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Rucio: Conceptual Model

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Abstract

This document describes the conceptual model of the new version of the ATLAS Distributed Data Management (DDM) system, Rucio. We describe core concepts of the system and the high level interactions between Rucio and clients.

The DDM system is designed to allow the ATLAS collaboration to manage the large volumes of data, both taken by the detector as well as generated or derived, in the ATLAS distributed computing system. Rucio supports permissions, accouting and quota on its accounts, which can represent an ATLAS user, physics group or central activity. Rucio allows the organisation of files into arbitary, overlapping datasets and the setting of selected metadata properties on both files and datasets. Replication rules can be set on files that instruct the system how to organise and manage replicas. Rucio can group storage elements by the setting of common properties that can be specified as part of a replication rule. Rucio manages ATLAS accessible storage elements by moving required files to them and deleting unnecessary files from them.

1 Introduction

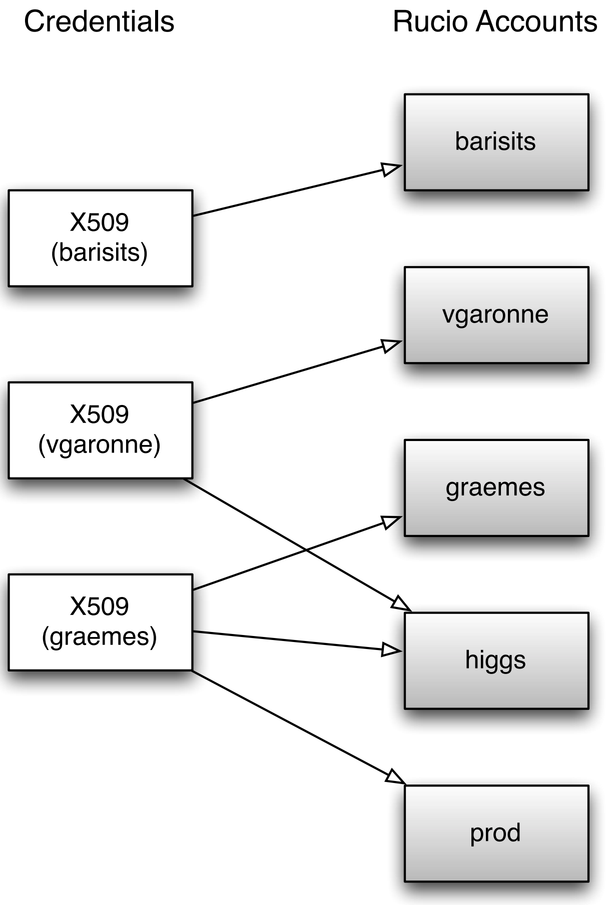
In this document we describe the conceptual model of the new version of ATLAS Distributed Data Management (DDM) system: codename Rucio. We introduce the core concepts Rucio uses to manage accounts, files, datasets and storage systems. A high level description of how users interact with the system is given where appropriate.

2 Rucio account

A Rucio account is the unit of assigning privileges in Rucio. It can represent individual users (like lgoossen, graemes, vgaronne, . . .), a group of users (like bphys, higgs, susy, . . .) or an organised production activity for the whole ATLAS collaboration (prod, tzero, . . .). A Rucio account is identified by a string.

Rucio actions are always conducted by a Rucio account. Each account has a namespace identifier called *scope* that is included in every name assigned to a collection of data created by that account (see §3.1). By default, Rucio accounts can only create identifiers in their own scope and not in any other.

A Rucio user is identified by his credentials, like X509 certificates, username/password, or token. Credentials can map to one or more accounts (N:M mapping). The Rucio authentication system checks if the used credentials are authorized to use the supplied Rucio account. The figure below gives an example of the mapping between credentials and Rucio accounts:



3 Datasets and files

ATLAS naturally has a large amount of data, which is physically stored in files. The actual distribution of the data over files is mostly incidental. The data consists usually, but not exclusively, of persistent C++ objects associated with physics events. Physicists need to be able to identify and operate on any arbitrary subset of this data: a dataset. Hence, a dataset might be a single file or multiple files[1].

Datasets may be overlapping in the sense that a subset of data, i.e. a single file or more files, can be part of multiple datasets.

New datasets can be defined based on the contents of existing datasets. In particular, it is possible to aggregate the contents of two or more datasets into a new one by taking the set union of their respective contents. While successive aggregations will implicitly create an aggregation hierarchy, this is not reflected in the naming of the datasets. Instead Rucio will merely record in the dataset metadata that it was created by performing such a union. Otherwise the dataset will be identical to one created by simple enumeration of the resulting contents, i.e. the corresponding files.

3.1 Dataset/file identifiers and scope

To be able to unambiguously refer to a logical file it needs to have an identifier. For a logical file this is the Logical File Name (LFN) which is composed of two strings: the scope identifier and the file label[2]. A single file is a dataset in itself and as such dataset identifiers follow the same scheme: Each dataset is identified by the Dataset Name (DSN) which is composed by the scope identifier and the dataset label.

The scope identifier partitions the dataset name space in several sub-spaces. The primary use case for this is to have separate scopes for production and individual users. There is a one to one relationship between account and scope. There are no particular constraints on the strings used for either scope and labels other than a restricted set of allowed characters. In particular, it is possible to use Universally Unique Identifiers (UUIDs) as labels.

Datasets/files are uniquely identified over all time. A DSN/LFN once used to refer to a dataset/file can never be reused to refer to another dataset/file, not even if the former has become obsolete or has been deleted from the system.

3.2 Dataset and file status

3.2.1 File status

The following status flags are supported for files:

- `Obsolete`: True/False

The obsolete flag indicates a file which, for one reason or another, should not be used by the collaboration. A file marked as obsolete will have all replicas removed from the system. Obsolete LFNs are remembered by the system to prevent accidental reuse in the future.

- `Lost`: True/False

The lost flag indicates that although the logical definition of the file still exists in Rucio, no physical replicas of the file currently exist. If the file is recovered from outside Rucio this flag can be changed from True to False.

[1] A dataset might be also a part of a file or a parts of multiple files, e.g. an event collection.

[2] A part of a file can be identified by an LFN and a sub-file identifier. The latter is a string and its interpretation depends on the nature of the file, e.g. event files might use an event number, or binary files might use an offset/size pair.

3.2.2 Dataset status

The dataset status is reflected by a set of attributes. Datasets in Rucio can have the following attributes:

- `Open`: True/False

A dataset might be a result of more than one computational process, therefore the definition of a dataset is not an atomic operation and can even extend over a large amount of time. For this purpose, a dataset has an open status to publish its availability, i.e. to reflect that its content is (not) complete. Open datasets cannot be used in aggregations. When the filling of the dataset is done, its state changes to closed and cannot thereafter be reopened.

- `Monotonic`: True/False

If the monotonic mode is enabled files cannot be removed from an open dataset. Once the monotonic flag is set to True it cannot be unset.

- `Hidden`: True/False

Datasets can be hidden so they do not show up in normal listing operations.

- `Obsolete`: True/False

The obsolete status means that a dataset and its definition should not be used anymore. Obsoleting a dataset does not obsolete its contents (however, one can instruct Rucio to obsolete all files which are in a particular dataset).

- `Complete`: True/False

The data a file points to can be temporarily or permanently lost, e.g. the system has lost all corresponding physical files. This is reflected in the lost status of the file and by the complete/incomplete status of all aggregate datasets containing them. The file content can be recovered and re-injected in the system causing the corresponding lost and complete/incomplete statuses to be updated.

Note that Rucio has no concept of dataset versioning. The loss of files is simply recorded as described above with a single flag, hence not recording in what order they were lost. Adding further files requires the definition of a new dataset with a new identifier. The latter dataset might reflect the relation with the former, but this is not required.

4 Metadata attributes

Metadata associated with a dataset/file is represented using attribute/value pairs. The set of available attributes is restricted. Metadata attributes are classified into four categories:

1. System-defined attributes: e.g. size, checksum, creationtime, modificationtime, status
2. Physics attributes: e.g. number of events, cross-section, or POOL GUID
3. Production attributes: e.g. storing information like which task or job produced the file
4. Data management attributes: necessary for the organisation of data on the grid (see §7)

For datasets, it is possible that the value of a metadata attribute is a function of the metadata of its constituents, e.g. the total size is the sum of the sizes of the constituents. In this case it is obviously not possible to assign a value to it.

Rucio supports searching for files and datasets based on metadata values.

5 Rucio Storage Element

A Rucio Storage Element (RSE) is a container for physical files. It is the smallest unit of storage space addressable within Rucio. It has an unique identifier and a set of meta attributes describing properties such as supported protocols, e.g. file, https, srm; host/port address; quality of service; storage type, e.g. disk, tape, . . . ; physical space properties, e.g. used, available, non-pledged; and geographical zone.

Rucio Storage Elements can be grouped in many logical ways, e.g. the UK RSEs, the Tier-1 RSEs, or the good RSEs. One can reference groups of RSEs by metadata attributes or by explicit enumeration of RSEs.

5.1 Physical File Name

The Physical File Name (PFN) is a fully qualified name identifying a replica of a file. PFNs may take the form of file names, URIs, or any other identifier meaningful to a Rucio Storage Element. The mapping between the LFN and the PFN is a deterministic function which also takes RSE and protocol into account.

Normally the upload to an RSE and the registration of an additional replica is an atomic operation. For trusted users like the Tier-0 and PanDA production systems, it is possible to register a replica uploaded independently.

6 Permission model

Rucio assigns permissions to accounts. Permissions are boolean flags designating whether an account may perform a certain action (read, write, delete) on a resource (RSE, account, replica, etc.).

7 Replica management

Replica management is based on replication rules defined on logical files. A replication rule is owned by an account and defines the minimum number of replicas to be available on a list of RSEs. Accounts are allowed to set multiple rules[3]. Rules may optionally have a limited lifetime and can be added, removed or modified at any time.

An example listing of replication rules is given below:

1. `prod`: 1x replica @ CERN, no lifetime

2. `higgs`: 2x replica @ GROUPDISK, no lifetime

3. `barisits`: 1x replica @ US-T2, until 2012-01-01 00:00

4. `vgaronne`: 2x replica @ T1, no lifetime

The Rucio rule engine validates the rules and creates transfer primitives to fulfil all rules, e.g. transfer a file from RSE A to RSE B. The rule engine is triggered when a file is created in the system, when a new rule is added to a file or when one explicitly requests for the rule to be applied on existing data. The rule engine will only create the minimum set of necessary transfer primitives to satisfy all rules.

An account can inject transfer primitives directly, e.g. transient replicas required for production operations. Notifications can be provided for the transfer request. All transfer requests are transient.

Deletion is triggered per RSE when storage policy dictates that space must be freed. A reaper service will look for replicas on that RSE that can be deleted without violating any replication rules. The reaper

[3] The system may reject rules if these violate other policies, e.g. a normal ATLAS user would not be allowed to set a rule which committed the system to generate 5PB of new replicas or to request replicas on an RSE tape system.

will use a Least Recently Used (LRU) algorithm to select replicas for deletion. The reaper service will also immediately delete all replicas of any file which is declared obsolete.

8 Accounting and quota

Accounting is the measure of how much resource, e.g. storage, an account has used as a consequence of its actions. Quota is a policy limit which the system applies to an account.

For storage accounting, Rucio accounts will only be accounted for the files they set replication rules on. Accounting is based on the replicas an account requested, not on the actual amount of physical replicas in the system. Consequently, it is expected that over-booking of physical space will be employed as a particular physical replica may satisfy several replication rules.

9 Notifications

External applications can require synchronisation on events relative to data availability and can subscribe to particular events, e.g. dataset state changes. Rucio will then publish a message to external application when it detects these events.

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Appendix A. Key concepts: Comparison matrix DQ2 vs. Rucio

Features	DQ2	Rucio
File identifier	GUID/LFN (Basename)	Scope + Label name
Dataset identifier	DUID/DSN	Scope + Label name
Versioning	Yes	No
Namespace	Global/Flat	Scoped
Unique PFN	No	Yes
Overlapping dataset	Yes	Yes
Storage Element Groups	No	Yes
Storage Element Tagging	No	Yes
Quota support	Group	Account (Group/User)
Dataset Replica completeness	Yes	No
Metadata namespace/support	System defined, Data placement	System defined, Physics, Production, Analysis, Data placement
Data discovery unit	Pattern	Metadata
Data operation unit	Dataset	Dataset, File
Multiple replica ownership	No	Yes
Dynamic placement	No	Yes
Replication rule support	No	Yes
Hidden data	Yes	Yes
Reuse of dataset name	No	No (but possibility to resuscitate dataset)
Notifications	Yes	Yes
Fine-grained accounting	Partially	Yes

Appendix B. Acronyms and Abbreviations

LFN Logical File Name.

LRU Least Recently Used.

DSN Dataset Name.

PFN Physical File Name.

RSE Rucio Storage Element.

UUID Universal Unique Identifier.