European Middleware Initiative

Definition of a Storage Accounting Record

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**Abstract:**

In this document a storage accounting record StAR is defined reflecting practical, financial and legal requirements of storage location, usage and space and data flow. The definition might be the base for a standardized schema or an extension of an existing record like the OGF UR.

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**Table of Contents**

1. Introduction 6

1.1. Purpose 6

1.2. About this Document 6

1.3. References 6

1.4. Document amendment procedure 6

1.5. Terminology 6

2. TeChnical description 8

2.1. Overview of the storage accounting record 8

2.1.1 Measuring Storage Resource Consumption 8

2.1.2 Record Structure & Content 8

2.1.3 Including Additional Information 8

2.2. Conventions and terms 8

2.2.1 Conventions used in the specification 9

2.2.2 Context 9

2.3. Related work 9

2.4. Record properties 9

2.4.1 StorageUsageRecord 9

2.4.2 StorageUsageRecords 10

2.4.3 RecordIdentity 10

2.4.4 StorageSystem 10

2.4.5 StorageShare 11

2.4.6 StorageMedia 11

2.4.7 StorageClass 11

2.4.8 FileCount 11

2.4.9 DirectoryPath 11

2.4.10 SubjectIdentity 11

2.4.11 LocalUser 12

2.4.12 LocalGroup 12

2.4.13 UserIdentity 12

2.4.14 Group 12

2.4.15 GroupAttribute 13

2.4.16 MeasureTime 13

2.4.17 ValidDuration 13

2.4.18 ResourceCapacityUsed 14

2.4.19 LogicalCapacityUsed 14

2.5. Intentionally left out properties 14

2.6. Field summary 15

2.7. Record Examples 16

2.7.1 Minimal Example 16

2.7.2 Local Usage Example 16

2.7.3 Grid Usage Example 17

2.7.4 Full Example 17

3. Conclusions 19

4. Appendix 20

4.1. Processing model 20

4.1.1 Identifying Record Overlap 20

4.1.2 Aggregating Records 21

# Introduction

## Purpose

Standardization is one of the main goals of EMI. The definition of a standard storage accounting record (StAR) is a first step towards enabling a shared storage infrastructure. StAR allows for accounting and reporting of the resources consumed by persons and groups in a common way.

The purpose of this document is to describe the format specification of StAR, which is planned to be implemented by the EMI storage providers and to be proposed to OGF as a standard. Though it was developed in the context of distributed storage in a Grid environment it is not specific to such a storage infrastructure. Due to the generic approach it can be used in any storage environment.

## About this Document

StAR tries to define a standardized way to exchange storage consumption data. This document does not address in detail how the records should be used, how the accounting data are aggregated, nor does it attempt to dictate the format in which the accounting records are stored at a local site. Furthermore, nothing is said regarding the communication mechanisms employed to exchange the records, i.e. transport layer, framing, authentication, integrity, etc.

The document is made by the Storage Accounting TF in the EMI Data group, Paul Millar, Ralph Müller-Pfefferkorn, Zolt Molnár, Jon Kerr Nilsen and Riccardo Zappi, and Henrik Thostrup Jensen from NDGF. During the making of the document, contacts have been made with organizations and potential user groups, such as NDGF, OGF, EGI, OSG, INFN, CMS and ATLAS, and internally in EMI with JRA1.4 (security) and JRA1.6 (standardization) resulting in valuable feedback and active cooperation. Special gratitude goes to Brian Bockleman (OSG), Andrea Cristofori (OGF) and John Alan Kennedy (OGF) for valuable comments.

## References

|  |  |
| --- | --- |
| **R1** | ISO Technical Committee TC 154 – <http://www.iso.org/iso/catalogue_detail?csnumber=40874> |
| **R2** | Key words for use in RFCs to Indicate Requirement Levels, RFC 2119 – <http://tools.ietf.org/html/rfc2119>  |
| **R3** | Usage record format recommendation – <http://ogf.org/documents/GFD.98.pdf> |

## Document amendment procedure

This document can be amended by the authors further to any feedback from other teams or people. Minor changes, such as spelling corrections, content formatting or minor text re-organisation not affecting the content and meaning of the document can be applied by the authors without peer review. Other changes must be submitted to peer review and to the EMI PEB for approval.

When the document is modified for any reason, its version number shall be incremented accordingly. The document version number shall follow the standard EMI conventions for document versioning. The document shall be maintained in the CERN CDS repository and be made accessible through the OpenAIRE portal.

## Terminology

|  |  |
| --- | --- |
| **StAR** | **St**orage **A**ccounting **R**ecord |
| FQDN | Fully Qualified Domain Name |
| ISO | International Organization for Standardization |
| **SLA** | Service Level Agreement |
| **OGF** | Open Grid Forum |
| **NDGF** | Nordic Data Grid Facility |
| **EGI** | European Grid Infrastructure |
| **OSG** | Open Science Grid |
| **INFN** | Istituto Nazionale di Fisica Nucleare |
| **CMS** | Compact Muon Solenoid |
| **ATLAS** | A Toroid LHC Aparatus |

# TeChnical description

## Overview of the storage accounting record

### Measuring Storage Resource Consumption

Measuring consumption of storage resources is distinctively different from the measurement of the consumption of computing resources in batch jobs. On a computing resource it is quite easy to continuously collect CPU usage information with a high time resolution - the operating system itself does it and an accounting system can access these data. Additionally, the resource usage data are usually strictly increasing, e.g. CPU time or wall clock time. A collection of storage resource consumption is much harder to achieve. The usage of each participant will vary over time and only few systems do permanently record the storage use of the single users or groups with a fine granularity in time. Usage snapshot are taken from time to time only resulting in rough consumption estimation especially in environments with a high fluctuation rate. Nevertheless, there is a need to do storage accounting both for the provider of storage resources and the users. It is the base for billing and for the development of a storage infrastructure.

### Record Structure & Content

The structure of the format described in this document can be split into logical parts, each describing an aspect of the resource consumption. The parts are

**Resource:** Fields describing the system the resource was consumed on. They can specify a certain subsystem of the storage system.

**Consumption Details:** Fields describing what the data is consuming, e.g. storage classes, directory path, etc.

**Identity:** Describes the person or group accountable for the resource consumption.

**Resource Consumption:** Fields describing how much of the described resource has been used.

Please note, that these logical sections are not necessarily directly reflected in record format. They are merely a good mental model to have in mind.

Most of the information in the record is common to all files, e.g. resource or identity description. Certain fields are aggregates over the consumed resources. This includes the consumption itself, but can also be consumption details, such as number of files.

The record is not intended to be used for describing intricate information about the consumption. E.g., filenames, per-file data or application metadata should not be included in the record. Such details are out of scope for the record and are not important for accounting of resource consumption.

To see examples of records, see section 2.7

### Including Additional Information

It is allowed to add additional fields with information in the record, e.g. for a more accurate description of the data that has consumed the resources.

If any user or group information is added it must be added under the SubjectIdentity block. This makes it possible to automatically remove user and group information.

## Conventions and terms

This section defines various key-words, conventions and terms used in the specification.

### Conventions used in the specification

The key words ”MUST”, ”MUST NOT”, ”REQUIRED”, ”SHALL”, ”SHALL NOT”, ”SHOULD”, ”SHOULD NOT”, ”RECOMMENDED”, ”MAY”, and ”OPTIONAL” in this document are to be interpreted as described in RFC 2119 [R2].

### Context

The specifications that are made in the following are based on a context that the reader needs to comprehend.

**A Storage resource** is a logical resource (either local or distributed) that allows an individual user or a group of users to store data. Such a system can contain single disks or can be created by pooling together physical storage media. This is transparent to the user and does not need to be considered when accounting for resource consumption.

**Storage accounting** is the recording and summarizing of the consumption of a storage resource by an individual user or a group of users in a specified time frame.

## Related work

The record format described in this document is clearly related to the usage record (UR) format recommendation of the OGF 98 standard [R3], as it tries to achieve a shared record format for accounting of consumed resources. Furthermore it shares several element names and semantics of the fields.

While efforts have been made to keep the StAR format close to the OGF UR format, the OGF UR does not allow for extensions and StAR and OGF UR have a limited number of properties in common. Hence, it has been decided to define a separate storage record format at this point in time.

## Record properties

This section describes the record properties and their fields and attributes. A summary of the fields is given in section 2.6, while examples of using the fields are given in section 2.7.

The format of the record is XML, using QNames. The currently defined name space is <http://eu-emi.eu/namespaces/2011/02/storagerecord>, denoted as “sr” in this document. All time and duration formats are ISO types [R1]. These design choices are made in order to keep the format as close as possible to OGF usage record format.

Many of the properties presented in this section are optional, however a few are not. For the required properties, it is explicitly listed that they must be present in the record. None of the properties are allowed to be repeated.

A record should only represent a single identity. This identity can either be a person or a group of users. If a record contains both user and group information, the implementation should assume that the resources have been consumed by the user in the context of the group information.

### StorageUsageRecord

This is the top container property of the record format.

* StorageUsageRecord MUST be present in the record.
* StorageUsageRecord MUST be top container for the record.
* StorageUsageRecord MUST NOT have a value.

#### Example

<sr:StorageUsageRecord>

<!—Record properties go in here -->

</sr:StorageUsageRecord>

### StorageUsageRecords

This property can hold a number of StorageUsageRecord properties, i.e., act as a container for several storage usage records.

* StorageUsageRecords MUST only contain StorageUsageRecord elements.
* StorageUsageRecords MUST NOT have a value.

#### Example

<sr:StorageUsageRecords>

<sr:StorageUsageRecord>

<!—Record properties go in here -->

</sr:StorageUsageRecord>

<sr:StorageUsageRecord>

<!—Record properties go in here -->

</sr:StorageUsageRecord>

</sr:StorageUsageRecords>

### RecordIdentity

This property describes the identity of the record. The field has two attributes: recordId and createTime. The recordId should be constructed in such a way that it is globally unique and records with the same value is not generated accidentally. Hence this field can be used to identify the record, and be used for duplicate detection. The createTime attribute describes when the record was created. It might differ from the time when the resource usage was measured (see section 4.16)

The field is similar to the field with the same name in the Usage Record standard.

* The RecordIdentity property MUST be present in the record.
* The RecordIdentity field MUST NOT have a value.
* The recordId attribute MUST be present in the record.
* The recordId attribute MUST have the type string.
* The createTime attribute MUST be present in the record.
* The createTime attribute MUST be an ISO timestamp.

#### Example

<sr:RecordIdentity

sr:createTime="2010-11-09T09:06:52Z"

sr:recordId="host.example.org/sr/87912469269276"/>

### StorageSystem

This property describes the storage system on which the resources have been consumed. This value should be chosen in such a way that it globally identifies the storage system, on which resources are being consumed. E.g., the FQDN of the storage system could be used.

In Grid terms, this would be a storage element.

* The StorageSystem property MUST be present in the record.
* The StorageSystem field MUST have the type string.
* The StorageSystem value SHOULD be constructed in such a way, that it globally identifies the storage system.
* For EGI the StorageSystem+StorageShare MUST be defined and reported so that ALL user storage at a site is recorded once and only once. i.e the sum of all records should reflect storage at the site and there should be no doublecounting.

#### Example

<sr:StorageSystem>host.example.org</sr:StorageSystem>

A single record per VO for the whole site is acceptable, as is one per disk server, or one per storage system (eg dcache)instance. The key is completeness and uniqueness.

The Glue2 attribute …… is the preferred solution

### StorageShare

This property describes the part of of the storage system which is accounted for in the record. For a storage system, which is split into several logical parts, this can be used to account for consumption on each of these parts. The value should be able to identity the share of the storage system, given the storage system property.

* The StorageShare field type MUST be a string.

#### Example

<sr:StorageShare>pool-003</sr:StorageShare>

### StorageMedia

This property describes the media type of storage that is accounted for in the record, e.g. “disk” or “tape”. This allows for accounting of different backend storage types.

* The StorageMedia field type MUST be a string.

#### Example

<sr:StorageMedia>disk</sr:StorageMedia>

### StorageClass

This property describes the class of the stored data, e.g. ”pinned”, ”replicated”, ”precious”. This is a descriptive value, which allows the storage system to provide details about the stored data.

* The StorageClass field type MUST be a string.

#### Example

<sr:StorageClass>replicated</sr:StorageClass>

### FileCount

This property describes the number of files which are accounted for in the record.

* The FileCount field type MUST be a positive non-zero integer.

#### Example

<sr:FileCount>42</sr:FileCount>

### DirectoryPath

This property describes the directory path being accounted for. If the property is included in the record, the record should account for all usage in the directory and only that directory.

* The DirectoryPath field type MUST be a string.

#### Example

<sr:DirectoryPath>/projectA</sr:DirectoryPath>

### SubjectIdentity

This property is a container for all user and group properties. Its purpose is to clearly mark one or more properties describing a user or group, i.e. the entity accountable for the resource consumption. The property is similar to the UserIdentity block in the OGF Usage Record format, but it can also be used for describing group affiliations.

* The SubjectIdentity property SHOULD be present in the record.
* The SubjectIdentity property SHOULD include at least one sub element.
* The SubjectIdentity field MUST NOT have a value.

#### Example

<sr:SubjectIdentity>

<!-- Various identity fields go in here -->

</sr:SubjectIdentity>

### LocalUser

This property describes the local user name of the person accountable for the resource consumption on the storage system. It can be defined on the operating system level or as an internal user name in the storage system.

* If included, the LocalUser property MUST be under the SubjectIdentity.
* The LocalUser field type MUST be a string.

#### Example

<sr:LocalUser>johndoe</sr:LocalUser>

### LocalGroup

This property describes the local user group accountable for the resource consumption on the storage system. It can be defined on the operating system level or as an internal group in the storage system.

* If included, the LocalGroup property MUST be under the SubjectIdentity.
* The LocalGroup field type MUST be a string.

#### Example

<sr:LocalGroup>binarydataproject</sr:LocalGroup>

### UserIdentity

This property describes the global identity of the user accountable for the resource consumption. The property should identify the user globally, such that clashes do not happen accidentally, e.g. it could be an X509 identity.

* If included, the UserIdentity property MUST be under the SubjectIdentity.
* The UserIdentity field type MUST be a string.

#### Example

<sr:UserIdentity>/O=Grid/OU=example.org/CN=John Doe

</sr:UserIdentity>

### Group

This property describes the global group accountable for the resource consumption. The property should identify the group globally, such that clashes do not happen accidentally, e.g. using a FQDN to construct it. In Grid terms, this would typically be the VO name.

* If included, the Group property MUST be under the SubjectIdentity.
* The Group field type MUST be a string.

#### Example

<sr:Group>binarydataproject.example.org</sr:Group>

### GroupAttribute

This property describes supplemental traits of the group property, e.g., sub-groups, role or authority. This makes it possible to account for segments of a group, while still being able to account for the group as a whole. The property consists of a type which denotes the type of attribute and an actual value for the attribute.

* If included, the GroupAttribute property MUST be under the SubjectIdentity.
* The GroupAttribute property can be repeated.
* The Group property MUST exist in the record if GroupAttribute is specified.
* The GroupAttribute type and field values MUST exist.
* The GroupAttribute type MUST have the type string.
* The GroupAttribute field type MUST be a string.

#### Examples

<sr:GroupAttribute sr:attributeType="role">production</sr:GroupAttribute>

<sr:GroupAttribute sr:attributeType="subgroup">analysis</sr:GroupAttribute>

<sr:GroupAttribute sr:attributeType="authority">

/O=Grid/OU=example.org/CN=host/auth.example.org

</sr:GroupAttribute>

### MeasureTime

This property describes a timestamp indicating when the measurement of the resource consumption was made.

* The MeasureTime field MUST be present in the record.
* The MeasureTime field type MUST be an ISO timestamp.

#### Example

<sr:MeasureTime>2010-10-11T09:31:40Z</sr:MeasureTime>

### ValidDuration

This property describes a duration indicating for how long the measurement is valid starting with its measurement time. The record must only be used for the time frame in which it is valid. The generation of records should be performed in such a way, that gaps should not occur. Note that a record can be “nullified” if a newer record is manifested, i.e. the most recent information should be used.

* The ValidDuration field MUST be present in the record.
* The ValidDuration field type MUST be an ISO duration.
* The value of ValidDuration SHOULD be in the order of the time interval the records are recorded in. Setting a very high value for ValidDuration can lead to situations where a user who removes all his data is still accounted for unless a record of zero usage is created.

#### Example

<sr:ValidDuration>PT3600S</sr:ValidDuration>

### ResourceCapacityUsed

This property describes the number of bytes used on the storage system. This is the main metric for measuring resource consumption. It should include all resources for which the identity of the record is accountable for.

ResourceCapacityUsed can include reserved space, file metadata, space used for redundancy in RAID setups, tape holes, or similar. The decision about including such “additional” space is left to the resource owner but should be made known to the user e.g. via the usage policy. In contrary the LogicalCapacityUsed (see section 2.4.19) denotes the pure file size.

* The ResourceCapacityUsed property MUST be present in the record.
* The ResourceCapacityUsed field type MUST be a nonnegative integer.
* ResourceCapacityUsed SHOULD include all resources that are used to store the files. The value MAY also include resources that are no longer in use but are unavailable for reuse, as documented in the appropriate SLA or usage policy documents.

#### Example

<sr:ResourceCapacityUsed>14728</sr:ResourceCapacityUsed>

**Implementation Note**

Using bytes saves us from the argument of discussing if 1000 or 1024 should be used as a base. However, this also means that the number reported can be very large. Therefore any implementation should use at least a 64-bit integer to hold this variable (a signed 64-bit integer will overflow at 8 Exabytes).

### LogicalCapacityUsed

This property describes an integer denoting the number of “logical” bytes used on the storage system by the identity of the record. By ‘logical” is meant the sum of bytes of the files stored, i.e. excluding reservation and any underlying replicas of files (see ResourceCapacityUsed in section 2.4.18).

* The LogicalCapacityUsed field type MUST be a nonnegative integer.

#### Example

<sr:LogicalCapacityUsed>13617</sr:LogicalCapacityUsed>

**Implementation Note**

Same as for ResourceCapacityUsed property (see section 2.4.18).

## Intentionally left out properties

In the preparation phase yielding the current draft of the record a number of properties were in discussion to be included. They are listed here for the sake of completeness.

**Site** This property would identify the site, at which the storage system is located, allowing easy grouping of several storage systems. However such a grouping is often defined elsewhere and is not always static.

**FileNames** Providing a list of file names in the record would allow per-file accounting, or allow certain files to be accounted for separately. However, the available properties like path, storage system, group, and user provide a sufficient definition of the resource consumption.

**File Metadata** The focus of the record is accounting. Any per-file data or metadata are out of scope of the record.

**SpaceAvailable** This property would describe how much space is available for the identity on the storage system. This property would however not report any form of consumption and is often difficult to determine.

**Transfer Information** The original suggestion included properties for describing how much data has been transferred. There are however a range of issues with this: A. network resources are not storage resources. B: Users transferring data are not necessarily the user owning the data. Thus, the accounting of the network usage should be defined elsewhere.

**StartTime / EndTime** They have been replaced by measurement time and valid duration as it is not really known when the actual measurement of the resource consumption is taken.

## Field summary

|  |  |  |  |
| --- | --- | --- | --- |
| **Field** | **Short Description** | **Field Type** | **Requirement** |
| StorageUsageRecord | Top container |  | REQUIRED |
| StorageUsageRecords | Container for grouping multiple records |  | OPTIONAL |
| RecordIdentity | Identity of the record |  |  |
| Attributes: |  |  |  |
| recordID | Global unique record ID | String | REQUIRED |
| createTime | Record creation time | ISO timestamp | REQUIRED |
| StorageSystem | Storage system description | String | REQUIRED |
| StorageShare | Part of the storage system accounted for | String | OPTIONAL |
| StorageMedia | Media type | String | OPTIONAL |
| StorageClass | Class of stored data | String | OPTIONAL |
| FileCount | Number of files accounted for | String | OPTIONAL |
| DirectoryPath | Directory path accounted for | String | OPTIONAL |
| SubjectIdentity | Container for user and group properties |  | RECOMMENDED |
| Elements: |  |  |  |
| LocalUser | User name on the storage system | String | OPTIONAL |
| LocalGroup | Group name on the storage system | String | OPTIONAL |
| UserIdentity | Global user ID | String | OPTIONAL |
| Group | Global group | String | OPTIONAL |
| GroupAttribute | Group attribute | String | OPTIONAL |
| attributeType | Type of attribute | String | REQUIRED if GroupAttribute is defined |
| MeasureTime | Time of measurement | ISO timestamp | REQUIRED |
| ValidDuration | Validity of the record | ISO duration | REQUIRED |
| ResourceCapacityUsed | Number of bytes used on the storage system | Nonnegative Integer | REQUIRED |
| LogicalCapacityUsed | Number of “logical” bytes used on the storage system | Nonnegative Integer | OPTIONAL |

Table 1: Summary of the fields of StAR

## Record Examples

### Minimal Example

Minimal record that is actually useful. There is no identity block, which should be interpreted as the record accounts for all usage on the storage system.

<sr:StorageUsageRecord

 xmlns:sr="http://eu-emi.eu/namespaces/2011/02/storagerecord">

 <sr:RecordIdentity sr:createTime="2010-11-09T09:06:52Z"

 sr:recordId="host.example.org/sr/87912469269276"/>

 <sr:StorageSystem>host.example.org</sr:StorageSystem>

 <sr:MeasureTime>2010-10-11T09:31:40Z</sr:MeasureTime>

 <sr:ValidDuration>PT3600S</sr:ValidDuration>

 <sr:ResourceCapacityUsed>13617</sr:ResourceCapacityUsed>

</sr:StorageUsageRecord>

### Local Usage Example

Example how a record accounting for a local user could look like.

<sr:StorageUsageRecord

 xmlns:sr="http://eu-emi.eu/namespaces/2011/02/storagerecord">

 <sr:RecordIdentity sr:createTime="2010-11-09T09:06:52Z"

 sr:recordId="host.example.org/sr/87912469269276"/>

 <sr:StorageSystem>host.example.org</sr:StorageSystem>

 <sr:SubjectIdentity>

 <sr:LocalUser>johndoe</sr:LocalUser>

 </sr:SubjectIdentity>

 <sr:StorageMedia>tape</sr:StorageMedia>

 <sr:FileCount>42</sr:FileCount>

 <sr:MeasureTime>2010-10-11T09:31:40Z</sr:MeasureTime>

 <sr:ValidDuration>PT3600S</sr:ValidDuration>

 <sr:ResourceCapacityUsed>913617</sr:ResourceCapacityUsed>

</sr:StorageUsageRecord>

### Grid Usage Example

Example how a record accounting for Grid usage could look like.

<sr:StorageUsageRecord

 xmlns:sr="http://eu-emi.eu/namespaces/2011/02/storagerecord">

 <sr:RecordIdentity sr:createTime="2010-11-09T09:06:52Z"

 sr:recordId="host.example.org/sr/87912469269276"/>

 <sr:StorageSystem>host.example.org</sr:StorageSystem>

 <sr:StorageShare>pool-003</sr:StorageShare>

 <sr:SubjectIdentity>

 <sr:Group>binarydataproject.example.org</sr:Group>

 <sr:GroupAttribute sr:attributeType="subgroup">ukusers</sr:GroupAttribute>

 </sr:SubjectIdentity>

 <sr:StorageMedia>disk</sr:StorageMedia>

 <sr:FileCount>42</sr:FileCount>

 <sr:MeasureTime>2010-10-11T09:31:40Z</sr:MeasureTime>

 <sr:ValidDuration>PT3600S</sr:ValidDuration>

 <sr:ResourceCapacityUsed>14728</sr:ResourceCapacityUsed>

 <sr:LogicalCapacityUsed>13617</sr:LogicalCapacityUsed>

</sr:StorageUsageRecord>

### Full Example

Example using all fields.

<sr:StorageUsageRecords

 xmlns:sr="http://eu-emi.eu/namespaces/2011/02/storagerecord">

 <sr:StorageUsageRecord>

 <sr:RecordIdentity sr:createTime="2010-11-09T09:06:52Z"

 sr:recordId="host.example.org/sr/87912469269276"/>

 <sr:StorageSystem>host.example.org</sr:StorageSystem> <sr:StorageShare>pool-003</sr:StorageShare>

 <sr:StorageMedia>disk</sr:StorageMedia>

 <sr:StorageClass>replicated</sr:StorageClass>

 <sr:FileCount>42</sr:FileCount>

 <sr:DirectoryPath>/home/projectA</sr:DirectoryPath>

 <sr:SubjectIdentity>

 <sr:LocalUser>johndoe</sr:LocalUser>

 <sr:LocalGroup>projectA</sr:LocalGroup>

 <sr:UserIdentity>/O=Grid/OU=example.org/CN=John Doe</sr:UserIdentity>

 <sr:Group>binarydataproject.example.org</sr:Group>

 <sr:GroupAttribute sr:attributeType="subgroup">ukusers</sr:GroupAttribute>

 </sr:SubjectIdentity>

 <sr:MeasureTime>2010-10-11T09:31:40Z</sr:MeasureTime>

 <sr:ValidDuration>PT3600S</sr:ValidDuration>

 <sr:ResourceCapacityUsed>14728</sr:ResourceCapacityUsed>

 <sr:LogicalCapacityUsed>13617</sr:LogicalCapacityUsed>

 </sr:StorageUsageRecord>

</sr:StorageUsageRecords>

# Conclusions

With the definition of the StAR record a first step in the establishment of a common storage accounting record has been done. The next phase will be to propose StAR to the Open Grid Forum to start a standardization process there. It is clear that this will need more time, will include further discussions and maybe even changes to StAR. The EMI partners will actively take part in this process.

Nevertheless, the EMI data group will begin to implement the StAR record into the EMI storage middleware even during the ongoing standardization process.

# Appendix

## Processing model

This appendix explains how to process storage records in order to get usable data. The reason for including this appendix is that accounting for storage is fundamentally different from batch jobs and hence must be treated different with regards to aggregation.

### Identifying Record Overlap

Storage records have a measurement time for when the resource consumption was measured. This consumption is valid until the expiration time in the record is reached. However a record can also be “invalidated” if a newer record is registered for the same resource. This is illustrated in Figure 1.

Figure : As time progresses, new records can invalidate old records by overlapping them in time. A record is depicted by a square. The stippled lines show where records have been invalidated. The fat line marks the resource consumption.

In Figure 1 **Error! Reference source not found.**it can be seen how resource consumption changes as new records come into the system, and how old records are invalidated. Note that in one time slot there are no valid records present, which means no resource consumption can be assumed.

As records can overlap in time, they cannot simply be summed up in order to identify total resource consumption. Hence to know how many resources have been consumed, one must ask for a certain point in time, at which valid records can be found and aggregated if needed. If there are multiple valid records for a given point in time, the recent one should be chosen. To find the resource consumption of a time interval (e.g. for visualizing resource consumption) a set of timestamps should be generated for the interval for which the resource consumptions can be found.

Most installations will probably generate the records at a regular interval, which will have fairly minimal overlap. However, a site could also choose to create records with very long longevity and only create new records when resource consumption change significantly, hence taking a lazy approach to generating storage records. Service consuming storage records must of course be able to deal with both cases.

The task of identifying overlapping records is further complicated by the fact that a resource can generate multiple records for different parts of the resource or splitting the resource consumption per user or group. A way to visualize this would be to stack several records on top of each other. In such cases - which are likely to be common - the task of selecting which records are valid and which are not becomes slightly more complex. There will be several records which are valid at the same time for the same resource. However, records will only be overlapping if they describe the same consumption.

To solve the problem of identifying if multiple records describe the same resource consumption, the concept of consumption identity is introduced. Note that this concept is not directly modeled into the record, but instead is something that is created from multiple properties in the record. This consumption identity is composed of the resource identity and the subject identity. The subject identity is defined by the SubjectIdentity property (which can contain a number of properties). The resource identity is defined by composing the following properties: StorageSystem, StorageShare, StorageMedia, and StorageClass. Note that not all of these are necessarily defined.

### Aggregating Records

Having established a method to identity if two records are describing the same consumption, it becomes possible to choose the set of currently valid records, while ensuring that no overlapping records exists. This means that is also becomes possible to aggregate records across storage shares, media, users, projects in order to identify resource consumption in various contexts. For such aggregations to make sense it is important that records are created in a non-overlapping fashion. This is highly recommended, but not dictated by this format specification.

When implementing a record consuming service, it is recommended that a good abstraction for choosing valid records from a given point in time is used as a basis for all queries. Without such an abstraction, extracting anything but the simplest data can become difficult. For relational databases, such an abstraction could be a set-returning function, which takes a timestamp as its argument.