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ARC BATCH SYSTEM BACK-END INTERFACE GUIDE WITH SUPPORT FOR GLUE 2

Description and developer's guide for ARC1

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1 Introduction

This document describes the Advanced Resource Connector [1] batch system back-end infrastructure. It aims to describe the infrastructure in enough detail that a developer can add a new local resource management system (LRMS) to the ARC middleware. It also intends to serve as a reference manual describing existing batch system interfaces. Note that the current solution described in this manual is not a real interface, it is too diffuse to be that.

The batch system back-ends are what tie the ARC grid middleware (through (ARC Resource-coupled EXecution service, A-REX [2]) to the underlying cluster management system or LRMS. The back-ends consist of set of shell and Perl scripts whose role are twofold:

1. to allow the GM, which is resided in A-REX, to manipulate jobs on the LRMS including job submit, cancel operations etc.
2. to collect information about jobs, users, batch system and the cluster itself for the Information System.

The former will be referred to as the job control back-end interface while the latter is the information system interface of the batch system back-ends. These two will be treated separately in the following sections.

1.1 ARC Classic

The ARC Classic has its own solution, please refer to [3].

1.2 ARC1

As of ARC version 0.9, which is to be the next generation ARC, the scripts are located in different directories within the NorduGrid subversion tree [4]. The job control interface scripts can be found under `arc1/trunk/src/services/a-rex/lrms/` while the information collectors are located in `arc1/trunk/src/services/a-rex/infoproviders/`.

The next generation of ARC supports both the classic NorduGrid information schema [5] and currently a minimal set of the GLUE specification version 2.0 schema [6].

2 Job control interface

Job control part of the LRMS interface is handled by the Grid Manager [7]. It takes care of preparing a native batch system submission script, managing the actual submission of the batch system job, cancellation of job on request and scanning for completed batch jobs. Besides the LRMS job control interface it is also the GM which provides e.g. the data staging and communication with the grid client, provides RTE environments, arranges file staging (to the node via LRMS capability), dealing with stdout/stderr, etc. The job control batch system interface of the GM requires three programs. These programs can be implemented any way the designer sees fit, but all the existing back-end interfaces use shell scripting for portability and ease of tailoring to a specific site. The GM will call the following programs: `cancel-LRMS-job`, `submit-LRMS-job`, and `scan-LRMS-job`. LRMS is replaced with the short hand name for the LRMS e.g. `cancel-pbs-job`. The scripts are described one by one in the following subsections. Useful information can also be found in the Section "8.6 LRMS Support" and Section "8.7 Runtime Environment" of the Grid-Manager guide [7].

2.1 Cancel-LRMS-job

If a grid user cancels his job, the message will reach the grid-manager. The manager will then call the `cancel-LRMS-job` for the suitable back-end. The cancel script is called with a text file containing information about the job. It is called the GRAMi file. It contains such information as the original xRSL option and the job id in the local LRMS. `Cancel-LRMS-job` must then use that information to find the job and remove it from the queue or actually cancel it if it is running in the LRMS.

2.2 Submit-LRMS-job

The submit program is the most involved. It is called by the GM once a new job arrives and needs to be submitted to the LRMS. Like cancel-LRMS-job it is given the grami file as argument on execution. Submit-LRMS-job then has to set up the session directories, run-time environment and anything else needed. Then it should submit the job to the local LRMS. This is normally done by generating a native job script for the LRMS and then running the local submit command, but it could also be done through an API if the LRMS supports it.

2.3 Scan-LRMS-job

Scan-LRMS-job is run periodically. Its job is to scan the LRMS for jobs that have finished. Once it has found a finished job it should write the exit-code of that job to the file `job.{gridid}.lrms_done` in the ARC jobstatus directory. Then it should call the gm-kick program the GM will then notice that the job has finished and start finalizing the job.

Generally two approaches are taken to find jobs that are done. One is asking the LRMS. First all started grid jobs are found in the jobstatus directory[‡]. This can be done by checking if the status is INLRMS in the jobs status file[§]. Then the LRMS is asked for the status of those jobs. If they are done they are marked as such and the GM is activated. The problem with this approach is that for most LRMSs the information about finished jobs are only available for a short period after the job finished. Therefore appropriate steps have to be taken if the job is known to have been started but is no longer present in the LRMS. The normal approach is to analyze the jobs status output in the session directory.

The second approach is to parse the LRMSs log files. This method has some drawbacks e.g. the GM has to be allowed read access to the logs. The back-end will then have to remember where in the log it was last time it ran. This information will have to be stored in a file some where on the front-end.

2.4 Configuration parser

Some of the back-ends will need information from the configuration file. Since this functionality can be shared among the back-ends, a configuration file parser written in bash has been provided separately for easy maintenance and extendability.

2.4.1 Functions

`config_parse_file <config_file>`

Parses a config file. It returns exit status 1 if the file cannot be read, or 0 otherwise. Badly formed lines are silently ignored. Option values can be surrounded by single quotes or double quotes. Values without quotes are also accepted. Multi-valued options are not supported currently. Only the last defined value is retained.

`config_import_section <section_name>`

Imports options from section `<section_name>` of the config file into environment variables of the form `'CONFIG_optionname'`. Already existing environment variables are overwritten.

Example:

```
source $ARC_LOCATION/libexec/config_parser.sh
config_parse_file /etc/arc.conf || exit 1
config_import_section common
config_import_section grid-manager
config_import_section infosys
echo $CONFIG_pbs_bin_path
```

[‡]normally `/var/spool/nordugrid/jobstatus/`, but can be set via the `controldir` variable of `arc.conf`

[§]`job.{gridid}.status`

3 Information System interface

The main purpose of the information system batch interface is to populate the nordugrid information model and the GLUE2 model with locally collected information obtained from the batch system. Important to recall that the locally collected information is broader than what the batch-system can offer, information taken from the grid-layer (mostly grid manager), from the front-end machine and from the `arc.conf` configuration file are also needed and used to populate the nordugrid information model [5] and the GLUE2 schema [6].

The information system interface consists of a set of Perl scripts which generates an XML output to `STDOUT`.

The following subsection describes the LRMS interface part of the information system. To support a particular LRMS a dedicated Perl module should be written that implements the interface presented in the next subsections. Furthermore hooks should be added to the `LRMS.pm` module, so that it uses the correct Perl module depending on the LRMS type.

The information collector scripts are divided between several separate scripts:

- `cluster+qju.pl` - driver for information collection. It calls all other information collectors and prints results in XML. The information collection is done by one single invocation of this script
- `InfoCollector.pm` - base class for all information collectors (i.e.: all files `*Info.pm`).
- `InfoChecker.pm` - used by `InfoCollector` to validate options and results against a “schema”.
- `GMJobsInfo.pm` - collects information about jobs from grid manager status files
- `HostInfo.pm` - collects other information that can be collected on the front end (hostname, software version, disk space for users, installed certificates, Runtime environments ...)
- `LRMSInfo.pm` - collects information that is LRMS specific (queues, jobs, local user limits ...) by calling the appropriate LRMS plugin. It also does validation of input options to the plugin and of the data returned by the plugin.
- `BATCH_SYSTEM_NAME.pm` - plugins for `LRMSInfo`. Only Fork, SGE and PBS are updated to the new framework
- `ARC0ClusterInfo.pm` - combines all information about A-REX and produces information structured according to the classic NG schema
- `ARC1ClusterInfo.pm` - combines all information about A-REX and produces information structured according to the GLUE2 schema

All information about the hosting environment and queues is collected by one invocation of the Perl script named `cluster+qju.pl`. The XML output is printed to `STDOUT` and it includes two representations of the output data, namely the classic NorduGrid information schema and an incomplete GLUE2 schema representation.

3.1 The LRMS Perl module interface

Each LRMS module should implement two functions: `lrms_info` and `get_lrms_options_schema`.

3.1.1 `get_lrms_options_schema`

This function is called without arguments and should return a “schema” hash declaring the configuration options specific for this LRMS plugin. This “schema” conforms to the format understood by `InfoChecker.pm` and is used to validate input options for the plugin.

3.1.2 `lrms_info`

The `lrms_info` function returns all LRMS specific information. This includes information about the cluster, queues, jobs and local user limits. The function is called with a hash of hashes containing all options required by the LRMS plugin. Some options are common to all plugins, and are described in table 1.

The `lrms_info` function should then return a hash of hashes with the sctructure described in table 3.

Table 1: The `lrms_options` hash used as input for the `lrms_info` function

key	value
jobs	array with local job IDs
queues	hash with queue names as keys and values being <code>queue_options</code> hashes (table 2)

Table 2: The `queue_options` hash

key	value
users	array with local UNIX user names

Table 3: The `lrms_info` hash returned by the `lrms_info` function

key	value
<code>lrms_type</code>	the type of LRMS e.g PBS
<code>lrms_version</code>	the version of the LRMS
<code>totalcpus</code>	total number of CPUs in the cluster
<code>queuedcpus</code>	total number of CPUs requested by LRMS queuing jobs (both grid and non-grid)
<code>usedcpus</code>	CPUs in the LRMS that are currently in use either by grid or non-grid jobs
<code>cpudistribution</code>	number of CPUs in a node and number of each type e.g. "8cpu:5 2cpu:100"
queues	a hash with keys being queue names and values being <code>queue_info</code> hashes as described in table 4
jobs	a hash with keys being LRMS job IDs and values being <code>jobs_info</code> hashes as described in table 6

Table 4: The `queue_info` hash

key	value
status	available slots in queue, negative number signals error
maxrunning	limit on number of running jobs
maxqueueable	limit on number of jobs queued on this queue
maxuserun	limit on number of running jobs per user
maxcputime	limit on maximum CPU time for a job in this queue in minutes
mincputime	limit on minimum CPU time for a job in this queue in minutes
efaultcput	default CPU time limit for a job in this queue in minutes
maxwalltime	limit on maximum wall time for a job in this queue in minutes
minwalltime	limit on minimum wall time for a job in this queue in minutes
defaultwallt	default wall time limit for a job in this queue in minutes
running	number of CPUs used by running jobs (both grid and non-grid) in the queue
queued	number of CPUs requested by queuing jobs in the queue
totalcpus	number of CPUs available to the queue
users	a hash with keys being local UNIX user names and values being <code>users_info</code> hashes as described in table 5

Table 5: The `users_info` hash

key	value
<code>freecpus</code>	number of freely available CPUs with their time limits in minutes (see <code>ComputingService.FreeSlotsWithDuration</code> in [6])
<code>queuelength</code>	estimated queue length for the specified user

Table 6: The `jobs_info` hash

key	value
<code>status</code>	LRMS jobstatus mapping*: Running \Rightarrow 'R', Queued \Rightarrow 'Q', Suspended \Rightarrow 'S', Exiting \Rightarrow 'E', Other \Rightarrow 'O'
<code>rank</code>	the job's position in the LRMS queue
<code>mem</code>	the memory usage of the job in kB
<code>walltime</code>	consumed wall-time in minutes
<code>cputime</code>	consumed CPU-time in minutes
<code>reqwalltime</code>	wall-time requested by job in minutes
<code>reqcputime</code>	CPU-time requested by job in minutes
<code>nodes</code>	list of execution hosts
<code>comment</code>	array of string comments about the job in LRMS, can be an empty array

4 Batch system specifics

This section presents the batch system specific implementation details including information on supported versions, constraints on batch system configuration, known limitations, `arc.conf` parameters and list of batch system features being utilized within the interface are described.

4.1 PBS

The Portable Batch System (PBS) is one of the most popular batch systems. PBS comes in many flavours such as OpenPBS (unsupported), Terascale Open-Source Resource and Queue Manager (TORQUE) and PBSPro (currently owned by Altair Engineering). ARC supports all the flavours and versions of PBS.

4.1.1 Recommended batch system configuration

PBS is a very powerful Local Resource Manager System with dozens of configurable options. Server, queue and node attributes can be used to configure the cluster's behaviour. In order to correctly interface PBS to ARC (mainly the information provider scripts) there are a couple of configuration REQUIREMENTS asked to be implemented by the local system administrator:

1. The computing nodes MUST be declared as cluster nodes (job-exclusive), at the moment time-shared nodes are not supported by the ARC setup. If you intend to run more than one job on a single processor then you can use the virtual processor feature of PBS.
2. For each queue, you MUST set one of the `max_user_run` or `max_running` attributes and its value SHOULD BE IN AGREEMENT with the number of available resources (i.e. don't set the `max_running` = 10 if you have only six (virtual) processors in your system). If you set both `max_running` and `max_user_run` then obviously `max_user_run` has to be less equal than `max_running`.
3. For the time being, do NOT set server limits like `max_running`, please use queue-based limits instead.

4. Avoid using the `max_load` and the `ideal_load` directives. The node's mom config file (<PBS home on the node>/mom_priv/config) should not contain any `max_load` or `ideal_load` directives. PBS closes down a node (no jobs are allocated to it) when the load on the node reaches the `max_load` value. The `max_load` value is meant for controlling time-shared nodes. In case of job-exclusive nodes there is no need for setting these directives, moreover incorrectly set values can close down your node.
5. Routing queues are not supported, those can't be used within ARC.

Additional useful configuration hints:

- If possible, please use queue-based attributes instead of server level ones (for the time being, do not use server level attributes at all).
- You may use the `"acl_user_enable = True"` with `"acl_users = user1,user2"` attribute to enable user access control for the queue.
- It is advisory to set the `max_queuable` attribute in order to avoid a painfully long dead queue.
- You can use node properties from the <PBS home on the server>/server_priv/nodes file together with the `resources_default.nodenames` to assign a queue to a certain type of node.

Checking your PBS configuration:

- The node definition can be checked by <PBS installation path>/bin/pbsnodes -a. All the nodes MUST have `ntype=cluster`.
- The required queue attributes can be checked as <PBS installation path>/bin/qstat -f -Q queueName. There MUST be a `max_user_run` or a `max_running` attribute listed with a REASONABLE value.

4.1.2 Relevant `arc.conf` options

Below the PBS specific configuration variables are collected.

- The PBS batch system back-end is enabled via setting the `lrms="pbs"` in the [common] configuration block. No need to specify the flavour or the version number of the PBS, simply use the "pbs" keyword as `lrms` configuration value.
- `pbs_bin_path` configuration variable of the [common] block should be set to the path to the `qstat`, `pbsnodes`, `qmgr` etc PBS binaries.
- `pbs_log_path` configuration variable of the [common] block should be set to the path of the PBS server logfiles which are used by the Grid-Manager to determine whether a PBS job is completed. If not specified, the Grid-Manager will use the `qstat` command to find completed jobs.
- `lrmsconfig` from the [cluster] block can be used as an optional free text field to describe further details about the PBS configuration (e.g. `lrmsconfig="single job per processor"`).
- `dedicated_node_string` from the [cluster] block specifies the string which is used in the PBS node config to distinguish the grid nodes from the rest. Suppose only a subset of nodes are available for grid jobs, and these nodes have a common `node property` string, this case the `dedicated_node_string` should be set to this value and only the nodes with the corresponding PBS `node property` are counted as grid enabled nodes. Setting the `dedicated_node_string` to the value of the PBS `node property` of the grid-enabled nodes will influence how the `totalcpus`, `user freecpus` is calculated. No need to set this attribute if the cluster is fully available for the grid and the PBS configuration does not use the `node property` method to assign certain nodes to grid queues.
- [queue/queueName] block. For each grid-enabled (or grid visible) PBS queue a corresponding [queue] block must be defined. `queueName` should be the PBS queue name.
- `scheduling_policy` from the [queue/queueName] block describes the scheduling policy of the queue. PBS by default offers the FIFO scheduler, many sites run the MAUI. At the moment FIFO & MAUI are supported values. If you have a MAUI scheduler you should specify the "MAUI" value since it modifies the way the queue resources are calculated. By default the "FIFO" scheduler type is assumed.

- `maui_bin_path` from the `[queue/queuenam]` block sets the path of the maui commands like `showbf` when "MAUI" is specified as `scheduling_policy` value. This parameter can be set in the `[common]` block as well.
- `queue_node_string` of the `[queue/queuenam]` block can be used similar to the `dedicated_node_string`. In PBS you can assign nodes to a queue (or a queue to nodes) by using the `node` property PBS node configuration method and assigning the marked nodes to the queue (setting the `resources_default.needsnodes = queue_node_string` for that queue). This parameter should contain the `node` property string of the queue-assigned nodes. Setting the `queue_node_string` changes how the `queue-totalcpus`, `user freecpus` are determined for this queue.

4.1.3 Implementation details

The job control batch interface makes use of the `qsub` command to submit native PBS jobscripts to the batch system. The following options are used:

```
-l nodes, cput, walltime, pvmem, pmem,
-W stagein, stageout
-e, -j eo
-q
-A
-N
```

For job cancellation the `qdel` command is used. To find completed jobs, i.e. to scan for finished jobs the `qstat` command or the `PBS server log file` is used.

The information system interface utilizes the `qstat -f -Q queuenam` and `qstat -f queuenam` commands to obtain detailed job and queue information. `qmgr -c "list server"` is used to determine PBS flavour and version. The `pbsnodes` command is used to calculate total/used/free cpus within the cluster. In case of a Maui scheduler the `showbf` command is used to determine user freecpu values. All these external PBS commands are interfaced via parsing the commands' output.

4.1.4 Known limitations

Some of the limitations are already mentioned under the PBS deployment requirements. No support for routing queues, difficulty of treating overlapping queues, the complexity of node string specifications for parallel jobs are the main shortcomings.

4.2 Fork

The Fork back-end is a simple back-end that interfaces to the local machine i.e. there is no batch system underneath. It simply forks the job, hence the name. The back-end then uses standard posix commands(e.g. `ps` or `kill`) to manage the job.

4.2.1 Recommended batch system configuration

Since fork is a simple back-end and does not use any batch system, there is no specific configuration needed of the underlying system.

4.2.2 Relevant arc.conf options

- The Fork back-end is enabled by setting `lrms="fork"` in the `[common]` configuration block.
- The queue must be named "fork" in the queue section.
- `fork_job_limit="cpunumber"`, this option is used to set the number of running grid jobs on the fork machine, allowing a multi core machine to use some or all of its cores for Grid jobs. The default value is 1.

4.2.3 Implementation details and known limitations

The Fork backend implements an interface to the “fork” unix command which is not a batch system. Therefore the backend should rather be seen as an interface to the operating system itself. Most of the “batch system values” are determined from the operating system (e.g. cpu load) or manually set in the configuration file.

Fork is not a batch system, therefore many of the queue specific attributes or detailed job information is not available. The support for the “Fork batch system” was introduced so that quick deployments and testing of the middleware can be possible without dealing with deployment of a real batch system since fork is available on every unix box. The Fork backend is not recommended to be used in production. The backend by its nature, has lots of limitations, for example does not support parallel jobs.

4.3 SGE

Sun Grid Engine, formerly known as Codine, is an open source batch system maintained by Sun. Runs on Linux, Solaris.

4.3.1 Recommended batch system configuration

Set up one or more SGE queues for access by grid users. Queues can be shared by normal and grid users. In case you want to set up more than one ARC queue, make sure that the corresponding SGE queues have no shared nodes among them. Otherwise the counts of free and occupied CPUs might be wrong. Only SGE versions 6 and above are supported.

4.3.2 Relevant arc.conf options

The SGE back-end requires that the following options are specified:

- The SGE batch system back-end is enabled by setting `lrms="sge"` in the `[common]` configuration block.
- `sge_root` must be set to SGE's install root.
- `sge_bin_path` configuration variable of the `[common]` block must be set to the path of the SGE binaries.
- `sge_cell`, `sge_qmaster_port` and `sge_execd_port` options might be necessary to set in special cases. See the `arc.conf(5)` man page for more details.
- `sge_jobopts` configuration variable of the `[queue]` block can be used to add custom SGE options to job scripts submitted to SGE. Consult SGE documentation for possible options.

Example:

```
lrms="sge"
sge_root="/opt/nlge6"
sge_bin_path="/opt/nlge6/bin/lx24-x86"
...
[queue/long]
sge_jobopts="-P atlas -r yes"
```

4.3.3 Implementation details

The SGE backend's commands are similar to the PBS commands. These commands are used in the code:

Submit job:

- `qsub -S /bin/sh` (specifies the interpreting shell for the job)

Get jobs status:

If the job state is not suspended, running or pending then its state is failed.

- `qstat -u '*' -s rs` (show the running and suspended jobs status)
- `qstat -u '*' -s p` (show the pending jobs status)
- `qstat -j job_id` (long job information)
- `qacct -j job_id` (finished job report)

Job terminating:

- `qdel job_id` (delete Sun Grid Engine job from the queue)

Queue commands:

- `qconf -spl` (show a list of all currently defined parallel environments)
- `qconf -sql` (show a list of all queues)
- `qconf -sep` (show a list of all licensed processors/slots)
- `qstat -g c` (display cluster queue summary)
- `qconf -sconf global` (show global configuration)
- `qconf -sq queue_name` (show the given queue configuration)

Other:

- `qstat -help` (show Sun Grid Engine's version and type)

4.3.4 Known limitations

Multi-CPU support is not well tested. All users are shown with the same quotas in infosys, even if they are mapped to different local users. The requirement that one ARC queue maps to one SGE queue is too restrictive, as the SGE's notion of a queue differs widely from ARC's definition. The flexibility available in SGE for defining policies is difficult to accurately translate into nordugrid's information schema. The closest equivalent of nordugrid-queue-maxqueueable is a per-cluster limit in SGE, and the value of nordugrid-queue-localqueued is not well defined if pending jobs can have multiple destination queues.

5 The ARC GLUE 2 implementation

ARC1 provides support for both the classic NorduGrid information schema [5] as well as an early minimal GLUE 2 implementation. The output is rendered in XML format.

Currently, the the following GLUE2 entities are included in ARC1:

- ComputingService
- ComputingEndpoint
- ComputingShare

While the following entities are still missing (TODO: According to our table in wiki, there should be some other sections as well):

- ApplicationEnvironment
- ExecutionEnvironment
- ComputingActivity
- Policy including MappingPolicy / AccessPolicy

The different entities with their attributes are described in their respective sections below.

5.1 ComputingService

Hardcoded Properties:

Property	Value
Capability	executionmanagement.jobexecution
Type	org.nordugrid.arex
QualityLevel	development
Complexity	endpoint=1, share=N, resource=1, where N is the number of queues in the configuration file

The following properties referring to job counts are obtained from GridManager's status files:

Property	Meaning
TotalJobs	Number of grid jobs which are not yet finished
RunningJobs	Number of grid jobs running
WaitingJobs	Number of grid jobs queued in the LRMS and waiting to be submitted to the LRMS

5.2 ComputingEndpoint

Property	Value
URL	https://hostname:port/arex
Technology	webservice
Interface	OGSA-BES
WSDL	https://hostname:port/arex/?wsdl
Semantics	http://www.nordugrid.org/documents/arex.pdf
SupportedProfile	WS-I 1.0 and HPC-BP
Implementor	NorduGrid
ImplementationName	ARC1
ImplementationVersion	0.9
QualityLevel	development
HealthState	ok – no detection of problems yet
ServingState	draining if the configuration has allownew=no, production otherwise
IssuerCA	from the <i>hostcert.pem</i> file
TrustedCA	from scanning the <i>certificates</i> directory
Staging	staginginout
JobDescription	ogf:jsdl:1.0

5.3 ComputingShare

A ComputingShare element is generated for each 'queue' section in the configuration.

Property	Value
BaseType	Share
Name	from the configuration
Description	“comment” configuration option
MappingQueue	from the configuration

The following properties are taken from the corresponding values returned by the LRMS plugin. Units are converted as necessary.

Property	LRMS plugin property
MaxCPUTime	maxcputime
MinCPUTime	mincputime
DefaultCPUTime	defaultcput
MaxWallTime	maxwalltime
MinWallTime	minwalltime
DefaultWallTime	defaultwallt

Property	Value
MaxTotalJobs	maxjobs from configuration
MaxRunningJobs	
MaxWaitingJobs	

Name

Attribute value: String
Example: Name : TODO
Related xRSL: TODO
UI role: ?
Description: Name of the application environment

Version

Attribute value: String
Example: Version: TODO
Related xRSL: TODO
UI role: TODO
Description: Name of the application environment

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