The EGI Workload Manager

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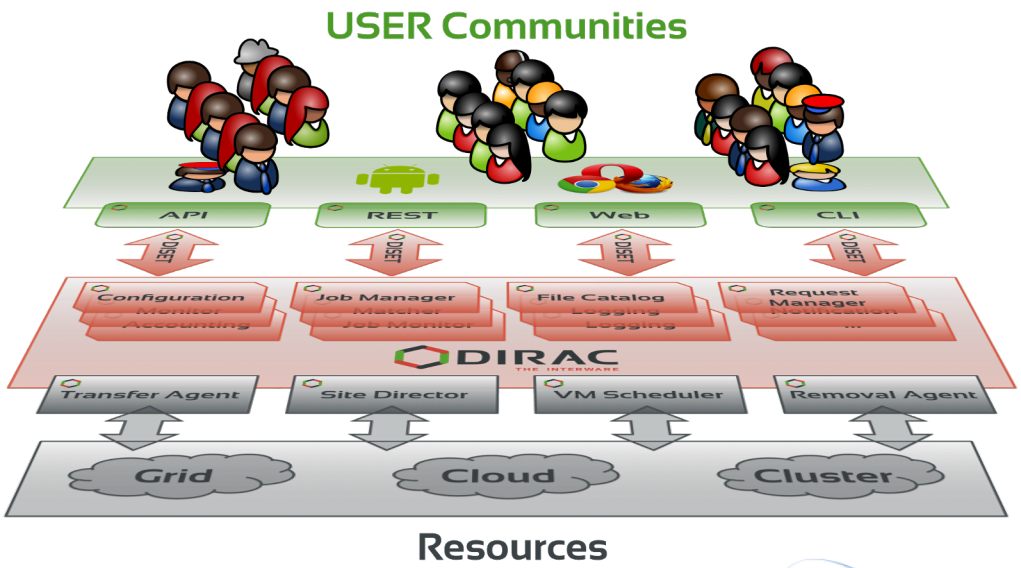
Outline

- DIRAC Interware project
- EGI Services
  - Managing jobs
  - Managing data
  - Managing computing resources
  - Managing workflows
- Development Framework
- Conclusions

Interware

- A software framework for distributed computing
- A **complete** solution to one (or more) user community
- Builds a layer between users and resources
- A *framework* shared by multiple experiments, both inside HEP, astronomy, and life sciences



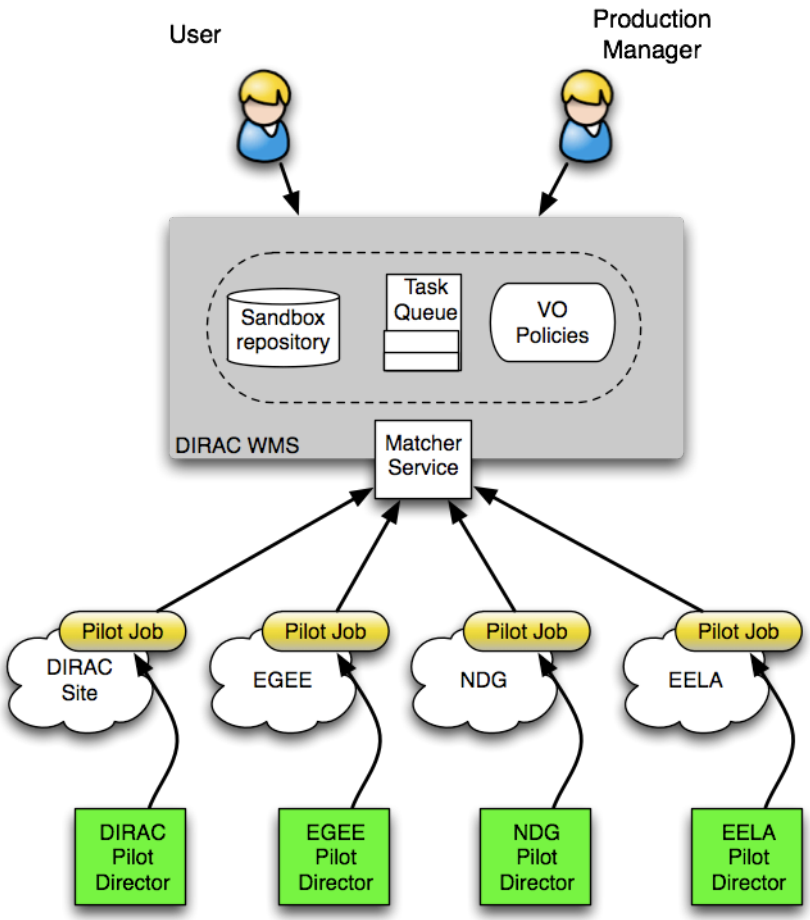
An open source project

- Started as an LHCb project, became experiment-agnostic in 2009
  - First users (after LHCb) end of 2009
- Developed by communities, for communities
  - Open source (GPL3+), GitHub hosted, python 2.7
  - No dedicated funding for the development of the "Vanilla" project
  - Publicly documented, active assistance forum, yearly users workshops, open developers meetings
  - 4 FTE as core developers, a dozen contributing developers
- The DIRAC consortium as representing body
  - CNRS, CERN, IHEP, KEK
  - PNNL, University of Montpellier, Imperial College

Managing user jobs

WMS: Pilots are federators

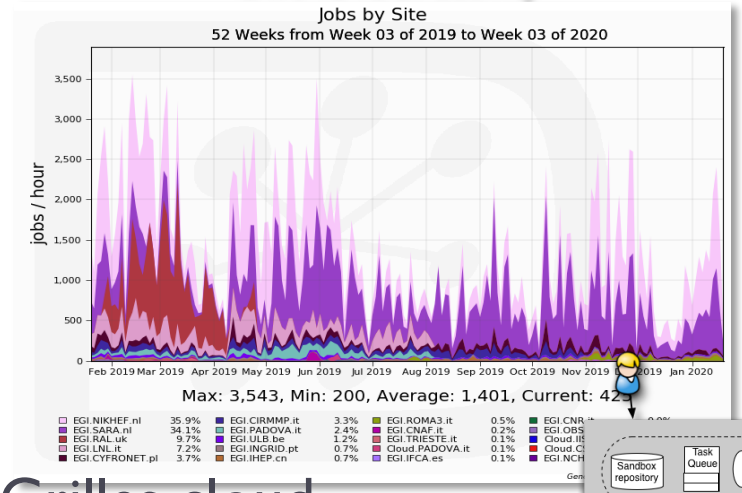
- Pilot jobs are submitted to computing resources by specialized Pilot Directors
- Pilots retrieve user jobs from the central Task Queue and steer their execution on the worker nodes including final data uploading
- Pilot based WMS advantages:
  - increases efficiency of the user job execution
  - allows to apply efficiently community policies at the Task Queue level
  - allows to integrate heterogeneous computing resources



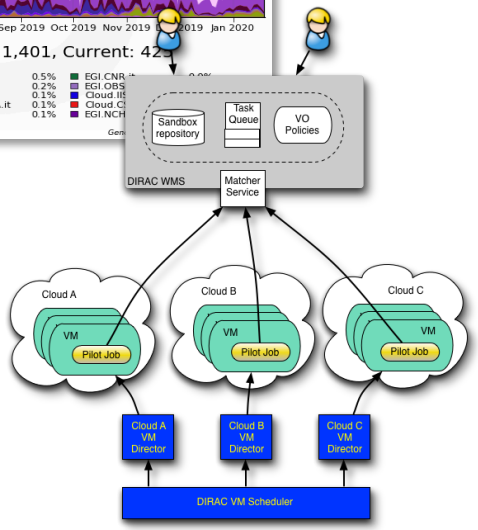
Computing Grids and Clouds

- DIRAC was initially developed with the focus on accessing conventional Grid computing resources
  - WLCG grid resources for the LHCb Collaboration

DIRAC4EGI activity

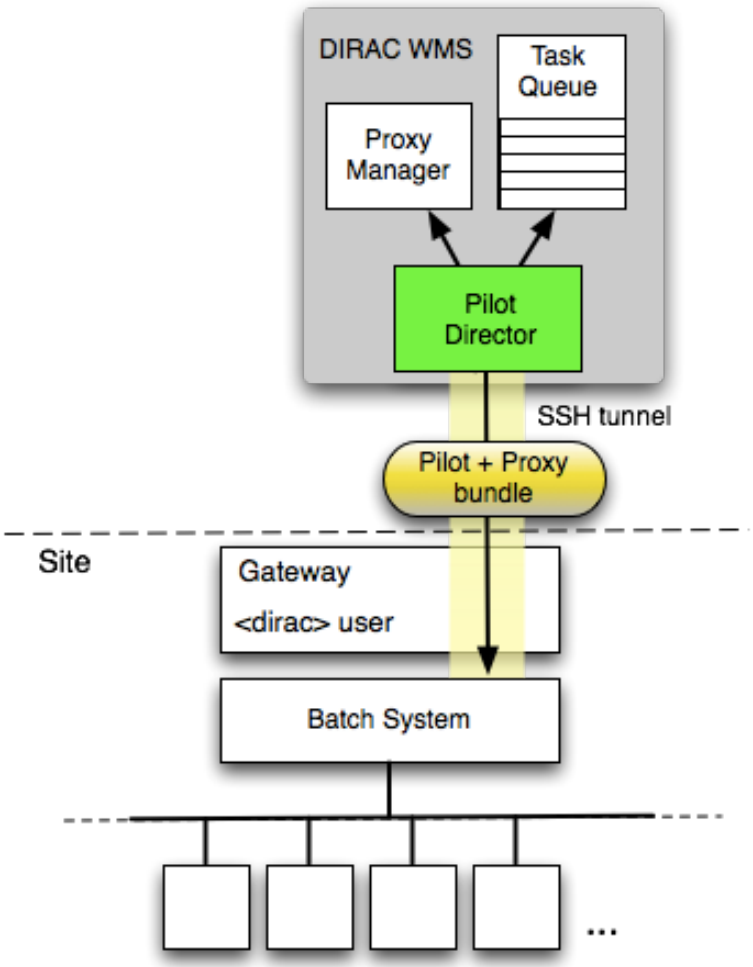


- Grid infrastructures
  - E.g. EGI, WLCG, OSG
  - CREAM, HTCondorCE, ARC
- Cloud infrastructures
  - EGI Federated Cloud, France-Grilles cloud
- Others
  - Vacuum, Volunteer grids



Standalone computing clusters

- Users can connect their own computing resources
  - Not making part of any grid infrastructure
- The user site can be:
  - a single computer or several computers without any batch system
  - a computing cluster with a batch system
    - LSF, BQS, SGE, PBS/Torque, Condor
      - Commodity computer farms
    - SLURM
      - HPC centers



User jobs

- Users are managing jobs using various tools
  - Command line (batch system like interface):

```
bash-4.2# dsub /bin/echo "Hello world"
53917277
bash-4.2# dstat
JobID      Owner     JobName   OwnerGroup   JobGroup   Site            Status    MinorStatus   SubmissionTime
==========================================================================================================
53917277   atsareg   Unknown   wenmr_user   NoGroup    EGI.NIKHEF.nl   Running   Application   2020-10-22 19:06:24

bash-4.2# doutput 53917277
bash-4.2# ls -l 53917277
total 4
-rw-r--r-- 1 71139 2062 12 Oct 22 19:06 std.out
```

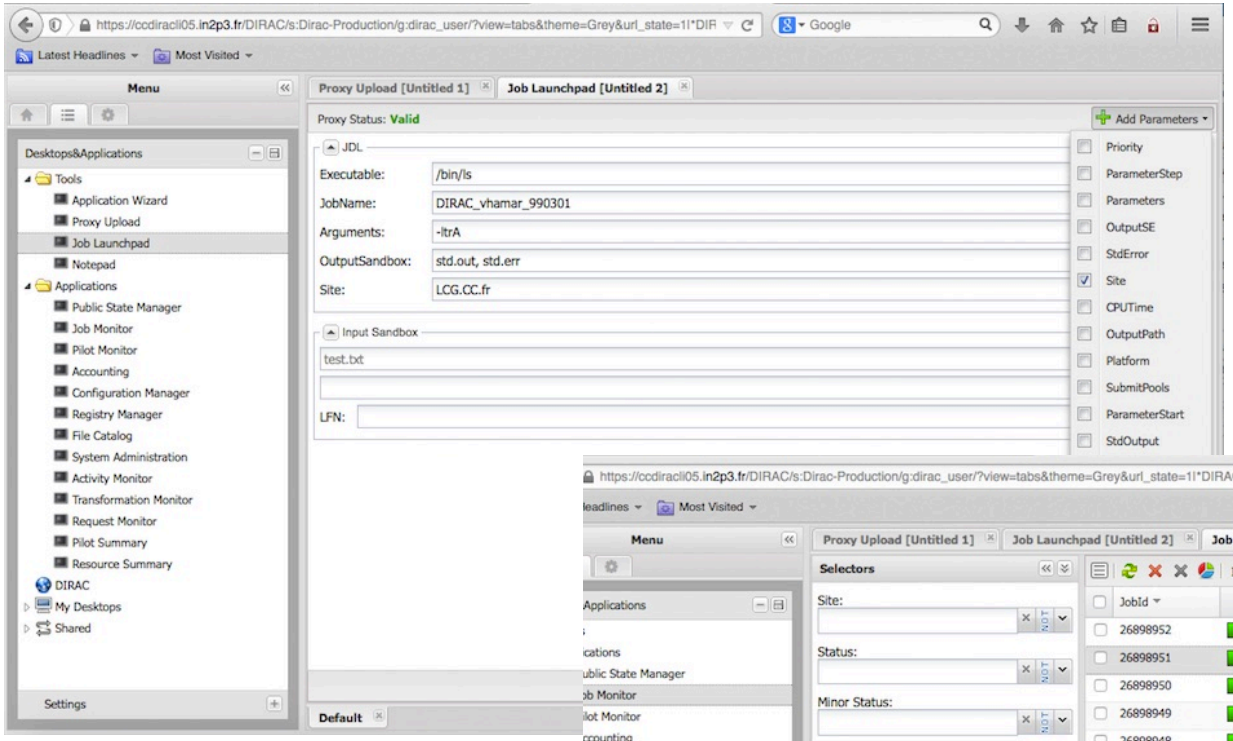
  - Python API

```
from DIRAC.Interfaces.API.Job import Job
from DIRAC.Interfaces.API.Dirac import Dirac

dirac = Dirac()
j = Job()

j.setCPUTime(500)
j.setExecutable('/bin/echo hello')
j.setExecutable('/bin/hostname')
j.setExecutable('/bin/echo hello again')
j.setName('API')

dirac.submitJob(j)
```

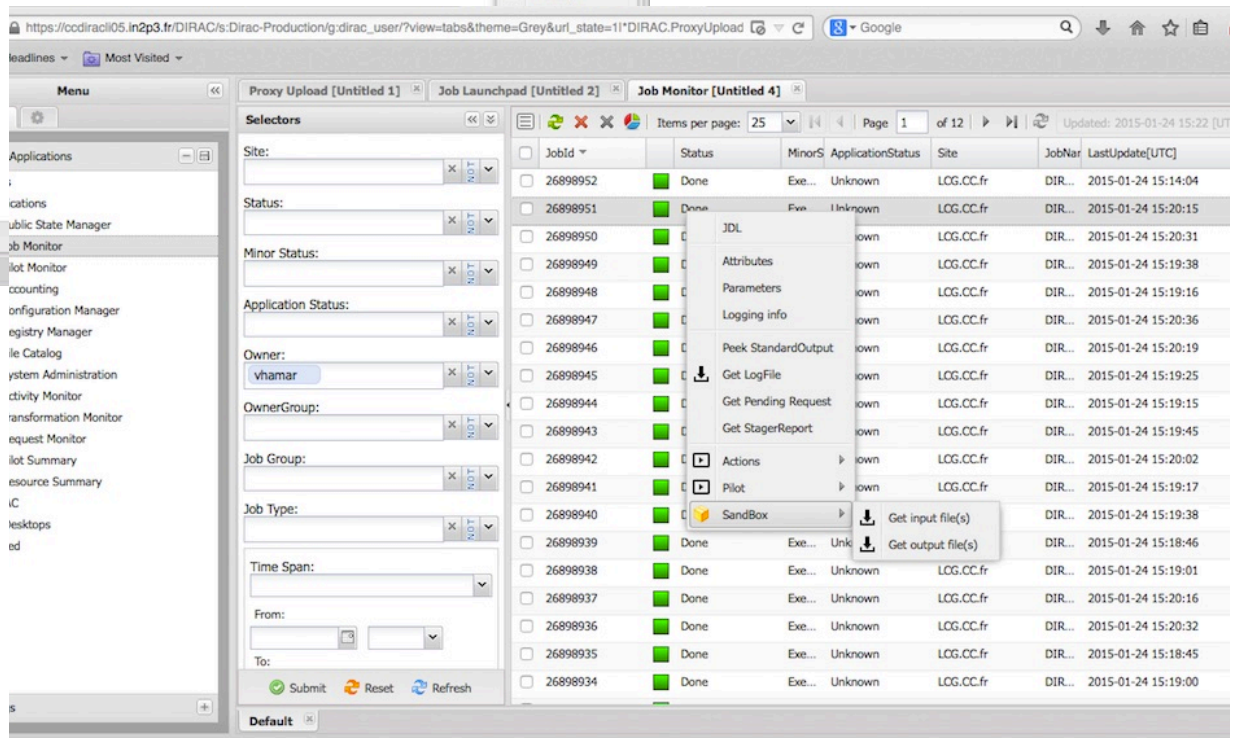
DIRAC client

- Several methods to install DIRAC client on user workstations/laptops (Linux flavors)
  - **dirac-install** installer tool
    - Rather tedious (see tutorials)
    - Suitable for various flavors of Linux
  - **Docker** container (Linux, MacOS)
    - docker run -it -v $HOME:$HOME -e HOME=$HOME diracgrid/client:egi
  - **CVMFS** client installation (Linux)
    - source /cvmfs/dirac.egi.eu/dirac/bashrc_egi
  - **Conda** environment (Linux, MacOS)
    - conda create -c conda-forge --name dirac ipython dirac-grid
      conda activate dirac

Web Interface



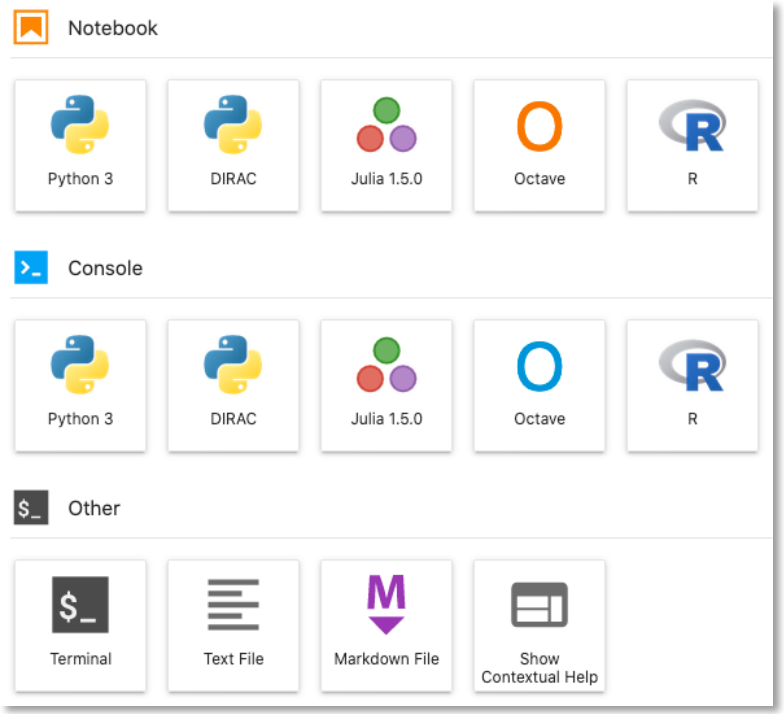
Job Launchpad



Job Monitoring

Other job interfaces

- REST API
  - A language neutral interface for job manipulation
- The next generation DIRAC service interface will be based on HTTPS
  - Will allow for a language neutral RPC interface
- Jupyter Notebook interface
  - Soon availalbe
  - DIRAC API enabled iPython shell
  - Terminal with DIRAC command line interface
  - Managing user credentials is being sorted out
    - Functional for users having grid certificates and registered in the Check-In SSO service



Bulk jobs with multiple parameters

- Example JDL

```
Executable = "testParametricJob.sh";
JobName = ”Parametric_%{Name}";
Arguments = "%{Energy}";
Parameters = 3;
Parameter.Energy = {0.1, 0.2, 0.3};
Parameter.Name = {“Good”, “Better”, “Best”};
StdOutput = "StdOut_%j";
StdError = "StdErr_%j";
InputSandbox = {"testJob.sh"};
OutputSandbox = {"StdOut_%j","StdErr_%j"};
```

- Bulk job submission is possible with all the interfaces
  - Most suitable for APIs

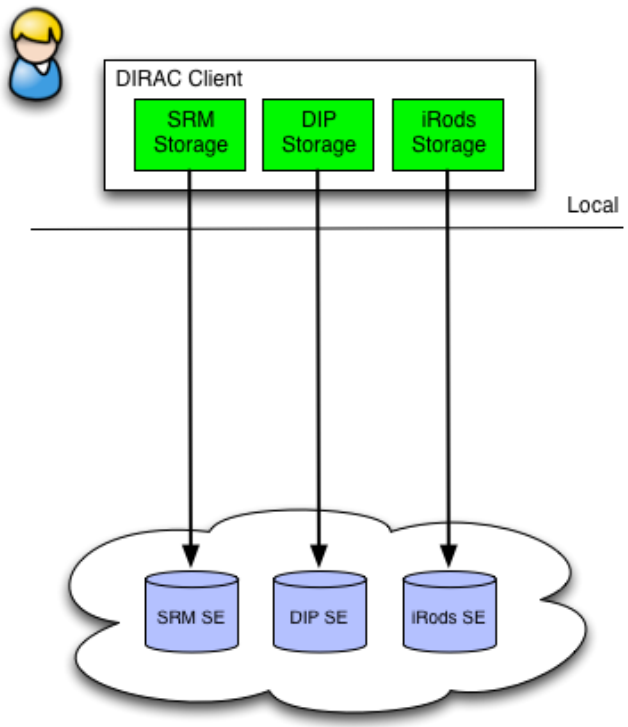
Managing user data

DMS basics

- **LFN**: unique identifier within DIRAC of a file
  - **Logical File Name**
  - (described as paths)
- **LFN**s are registered in **catalog**(s).
  - and there are implementations like the DFC
    - and you can connect as many catalogs as you want
      - (including the LFC or Rucio catalog)
- **LFN**s *may* have **PFN**s, stored in **SE**s.
  - **Physical File Name** on **Storage Elements**
- **PFN**s can be accessed with several protocols.
  - e.g. root, gsiftp, srm, http, file, dips
  - (and can also be brought online - i.e. staged)

Storage plugins

- Storage element abstraction with a client implementation for each access protocol
  - DIPS – DIRAC data transfer protocol
  - FTP, HTTP, WebDAV
  - SRM, XROOTD, RFIO, DCAP, etc
    - HEP centers specific protocols
    - Using gfal2 library developed at CERN
  - S3, Swift, CDMI: cloud specific data access protocols



- Each SE is seen by users as a logical entity
  - With some specific operational properties
    - Archive, limited access, etc
  - SE's can be configured with multiple protocols

- New data access technologies require creating new specific plug-ins

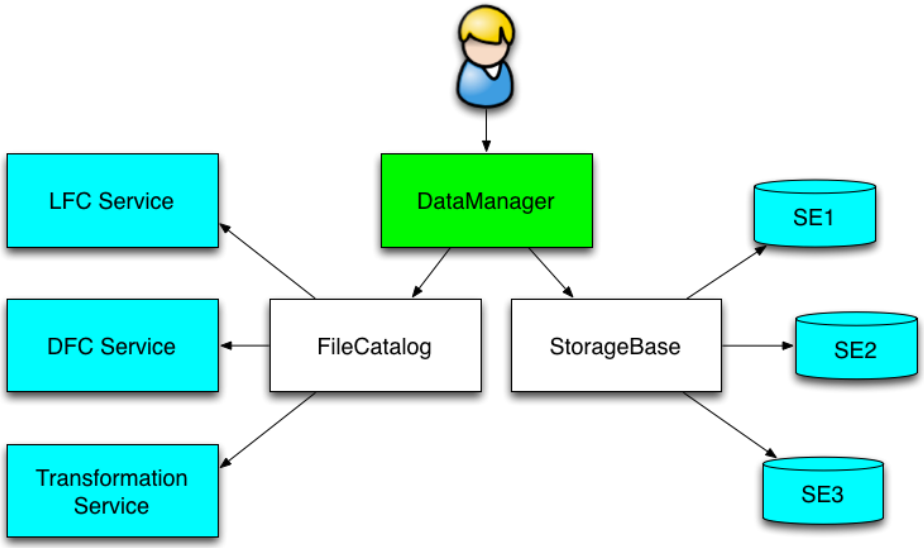
File Catalog Service

- File Catalog is a service to keep track of all the physical file replicas in all the SE's
  - Stores also file properties:
    - Size, creation/modification time stamps, ownership, checksums
    - User ACLs
- DIRAC relies on a *central* File Catalog
  - Defines a single logical name space for all the managed data
  - Organizes files hierarchically like in common file systems

Combined data API

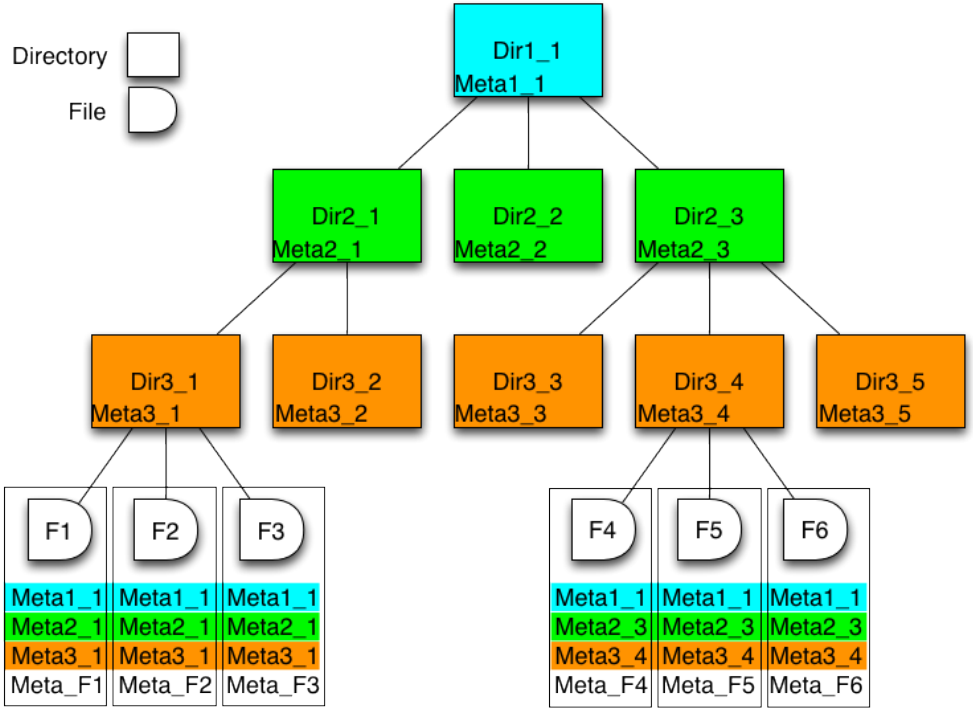
- Together with the data access components DFC allows to present data to users as a single global file system

- DataManager API is a single client interface for logical data operations



File Catalog: Metadata

- DFC is Replica and Metadata Catalog
  - User defined metadata
  - The same hierarchy for metadata as for the logical name space
    - Metadata associated with files and directories
    - Allow for efficient searches
  - Efficient Storage Usage reports
    - Suitable for user quotas



- Example query:
  - `find /lhcb/mcdata LastAccess < 01-01-2012 GaussVersion=v1,v2 SE=IN2P3,CERN Name=*.raw`

Integrating user storages

- Deploying a DIRAC Storage Element service in front of a user File Server
  - Needs minimal DIRAC installation on the server
    - Plus adding a record to the Configuration Service
  - Files should be registered in the DIRAC File Catalog
    - **dirac-dms-register-directory** tool
      - keeping file hierarchical namespace
      - registering file checksums
  - The SE will be accessible with the user credentials and ACL defined in the File Catalog
  - Example: Eiscat-disk Storage Element
    - With 117M files registered in a dedicated File Catalog

DM user interfaces

- Command line tools
  - Multiple dirac-dms-… commands
  - File Catalog console (dirac-dms-filecatalog-CLI)
  - *https://dirac.readthedocs.io/en/latest/UserGuide/commands.html*
- COMDIRAC
  - Representing the logical DIRAC file namespace as a parallel shell
    - **dls, dcd, dpwd, dfind, ddu,** etc commands
  - Commands for file upload/download/replication
    - **dput, dget, drepl**

```
bash-4.2# dput test.jdl /enmr.eu/user/a/atsareg/test/test.jdl
bash-4.2# dls -L /enmr.eu/user/a/atsareg/test/test.jdl
-rwxrwxr-x 1 atsareg wenmr_user 256 2020-10-22 22:33:12 test.jdl
   CYFRONET-USER   dips://dirac-dms.egi.eu:9148/DataManagement/StorageElement/enmr.eu/user/a/atsareg/test/test.jdl
bash-4.2# rm test.jdl
bash-4.2# dget /enmr.eu/user/a/atsareg/test/test.jdl
bash-4.2# ls test.jdl
test.jdl
bash-4.2# drm /enmr.eu/user/a/atsareg/test/test.jdl

1 object(s) removed in total
```

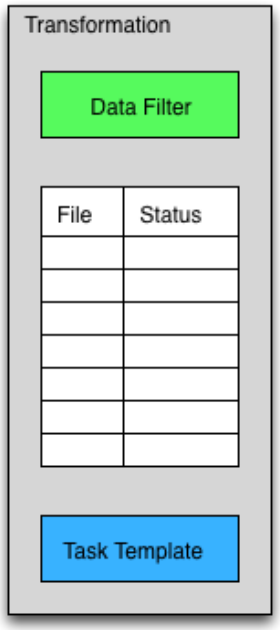
Managing workflows

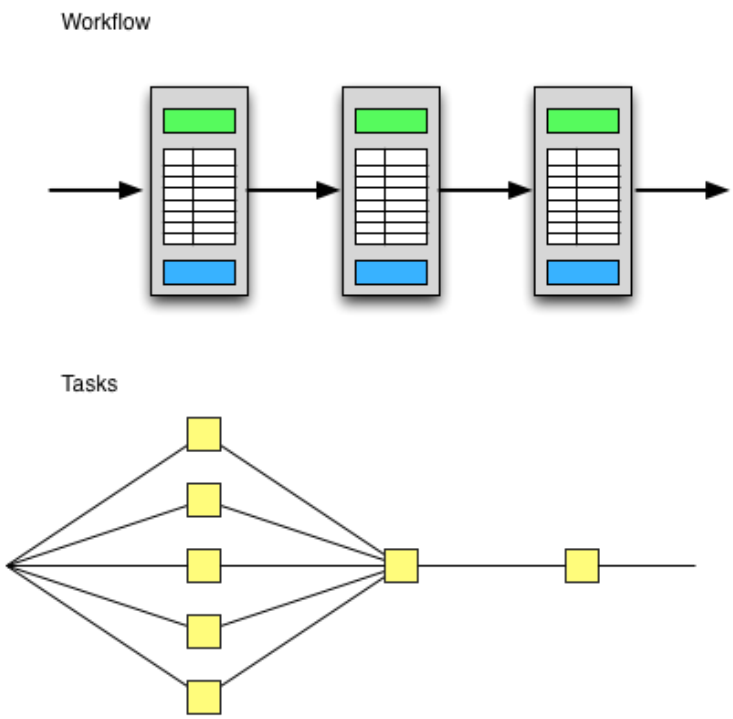
Massive operations

- DIRAC can deal with large numbers of jobs
  - > 100K simultaneously running jobs
  - > 10M jobs in the WMS
- DIRAC can deal with large volumes of scientific data
  - 10's of Petabytes
  - 10^7-10^8 of files and directories
- There is a need for massive (bulk) operations
  - Examples:
    - Submit and monitor 50K jobs
    - Replicate 10^5 files from SE A to SE B
    - Remove 10^5 files and all their replicas in all the storages
- Massive operations supported
  - Asynchronous execution
  - Automatic failure recovery
  - Data integrity checking
  - Automated data driven workflows

Transformation System for data driven workflows

- Data driven workflows as chains of data transformations
  - Transformation: input data filter + recipe to create tasks
  - Tasks are created as soon as data with required properties is registered into the system
  - Tasks:
    - Jobs submission
    - Data replication, removal
    - *etc*





- Transformations can be used for automatic data driven bulk data operations
  - Scheduling RMS tasks
  - Often as part of a more general workflow

Useful links

- DIRAC Project site: http://diracgrid.org
- Guides: https://dirac.readthedocs.io/en/latest/
- Tutorials:
  - https://github.com/DIRACGrid/DIRAC/wiki/DIRAC-Tutorials
  - https://github.com/DIRACGrid/COMDIRAC/wiki

Backup slides

DIRAC Framework

DIRAC Framework

- DIRAC systems consist of well defined components with clear recipes for developing

  Services

  passive components reacting to client request

  Keep their state in a database

  Agents

  Light permanently running distributed components, animating the whole system

  Clients

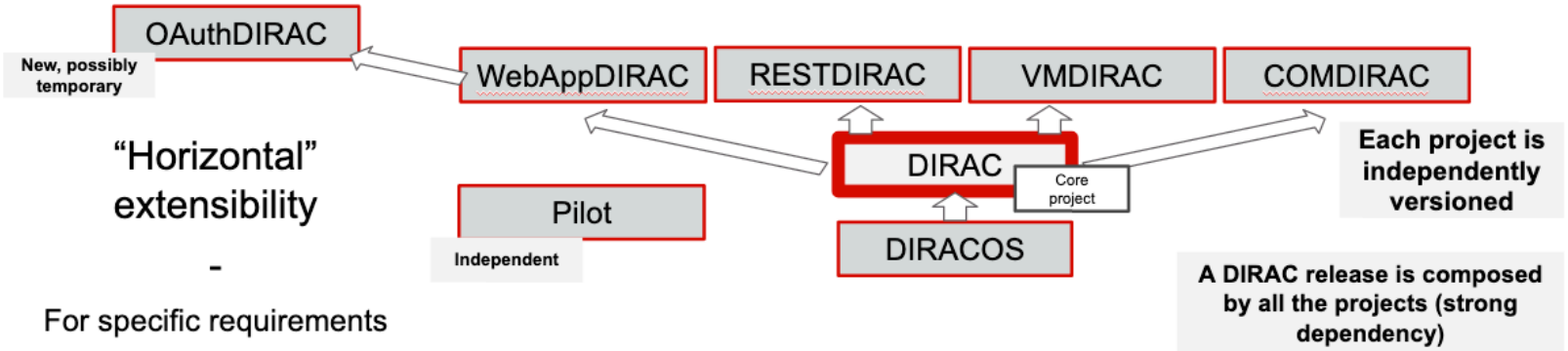
  Used in user interfaces as well as in agent-service, service-service communications

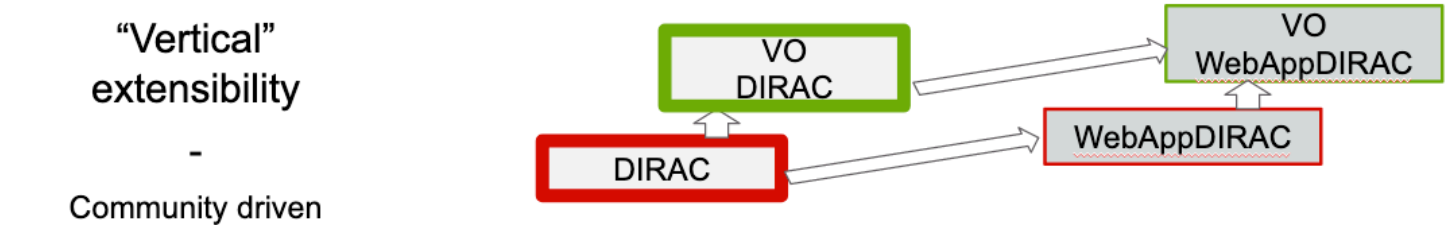
DIRAC Framework

- The Framework allows to easily build these components concentrating on the business logic of the applications
  - Development environment: Python, MySQL
  - Using framework services (configuration, service discovery, access control, etc)
  - Specific functionality can be provided in many cases as plugin modules, e.g.
    - Data access policies
    - Job scheduling policies

Extending DIRAC

- Adding new general or community specific functionalities
  - Or overriding existing algorithms
- Tools for extensions packaging and deployment
  - Example extensions in the EGI DIRAC installation
    - EiscatDIRAC: File Catalog with custom file ACLs
    - EscapeDIRAC: Corsica application portal





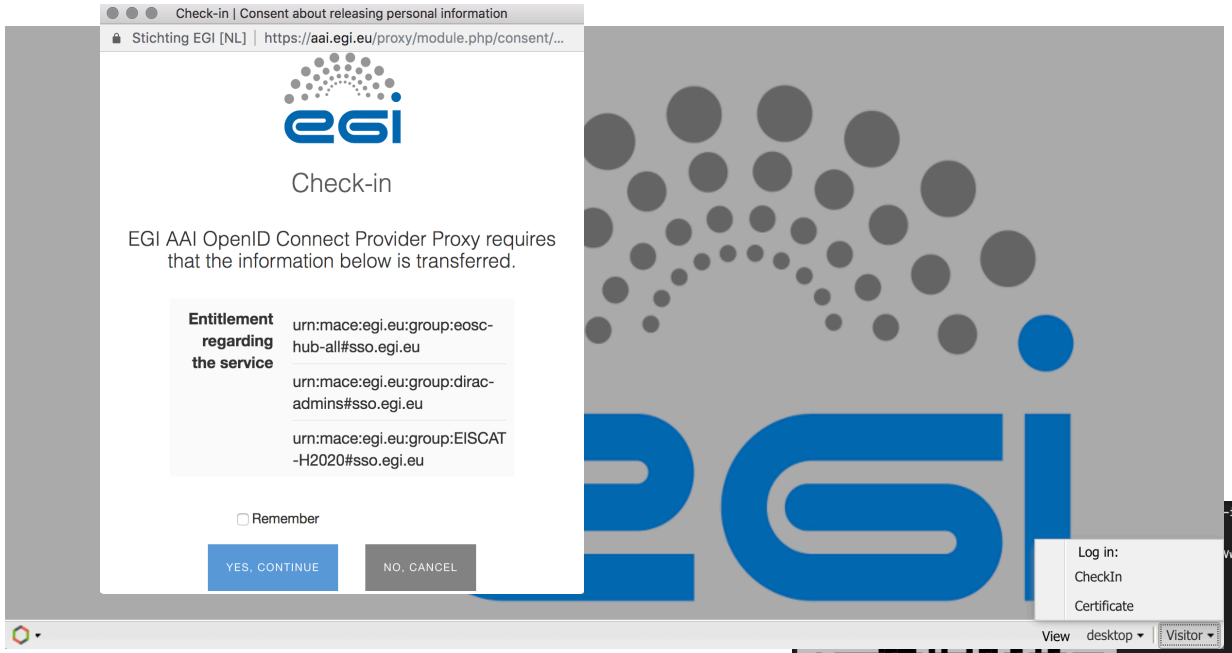
DIRAC is evolving

- Several ongoing developments
  - dips:// → https://
    - **dips**: proprietary DIRAC protocol for RPC calls
    - **http(s)**: frameworks already exists in python 2&3 for server-side (*tornado* framework) and client side (*requests* Python module)
  - Python 3
    - Migration started, first production release next year
      - DIRAC client in Python 3 available before
  - DIRAC ←→ Rucio bridge
    - Development in the context of Belle II and SKA collaborations

SSO solutions

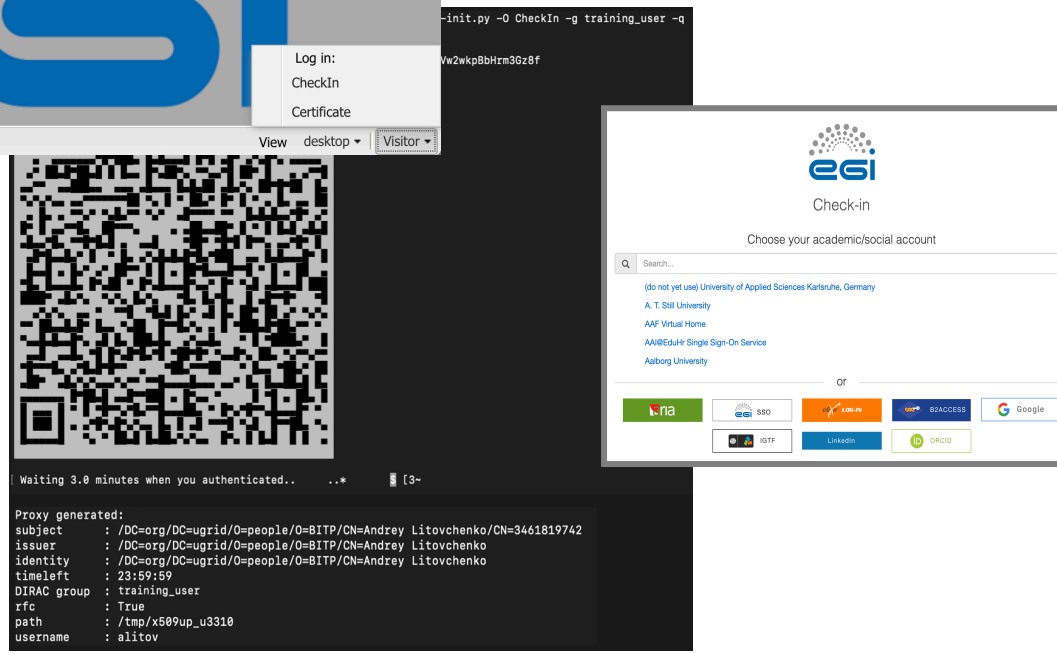
- There are multiple examples of SSO solutions
- The EGI Check-in service enables access to EGI services and resources using federated authentication mechanisms
  - A hub between federated Identity Providers (IdPs) and Service Providers (SPs) that are part of EGI

Oauth/OIDC Authentication



Web Portal

functional prototype



Command Line

functional prototype

Conclusions

- Large scientific communities have to employ various geographically distributed computing and storage resources
- DIRAC provides a framework for building distributed computing systems aggregating multiple types of resources
- DIRAC provides an integrated solution with a reach set of ready to use services for managing computing resources, application workloads and data
- DIRAC modular architecture allows for extending the existing functionality to build high level services specific for particular user communities and architectures

http://diracgrid.org

Acknowledgement

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Useful links

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