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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 its 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 that instruct the system how to organise and manage replicas. Replication policies can be set, allowing the automatic generation of rules based on metadata. 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

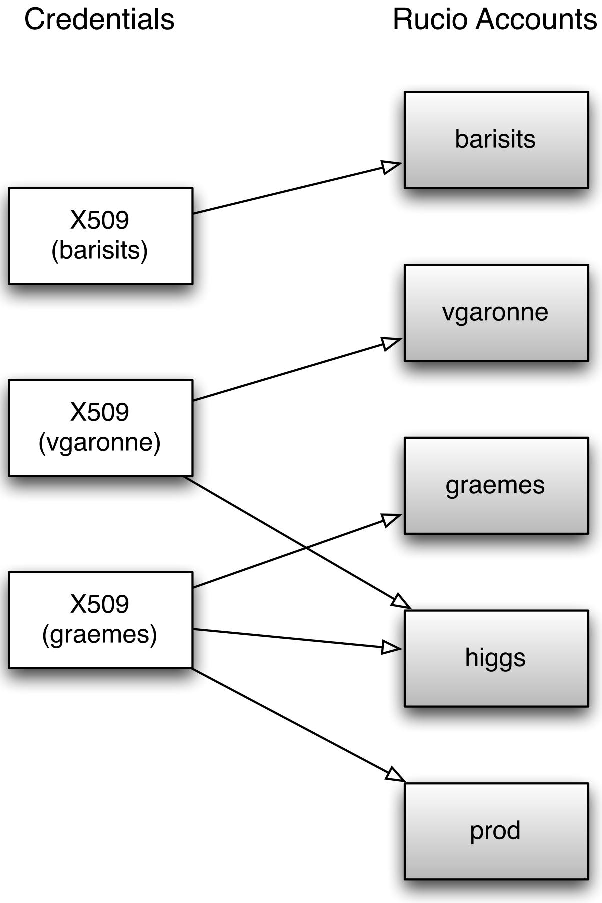
In this document we describe the conceptual model of the new version of ATLAS Distributed Data Management (DDM) system: codename Rucio. We introduce the core concepts Rucio uses to manage accounts, files, datasets and storage systems. A high level description of how users interact with the system is 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 their credentials, like X509 certificate, 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 authorised 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, but either case this dataset unit is that on which most users will act most of the time.

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.

The most common aggregation scheme in ATLAS is hierarchical, e.g., run datasets aggregated into sub-periods, sub-periods into periods, periods into a year of data. However, Rucio also will support horizontal aggregation of files between any datasets.

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. 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 of the scope identifier and the dataset label.

The scope identifier partitions the dataset name space into 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.

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.

3.2.3 Dataset Replication Policy

THIS SECTION IS DRAFT FOR DISCUSSION

The question of file distribution in datasets is an important one. If the file content of datasets is very widely distributed across many sites this will maximise the availability of CPU resources that can be used to process this data. If the files are concentrated at one site this might be optimal for processing which required the use of many files at the one time (e.g., merging and archiving to tape). Using the wrong distribution policy will impact on the efficiency of processing the data.

Therefore Rucio will support a hinting mechanism which will allow clients to suggest to the system what the optimal distribution across sites will be. This will influence the way that the system distributes files when it is satisfying rules (however, the distribution will be consistent with the rules, e.g., a rule which directs the data to a specific site will mean that replication policy could not take effect).

It is therefore proposed to support the following flag at the dataset level:

- `ReplicationPolicy`: RPValue

Precise values of RPValue and the effects they will have need to be discussed. However, it should be possible to concentrate dataset content at as few sites as possible or to distribute the data as widely as possible or to adopt some intermediate strategy.

In any case, given other constraints in the data management system, it will be very beneficial to overall efficiency if job processing systems to not rely on 100% of files being at a specific site, but will be able to process data at other sites or transfer as needed in order to complete tasks.

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, POOL GUID
3. Production attributes: e.g., task and job ID that produced the file, processing campaign ID
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.

When appropriate and requested, Rucio will check metadata values for validity, rejecting the attempt to set invalid values. This can used to ensure that, e.g., POOL GUID is unique and that the Job ID is a positive integer.

Rucio supports searching for files and datasets based on metadata values. Wildcard queries or range operations will only be supported on certain metadata fields. e.g., processing tag can be searched using wildcards, task ID can be searched using range operators, but scope can only be an exact match.

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.

RSE tags are expanded at transfer time to enumerate target sites. Post-facto changes to the sites in an RSE tag list will not affect currently replicated files.

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. It may also consider the filename, allowing a separation of PFN based on scope, project or other criteria.

Normally the upload to an RSE and the registration of an additional replica is a single 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

7.1 Replication Rules

Replica management is based on replication rules defined on datasets. 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[1]. Rules may optionally have a limited lifetime and can be added, removed or modified at any time. Rules can also be locked, which will prevent their modification until an explicit unlock operation is performed.

An example listing of replication rules is given below:

1. `prod`: 1x replica @ CERN, no lifetime
2. `prod`: 1x replica @ T1TAPE, no lifetime, locked
3. `higgs`: 2x replica @ GROUPDISK, no lifetime
4. `barisits`: 1x replica @ UST2, until 2012-01-01 00:00
5. `vgaronne`: 2x replica @ T1, no lifetime
6. `graemes`: 1x replica @ GLASGOW, until 2011-12-25 00:00

The Rucio rule engine validates the rules and creates transfer primitives to fulfil all rules, e.g., transfer some files 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 dataset 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.

Files inherit all rules from all datasets they are members of. This allows users of the system to interact at the dataset level and Rucio will propagate these rules to the appropriate files. The dataset ReplicationPolicy (see §3.2.3) will affect how the system groups files in the same dataset across potential RSEs.

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 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.

7.2 Transfer Primitives

Accounts 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.

The injection of transfer primitives requires a specific privileges to prevent abuse of this feature.

[1] 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.

7.3 Policies

Policies are system entities which generate rules or transfer requests based on matching particular dataset metadata at registration time. Polices are owned by an account and can only generate rules for that account. Policies may have a lifetime, after which they will expire.

An example of a policy is given below:

Attribute	Value
Owner	tzero
match	project=data11_7TeV, dataType=RAW, stream=physics_*
rule	1@CERNTAPE, 1 @T1TAPE
lifetime	2012-01-01 00:00

Policies can also create transfer primitives, so generate extra copies of data as it is produced:

Attribute	Value
Owner	prod
match	project=mc11_7TeV, dataType=merge.AOD, tag=*(p795|p796|p805)*, ReplicationPolicy=RPValue
rule	1@T1DISK, 1@T2DISK
transfer	1@T1DISK, 2@T2DISK
lifetime	2011-12-01 00:00

In this case the transfer request is for *extra* copies, in addition to those set by rules. (This is different behaviour to that for rules themselves, which are always independent.)

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. Quotas will be available which apply to an account at a specific RSE tag or globally.

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
Dataset Distribution Policy	Only complete at site	Flexible
Replica Lifetime	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.