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The GridWay Metascheduler

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dsa-research.org

Open Source Grid & Cluster

Oakland CA, May 2008

Universidad Complutense Madrid

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Contents

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- What is GridWay?
- Architecture
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- Scheduling Policies
- Examples of Grid Deployments
- History

Introduction

- **Resource selection:** Where do I execute my job ?
- **Resource preparation:** What do I need?
- **Job submission:** How do I submit my job?
- **Job monitoring:** How is my job doing?
- **Job migration:** Is there any better resource?
- **Job termination:** How do I get my output?

Introduction

- **Meta-scheduler:** Job to resource (**other schedulers**) matching (*execution management*).
- **Goal:** Optimize the performance according to a given metric (performance model):
  - Global Throughput
  - Resource usage
  - Application – Stand-alone, HPC, HTC and self-adaptive
  - User usage
- **Grid characteristics**
  - Heterogeneity (job requirements)
  - Dynamism (high fault rate, load, availability, price)
  - Site autonomy

What is GridWay?

The GridWay meta-scheduler is a scheduler virtualization layer on top of basic Globus services (GRAM, MDS & GridFTP)

For the user

- A LRM-like environment for submitting, monitoring, and controlling jobs

For the developer

- An standard-base development framework for Grid Applications

For the sysadmin

- A policy-driven job scheduler
- User-side Grid Accounting

For the Grid architect / solution provider

- A modular component to use different infrastructures
- A key component to deploy different Grids (enterprise, partner, utility…)

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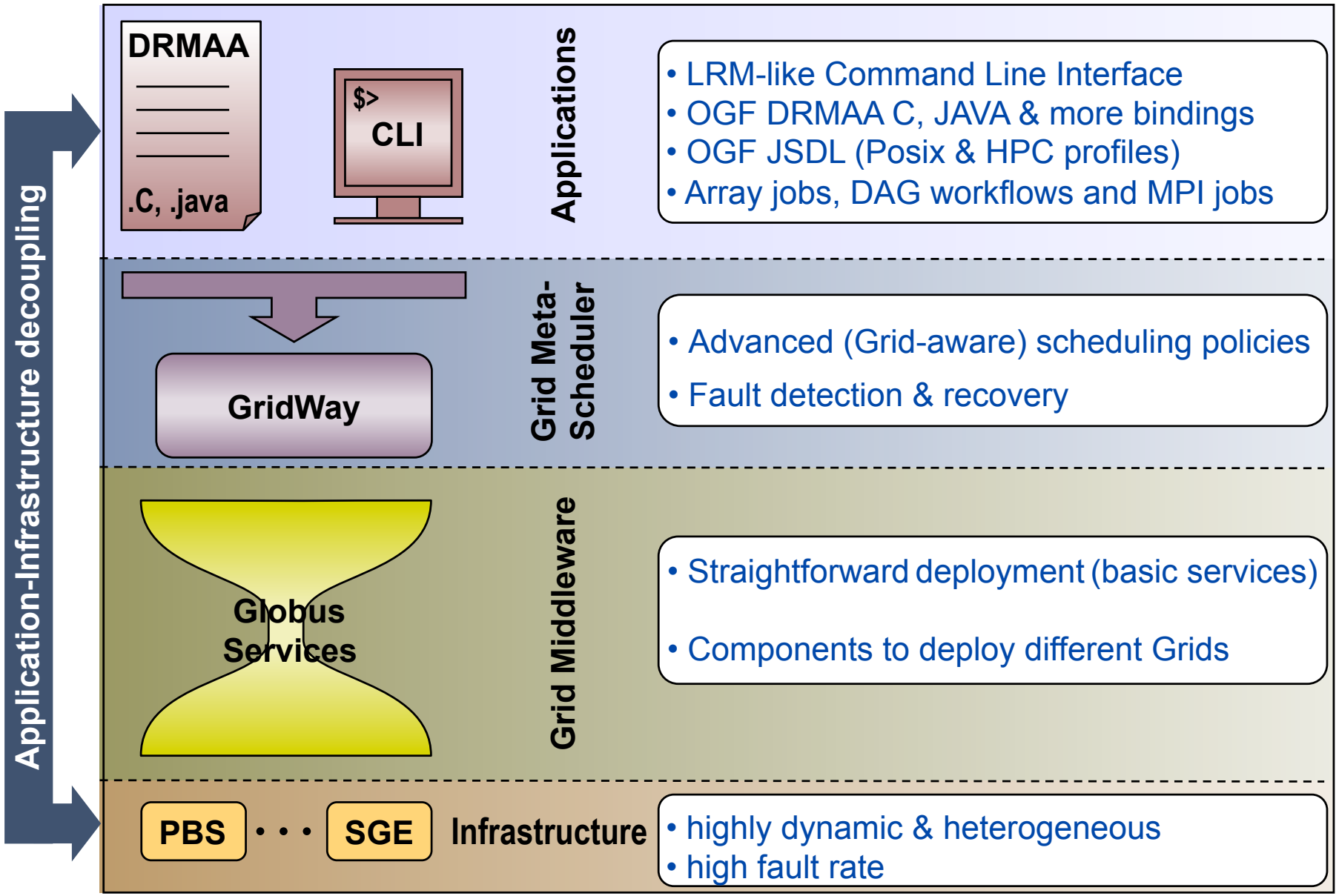
Architecture



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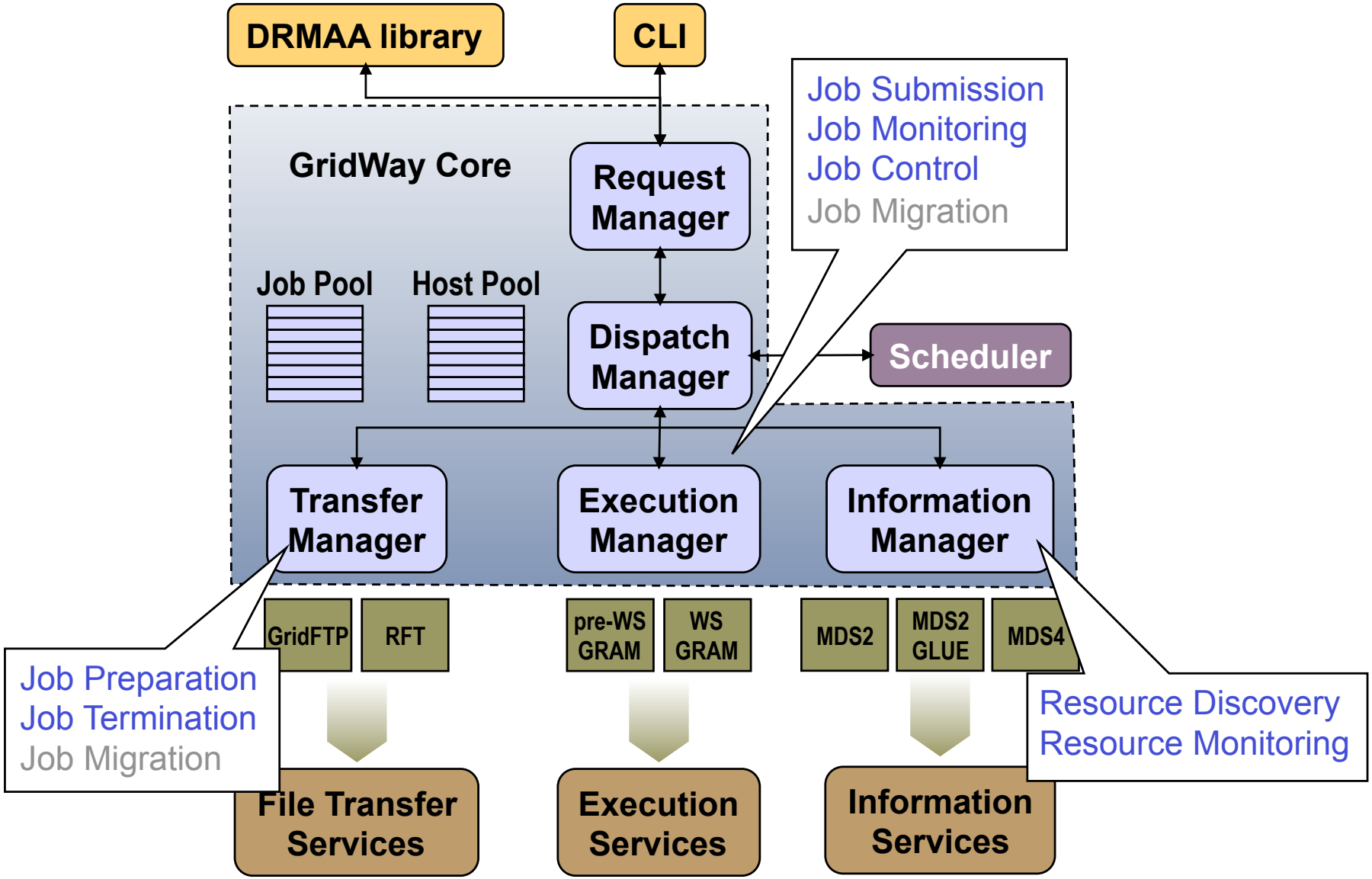
Components



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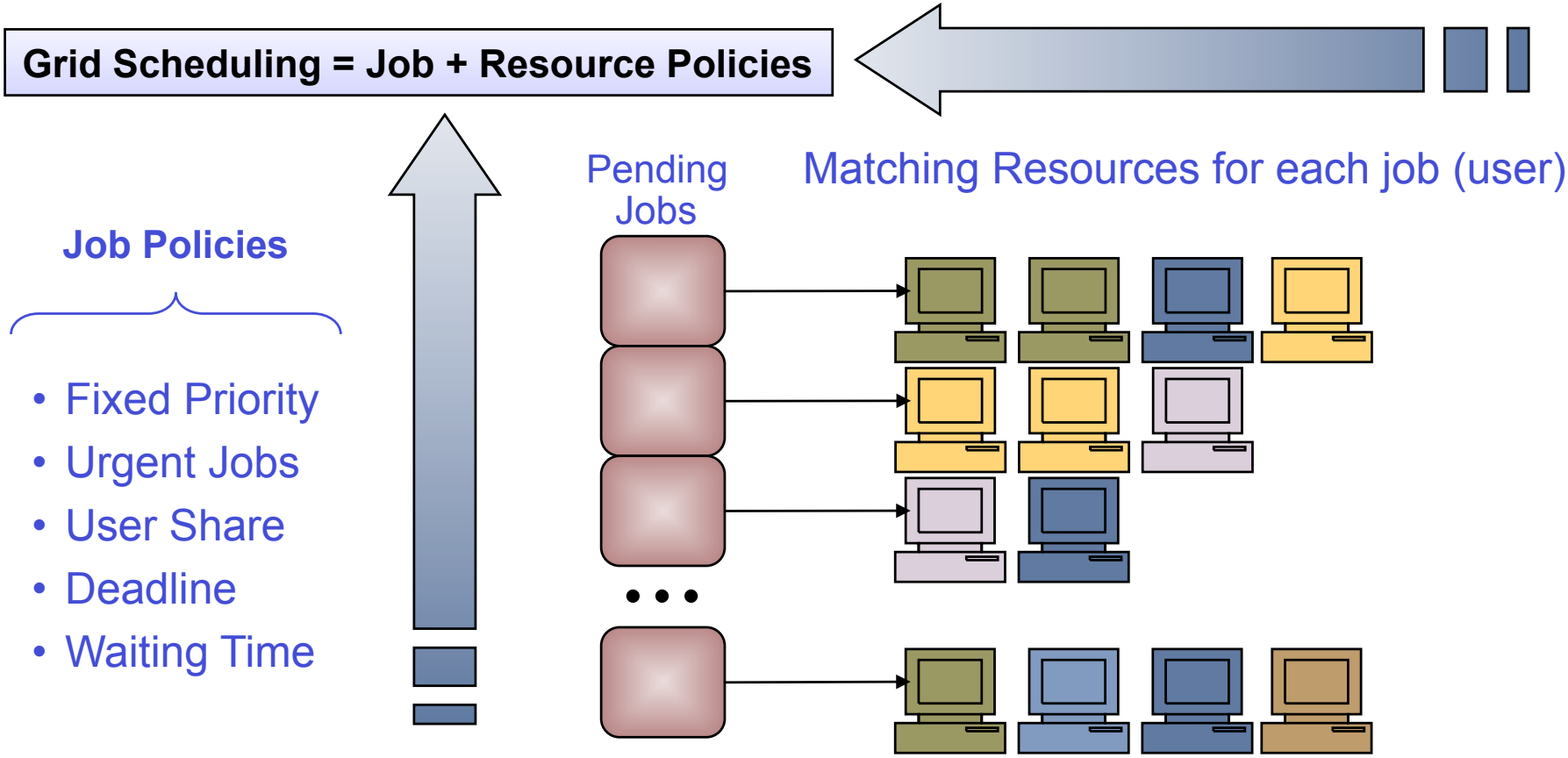
Scheduling Policies

Resource Policies

- Rank Expressions
- Fixed Priority
- User Usage History
- Failure Rate

Grid Scheduling = Job + Resource Policies



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Installation

1. Installing GridWay standalone
   - Uncompress tarball -> gw-<version>.tar.gz
   - ./configure
     - There are many options -- check them out in the manual
   - make
   - make install

2. Enabling GridWay in Globus
   - ./configure --enable-gridway

More information in the Installation & Configuration Guide
www.gridway.org/documentation/guides.php

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Configuration

- $GW_LOCATION/etc/gwd.conf
  - Configuration options for the GridWay daemon (GWD)
- $GW_LOCATION/etc/sched.conf
  - Configuration options for GridWay built-in scheduling policies
- $GW_LOCATION/etc/job_template.default
  - Default values for job template
- $GW_LOCATION/etc/gwrc
  - Default environment variables for MADs

More information in the Installation & Configuration Guide
www.gridway.org/documentation/guides.php

Enterprise Grids

Characteristics

- "Small" scale infrastructures (campus/enterprise) with one meta-scheduler instance
- Resources within the same administration domain that may be running different LRMS and be geographically distributed

Goal & Benefits

- Integrate heterogeneous systems
- Improve return of IT investment
- Performance/Usage maximization

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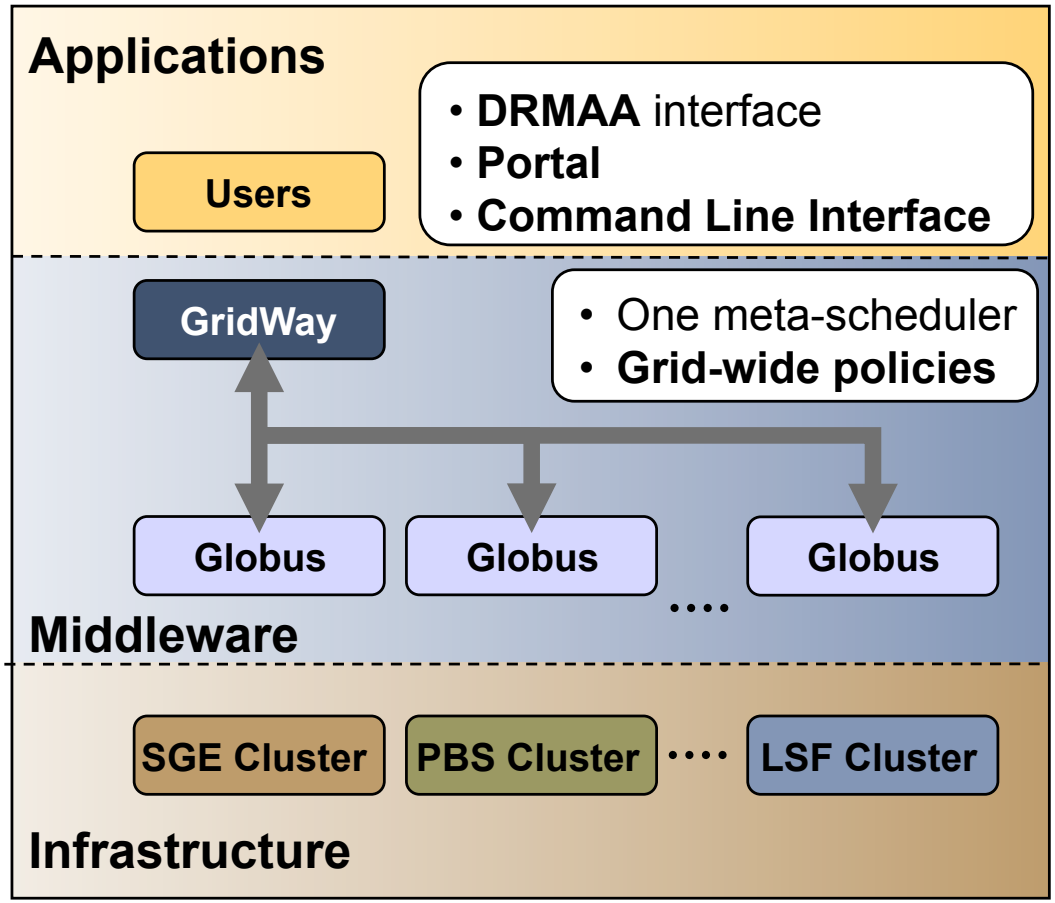
Enterprise Grids

Architecture



Examples

European Space Astronomy Center
- Data Analysis from space missions
- DRMAA

UABGrid, University of Alabama
- Bioinformatics applications

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Partner Grids

Characteristics

- "Large" scale infrastructures with one or several meta-schedulers
- Resources belong to different administrative domains

Goal & Benefits

- Large-scale, secure and reliable sharing of resources
- Support collaborative projects
- Access to higher computing power to satisfy peak demands

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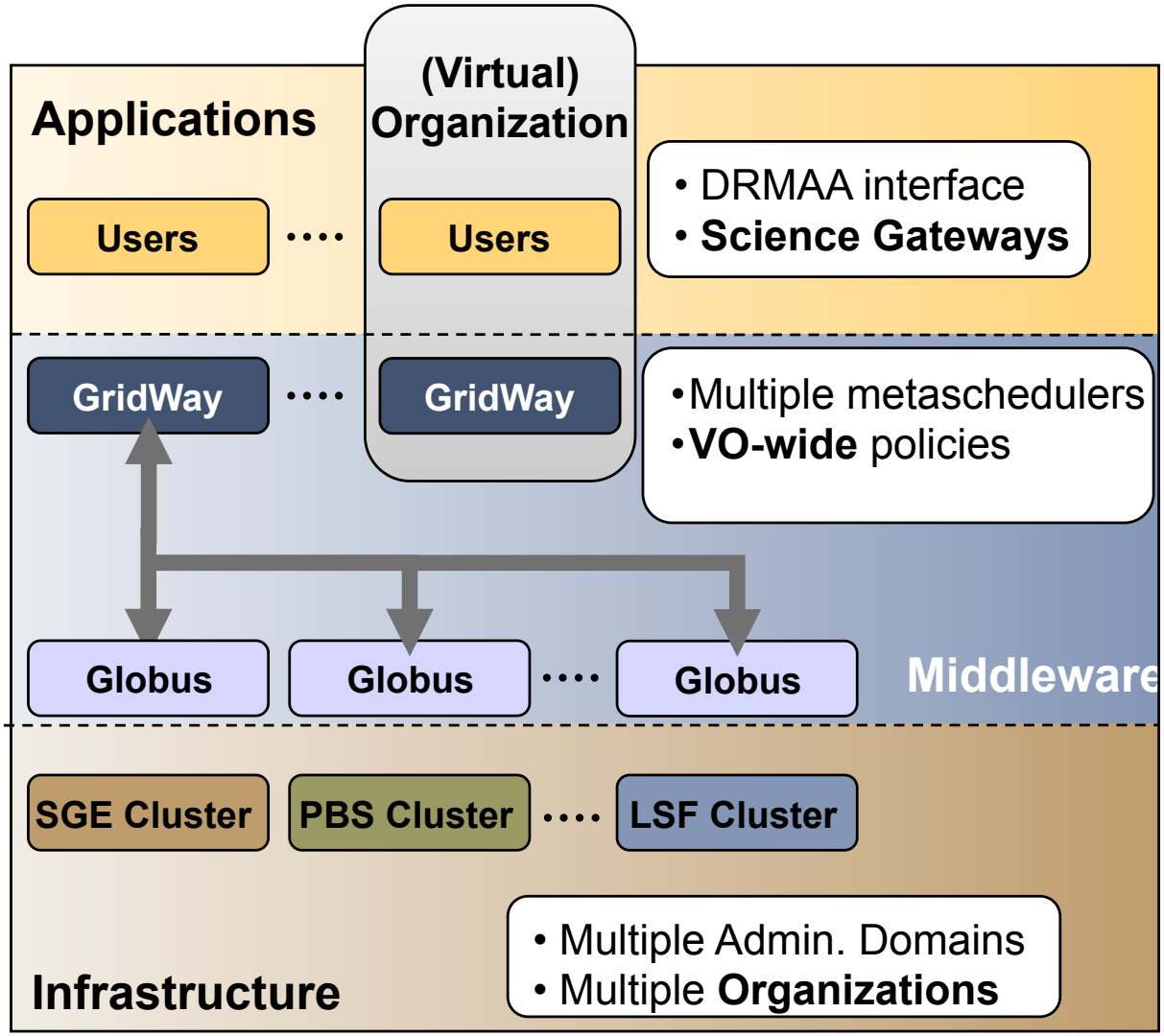
Partner Grids

Architecture



Examples

EGEE-II

- gLite-LHC interoperability
- Virtual Organizations

  Fusion: Massive Ray Tracing

  Biomed: CD-HIT (Worflow)

AstroGrid-D, German Astronomy Community Grid

- Supercomputing resources
- Astronomy-specific resources
- GRAM interface

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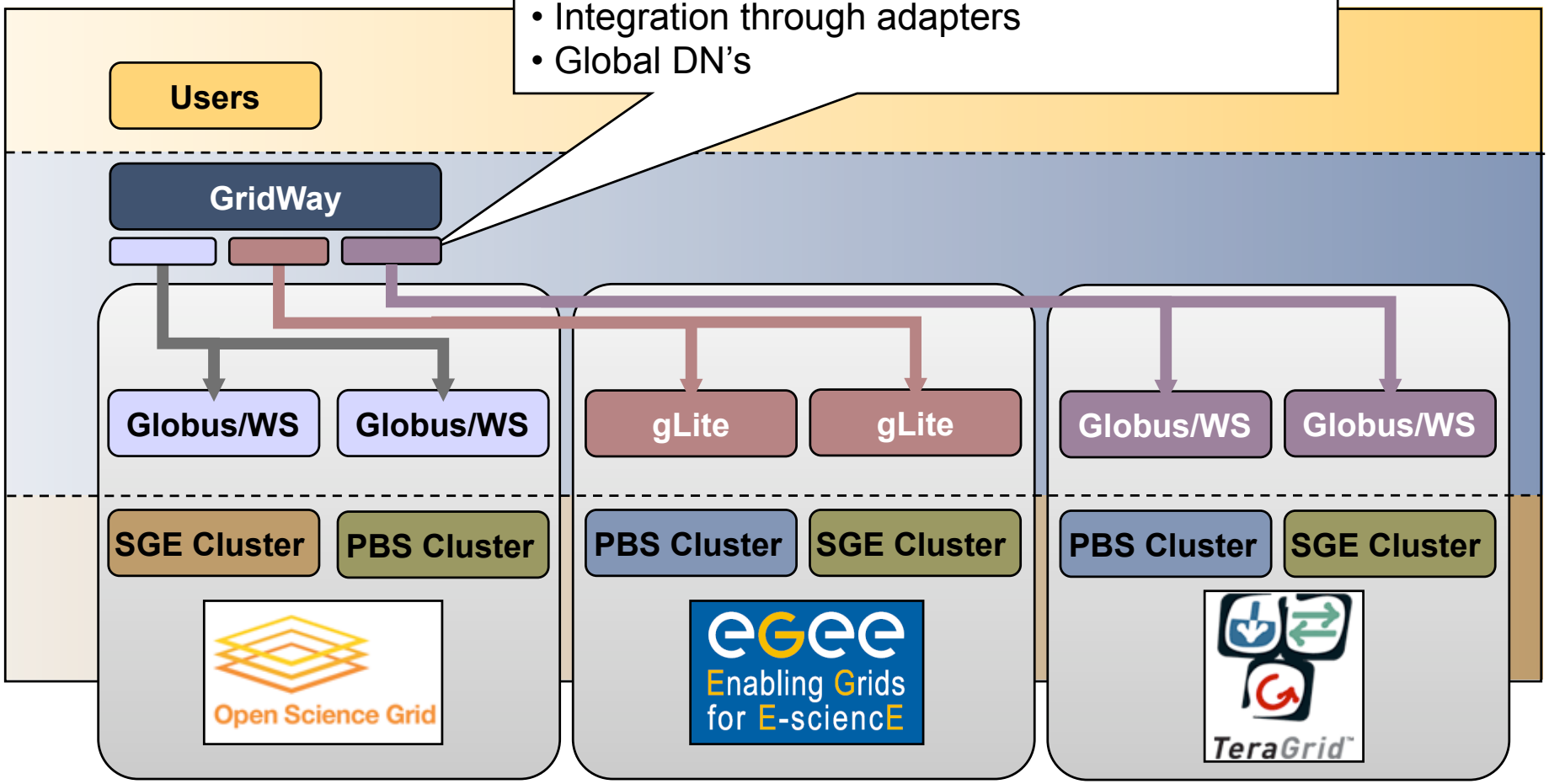
A Tool for Interoperability

- Different Middlewares (e.g. WS and pre-WS)
- Different Data/Execution architectures
- Different Information models
- Integration through adapters
- Global DN's



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History

- Started in **2002**, as a research only effort (releases were distributed on request)
- First open source release (v4.0) in **January 2005** (Apache license v2.0)
- In **2006** started the incubation - ended in January 2007 (the first incubator to become a Globus project)
- In June **2007** GridWay became part of the Globus Toolkit
- Since January 2005, more than 1000 downloads from 80 different countries, 25% are private companies and 75% are universities and research centers.
- Best-effort support provided

History

- Community – **Open Source Project**.
- Adheres to Globus Development Philosophy
- Development Infrastructure (thanks to Globus Project!)
  - Mailing Lists
  - Bugzilla
  - CVS
- You are very welcome to contribute:
  - Reporting Bugs (gridway-user@globus.org)
  - Making feature requests (gridway-user@globus.org)
  - Contributing with your own developments (gridway-dev@globus.org)

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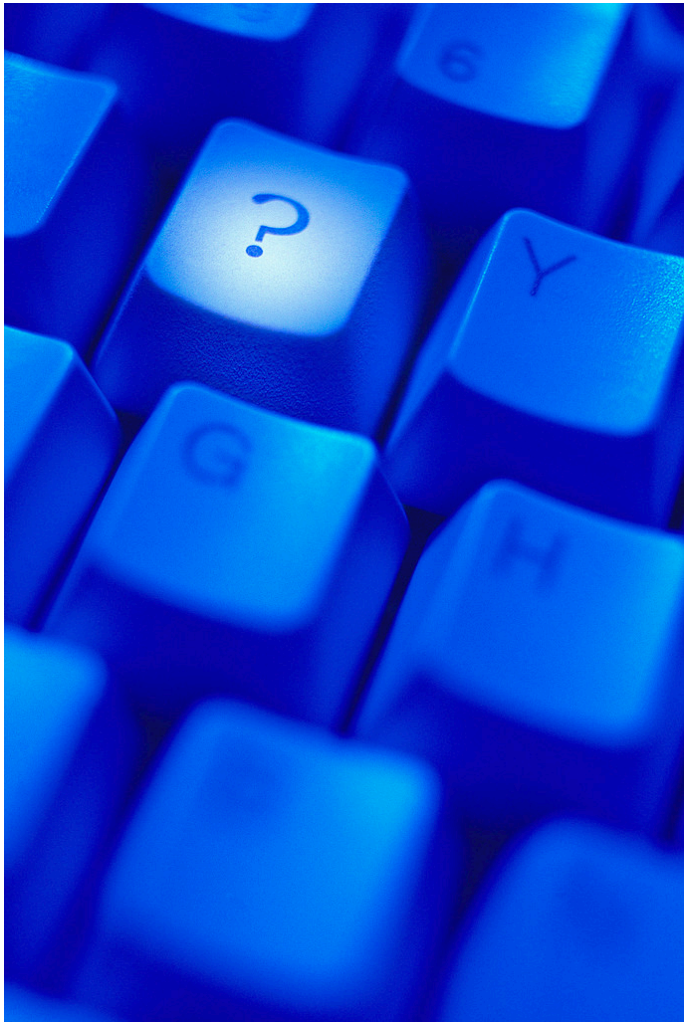
Questions?



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Using GridWay: CLI

Javier Fontan & Ruben S. Montero
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Contents

- User set up
- Job Definition
- Job Life-cycle
- Job Submission
- Job & Host Monitoring
- Job Control
- Sample Session

User Set Up

- Usually in a multi-user setting (single-user also possible)
- User environment (sh)
  - `export GW_LOCATION=/usr/local/gw`
  - `export PATH=$PATH:$GW_LOCATION/bin`
  - `CLASSPATH=$GW_LOCATION/lib/drmaa.jar:$CLASSPATH`
  - `LD_LIBRARY_PATH=$GW_LOCATION/lib:$LD_LIBRARY_PATH`
- Check $GW_LOCATION
  - `etc` configuration files
  - `share/doc` documents (www.gridway.org)
  - `share/examples` templates and howtos
  - `var` log information (debugging)

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Accounts

- cepheus.dacya.ucm.es - accessible through ssh
- gwtutorialXX
- gwtutorialXX

  where XX=00,01,02,03…
- Certificate passphrase: gridcv07
- $HOME/examples/drmaa
  - drmaa_c
  - drmaa_java
  - drmaa_perl
  - drmaa_ruby
  - drmaa_python

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Job Definition

- Each job is defined within an **experiment directory** (default paths)
- **Execution variables**
  - `EXECUTABLE = bin.${ARCH }`
  - `ARGUMENTS = ${TASK_ID }`
  - `ENVIRONMENT = SCRATCH_DIR=/tmp` (Also GW_* vars. are set)
- **I/O files relative to exp dir (also abs path, file://, gsiftp://, http://)**
  - `INPUT_FILES = param.${TASK_ID } param, inputfile`
  - `OUTPUT_FILES = outputfile, bin bin. ${ARCH }`
- **Standard streams**
  - `STDIN_FILE = /dev/null`
  - `STDOUT_FILE = stdout_file.${JOB_ID }`
  - `STDERR_FILE = stderr_file.${JOB_ID }`

Job Definition

- **Resource selection parameters**
  - `REQUIREMENTS = ARCH = "i686" & CPU_MHZ > 1000`
  - `RANK = (CPU_MHZ * 2) + FREE_MEM_MB`
- **Job Type**
  - `TYPE = mpi`
  - `NP = 16`
- **Advanced definition parameters**
  - Checkpointing parameters
  - Failure handling
  - Performance
  - Re-scheduling
  - Execution Configuration

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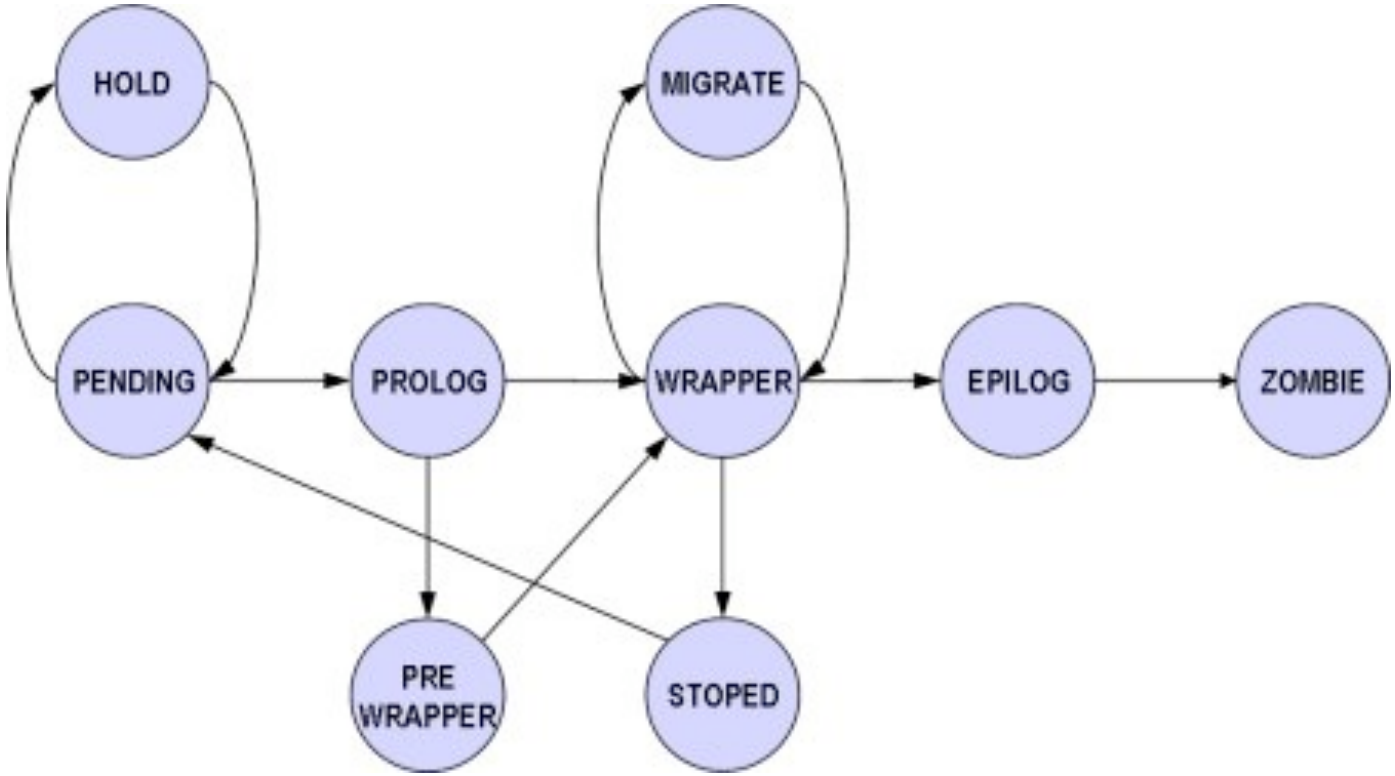
Job Definition

Job Submission Description Language

- describing the job requirements for submission to resources (equivalent to job templates)
- OGF standard (*https://forge.gridforum.org/sf/projects/jsdl-wg*)
- `jsdl2gw` command to do the translation

```
…
<jsdl:Application>
 <jsdl:ApplicationName>ls</jsdl:ApplicationName>
  <jsdl-posix:POSIXApplication>
  <jsdl-posix:Executable>/bin/ls</jsdl-posix:Executable>
  <jsdl-posix:Argument>-la file.txt</jsdl-posix:Argument>
  <jsdl-posix:Environment name="PATH">/sbin</jsdl-posix:Environment>
…
```

Job Life-cycle



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Job Submission

- Simple Jobs

```
$ gwsubmit example/jt
```

- Array Jobs ($TASK_ID and custom parametric var.)

```
$ gwsubmit -v   -n 4   pi.jt
ARRAY ID: 0
TASK JOB
0     3
1     4
2     5
3     6
```

Job Submission

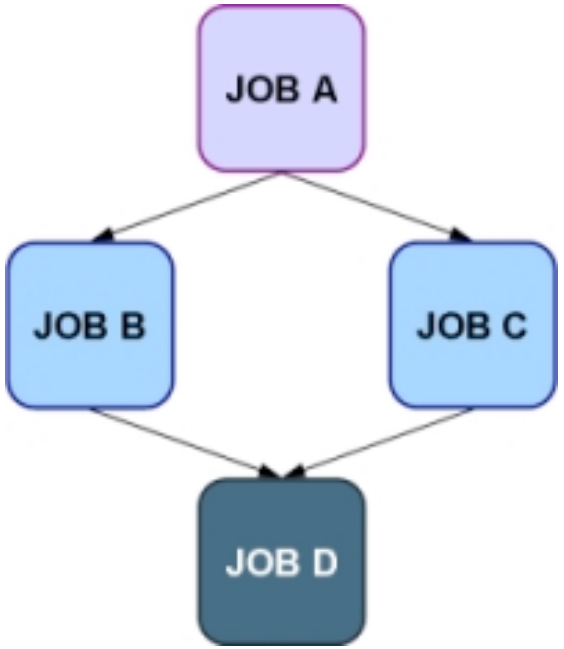
- DAG Workflows

```
• $ gwsubmit -v -t A.jt
  JOB ID: 5

• $ gwsubmit -v -t B.jt -d "5"
  JOB ID: 6

• $ gwsubmit -v -t C.jt -d "5"
  JOB ID: 7

• $ gwsubmit -t C.jt -d "6 7"
```



- **from GW5.2 onwards, you can use dagman workflows with gwdagman…**

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Job & Host Monitoring

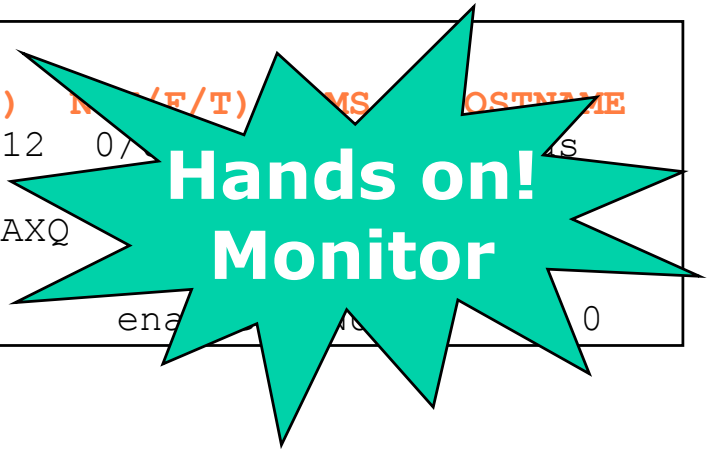
- Use gwhost command to see available resources:

```
HID  PRIO   OS          ARCH    MHZ  %CPU   MEM(F/T)  DISK(F/T)     N(U/F/T)  LRMS       HOSTNAME
0    1     Linux2.6 x86      3216   0    44/2027   26742/71812  0/0/2     Fork       cygnus
1    1                       0      0        0/0           0/0  0/0/0                orion
2    1      Linux2.6 x86_6 2211   100 819/1003 27083/77844  0/2/4     PBS        hydrus
3    1      Linux2.6 x86   3216   163 393/2027 11257/11812  0/2/2     Fork       draco
4    1      Linux2.6 x86_6 2211    66 943/1003 72485/77844  0/5/5     SGE        aquila
```

- and get more detailed information specifying a Host ID:

```
$ gwhost 0
HID  PRIO   OS          ARCH    MHZ  %CPU   MEM(F/T)  DISK(F/T)     N(U/F/T)  LRMS       HOSTNAME
0    1      Linux2.6 x86    3216     0    50/2027   6393/18812   0/0/2     Fork       cygnus

QUEUENAME              SL(F/T)  WALLT  CPUT   COUNT  MAXR   MAXQ
PRIORITY
default                0/2      0      -1     0      -1     0      ena                    0
```



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Job & Host Monitoring

- Resources that match job requirements with gwhost -m 0:

```
$ gwhost -m 0
HID QNAME      RANK  PRIO  SLOTS HOSTNAME
0   default    0     1     0     cygnus.dacya.ucm.es
2   default    0     1     3     hydrus.dacya.ucm.es
6   qlong      0     1     3     hydrus.dacya.ucm.es
4   all.q      0     1     3     aquila.dacya.ucm.es
```

- Follow the evolution of the job with gwps & gwhistory:

```
$ gwps
USER    JID DM   EM   START    END      EXEC     XFER     EXIT NAME  HOST
gwtut00 0   done ---- 20:16:28 20:18:16 0:00:55 0:00:08 0    stdin aquila/SGE
tinova  1   done ---- 12:26:46 12:31:15 0:03:55 0:00:08 0    stdin hydrus/PBS
tinova  2   pend ---- 12:38:38 --:--:-- 0:00:00 0:00:00 --   t.jt  --
```

```
$ gwhistory 4
HID START    END      PROLOG  WRAPPER EPILOG  MIGR    REASON QUEUE   HOST
2   12:58:04 12:58:16 0:00:06 0:00:04 0:00:02 0:00:00 ----   default hydrus/PBS
```

Job control

- **Jobs Signals**
  - Kill (default, if no signal specified).
  - Stop job.
  - Resume job.
  - Hold job.
  - Release job.
  - Re-schedule job.
  - Hard kill

```
gwkill [-h] [-a] [-k | -t | -o | -s | -r | -l | -9] <job_id \
[job_id2 ...] | -A array_id>
```

- **Synchronization**

```
gwwait [-h] [-a] [-v] [-k] <job_id...| -A array_id>
```

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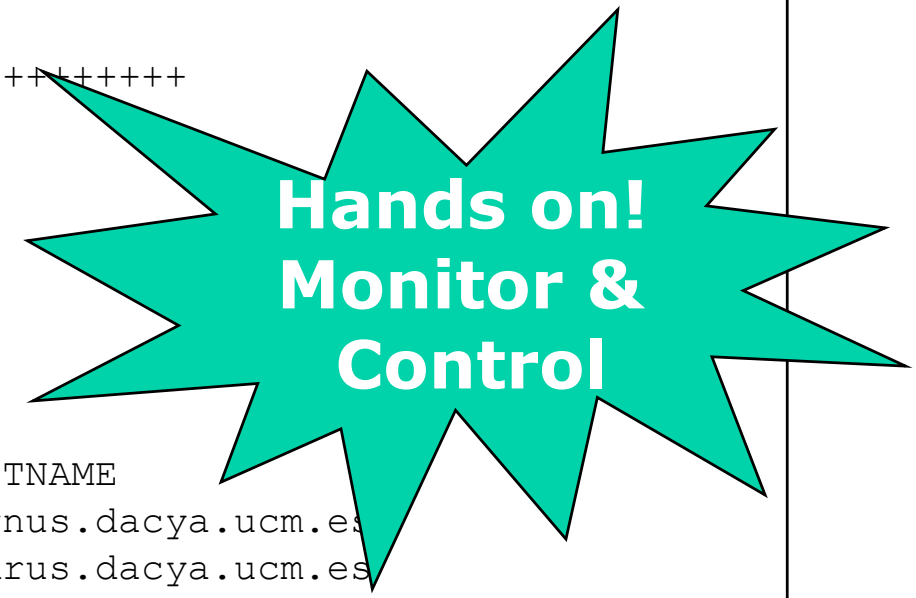
Sample Session

```
$ grid-proxy-init
    Creating proxy .++++++++++++
    ..................................++++++++++++
     Done
$ vi job.template
    EXECUTABLE=/bin/ls
    STDOUT=stdout.$(JOB_ID)
    STDERR=stderr.$(JOB_ID)
$ gwsubmit job.template
$ gwhost -m 0
    HID QNAME       RANK   PRIO   SLOTS HOSTNAME
    0   default     0      1      0     cygnus.dacya.ucm.es
    1   default     0      1      3     hydrus.dacya.ucm.es
$ gwps -c 1
    USER    JID DM   EM   EXEC    XFER    EXIT NAME          HOST
    gwtut00 0   done ---- 0:00:05 0:00:04 0    job.template hydrus/PBS
$ls -lt stderr.4 stdout.4
    -rw-r--r-- 1 gwtut00 gwtut00 0  2007-09-07 12:58 stderr.4
    -rw-r--r-- 1 gwtut00 gwtut00 72 2007-09-07 12:58 stdout.4
$ cat stdout.4
    job.env
    stderr.execution
    stderr.wrapper
```



For More Information

- User guide
- Command reference guide

http://www.gridway.org/documentation/guides.php

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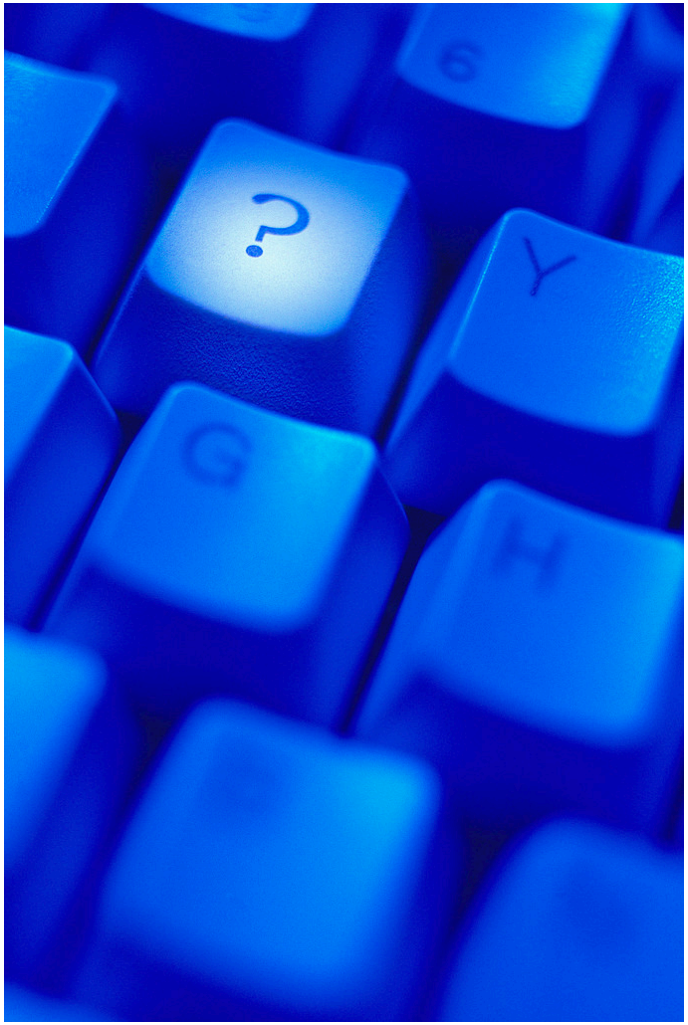
Questions?



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Developing Applications with GridWay: DRMAA

Javier Fontan & Ruben S. Montero

dsa-research.org

Open Source Grid & Cluster

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Contents

- Introduction
- Program Structure and Compilation
- DRMAA Directives and Functions
- More Information

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What is DRMAA?

- Distributed Resource Management Application API
  - http://www.drmaa.org
- Open Grid Forum Standard
- Homogeneous interface to different Distributed Resource Managers (DRM):
  - SGE, Condor, PBS/Torque…
- GridWay implementation
  - C & JAVA
  - Perl, Ruby & Python
    - > check the development release GW 5.3

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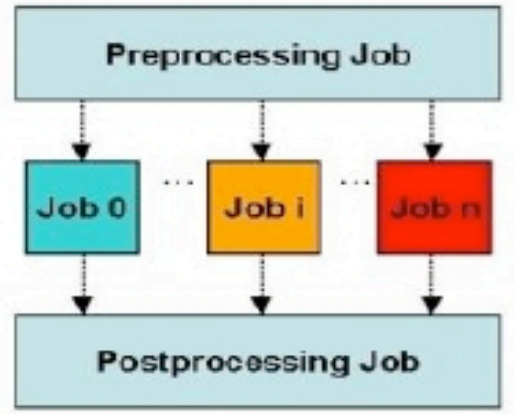
Programming Model

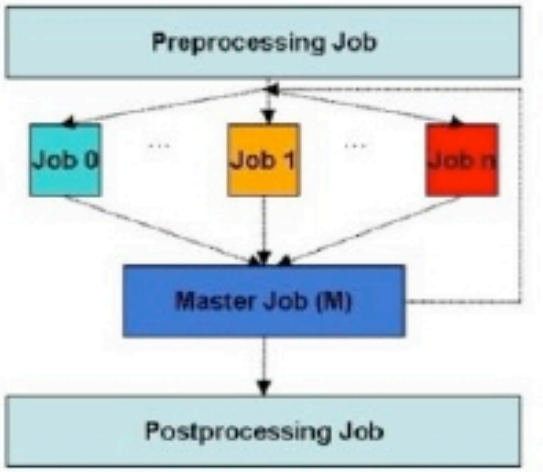
Application Profiles

- Embarrasingly Distributed




```
rc = drmaa_init (contact, err);
// Execute initial job and wait for it
rc = drmaa_run_job(job_id, jt, err);
rc = drmaa_wait(job_id, &stat, timeout, rusage, err);
// Execute n jobs simultaneously and wait
      rc       =       drmaa_run_bulk_jobs(job_ids,jt,1,
JOB_NUM,1,err);
rc = drmaa_synchronize(job_ids, timeout, 1, err);
// Execute final job and wait for it
rc = drmaa_run_job(job_id, jt, err);
rc = drmaa_wait(job_id,&stat, timeout, rusage, err);
rc = drmaa_exit(err_diag);
```

- Master-Worker




```
rc = drmaa_init(contact, err_diag);
// Execute initial job and wait for it
rc = drmaa_run_job(job_id, jt, err_diag);
rc = drmaa_wait(job_id, &stat, timeout, rusage, err_diag);
while (exitstatus != 0)
{
// Execute n Workers concurrently and wait
  rc = drmaa_run_bulk_jobs(job_ids, jt, 1, JOB_NUM, 1,
err_diag);
rc = drmaa_synchronize(job_ids, timeout, 1, err_diag);
// Execute the Master, wait and get exit code
rc = drmaa_run_job(job_id, jt, err_diag);
   rc = drmaa_wait(job_id, &stat, timeout, rusage,
err_diag);
rc = drmaa_wexitstatus(&exitstatus, stat, err_diag);
}
rc = drmaa_exit(err_diag);
```

Program Structure and Compilation

- Include the DRMAA library:

```
#include "drmaa.h"
```

- Verify the following environment variable:

```
export LD_LIBRARY_PATH=$LD_LIBRARY_PATH:$GW_LOCATION/lib/
```

- Include the compiling and linking options for DRMAA:

```
-L $GW_LOCATION/lib
-I $GW_LOCATION/include
-ldrmaa
```

- Example:

```
$ gcc example.c -L $GW_LOCATION/lib \
    -I $GW_LOCATION/include -ldrmaa -o example
```

Session Management

- Initialization and finalization

```
int drmaa_init (const char *contact, char *error_diagnosis, size_t error_diag_len);
int drmaa_exit (char *error_diagnosis, size_t error_diag_len);
```

Auxiliary Functions

- Getting Information

const char * **drmaa_strerror** (int drmaa_errno);

int **drmaa_get_contact** (char *contact, size_t contact_len, char *error_diagnosis, size_t error_diag_len);

int **drmaa_version** (unsigned int *major, unsigned int *minor, char *error_diagnosis, size_t error_diag_len);

int **drmaa_get_DRM_system** (char *drm_system, size_t drm_system_len, char *error_diagnosis, size_t error_diag_len);

int **drmaa_get_DRMAA_implementation** (char *drmaa_impl, size_t drmaa_impl_len, char *error_diagnosis, size_t error_diag_len);

Job Template

- Allocation and Deletion

```
int drmaa_allocate_job_template (drmaa_job_template_t **jt, char
        *error_diagnosis, size_t error_diag_len);
int drmaa_delete_job_template (drmaa_job_template_t *jt, char *error_diagnosis,
        size_t error_diag_len);
```

- Parameter Setting/Getting

```
int drmaa_set_attribute (drmaa_job_template_t *jt, const char *name, const char
        *value, char *error_diagnosis, size_t error_diag_len);
int drmaa_get_attribute (drmaa_job_template_t *jt, const char *name, char *value,
        size_t value_len, char *error_diagnosis, size_t error_diag_len);
int drmaa_set_vector_attribute (drmaa_job_template_t *jt, const char *name, const
        char *value[ ], char *error_diagnosis, size_t error_diag_len);
int drmaa_get_vector_attribute (drmaa_job_template_t *jt, const char *name,
        drmaa_attr_values_t **values, char *error_diagnosis, size_t error_diag_len);
int drmaa_get_attribute_names (drmaa_attr_names_t **values, char
        *error_diagnosis, size_t error_diag_len);
int drmaa_get_vector_attribute_names (drmaa_attr_names_t **values, char
        *error_diagnosis, size_t error_diag_len);
```

Job Template Compilation

DRMAA_REMOTE_COMMAND
DRMAA_V_ARGV
DRMAA_V_ENV
DRMAA_INPUT_PATH
DRMAA_OUTPUT_PATH
DRMAA_ERROR_PATH
DRMAA_WD
DRMAA_JOB_NAME
DRMAA_JS_STATE
DRMAA_SUBMISSION_STATE_ACTIVE
DRMAA_SUBMISSION_STATE_HOLD
DRMAA_PLACEHOLDER_HD
DRMAA_PLACEHOLDER_INCR
DRMAA_PLACEHOLDER_WD
DRMAA_DEADLINE_TIME
DRMAA_DEADLINE_TIME

GridWay Specific Job Template Compilation

DRMAA_GW_TOTAL_TASKS
DRMAA_GW_JOB_ID
DRMAA_GW_TASK_ID
DRMAA_GW_PARAM
DRMAA_GW_MAX_PARAM
DRMAA_GW_ARCH
DRMAA_V_GW_INPUT_FILES
DRMAA_V_GW_OUTPUT_FILES
DRMAA_V_GW_RESTART_FILES
DRMAA_GW_RESCHEDULE_ON_FAILURE
DRMAA_GW_NUMBER_OF_RETRIES
DRMAA_GW_RANK
DRMAA_GW_REQUIREMENTS
DRMAA_GW_TYPE
DRMAA_GW_TYPE_SINGLE
DRMAA_GW_TYPE_MPI
DRMAA_GW_NP

Job Submission

- Simple Job Submission

```
int drmaa_run_job (char *job_id, size_t job_id_len, drmaa_job_template_t *jt, char
        *error_diagnosis, size_t error_diag_len);
```

Job Synchronize and Wait

- Wait for Job Completion

```
int drmaa_wait (const char *job_id, char *job_id_out, size_t job_id_out_len, int *stat,
        signed long timeout, drmaa_attr_values_t **rusage, char *error_diagnosis,
        size_t error_diag_len);
```

  - **job_id** value could be DRMAA_JOB_IDS_SESSION_ANY or DRMAA_JOB_IDS_SESSION_ALL

Auxiliary Functions

- Interpreting Job Status Code

```
int drmaa_wexitstatus (int *exit_status, int stat, char *error_diagnosis, size_t
        error_diag_len);
int drmaa_wifexited (int *exited, int stat, char *error_diagnosis, size_t
        error_diag_len);
int drmaa_wifsignaled (int *signaled, int stat, char *error_diagnosis, size_t
        error_diag_len);
int drmaa_wtermsig (char *signal, size_t signal_len, int stat, char *error_diagnosis,
        size_t error_diag_len);
```

Helper Functions

- String Lists

```
int drmaa_get_next_attr_name (drmaa_attr_names_t *values, char *value, size_t
        value_len);
int drmaa_get_next_attr_value (drmaa_attr_values_t *values, char *value, size_t
        value_len);
int drmaa_get_num_attr_names (drmaa_attr_names_t *values, size_t *size);
int drmaa_get_num_attr_values (drmaa_attr_values_t *values, size_t *size);
void drmaa_release_attr_names (drmaa_attr_names_t *values);
void drmaa_release_attr_values (drmaa_attr_values_t *values);
```

Job Status and Control

- Get Job Status

```
int drmaa_job_ps (const char *job_id, int *remote_ps, char *error_diagnosis, size_t
        error_diag_len);
```

  > **remote_ps** returns DRMAA_PS_QUEUED_ACTIVE, DRMAA_PS_RUNNING, DRMAA_PS_USER_ON_HOLD, DRMAA_PS_DONE, DRMAA_PS_FAILED or DRMAA_PS_UNDETERMINED

- Job Control

```
int drmaa_control (const char *jobid, int action, char *error_diagnosis,  size_t
        error_diag_len);
```

  > **action** value can be DRMAA_CONTROL_SUSPEND, DRMAA_CONTROL_RESUME, DRMAA_CONTROL_TERMINATE, DRMAA_CONTROL_HOLD or DRMAA_CONTROL_RELEASE

Job Synchronize and Wait

- Synchronize Jobs

```
int drmaa_synchronize (const char *job_ids[], signed long timeout, int dispose, char
        *error_diagnosis, size_t error_diag_len);
```

> **timeout** value could be DRMAA_TIMEOUT_WAIT_FOREVER or DRMAA_TIMEOUT_NO_WAIT

Job Submission

- Bulk Job Submission

```
int drmaa_run_bulk_jobs (drmaa_job_ids_t **jobids, drmaa_job_template_t *jt, int
        start, int end, int incr, char *error_diagnosis, size_t error_diag_len);
```

Helper Functions

- String Lists

```
int drmaa_get_next_job_id (drmaa_job_ids_t *values, char *value, size_t
        value_len);
int drmaa_get_num_job_ids (drmaa_job_ids_t *values, size_t *size);
void drmaa_release_job_ids (drmaa_job_ids_t *values);
```

DRMAA Error Codes

DRMAA_ERRNO_SUCCESS
DRMAA_ERRNO_INTERNAL_ERROR
DRMAA_ERRNO_DRM_COMMUNICATION_FAILURE
DRMAA_ERRNO_AUTH_FAILURE
DRMAA_ERRNO_INVALID_ARGUMENT
DRMAA_ERRNO_NO_ACTIVE_SESSION
DRMAA_ERRNO_NO_MEMORY
DRMAA_ERRNO_INVALID_CONTACT_STRING
DRMAA_ERRNO_DEFAULT_CONTACT_STRING_ERROR
DRMAA_ERRNO_DRMS_INIT_FAILED
DRMAA_ERRNO_ALREADY_ACTIVE_SESSION
DRMAA_ERRNO_DRMS_EXIT_ERROR
DRMAA_ERRNO_INVALID_ATTRIBUTE_FORMAT
DRMAA_ERRNO_INVALID_ATTRIBUTE_VALUE
DRMAA_ERRNO_CONFLICTING_ATTRIBUTE_VALUES
DRMAA_ERRNO_TRY_LATER
DRMAA_ERRNO_DENIED_BY_DRM
…

For More Information

- Application Developer Guide (DRMAA C/JAVA bindings)
- DRMAA C Howtos
- DRMAA JAVA Howtos
- DRMAA C Reference
- DRMAA JAVA Reference
- DRMAA JAVA TestSuite
- And info about the scripting languages bindings

http://www.gridway.org/documentation/guides.php

the globus alliance
www.globus.org

Questions?