part of this service)*
Type	*ServiceType_t*	*1*		*The type of service according to a namespace-based classification (the namespace MAY be related to a middleware name, an organization or other concepts; org.ogf.glue is reserved for the OGF GLUE Working Group)*
QualityLevel	*QualityLevel_t*	*1*		*Maturity of the service in terms of quality of the software components*
StatusInfo	*URI*	*		*Web page providing additional information like monitoring aspects*
Complexity	*String*	*0..1*		*Human-readable summary description of the complexity in terms of the number of endpoint types, shares and resources. The syntax should be: endpointType=X, share=Y, resource=Z.*
Attribute	Type	Mult	Unit	Description
No extra properties are defined in the specialized entity.				
Association End		Mult.		Description
StorageEndpoint.ID [redefines Endpoint.ID]		*		A storage service exposes zero or more storage endpoints.
StorageShare.ID [redefines Share.ID]		*		A storage service serves zero or more storage shares.
StorageManager.ID [redefines Manager.ID]		*		A storage service provides zero or more storage managers.

StorageAccessProtocol.ID	*	A storage service offers zero or more storage access protocols.
StorageServiceCapacity.ID	*	A storage service has zero or more storage service capacities.
Inherited Association End	Mult.	Description
Extension.Key	*	The entity MAY be extended via key-value pairs.
Contact.ID	*	A service has zero or more contacts.
Location.ID	0..1	A service is primary located at a location.
Service.ID	*	A service is related to zero or more services.

The Storage Service MAY expose Storage Endpoints enabling management of or access to different types of storage extent. The usage of storage is typically constrained by policies, thus implying service differentiation. The Storage Share concept describes a portion of the managed storage extents with a homogeneous set of usage policies. The storage extents used to implement the Shares are locally managed by one or more Storage Managers, and their properties are described by Data Stores.

9.2. StorageServiceCapacity

The `StorageServiceCapacity` class summarizes capacity-related information for all the `StorageShares` and `DataStores` of a given homogeneous type. The summaries MAY be compared to the sums of the relevant `StorageShareCapacity` attributes for the `StorageShares` of the given type. Capacities of overlapping `StorageShares` MUST only be counted once. An inconsistency between a summary value and the corresponding sum of relevant attributes MAY occur if part of the capacity is not explicitly published, or if the attributes concerned could not all be exactly determined or recorded at the same time. The summaries MAY also be compared to the sums of the relevant attributes of the `DataStores` of the given type, where inconsistencies MAY arise due to similar causes.

Entity	Inherits from			Description
StorageServiceCapacity	Entity			Description of the size and usage of a homogenous storage extent; the storage extent is aggregated at the storage service level by type.
Inherited Attribute	Type	Mult	Unit	Description
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed,* *the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	Type	Mult.	Unit	Description
Type	StorageCapacity_t	1		The type of storage capacity.
TotalSize	UInt64	0..1	GB	The total amount of storage of this Type (the sum of free, used and reserved).
FreeSize	UInt64	0..1	GB	The amount of storage which is free for new data to be stored. This SHOULD include space occupied by cached copies of objects which can be deleted automatically to make room for new ones.
UsedSize	UInt64	0..1	GB	The amount of storage which is occupied by stored data. This SHOULD exclude space occupied by cached copies of objects which can

				be deleted automatically to make room for new ones.
ReservedSize	UInt64	0..1	GB	The amount of storage which is not occupied by stored data, but has been reserved for use by a specific user or group, and hence is not free for the storage of new data except in the context of that reservation.
Association End		**Mult.**	**Description**	
StorageService.ID		1	A storage service capacity is related to one storage service.	
Inherited Association End		**Mult.**	**Description**	
Extension.Key		*	The entity MAY be extended via key-value pairs.	

9.3. StorageAccessProtocol

A `StorageAccessProtocol` describes a protocol that can be used to store data in or retrieve data from `StorageShares`. The "file" protocol indicates that for `ComputingServices` given by `ToComputingService` objects the `StorageShares` are available through POSIX I/O. The mount point details are given by corresponding `ToStorageService` objects published by those `ComputingServices`. Most protocols require a negotiation between the client and a `StorageEndpoint`. For example, a `StorageEndpoint` implementing a version of the SRM protocol may be asked for a data transfer URL corresponding to a desired access protocol. An access protocol that does not require prior negotiation MAY be published as one or more `StorageEndpoints` with an InterfaceName corresponding to that protocol.

Entity	Inherits from			Description
StorageAccessProtocol	Entity			A type of protocol available to access the underlying storage extents.
Inherited Attribute	**Type**	**Mult**	**Unit**	**Description**
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed,* *the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	**Type**	**Mult.**	**Unit**	**Description**
Type	StorageAccessProtocol_t	1		An identifier for the protocol.
Version	String	1		The version of the protocol supported by the interface, as defined by the protocol specification.
MaxStreams	UInt32	0..1	stream	The maximum number of parallel network streams which can be used for a single data transfer operation using this protocol.
Association End		**Mult.**	**Description**	
StorageService.ID		1	A storage access protocol is related to one storage service.	
ToComputingService		*	A storage access protocol MAY be used by zero or more computing services.	
ToCloudComputingService		*	A storage access protocol MAY be used by zero or more cloud computing services.	
Inherited Association End		**Mult.**	**Description**	
Extension.Key		*	The entity MAY be extended via key-value pairs.	

If a type of Storage Access Protocol needs to be discoverable, then the StorageAccessProtocol class SHOULD be used to advertise it. If a certain Access Protocol has an associated URL and this URL needs to be discoverable, then the Access Protocol SHOULD be also published via the StorageEndpoint class.

9.4. StorageEndpoint

A StorageEndpoint represents a service that may be contacted by clients to manage StorageShares, to store or retrieve data or to perform other operations related to a storage system. The StorageEndpoint typically implements a storage control protocol specified by the InterfaceName, which allows for the manipulation of StorageShares and the properties of their data content. Access to StorageShares for storing or retrieving data often has to be negotiated through the given control protocol. The available access protocols MAY be published in StorageAccessProtocol objects. The StorageEndpoint interface MAY also be used to publish the endpoint(s) of an access protocol that does not require prior negotiation. The Storage Endpoint may be able to serve only a subset of the StorageShares within the StorageService, in which case that subset MAY be indicated through explicit associations with those StorageShares.

Entity	Inherits from			Description
StorageEndpoint	Endpoint			An Endpoint usable for managing Storage Shares or for accessing data stored in them; it MAY also be used to expose complementary capabilities which form part of the overall Storage Service.
Inherited Attribute	**Type**	**Mult**	**Unit**	**Description**
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed, the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
URL	*URI*	*1*		*Network location of the endpoint to contact the related service*
Capability	*Capability_t*	***		*The provided capability according to the OGSA architecture*
Technology	*EndpointTechnology_t*	*0..1*		*Technology used to implement the endpoint*
InterfaceName	*InterfaceName_t*	*1*		*Identification of the interface*
InterfaceVersion	*String*	*0..**		*Version of the interface*
InterfaceExtension	*URI*	***		*Identification of an extension to the interface*
WSDL	*URI*	***		*URL of the WSDL document describing the offered interface (applies to Web Services endpoint)*
SupportedProfile	*URI*	***		*URI identifying a supported profile*
Semantics	*URI*	***		*URI of a document providing a human-readable description of the semantics of the endpoint functionalities*
Implementor	*String*	*0..1*		*Main organization implementing this software component*
ImplementationName	*String*	*0..1*		*Name of the implementation*
ImplementationVersion	*String*	*0..1*		*Version of the implementation (e.g., major version.minor version.patch version)*

QualityLevel	*QualityLevel_t*	*1*		*Maturity of the endpoint in terms of quality of the software components*
HealthState	*EndpointHealthState_t*	*1*		*A state representing the health of the endpoint in terms of its capability of properly delivering the functionalities*
HealthStateInfo	*String*	*0..1*		*Textual explanation of the state endpoint*
ServingState	*ServingState_t*	*1*		*A state specifying if the endpoint is accepting new requests and if it is serving the already accepted requests*
StartTime	*DateTime_t*	*0..1*		*The timestamp for the start time of the endpoint*
IssuerCA	*DN_t*	*0..1*		*Distinguished name of Certification Authority issuing the certificate for the endpoint*
TrustedCA	*DN_t*	*		*Distinguished name of the trusted Certification Authority (CA), i.e., certificates issued by the CA are accepted for the authentication process*
DowntimeAnnounce	*DateTime_t*	*0..1*		*The timestamp for the announcement of the next scheduled downtime*
DowntimeStart	*DateTime_t*	*0..1*		*The starting timestamp of the next scheduled downtime*
DowntimeEnd	*DateTime_t*	*0..1*		*The ending timestamp of the next scheduled downtime*
DowntimeInfo	*String*	*0..1*		*Description of the next scheduled downtime*
Attribute	Type	Mult.	Unit	Description
No extra properties are defined in the specialized entity.				
Association End		Mult.	Description	
StorageService.ID [redefines Service.ID]		1	A storage endpoint is part of a storage service.	
StorageShare.ID [redefines Share.ID]		*	A storage endpoint MAY pass activities to zero or more storage shares.	
Inherited Association End		Mult.	Description	
Extension.Key		*	The entity MAY be extended via key-value pairs.	
AccessPolicy.ID		*	An endpoint has assocated zero or more AccessPolicies.	

9.5. StorageShare

A `StorageShare` is a composition of extents from one or more `DataStores`. `StorageShares` that overlap, i.e. share the same underlying extent, have the same SharingID, which in that case MUST neither be empty nor the reserved string "dedicated". A `DataStore` represents a physical device or set of devices that are able to hold data (e.g. a disk farm or a tape robot). A `StorageShare` need not be composed of homogeneous devices.

The AccessLatency gives the maximum latency category for a object stored in the StorageShare to be made available for reading. For example, if the `StorageShare` comprises both disk and tape storage, and data may need to be recalled from tape, the published AccessLatency is "nearline", although a given data object may in fact be immediately accessible on disk.

The RetentionPolicy indicates at a coarse granularity the probability of the `StorageShare` losing data. For example, "custodial" represents a very low probability, while "replica" indicates that the `StorageShare` is not suitable for keeping the only copy of precious data, but may be used for keeping a replica of such data.

The ExpirationMode indicates what happens to data whose lifetime has expired, if ever. The Identifier allows the `StorageShare` to be given a tag that is meaningful for the UserDomain(s) served by the `StorageShare`. For example, for version 2.2 of the SRM control protocol a `StorageShare` would represent a Space and the Identifier the corresponding SpaceTokenUserDescription. Capacity-related information is made available through `StorageShareCapacity` objects. A `StorageShare` may not be available through `StorageEndpoints` not explicitly related to the Share.

Entity	Inherits from			Description
StorageShare	Share			A utilization target for a set of extents in Data Stores, defined by a set of configuration parameters and policies and characterized by status information.
Inherited Attribute	*Type*	*Mult*	*Unit*	*Description*
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed,* *the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Description	*String*	*0..1*		*Description of this share*
Attribute	Type	Mult.	Unit	Description
ServingState	ServingState_t	1		A state specifying whether the Share is open to place new requests, and if it is currently offering any requests already present for execution.
Path	String	0..1		A default namespace where data objects are logically placed when they are stored into this Share. This will typically be used as a prefix when generating a file name under which the data object is stored.
AccessMode	AccessMode_t	0..*		An identifier for the type of access and usage allowed for this Share.
SharingID	LocalID_t	1		A local identifier common to the set of Storage Shares which use the same underlying extents, i.e. which share the same pool of storage space. (‘dedicated’ is a reserved value which means that the Storage Share extents are not shared with other Storage Shares.)
AccessLatency	AccessLatency_t	1		The maximum latency category under normal operating conditions for a data object stored in this share to be made available for reading.
RetentionPolicy	RetentionPolicy_t	*		The quality of data retention, which indicates the probability of the storage system losing a data object.
ExpirationMode	ExpirationMode_t	0..3		An attribute which indicates support for data objects with infinite and/or finite lifetimes, and what actions the storage service may take upon the expiration of a object lifetime.
DefaultLifeTime	UInt32	0..1	s	The default lifetime assigned to a new data object if no explicit lifetime is specified.
MaximumLifeTime	UInt32	0..1	s	The maximum lifetime that may be requested for a data object.
MaxObjectSize	UInt64	0..1	MB	Maximum size of a data object who can be stored in this share
MinObjectSize	UInt64	0..1	MB	Minimum size of a data object who can be stored in this share
Tag	String	0..1		An identifier defined by a User Domain which identifies a Share with a specific set of properties.
NumberOfFiles	UInt32	0..1		Optional attribute that describes the number of files stored in this StorageShare
Association End		Mult.	Description	
StorageEndpoint.ID [redefines Endpoint.ID]		*	A storage share is consumed via zero or more endpoints.	
DataStore.ID [redefines Resource.ID]		*	A storage share is defined on zero or more data stores.	

StorageService.ID [redefines Service.ID]	1	A storage share participates in a storage service.
StorageShareCapacity.ID	*	A storage share offers zero or more storage share capacities.
Inherited Association End	Mult.	Description
Extension.Key	*	The entity MAY be extended via key-value pairs.
MappingPolicy.ID	*	A share has zero or more mapping policies.

A Storage Share represents a utilization target of one or more storage extents with a set of policies which are homogeneous. If many User Domains are mapped to a Storage Share via a Mapping Policy, then they are assumed to be able to use the Share uniformly. A Storage Share MAY have many types of Storage Capacity. The usage of each type of Storage Capacity is described by the StorageShareCapacity class.

9.6. StorageShareCapacity

The `StorageShareCapacity` class provides a set of attributes related to the size of the data storage extents associated with a `StorageShare`. One `StorageShare` MAY have several associated `StorageShareCapacity` objects of different types, which may be related either to the physical nature of the storage medium or to the intended use, e.g. accounting or resource discovery. It is therefore possible that the same physical storage MAY be reported in more than one object. The size information generally relates to the values as seen by a user of the `Service`, which may not correspond directly to the size of the physical storage media which underly it. For example, disk servers may include parity disks or hot spares which are not directly visible to users.

The semantics of this class are the same as the `StorageServiceCapacity` class which represent the size of the entire `Storage Service`, but the classes are different since the relations are different. In general it cannot be assumed that the `Storage Service Capacity` is the sum of all the corresponding `Storage Share Capacities`, both because some information at the `Share` level MAY not be published, and because multiple `StorageShare` objects MAY share the same physical storage. There may also be differences in timing or accuracy in the underlying services which collect the information.

Entity	Inherits from			Description
StorageShareCapacity	Entity			A description of the size and usage of a homogenous storage extent available to a Storage Share.
Inherited Attribute	*Type*	*Mult*	*Unit*	*Description*
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed,* *the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	Type	Mult.	Unit	Description
Type	StorageCapacity_t	1		The type of storage capacity.
TotalSize	UInt64	0..1	GB	The total amount of storage of this Type (the sum of free, used and reserved).
FreeSize	UInt64	0..1	GB	The amount of storage which is free for new data to be stored. This SHOULD include space occupied by cached copies of objects which can

				be deleted automatically to make room for new ones.
UsedSize	UInt64	0..1	GB	The amount of storage which is occupied by stored data. This SHOULD exclude space occupied by cached copies of objects which can be deleted automatically to make room for new ones.
ReservedSize	UInt64	0..1	GB	The amount of storage which is not occupied by stored data, but has been reserved for use by a specific user or group, and hence is not free for the storage of new data except in the context of that reservation.
Association End		Mult.		Description
StorageShare.ID		1		A storage share capacity is related to one storage share.
Inherited Association End		Mult.		Description
Extension.Key		*		The entity MAY be extended via key-value pairs.

The Storage Share Capacity is useful to express the usage information of a homogenous storage extent allocated to a Share. Such usage information refers to use by the User Domains which are related to the Storage Share via Mapping Policies.

9.7. StorageManager

The `StorageManager` class respresents the software system which manages the data storage media. If different media, e.g. tape and disk, are managed by different software systems there MAY be multiple `StorageManager` instances for a single `StorageService`. In some systems there may be a number of layers of software, but this cannot be represented. At present no attributes are defined beyond those inherited from the `Manager` entity, i.e. the Name and Version of the software product.

Entity	Inherits from			Description
StorageManager	Manager			The primary software component locally managing one or more Data Stores. It MAY also be used to describe aggregated information about the managed resources.
Inherited Attribute	Type	Mult	Unit	Description
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed,* *the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
ProductName	*String*	*1*		*Name of the software product adopted as manager*
ProductVersion	*String*	*0..1*		*Version of the software product adopted as manager*
Attribute	Type	Mult.	Unit	Description
No extra properties are defined in the specialized entity.				
Association End		Mult.		Description
StorageService.ID [redefines Service.ID]		1		A storage manager participates in a storage service.
DataStore.ID [redefines Resource.ID]		*		A storage manager manages zero or more data stores.
Inherited Association End		Mult.		Description
Extension.Key		*		The entity MAY be extended via key-value pairs.

9.8. DataStore

The `DataStore` class represents the physical storage systems underlying the `Storage Service`. Typically there will be one `DataStore` instance for each homogeneous type of storage, e.g. tape and disk. However, multiple objects of the same Type MAY be published if the storage is segmented at a high level, e.g. if there are two separate robotic tape stores. The size information relates to the physical capacity of the storage media, which may differ from the values reported in the Capacity classes.

Entity	Inherits from			Description
DataStore	Resource			An abstract description of a sufficiently homogeneous storage device providing a storage extent, managed by a local software component (Storage Manager), part of a Storage Service, reachable via zero or more Endpoints and having zero or more Shares defined on it. A Data Store refers to a category of storage with summary information on the storage capacity.
Inherited Attribute	**Type**	**Mult.**	**Unit**	**Description**
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*S*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed, the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	**Type**	**Mult.**	**Unit**	**Description**
Type	DataStoreType_t	1		The type of storage medium.
Latency	AccessLatency_t	1		The actual latency category under normal operating conditions for a data object stored in this Data Store.
TotalSize	UInt64	0..1	GB	The total size of the storage extent within the Data Store (free plus used).
FreeSize	UInt64	0..1	GB	The amount of storage which is not currently occupied by stored data.
UsedSize	UInt64	0..1	GB	The amount of storage which is currently occupied by stored data.
Association End		**Mult.**	**Description**	
StorageManager.ID [redefines Manager.ID]		1	A data store is managed by a storage manager.	
StorageShare.ID [redefines Share.ID]		*	A data store provides capacity in terms of zero or more storage shares.	
Inherited Association End		**Mult.**	**Description**	
Extension.Key		*	The entity MAY be extended via key-value pairs.	

9.9. ToComputingService

The `ToComputingService` class describes a network connection between a `Storage Service` and a `Computing Service` which has a level of performance significantly better than the general WAN connection. It is assumed that such a connection applies to the entirety of those Services, i.e. to all Worker Nodes within the `Computing Service` and all storage within the `Storage`

Service. However, the connection MAY depend on the Access Protocol used to transfer the data. Some Access Protocols may only be available from a restricted set of Computing Services, and this may also be published using the ToComputingService class.

Entity	Inherits from			Description
ToComputingService	Entity			A description of the network link quality between a Storage Service and a computing service, and/or of a potentially dedicated access protocol that the Computing Service may use to access the Storage Service.
Inherited Attribute	**Type**	**Mult.**	**Unit**	**Description**
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed, the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	*		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	**Type**	**Mult.**	**Unit**	**Description**
NetworkInfo	NetworkInfo_t	0..1		The type of network connection available between the Storage Service and Computing Service.
Bandwidth	UInt32	0..1	Mb/s	The nominal bandwidth available between the Storage Service and Computing Service via this connection.
Association End			**Description**	
StorageAccessProtocol.ID		*	The storage service MAY be accessed via an access protocol by a certain computing service.	
ComputingService.ID		1	Is associated to a computing service.	
StorageService.ID		1	Is associated to a storage service.	
Inherited Association End		**Mult.**	**Description**	
Extension.Key		*	The entity MAY be extended via key-value pairs.	

9.10. ToCloudComputingService

The ToCloudComputingService class describes a network connection between a Storage Service and a Cloud Computing Service which has a level of performance significantly better than the general WAN connection. It is assumed that such a connection applies to the entirety of those Services, i.e. to all Virtual machines within the Cloud Computing Service and all storage objects within the Cloud Storage Service. However, the connection MAY depend on the Access Protocol used to transfer the data and to restrictions in data access to the data itself. Some Access Protocols may only be available from a restricted set of Compute Services, and this may also be published using the ToCloudComputingService class.

It is important to note that this entity applies only to a CloudStorageService which relates to a given CloudComputingService (ex. to provide EBS storage to an IaaS service), not to generic Cloud Storage service such as Storage-as-a-Service.

Entity	Inherits from	Description

ToCloudComputingService	Entity			A description of the network link quality between a Storage Service and a computing service, and/or of a potentially dedicated access protocol that the Computing Service may use to access the Storage Service.
Inherited Attribute	**Type**	**Mult.**	**Unit**	**Description**
CreationTime	*DateTime_t*	*0..1*		*Timestamp describing when the entity instance was generated*
Validity	*UInt64*	*0..1*	*s*	*The duration after CreationTime that the information presented in the Entity SHOULD be considered relevant. After that period has elapsed,* *the information SHOULD NOT be considered relevant*
ID [key]	*URI*	*1*		*A global unique ID*
Name	*String*	*0..1*		*Human-readable name*
OtherInfo	*String*	***		*Placeholder to publish info that does not fit in any other attribute. Free-form string, comma-separated tags, (name, value) pair are all examples of valid syntax*
Attribute	**Type**	**Mult.**	**Unit**	**Description**
NetworkInfo	NetworkInfo_t	0..1		The type of network connection available between the Storage Service and Compute Service.
Bandwidth	UInt32	0..1	Mb/s	The nominal bandwidth available between the Storage Service and Compute Service via this connection.
Association End			**Description**	
StorageAccessProtocol.ID		*	The storage service MAY be accessed via an access protocol by a certain computing service.	
CloudComputingService.ID		1	Is associated to a cloud computing service.	
StorageService.ID		1	Is associated to a storage service.	
Inherited Association End		**Mult.**	**Description**	
Extension.Key		*	The entity MAY be extended via key-value pairs.	

10. Relationship to OGF Reference Model

In this section, we describe the integration of the GLUE information model with the OGF Reference Model [RM]. The reference model defines the concept of Grid Component. In GLUE, a root concept called Entity is defined. Such a root concept MAY be defined as a specialization of the Grid Component concept, that means that all properties are inherited by the GLUE classes. In Figure 5, we represent this relationship by a UML class diagram.

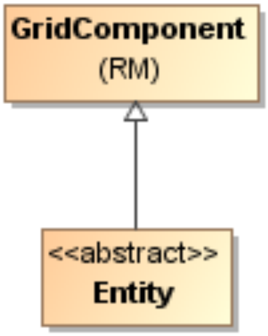


Figure 5 GLUE and Reference Model integration

11. Security Considerations

This section considers security implications when using the GLUE 2.0 conceptual model. It follows the advice given in RFC-3552.

As the conceptual model of GLUE 2.0 provides limited scope for embedding security information many of these concerns listed here are delegated to the concrete data models and to the underlying software implementations. Nonetheless, some points are independent of which concrete data model is employed so some discussion is appropriate.

When deploying an information service conforming to the GLUE 2.0 conceptual model, consideration should be given to the points discussed below.

11.1. Communication security

The GLUE conceptual model is independent of how information is stored and how that information is exchanged between agents. Because of this, concern for communication security is largely delegated to the underlying concrete data model and software implementations.

11.1.1. Confidentiality

The GLUE conceptual model contains information that MAY be personal or confidential in nature. Contact details and indications of end-user activity MAY fall into this category.

Conforming implementations should identify which components of the data should be considered confidential and appropriate precautions should be in place to safeguard against disclosure to unintended audiences.

11.1.2. Data integrity

The information within GLUE has many potential uses, from operational to accounting. How accurate the information is MAY depend on many factors, including the integrity of software agents that publish data and the transport used to propagate information.

The software used to provide an information service MAY cache GLUE information. If so, the caches provide additional points where data integrity MAY be compromised.

11.1.3. Peer Entity authentication

No explicit description of the agents that publish information is included within the GLUE conceptual model. This prevents authentication information from being included within the abstract model.

In general, support for peer-entity authentication is delegated to the concrete data model or the underpinning software. In many cases the agents will act on behalf of some AdminDomain; if so, elements of peer entity authentication (e.g., public/private key-pairs) MAY be included using the described schema extension mechanisms provided issues with data integrity are understood.

11.2. Non-repudiation

The GLUE conceptual model contains no explicit description of the publishing agents that provide GLUE information. This prevents explicitly support for non-repudiation. In many cases a set of publishing agents will provide information for Services in some AdminDomain. If so, then it is the AdminDomain that asserts the non-repudiation of the data the publishing agents provide.

Non-repudiation MAY require information from whoever asserts the non-repudiation of the data; for example, a cryptographic certificate of some AdminDomain. If the publishing agent is identified with an AdminDomain then this information MAY be included using the schema extension mechanisms of the AdminDomain (via OtherInfo or Extension). It is also possible for this information to be included in fields specific to the concrete data model or it MAY be provided outside of the GLUE conceptual model.

In addition, information MAY be published with corresponding non-repudiation information, such as a cryptographic signature. Signatures MAY be included using schema extensions (OtherInfo or Extension) or MAY be included in fields specific to the concrete data model.

11.3. System security

The GLUE conceptual model intended use is to provide an abstract view of a grid system. There are many processes that MAY make use of this information, each MAY depend on the GLUE conceptual model to undertake work.

11.3.1. Unauthorized usage

The GLUE conceptual model has no explicit description of end-users of the schema information and no explicit description of authorized usage. In general, is assumed that any authorization controls for access to the GLUE information is provided by specific concrete bindings and software implementation.

It MAY be possible to identify a UserDomain with those agents authorised to use GLUE information and embed authorization information using described schema extension mechanisms, provided issues with data integrity are understood.

11.3.2. Inappropriate Usage

The GLUE conceptual model provides no mechanism for describing appropriate usage and does not include a data-processing model, so providing a description of inappropriate usage is considered out-of-scope.

Individual grids MAY describe what they consider appropriate usage of GLUE information and implement appropriate procedures to ensure this policy is enacted.

11.4. Specific attacks

RFC-3552 describes several specific attacks that MUST be considered. These are detailed below.

11.4.1. Eavesdropping

Some information described in the GLUE conceptual model MAY be sensitive in nature; this MAY include contact details and descriptions of user activity. Appropriate care should be taken to prevent unintended access or disclosure to an unintended audience.

11.4.2. Replay

Grid operations MAY depend on information provided in the GLUE conceptual model.

If a system implementing the GLUE 2.0 conceptual model is susceptible to a replay attack then it is possible for part (possibly all) of the information in the conceptual model to be reverted to some previous state as seen by some (possible all) end users. Please note that this is a specific case of the more general modification attack.

A replay attack MAY result in disrupted service. If security attributes, such as authorization, are embedded within the GLUE conceptual model then a replay attack MAY result in inappropriate access to data. Underlying concrete models and software implementations should prevent replay attacks.

11.4.3. Message insertion

The ability to insert information is key to providing accurate information. However, inserting incorrect information MAY have a detrimental effect to the running systems; for example, there are attributes in the conceptual model that accept multiple values. If incorrect values are included, the systems MAY suffer.

Many aspects of GLUE provide service discovery. Inserting false information would allow unauthorised services to publish their presence and attract activity. This MAY be used as a basis for further attacks. Underlying concrete models and software implementations should ensure that any agent's ability to insert information is limited and appropriate.

11.4.4. Deletion

The ability to delete information from an information service could interfere with normal operations; for example, if Services are removed then activity that would use those services MAY be affected; if AdminDomains are removed then normal operation procedures MAY be impossible; if security components are removed (such as X509 certificates) then facilities such as non-repudiation MAY become ineffectual. Underlying concrete models and implementing software should ensure that any ability of an agent to delete information is limited and appropriate.

11.4.5. Modification

The ability for an agent to modify information stored in an information service is key to providing accurate information. However, concrete data models and software implementation should place limits such that the agents' ability to modify information is controlled and appropriate.

11.4.6. Man-in-the-middle

For a system implementing the GLUE conceptual model, a successful man-in-the-middle attack MAY lead to arbitrary modification of data (see 9.4.5). It MAY also allow deleting existing data (see 9.4.4) or adding additional data (see 9.4.3). This MAY have severe influence on the systems based on GLUE information. Underlying concrete models and implementing software should understand the risk from man-in-the-middle attacks and provide appropriate security against them.

11.4.7. Denial of service attacks

A Denial of Service attack is one that attempts to prevent normal operation of systems. Perhaps, the most obvious is to prevent or corrupt the flow of information. Systems using the GLUE conceptual model should understand the consequences of a partial or complete lack of information. Appropriate measures should be taken to ensure the systems continue to run to the extent possible.

12. Author Information

Stephen Burke
Science and Technology Facilities Council
Rutherford Appleton Laboratory
Harwell Science and Innovation Campus
Chilton, Didcot, Oxfordshire, OX11 0QX (UK)
E-mail: s.burke@rl.ac.uk

John-Paul Navarro
University of Chicago/Argonne National Laboratory
Mathematics & Computer Science Division, Building 221
9700 S. Cass Avenue
Argonne, IL 60439 (USA)
E-mail: navarro@mcs.anl.gov

Shiraz Memon
Forschungszentrum Jülich GmbH
Wilhelm-Johnen-Straße
52425 Jülich (Germany)
E-mail: a.memon@fz-juelich.de

Alessandro Paolini
EGI Foundation
Science Park 140
1098 XG Amsterdam (The Netherlands)
E-mail: alessandro.paolini@egi.eu

Baptiste Grenier
EGI Foundation
Science Park 140
1098 XG Amsterdam (The Netherlands)
E-mail: baptiste.grenier@egi.eu

Enol Fernandez

glue-wg@ogf.org

EGI Foundation
Science Park 140
1098 XG Amsterdam (The Netherlands)
E-mail: enol.fernandez@egi.eu

Marco Verlato
INFN-Padova
Via Marzolo 8
35131 Padova (Italy)
E-mail: marco.verlato@pd.infn.it

Paolo Andreetto
INFN-Padova
Via Marzolo 8
35131 Padova (Italy)
E-mail: paolo.andreetto@pd.infn.it

13. Contributors & Acknowledgements

We gratefully acknowledge the contributions made to this document (in no particular order) by Paul Strong, Ellen Stokes, Hiro Kishimoto, David Snelling, Flavia Donno, Cal Loomis, Shiraz Memon, Matt Viljoen, Steve Traylen and all people who provided constructive and valuable input in the discussion.

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A. Place-holder values for unknown data

Whilst people endeavor to provide accurate information, there MAY be situations where specific GLUE attributes MAY be assigned place-holder (or dummy) values. These place-holder values carry some additional semantic meaning; specifically, that the correct value is currently unknown and the presented value should be ignored. This appendix describes a set of such place-holder values.

Some attributes within the GLUE schema are required whilst others are optional. If the attribute is optional and the corresponding information is unavailable, the information provider MUST either publish a place-holder or not to publish the attribute. If the attribute is required, then the information MUST either publish a place-holder value or refrain from publishing the GLUE object.

If a place-holder value is published, it MUST conform to the scheme described in this appendix. This is to increase the likelihood that software will understand the nature of the information it receives.

This appendix describes place-holder values that have be chosen so they are obvious "wrong" to humans, unlikely to occur under normal operation and valid within the attribute type. This also allows for detection of failing information provider components.

A.1. Use cases

There are two principle use-cases for place-holder values, although others MAY exist.

Scenario 1. a static value has no good default value and has not been configured for a particular site.

Some provisions for GLUE Schema provide templates. These templates MAY contain attributes that have no good default value; for example, supplying the correct value MAY require site-specific knowledge. Whilst it is expected that these attributes be configured, it is possible that this does not happen, so exposing the attributes' default values.

Scenario 2. information provider is unable to obtain a dynamic value.

A dynamic value is provided by an information provider by querying the underlying grid resources. This query will use a number of ancillary resources (e.g., DNS, network hardware) that might fail; the grid services might also fail. If an attribute is required and the current value is unobtainable, a place-holder value MUST be used.

A.2. Place-holder values

This section describes a number of values that MAY be represented within a given address space (e.g., Strings/UTF-8, Integers, FQDNs, IPv4 address space). Each of the different types are introduced along with the place-holder value and a brief discussion on usage, rational and any other considerations.

A.3. Extended booleans

The reserved value “undefined” SHOULD be used. The way to express that no value is published MUST be defined in the documents defining the realization to concrete data models (e.g., [GLUE-REAL]).

A.4. Simple strings

(ASCII/UTF-8) should use "UNDEFINEDVALUE" or should start "UNDEFINEDVALUE:"

Upper-case letters make it easier to spot and a single word avoids any white-space issues.
A short error message MAY be incorporated into the message by appending the message after the colon.

Examples:
UNDEFINEDVALUE
UNDEFINEDVALUE: unable to contact torque daemon.

Using UNDEFINEDVALUE is a default option for strings that have no widely-known structure. If a value is of a more restrictive sub-type (e.g., FQDNs, FQANs, URIs) described below, then the rules for more restrictive form MUST be used.

A.5. Fully qualified domain names

They MUST use a hostname ending either "example.org" for scenario 1, or "invalid" for scenario 2.

RFC 2606 defines two second-level domains: "example.org" and "example.com". These domains have the advantage of ending with a recognisable TLD, so are recognisable as a DNS name. Default configuration (scenario 1, above) MUST use DNS names that end "example.org"

RFC 2606 also reserves the "invalid" Top-Level-Domain (TLD) as always invalid and clearly so. For dynamic information gathering, a value ending "invalid" MUST be used.

In both cases, additional information MAY be included by specifying a prefix to "example.org" or "invalid". This MAY be used to specify the class of machine that should be present. For dynamic infomation, if the class of machine is not published then the FQDN "unknown.invalid" MUST be used.

Examples:
www.example.org
your-CE.example.org
unknown.invalid
site-local-BDII.invalid

A.6. IPv4 address

It MUST use 192.0.2.250

There are several portions of IPv4 addresses that should not appear on a network, but none that are reserved for documentation or to specify a non-existent address. Using any address leads to the risk of side-effects, should this value be used.

The best option is an IP address from the 192.0.2.0/24 subnet. This subnet is defined in RFC 3330 as "TEST-NET" for use in documentation and example code. For consistency, the value 192.0.2.250 MUST be used.

A.7. IPv6 addr

It MUST use 2001:DB8::FFFF

There is no documented undefined IPv6 address. RFC 3849 reserves the address prefix 2001:DB8::/32 for documentation. For consistency, the address 2001:DB8::FFFF MUST be used.

A.8. Integers

It MUST use "all nines"
For uint32/int32 this is 999,999,999
For uint64/int64 this is 999,999,999,999,999,999

For integers, all numbers expressible within the encoding (int32/uint32/etc.) are valid so there is no safe choice.

If an unsigned integer is encoded as a signed integer, it is possible to use negative numbers safely. However, these numbers will be unrepresentable if the number is stored as an unsigned integer. For this reason a negative number place-holder MUST not be used.

The number was chosen for three reasons. First, attribute scales are often chosen to reduce the likelihood of overflow: numbers towards MAXINT (the large number representable in an integer domain) are less likely to appear. Second, repeated numbers stand out more clearly to humans. Finally, the statistical frequency of measured values often follows Benford's law, which indicates that numbers starting with "1" occur far more frequently than those starting with "9" (about six times more likely). For these reasons, information providers MUST use all-nines to indicate a `place-holder`.

A.9. File path

It MUST start either "/UNDEFINEDPATH" or "\UNDEFINEDPATH".

As with the simple string, a single upper-case word is recommended. The initial slash indicates that the value is a path. Implementations MUST use whichever slash is most appropriate for the underlying system (Unix-like systems use a forward-slash). Software should accept either value as an unknown-value place-holder.

Additional information MAY be encoded as data beyond the initial UNDEFINEDPATH, separated by the same slash as started the value. Additional comments should not use any of the following characters: \ [ ] ; = " : | , * .

Examples:
/UNDEFINEDPATH
\UNDEFINEDPATH
/UNDEFINEDPATH/Path to storage area
/UNDEFINEDPATH/Broker unavailable

A.10. Email addresses

It MUST use an undefined FQDN for the domain.

RFC 2822 defines emails addresses to have the form: <local-part> '@' <domain>

The <domain> MUST be an undefined FQDN; see above for a complete description. For email addresses, information providers should use "example.org" for scenario 1. and "unknown.invalid" for scenario 2.

The <local-part> MAY be used to encode a small amount of additional information; for example, it MAY indicate the class of user to whom the email address should be delivered. If no such information is to be encoded the value "user" MUST be used.

Examples:
  user@example.org
  user@unknown.invalid
  site-local-contact@example.org
  local-admin@example.org

A.11. Uniform Resource Identifier (URI)

It is schema-specific

RFC 3986 defines URIs as a "federated and extensible naming system." All URIs start with a schema-name part (e.g., "http") and no schema-name has been reserved for undefined or documenting example values.

For any given URI schema ("http", for example), it MAY be possible to define a place-holder value within that name-space. If a GLUE value has only one valid schema, the undefined value MUST be taken from that schema. If several schemata are possible, one MUST be chosen from the available options. This should be the most commonly used.

Take care with the URI encoding. All place-holder URI values MUST be valid URIs. If additional information is included, it MUST be encoded so the resulting URI is valid.

For schemata that MAY include a FQDN (e.g., a reference to an Internet host), an undefined URI MUST use an undefined FQDN; see above for details on undefined FQDNs.

URI schemata that reference a remote data object (e.g., "http", "ftp", "https"), additional information MAY be included as the path. The FQDN indicates that the value is a place-holder, indicating an place-holder value, so information providers should not specify "UNDEFINEDPATH".

For "file" URIs, the path part MUST identify the value as unknown and MUST use the forward-slash variant; see above for details on undefined paths.

For "mailto" URIs (http://www.ietf.org/rfc/rfc2368.txt) encapsulates valid email addresses with additional information (such as email headers and message body). Place-holder mailto URIs MUST use an unknown email address (see above). Any additional information MUST be included in the email body.

There MAY be other schemata in use that are not explicitly covered in this section. A place-holder value should be agreed upon within whichever domain such schemata are used. This place-holder value should be in the spirit of the place-holder values described so far.

Examples:
  http://www.example.org/
  httpg://your-CE.example.org/path/to/end-point
  httpg://unknown.invalid/User%20certificate%20has%20expired
  mailto:site-admin@example.org

```
mailto:user@maildomain.invalid?body=Problem%20connecting%20to%20WLMS
file:///UNDEFINEDPATH
file:///UNDEFINEDPATH/path%20to%20some%20directory
```

A.12. X.509 Distinguished Names

It MUST start O=Grid,CN=UNDEFINEDUSER

X.509 uses a X.500 namespace, represented as several Relative Domain-Names (RDNs) concatenated by commas (we refer to syntax defined in IETF RFC 4514). The final RDN is usually a single common name (CN), although multiple CNs are allowed.

Unknown DN values MUST have at least two entries: an initial O=Grid followed immediately by CN=UNDEFINEDUSER.

Additional information MAY be encoded using extra CN entries. These MUST come after CN=UNDEFINEDUSER.

Examples:

```
O=Grid,CN=UNDEFINEDUSER
O=Grid,CN=UNDEFINEDUSER/CN=Your Grid certificate DN here
O=Grid,CN=UNDEFINEDUSER/CN=Cannot access SE
```

A.13. Fully Qualified Attribute Name (FQAN)

It MUST use a VO of "vo.example.org" (for scenario 1.) or "unknown.invalid" (for scenario 2).

The "VOMS Credential Format" document,

http://edg-wp2.web.cern.ch/edg-wp2/security/voms/edg-voms-credential.pdf

states that FQANs MUST have the form:

```
/VO[/group[/subgroup(s)]][/Role=role][/Capability=cap]
```

Where VO is a well-formed FQDN. Unlike FQDNs, VO names MUST be lower-case. The place-holder value for FQAN is derived from the place-holder FQDN (see Section A.5). It MUST have no subgroup(s) or Capability specified.

Any additional information MUST be encoded within a single Role name. Care should be taken that only valid characters (A-Z, a-z, 0-9 and dash) are included.

Examples:

```
/vo.example.org
/vo.example.org/Role=Replace-this-example-with-your-FQAN
/unknown.invalid
/unknown.invalid/Role=Unable-to-contact-CE-Error-42
```

A.14. Geographic locations

It MUST use longitude 0 degrees, latitude 0 degrees.

Meridians of longitude are taken from (-180,180] degrees, whilst parallels of latitude are taken from [-90,90] degrees. For a place-holder value to be a valid location, it MUST also be taken from these ranges.

By a happy coincidence, the (0,0) location is within the Atlantic Ocean, some 380 miles (611 kilometers) south of the nearest country (Ghana). Since this location is unlikely to be used and repeated numbers are easier for humans to spot, (0,0) MUST be used to specify an place-holder location.

B. Data Types

This section contains the definition of attribute types defined within this model. The enumerated types may be either closed or open. For properties whose type defines a closed enumeration, one of the defined values MUST be chosen; any other value is not valid. For properties whose type defines an open enumeration, one of the defined values MAY be chosen, but nevertheless any other value compatible with the string type and with the recommended syntax is allowed. Before defining a new open enumeration value, it is recommended to apply the “GLUE2 Enumerations procedures and best practices” (http://redmine.ogf.org/projects/glue-wg/wiki/Enumerations_procedures_and_best_practices_v10). The enumeration values MUST be lower-case.

B.1. AccessLatency_t

Closed enumeration:

Value	Description
nearline	A file MAY have its only copies in a "nearly online" component of the storage system, typically a fully automated tape robot, but also a remote storage system could fit this qualification. Such a facility will need an unspecified amount of time to make a copy of the file available on the disk component of the container under consideration. When a file is not in use, its disk copies MAY be removed. Hence the system cannot guarantee that a file will be immediately available on disk
offline	A file MAY have its only copies in an offline component of the storage system, for example a tape library that is not connected to an automated tape robot. Hence an operator intervention MAY be needed to make a copy of a file available that has a lower latency
online	Files are always stored on a medium with an access time less than a minute (e.g., a disk)

B.2. AccType_t

Open enumeration:

Value	Description
GPU	GPU architecture
MIC	Intel MIC architecture
FPGA	Generic FPGA accelerator

B.3. AppEnvState_t

Open enumeration:

Value	Description
Installable	The application environment is not installed, but MAY be dynamically installed
installationfailed	The application environment was being installed, but the installation process failed
installedbroken	The application environment is installed, but the verification failed
installednotverified	The application environment is installed, but not yet verified
installedverified	The application environment is installed and successfully verified
installingautomatically	The application environment is not installed, but is being installed automatically
installingmanually	The application environment is not installed, but is being installed manually
notinstallable	The application environment is not installed and not installable
pendingremoval	The application environment is installed, but is due to be removedwill be removed as soon as possible
Removing	The application environment is installed, but it is being removed

B.4. ApplicationHandle_t

Open enumeration:

Value	Description
executable	Access based on running directly the main executable of the application (this MAY require set-up of the environment)
module	Access based on loading modules via Environment Modules (http://modules.sourceforge.net/)
path	Access based on using an explicit path where the software is installed on the file system
softenv	Access based on loading SoftEnv keys (http://www.mcs.anl.gov/systems/software/softenv/softenv-intro.html)

B.5. Benchmark_t

Open enumeration:

Value	Description
bogomips	BogoMips
cfp2006	SPEC CFP 2006 floating point benchmark
cint2006	SPEC CINT 2006 integer benchmark
linpack	LINPACK benchmark
specfp2000	SPECfp2000 floating point benchmark
specint2000	SPECint2000 integer benchmark

B.6. Capability_t

List of values initially drafted from [OMII-DJRA2.1, OGF-GFD80]. Open enumeration:

Value	Description
data.access.flatfiles	capacity of providing access to a flat file
data.access.relational	capacity of providing access to a relational data source
data.access.xml	capacity of providing access to an XML data source
data.management.diskimage	capacity of managing the creation of mountable disk images objects
data.management.file	capacity of managing the creation of files
data.management.genericobject	capacity of managing the creation of generic storage objects
data.management.replica	capacity of managing the creation of file replicas upon request
data.management.storage	capacity of managing a storage resource, from simple systems like disk-servers to complex hierarchical systems
data.management.transfer	capacity of managing a transfer of files from the start to the completion

data.naming.resolver	capacity of resolving one name to another (for example, search the associated abstract name to a certain human-oriented name)
data.naming.scheme	capacity of attaching names to data resources. (To evaluate if it should moved to the main category infrastructure instead of data). In OGSA, a three-level naming scheme is defined: (1) human-oriented name, (2) abstract name and (3) address
data.transfer	capacity of moving a file from one network location to another. It refers to the actual transfer (e.g., as performed by protocols like FTP, GridFTP, or HTTP)
executionmanagement.candidatesetgenerator	capacity of determining the set of resources in which a unit of work MAY execute
executionmanagement.dynamicvmdeploy	capacity of dynamically deploying a virtual machine image in a worker node
executionmanagement.executionandplanning	capacity of building schedules for jobs, that is, the capability of defining mappings between services and resources, possibly with time constraints
executionmanagement.jobdescription	capacity of letting users be able to describe a job submission request based on a machine-processable language
executionmanagement.jobexecution	capacity of executing a job or set of jobs.
executionmanagement.jobmanager	capacity of managing the execution of a job or set of jobs from start to finish
executionmanagement.reservation	capacity of managing reservation of resources for future usage
information.discovery	capacity of locating unknown resources or services, possibly satisfying a set of requirements
information.logging	capacity of recording data, often chronologically
information.model	capacity of modelling resources based on a community accepted definition
information.monitoring	capacity of periodically observing measurements, transform them and make available to users or other applications
information.provenance	capacity of providing long-term storage of information related to Grid activity and to let this information be accessed by users or other applications.
security.accounting	capacity of systematically recording, reporting, and analyzing the usage of resources
security.attributeauthority	capacity of associating a user with a set of attributes in a trusted manner to a relying party, by way of digitally signed assertions
security.authentication	capacity of providing authentication mechanisms for Grid users machine and services
security.authorization	capacity of handling authorization aspects, making authorization decisions about the subject and the requested mode of access based upon combining information from a number of distinct sources
security.credentialstorage	capacity of providing an online credential repository that allows users to securely obtain credentials when and where needed
security.delegation	capacity for a user to give a service the authority to undertake specific activities or decisions on its behalf
security.identymapping	capacity of mapping Grid-level credentials to local level credentials (e.g., mapping a user X.509 certificate into a UNIX account).

B.7. CloudComputingInstanceState_t

For the values of this type, we RECOMMEND the following syntax:

- namespace:state
- namespace:state:substate

Open enumeration:

Value	Description
bes:error	(a terminal state): the activity has failed due to some system error/failure event, such as failure of a computational resource that the activity was running on
bes:finished	(a terminal state): the activity has terminated successfully. Successful termination implies that the activity exited of its own accord rather than due to some failure in the BES or of the computational resources on which the activity was running. Note that a successfully terminating activity MAY nevertheless return an error code as its return value
bes:pending	the service has created a record for an activity but not yet instantiated it on a suitable computational resource or enabled it to start execution on such a resource

bes:running	the activity is executing on some computational resource
bes:terminated	(a terminal state): the client – which might be some system administrator (and hence not necessarily the client who originated the request to create the activity) – has issued a TerminateActivity request
bes:suspended	the activity is currently in suspended state. Some resources for the activity may be reserved into the the system, but no computing resources are utilized

For more information on the BES state model, see [BES].

B.8. CloudComputingInstanceType_t

Closed enumeration:

Value	Description
collectionelement	A VM submitted as part of a collection of individual VMs which do not communicate among them
parallelelement	A VM submitted as part of a collection of individual VM which communicate among them (ex. part of a computing cluster)
single	An individual stand-alone VM

B.9. CloudComputingManagerType_t

Open enumeration:

Value	Description
openstack	OpenStack
opennebula	OpenNebula
wnodes	WNoDeS
synnefo	Synnefo
cloudstack	Apache CloudStack
Vcloud	VMWare vCloud

B.10. CloudResourceName_t

Closed enumeration:

Value	Description
flavour	Resource flavour, comprensive of disk, CPU, ram, memory and network
network	Network usage (amount of kilobytes inbound/outbound from the VM network interfaces)
networkin	Network inbound usage (amount of kilobytes inbound from the VM network interfaces)
networkout	Network outbound usage (amount of kilobytes outbound from the VM network interfaces)
cpu	Number of vCPU associated to the VM. A vCPU seen by the OS is considered in use, even if it is in idle mode
gpu	Number of vGPU associated to the VM. A vGPU seen by the OS is considered in use, even if it is in idle mode
memory	RAM associated to the VM in MBs. Memory associated to the VM, and seen by the OS, is accounted even if free in the OS space.
storage	Storage associated to the VM in GBs. It includes all the type of storage associated to the VM, both block storage or ephemeral storage or OS disk image storage
ephemeralstorage	Ephemeral storage associated to the VM in GBs
blockstorage	Block storage associated to the VM in GBs. The entire amount of the block storage device disk is accounted, even if storage is not used by the OS
osdiskstorage	Storage associated to the VM Image OS disk in GB. The entire amount of the block storage device disk is accounted, even if storage is not used by the OS.
softwarelicense	License for the usage of software on the VM image disk. This shall include all the licensing prices for all the software installed in the VM besides the OS
oslicense	License for the usage of the OS on the VM image disk.

B.11. ComputingActivityState_t

For the values of this type, we RECOMMEND the following syntax:

- namespace:state

- namespace:state:substate

Open enumeration:

Value	Description
bes:failed	(a terminal state): the activity has failed due to some system error/failure event, such as failure of a computational resource that the activity was running on
bes:finished	(a terminal state): the activity has terminated successfully. Successful termination implies that the activity exited of its own accord rather than due to some failure in the BES or of the computational resources on which the activity was running. Note that a successfully terminating activity MAY nevertheless return an error code as its return value
bes:pending	the service has created a record for an activity but not yet instantiated it on a suitable computational resource or enabled it to start execution on such a resource
bes:running	the activity is executing on some computational resource
bes:terminated	(a terminal state): the client – which might be some system administrator (and hence not necessarily the client who originated the request to create the activity) – has issued a TerminateActivity request

For more information on the BES state model, see [BES].

This attribute type is an open enumeration. Examples of additional values are:

- a middleware provider is using its own state model defined before the BES specification:
    - NorduGrid defines the state *accepting* which MAY be represented as (see [ng-schema], page 28):
        - nordugrid:accepting
    - gLite WMS defines the state *scheduled* which MAY be represented as:
        - glite-wms:scheduled
    - gLite CREAM defines the state *registered* which MAY be represented as:
        - glite-cream:registered
        - (see https://edms.cern.ch/document/595770)
- a middleware provider defined an extension of BES state model which is not part of an official OGF specification
    - NorduGrid defined an extension the bes:pending by adding two substates:
        - nordugrid-bes:pending:accepting
        - nordugrid-bes:pending:accepted

B.12. ComputingActivityType_t

Closed enumeration:

Value	Description
collectionelement	A job submitted as part of a collection of individual jobs which do not communicate among them
parallelelement	A job submitted as part of a collection of individual jobs which communicate among them
single	An individual stand-alone job
workflownode	A job submitted as part of a workflow

B.13. ComputingManagerType_t

Open enumeration:

Value	Description
bqs	CC-IN2P3 Batch Queue System
condor	Condor
fork	Based on fork primitive
loadleveler	IBM LoadLeveler
lsf	Platform Load Sharing Facility
openpbs	Open PBS
sungridengine	Sun Grid Engine
torque	Torque

torquemaui	Torque with MAUI

B.14. ContactType_t

Open enumeration:

Value	Description
general	Contact for persons to ask about general issues
security	Contact for persons responsible for security
sysadmin	Contact for the system administrators
usersupport	Contact for user support

B.15. ContextualizationName_t

Open enumeration:

Value	Description
cloud-init	Ubuntu CloudInit
bash	Generic bash script

B.16. CPUMultiplicity_t

Closed enumeration:

Value	Description
multicpu-multicore	The execution environment is run by multiple physical CPUs with a multiple cores each
multicpu-singlecore	The execution environment is run by multiple physical CPUs with a single core each
singlecpu-multicore	The execution environment is run by a single physical CPU with multiple cores
singlecpu-singlecore	The execution environment is run by a single physical CPU with a single core

B.17. CPUVirtualizationT_t

Open enumeration:

Value	Description
emulation	Full virtualization with emulation
paravirtualization	Para-virtualization
hardware	Hardware assisted virtualization

B.18. DataStoreType_t

Open enumeration:

Value	Description
disk	The storage capacity is provided by magnetic disks
optical	The storage capacity is provided by optical disks
tape	The storage capacity is provided by magnetic tapes

B.19. DateTime_t

The DateTime_t is based on the extended ISO 8061 format:

- [-]CCYY-MM-DDThh:mm:ss[Z|(+|-)hh:mm]

This data type maps the dateTime XSD simple type. We restrict this syntax to UTC time zone as follows:

- yyyy '-' mm '-' dd 'T' hh ':' mm ':' ss 'Z'

B.20. DiskVirtualizationT_t

Open enumeration:

Value	Description
qcow2	QCOW2
raw	RAW Image
vmdk	VMDK

B.21. DN_t

Distinguished Name as defined by RFC 4514 (http://www.rfc-editor.org/rfc/rfc4514.txt).
X.509 uses a X.500 namespace, represented as several Relative Domain-Names (RDNs) concatenated by forward-slashes. The final RDN is usually a single common name (CN), although multiple CNs are allowed.

B.22. EndpointAuthentication_t

Open enumeration:

Value	Description
none	No authentication is configured on the endpoint
x509	X590 authentication is configured
oidc	OpenID Connect authentication is configured
saml2	SAML 2.0 authentication is configured

B.23. EndpointHealthState_t

Closed enumeration:

Value	Description
critical	It was possible to check the state of the endpoint and either it was not running or it was above some "critical" threshold
ok	It was possible to check the state of the endpoint and it appeared to be functioning properly
other	It was possible to check the state of the endpoint, but this is not covered by the defined states
unknown	It was not possible to check the state of the endpoint
warning	It was possible to check the state of the endpoint, but it appeared to be above some "warning" threshold or did not appear to be working properly
downtime	It was possible to check the state of the endpoint, but it appeared to be on maintenance and may not work properly

B.24. EndpointTechnology_t

Open enumeration:

Value	Description
corba	The endpoint is implemented using CORBA technologies
jndi	The endpoint is implemented using JNDI
webservice	The endpoint is implemented as a Web Service

B.25. ExpirationMode_t

Closed enumeration:

Value	Description

neverexpire	Support for files with infinite lifetime: they MAY only be removed by authorized clients, not by the storage system itself
releasewhenexpired	Support for files that have finite lifetimes and on expiration will be removed by the storage system
warnwhenexpired	Support for files that have finite lifetimes, but on expiration cannot be removed by the storage system itself. The data content of an expired file MAY be deleted if it MAY be recovered from an archive. New store operations MAY fail for certain clients until (some of the) expired files have either been removed by authorized clients, or have had their lifetimes increased

B.26. ExtendedBoolean_t

Closed enumeration:

Value	Description
false	boolean false
true	boolean true
undefined	the value cannot be measured

B.27. HostAccessInfo_t

Closed enumeration:

Value	Description
none	No default credentials are present in the machine, access credentials shall be injected by the middleware
passwd	Pre-set username/password
rsa	Pre-set RSA key set

B.28. InterfaceName_t

Open enumeration:

Value	Description
ogf.bes	The Open Grid Forum Basic Execution Service
ogf.srm	The Open Grid Forum Storage Resource Manager

B.29. JobDescription_t

Open enumeration:

Value	Description
condor	Condor
egee:jdl	EGEE Job Description Language
globus:rsl	Globus RSL
nordugrid:xrsl	Nordugrid XSRL [XSRL]
ogf:jsdl:1.0	Job Description Submission Language 1.0

B.30. License_t

Open enumeration:

Value	Description
commercial	Commercial license
opensource	Open Source license approved by the OSI (Open Source Initiative)
unknown	Unknown license type

B.31. LocalID_t

The base type is the string with the following restrictions:

- first char in a-zA-Z
- following characters in [\w\-\.\:]
    - \w = [a-zA-Z_0-9]

B.32. NetworkInfo_t

Open enumeration:

Value	Description
100megabitethernet	Network based on 100 MBit/s Ethernet technology
gigabitethernet	Network based on 1 GBit/s Ethernet technology
infiniband	Network based on Infiniband technology
myrinet	Network based Myrinet technology

B.33. NetworkConfigurationProtocol_t

Open enumeration:

Value	Description
all	All protocols
tcp	TCP protocol
udp	UDP protocol
cmp	CMP protocol
ipsec	IPSec protocol

B.34. NetworkConfigurationDirection_t

Open enumeration:

Value	Description
inbound	Inbound connection
outbound	Outbound connection

B.35. NetworkConfigurationAddressRange_t

The base type is the string limited to the CIDR range address notation: like 192.168.0.0/16, fc00::/7 or 8.8.8.8./32:

B.36. NetworkConfigurationPort_t

The base type is the string limited to one of the following possible formats:

- Specification of a port: 80
- Specification of multiple ports: 80,443
- Specification of a range of ports: 25000:25009

B.37. NetworkType_t

Open enumeration:

Value	Description
public	Connection to an externally routable network, more networks can be available.
public_only	Exclusive connection to an externally routable network.
private	Connection a private network, more networks can be available.
private_only	Exclusive connection to a private network.

B.38. NetVirtualizationT_t

Open enumeration:

Value	Description
none	No network isolation
vswitch	vSwitch isolation
ebtables	EBtables isolation
vlan	VLAN isolation

firewall	Firewall isolation

B.39. OSFamily_t

Open enumeration:

Value	Description
linux	Family of operating systems based on Linux kernel
macosx	Family of operating systems based on MacOS X
solaris	Family of operating systems based on Solaris
windows	Family of operating systems based on Windows

B.40. OSName_t

Open enumeration:

Value	Description
aix	AIX
centos	CentOS
debian	Debian
fedoracore	RedHat Fedora
gentoo	Gentoo Linux
leopard	Mac OS X 10.5 (Leopard)
linux-rocks	
mandrake	Mandrake
redhatenterpriseas	RedHat Enterprise Server
scientificlinux	Scientific Linux
scientificlinuxcern	Scientific Linux CERN
suse	SUSE
ubuntu	Ubuntu
windowsvista	Microsoft Windows Vista
windowsxp	Microsoft Windows XP

B.41. Period_t

Open enumeration:

Value	Description
once	The metric is calculated once in the lifetime of the service
asaccounted	The metric is calculated with the same granularity as it is accounted
daily	The metric is calculated daily
monthly	The metric is calculated monthly
yearly	The metric is calculated yearly

B.42. Platform_t

Open enumeration:

Value	Description
amd64	AMD 64bit architecture
i386	Intel 386 architecture
itanium	Intel 64-bit architecture
powerpc	PowerPC architecture
sparc	SPARC architecture

B.43. PolicyScheme_t

Open enumeration:

Value	Description
basic	The basic scheme
gacl	GridSite Access Control List

A policy scheme is defined by a syntax for rules and by a matching algorithm defining how a string MAY be matched against the published rules. For the *basic* policy scheme, the following syntax MUST be used (defined in EBNF form [EBNF]):

- BASIC RULE ::= (DN_NAME | VO_NAME | ‘ALL’)
- DN_RULE ::= ‘dn:’ DN_NAME
- VO_RULE ::= ‘vo:’ [a-zA-Z0-9-_\.]+
- DN_NAME ::=

As a matching algorithm, the basic scheme adopts the exact match (if at least one rule provides an exact match or the rule ‘ALL’ is present, then the subject is authorized to be mapped into the related share). More complex policy schemes SHOULD be defined in profile documents.

Examples of policies expressed using the basic syntax are:

- `dn:/C=XX/O=YYYY/OU=Personal Certificate/L=ZZZZ/CN=NAME SURNAME`
    - matches the user proving to have a certificate identified by this DN
- `vo:/vo_a`
    - matches all the users proving to be part of the vo_a

B.44. QualityLevel_t

Closed enumeration:

Value	Description
development	The component is under active development both in functionalities and interfaces
pre-production	The component has completed the development and passed the testing phase; it is being used in real world scenarios
production	The component completed the development and is considered stable for real world scenarios
testing	The component has completed the development phase and is under testing

B.45. ReservationPolicy_t

Closed enumeration:

Value	Description
mandatory	Jobs MUST be submitted only via advance reservation
none	No reservation is supported
optional	Jobs MAY be submitted via advance reservation, but this is not required

B.46. ResourceScope_t

Open enumeration:

Value	Description
any	Any scope (commercial or non-commercial)
commercial	Access by commercial organizations for commercial usage
noncommercial	Access by no-profit or public organizations for non-commercial usage
research	Access for research by any organization, commercial or non-commercial
noncommercialresearch	Access for research by no-profit or public organizations for non-commercial usage
Institutions	Access for public organization, institutions or governments for any scope
euonly	Access restricted to users of EU based countries
owncountryonly	Access restricted to users of the same country of the provider

B.47. RetentionPolicy_t

Open enumeration:

Value	Description
custodial	Low probability of loss
output	An intermediate level and is appropriate for data which MAY be replaced by lengthy or effort-full processes

replica	The highest probability of loss, but is appropriate for data for which a certain amount of loss MAY be tolerated, in particular when other copies MAY be accessed in a timely fashion

B.48. SchedulingPolicy_t

Open enumeration:

Value	Description
fairshare	Statistically guarantees the allocated share
fifo	First-In First-Out
random	Random choice

B.49. ServiceType_t

The RECOMMENDED syntax is in reverse-DNS prefix. The first element is a top-level domain, while the second element is a namespace (the namespace MAY be related to a middleware name, an organization or other concepts; org.ogf.glue is reserved for the OGF GLUE Working Group). The defining body SHOULD have a claim on the corresponding forward DNS name (e.g., org.nordugrid.arex SHOULD be defined by the owners of the nordugrid.org domain name).

Open enumeration:

Value	Description
org.ogf.glue*	Prefix reserved for the OGF GLUE Working Group
org.glite.fts	gLite File Transfer Service
org.glite.lb	gLite Logging and Booking Service
org.glite.wms	gLite Workload Management Service
org.nordugrid.arex	NorduGrid Resource Coupled Execution Service
org.nordugrid.isis	NorduGrid Information Index Service
org.nordugrid.storage	NorduGrid Storage Service
org.teragrid gridftp	TeraGrid GridFTP
org.teragrid.condor-g	TeraGrid Condor-g
org.teragrid.globus-mds4	TeraGrid Globus MDS 4
org.teragrid.gpfs	TeraGrid GPFS
org.teragrid.gsi-openssh	TeraGrid gsi-enabled openssh
org.teragrid.prewsgram	TeraGrid pre-WS Globus GRAM
org.teragrid.rft	TeraGrid Reliable File Transfer
org.teragrid.srb	TeraGrid Storage Resource Broker
org.teragrid.ws-delegation	TeraGrid WS-Delegation Service
org.teragrid.ws-gram	TeraGrid WS-GRAM Service
org.teragrid.ws-ogsadai	TeraGrid OGSA-DAI
org.cloud.iaas	Cloud Infrastructure-as-a-Service
org.cloud.saas	Cloud Storage-as-a-Service

B.50. ServingState_t

Closed enumeration:

Value	Description
closed	The endpoint is not accepting request nor is serving them
draining	The endpoint is not accepting requests, but is serving requests in the queue
production	The endpoint is both accepting and serving requests
queueing	The endpoint is accepting requests, but is not serving them

B.51. Staging_t

Closed enumeration:

Value	Description
none	No staging of files supported
stagingin	Automatic staging in of files supported
staginginout	Automatic staging in and out of files supported
stagingout	Automatic staging out of files supported

B.52. StorageAccessProtocol_t

Open enumeration:

Value	Description
afs	Andrew File System protocol
dcap	DCache access protocol
file	POSIX access
gsidcap	DCAP with GSI authentication
gsiftp	FTP with GSI authentication
gsirfio	RFIO with GSI authentication
http	HyperText Transfer Protocol
https	Secured HyperText Transfer Protocol
nfs	Network File System protocol
rfio	Remote File Input/Output protocol
root	File transfer protocol for the ROOT framework
xrootd	xrootd protocol

B.53. StorageCapacity_t

Open enumeration:

Value	Description
online	Available storage capacity accessible in less than a minute in normal operating conditions
installedonline	Online storage capacity including temporarily unavailable portions which would be accessible in less than a minute in normal operating conditions
nearline	Available storage capacity accessible in more than a minute and less than two days without human intervention in normal operating conditions
installednearline	Nearline storage capacity including temporarily unavailable portions which would be accessible in more than a minute and less than two days without human intervention in normal operating conditions
offline	Storage capacity possibly requiring human intervention for access in normal operating conditions
cache	Storage capacity accessible in less than a minute used internally by the storage system and not directly exposed to the user

B.54. StorageManagerType_t

Open enumeration:

Value	Description
castor	CERN Advanced STOrage manager, disk and tape management system
dcache	Disk Cache, disk managing system with ability to control tape backends (e.g., Enstore)
enstore	Tape Storage system, tape management system
gpfs	General Parallel File System, disk management system
sse	Smart Storage Element, disk management system
tsm	IBM Tivoli Storage Manager, disk and tape management system
swift	OpenStack SWIFT
cdmi-proxy	CDMI Proxy

B.55. VirtType_t

Open enumeration:

Value	Description
emulation	Full virtualization with emulation
paravirtualization	Para-virtualization
hardware	Hardware assisted virtualization
vgpu	NVidia vGPU