DRMAAv2 - An Introduction

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http://www.drmaa.org/

History

DRMAA
Distributed Resource Management Application API — www.drmaa.org

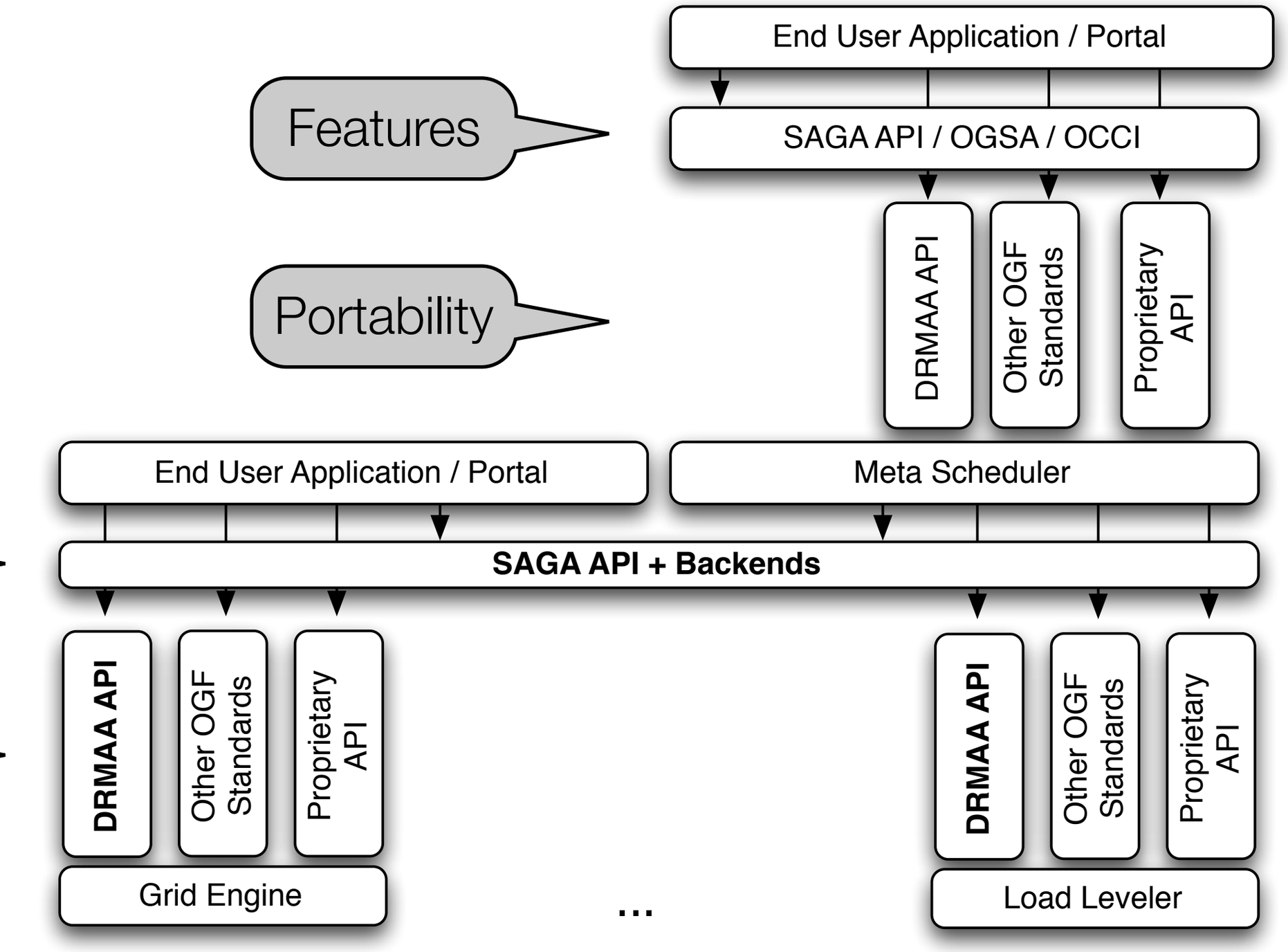
- DRMAA group established in 2002
- Goal: Standardized API for distributed resource management systems (DRMS)
  - Low-level **portability** for cluster and grid infrastructure applications
  - Simple design, **bottom-up philosophy**
- Different DRMAA 1.0 documents
  - June 2004 - DRMAA 1.0 Proposed Recommendation (GFD.22)
  - April 2008 - Shift to IDL based root specification, some clarifications (GFD.130)
  - June 2008 - DRMAA 1.0 Grid Recommendation (GFD.133)
  - Official language binding documents for C, Java, Python (GFD.143)
  - Experience reports, tutorials, unofficial language bindings for Perl, Ruby and C#

OGF Specs

DRMAA
Distributed Resource Management Application API — www.drmaa.org

Features

Portability



DRMAAv1 Success Story

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- Product-quality implementations of DRMAA C and Java, broad industrial up-take
  - *Grid Engine* since 2006
  - *Condor* since 2006
  - *PBS/Torque*, *LSF*, *LoadLeveler*, *Kerrighed*, *SLURM*, *Globus* (via *GridWay*) (third-party implementations)
- Large and silent user community
  - Meta schedulers accessing DRM resources (Galaxy, QosCosGrid, MOAB, eXludus, OpenDSP, EGEE, Unicore, SAGA, ...)
  - Applications or portals accessing DRM resources (BLAST, workflow processing, finance sector, seismic data, Mathematica, ...)
  - Hundreds (?) of unknown Grid Engine users

DRMAA v1 C Example

DRMAA
Distributed Resource Management
Application API — www.drmaa.org

```
#include "drmaa.h"

int main(int argc, char **argv) {
     char error[DRMAA_ERROR_STRING_BUFFER];
     int errnum = 0;
     drmaa_job_template_t *jt = NULL;

     errnum = drmaa_init(NULL, error, DRMAA_ERROR_STRING_BUFFER);
     if (errnum != DRMAA_ERRNO_SUCCESS) return 1;
     errnum = drmaa_allocate_job_template(&jt, error, DRMAA_ERROR_STRING_BUFFER);
     if (errnum != DRMAA_ERRNO_SUCCESS) return 1;
     drmaa_set_attribute(jt, DRMAA_REMOTE_COMMAND, "sleeper.sh",
                         error, DRMAA_ERROR_STRING_BUFFER);
     const char *args[2] = {"5", NULL};
     drmaa_set_vector_attribute(jt, DRMAA_V_ARGV, args, error,
                            DRMAA_ERROR_STRING_BUFFER);
     char jobid[DRMAA_JOBNAME_BUFFER];
     errnum = drmaa_run_job(jobid, DRMAA_JOBNAME_BUFFER, jt, error,
                    DRMAA_ERROR_STRING_BUFFER);
     if (errnum != DRMAA_ERRNO_SUCCESS) return 1;
     errnum = drmaa_delete_job_template(jt, error, DRMAA_ERROR_STRING_BUFFER);
     errnum = drmaa_exit(error, DRMAA_ERROR_STRING_BUFFER);
     return 0;
}
```

DRMAA v1 Got Old

DRMAA
Distributed Resource Management Application API — www.drmaa.org

- DRM systems got better
  - Concept of resources, session persistency, advance reservation, parallel jobs, many-core systems, queues, state models, WS-* stuff, ...
- Some obsolete / never implemented features
  - Date / time handling, host-to-host file staging, specialized job states, ...
- Awkward design decisions
  - Job synchronization, job monitoring, data reaping, native specification, ...
- DRMAAv2 work started 2009
  - Public survey, Sun customer feedback, implementation experiences, ...
  - Close collaboration with SAGA, GAT, and OCCI WG; considered JSDL & BES
  - Performant investigation of current DRM systems (poor Mariusz)

DRMAAv2 Design Approach

DRMAA
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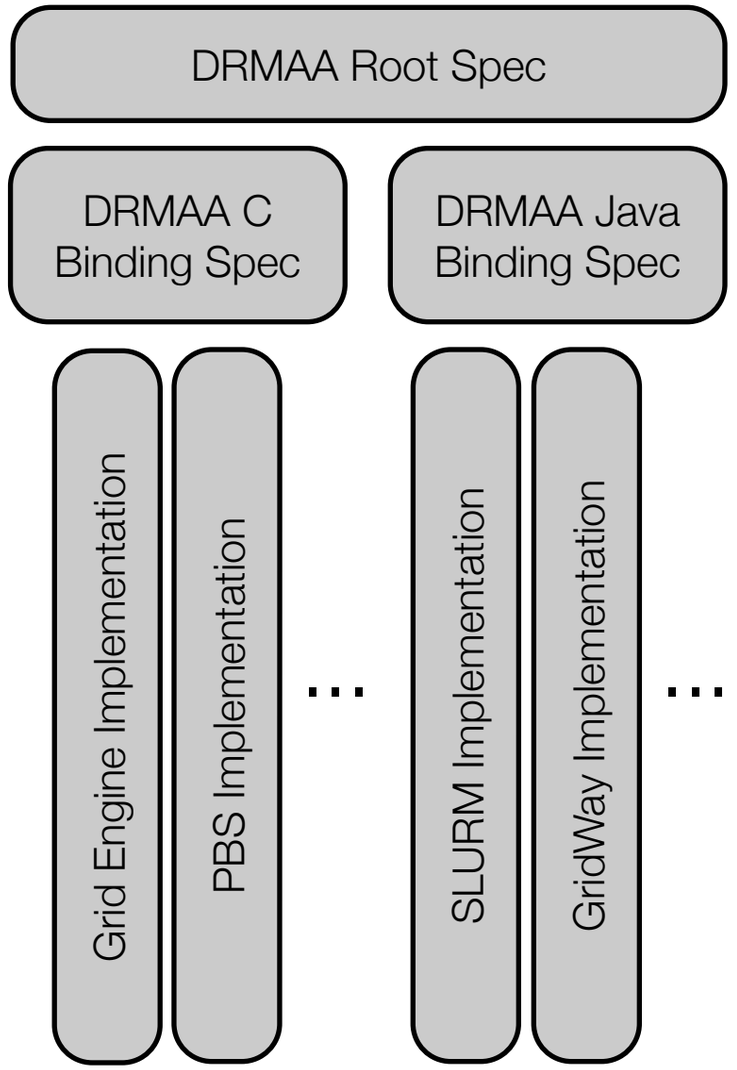
- All behavioral aspects in the IDL-based root specification
  - Same model as W3C DOM, OGF SAGA, ...
  - What functions are offered ? How are they grouped ?
  - What are possible error conditions ?
    - For language binding designers and implementors
- Language binding just defines syntactical mapping
  - „DRMAA IDL construct A maps to programming language construct B“
  - Root spec demands some design decisions (e.g. „UNSET“)
- End users should get separate man pages



DRMAAv2 Layout

DRMAA
Distributed Resource Management Application API — www.drmaa.org

interface **SessionManager**

interface **DrmaaCallback**

struct **DrmaaNotification**

Establish session with the DRM system

interface **JobSession**

interface **Job**

interface **JobArray**

struct **JobTemplate**

struct **JobInfo**

interface **ReservationSession**

interface **Reservation**

struct **ReservationTemplate**

struct **ReservationInfo**

interface **MonitoringSession**

struct **MachineInfo**

struct **QueueInfo**

struct **SlotInfo**

Work with jobs / advance reservation / monitoring features of the DRM system

Exceptions

Enumerations

interface **DrmaaReflective**

Optional vs. Implementation-Specific

DRMAA
Distributed Resource Management Application API — www.drmaa.org

- Make non-mandatory things explicit
- `DrmaaCapability` enumeration
  - One enum per optional feature + `SessionManager::supports` method
- `DrmaaReflective` interface
  - Lists of implementation-specific attributes + generic getter / setter functions

```
enum DrmaaCapability {
      ADVANCE_RESERVATION, RESERVE_SLOTS, CALLBACK, BULK_JOBS_MAXPARALLEL, JT_EMAIL,
      JT_STAGING, JT_DEADLINE, JT_MAXSLOTS, JT_ACCOUNTINGID, RT_STARTNOW, RT_DURATION,
      RT_MACHINEOS, RT_MACHINEARCH };
interface DrmaaReflective {
      readonly attribute StringList jobTemplateImplSpec;
      readonly attribute StringList jobInfoImplSpec;
      ...
      string getInstanceValue(in any instance, in string name);
      void setInstanceValue(in any instance, in string name, in string value);
      string describeAttribute(in any instance, in string name); }
```

Stakeholders

DRMAA
Distributed Resource Management Application API — www.drmaa.org

- Distributed resource management (DRM) system
  - Distributes computational tasks on execution resources
  - Central scheduling entity
- DRMAA implementation / library : Implementation of a language binding, semantics as in the root spec

- Submission host: Resource that runs the DRMAA-based application
- Execution host: Resource that can run a submitted computational task
- Job: One or more operating system processes on a execution host

DRMAA	Reference	GLUE 2.0	Reference [1]
DRM system	Section 1.1	Manager	Section 5.9
Execution host	Section 1.1	ExecutionEnvironment + ComputingManager	Section 6.4 / 6.6
Socket	Section 5.3.3	Physical CPU	Section 6
Core	Section 5.3.4	Logical CPU	Section 6
Job	Section 1.1	ComputingActivity	Section 6.9
Job category	Section 1.4	ApplicationEnvironment	Section 6.7
`UNSET` value	Section 1.3	Placeholder values for unknown data	Appendix A

DRMAAv2 Session Manager

DRMAA
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- Create multiple connections to one (or more) DRM system(s) at a time
- `JobSession / ReservationSession`
  - Persistent storage of session state (at least) on submission machine
  - Can be reloaded by name, explicit reaping
- `MonitoringSession`
  - Read-only semantic, global view on all machines
- Maps nicely to SAGA and friends - management vs. monitoring
- Security remain out of scope for DRMAA
- Explicitly supports the portal / command-line tools use case
- Old concept of contact strings from DRMAAv1

DRMAAv2 Session Manager

DRMAA
Distributed Resource Management Application API — www.drmaa.org

```
interface SessionManager{
     readonly attribute string drmsName;
     readonly attribute Version drmsVersion;
     readonly attribute string drmaaName;
     readonly attribute Version drmaaVersion;
     boolean supports(in DrmaaCapability capability);
     JobSession createJobSession(in string sessionName, in string contact);
     ReservationSession createReservationSession(
                         in string sessionName, in string contact);
     JobSession openJobSession(in string sessionName);
     ReservationSession openReservationSession(in string sessionName);
     MonitoringSession openMonitoringSession (in string contact);
     void closeJobSession(in JobSession s);
     void closeReservationSession(in ReservationSession s);
     void closeMonitoringSession(in MonitoringSession s);
     void destroyJobSession(in string sessionName);
     void destroyReservationSession(in string sessionName);
     StringList getJobSessionNames();
     StringList getReservationSessionNames();
     void registerEventNotification(in DrmaaCallback callback);
};
```

DRMAAv2 Event Callback

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- Optional support for event push notification
- Application implements `DrmaaCallback` interface
- Demands some additional rules from the language binding
- Push notification at least supported in Grid Engine
- Heavily demanded by SAGA and end users
- Polling by the library is allowed
- Nested callbacks are forbidden
- Scalability is out of scope

```
interface DrmaaCallback {
     void notify(in DrmaaNotification notification);
};
struct DrmaaNotification {
     DrmaaEvent event;
     string jobId;
     string sessionName;
     JobState jobState;
};
enum DrmaaEvent {
     NEW_STATE, MIGRATED, ATTRIBUTE_CHANGE
};
```

DRMAA v2 Job Session

DRMAA
Distributed Resource Management Application API — www.drmaa.org

- New: Fetch list of supported job categories (portal case)
- New: `Job` filtering
- New: `JobArray`
- New: `maxParallel` restriction for bulk jobs
- Old `synchronize()` was replaced by class-based state waiting approach
  - More responsive
  - Get rid of partial job failure problems

```
interface JobSession {
      readonly attribute string contact;
      readonly attribute string sessionName;
      readonly attribute StringList jobCategories;
      JobList getJobs(in JobInfo filter);
      JobArray getJobArray(in string jobArrayId);
      Job runJob(in JobTemplate jobTemplate);
      JobArray runBulkJobs( in JobTemplate jobTemplate,
                            in long beginIndex,
                            in long endIndex,
                            in long step,
                            in long maxParallel);
      Job waitAnyStarted(in JobList jobs,
                         in TimeAmount timeout);
      Job waitAnyTerminated(in JobList jobs,
                            in TimeAmount timeout);
};
native ZERO_TIME;
native INFINITE_TIME;
```

Job Categories

- Consider deployment properties
  - Path settings, environment variables, software installed, application starters, ...
- Job category references a site-specific configuration
- Non-normative set of recommendations on DRMAA home page
  - Idea is to perform updates without spec modification
  - Site operators should be allowed to create their own job categories (configuration of the implementation)
  - Initial set derived from JSDL SPMD Extension (GFD.115) + experience
  - Proposals welcome ...

Everybody Loves State Models

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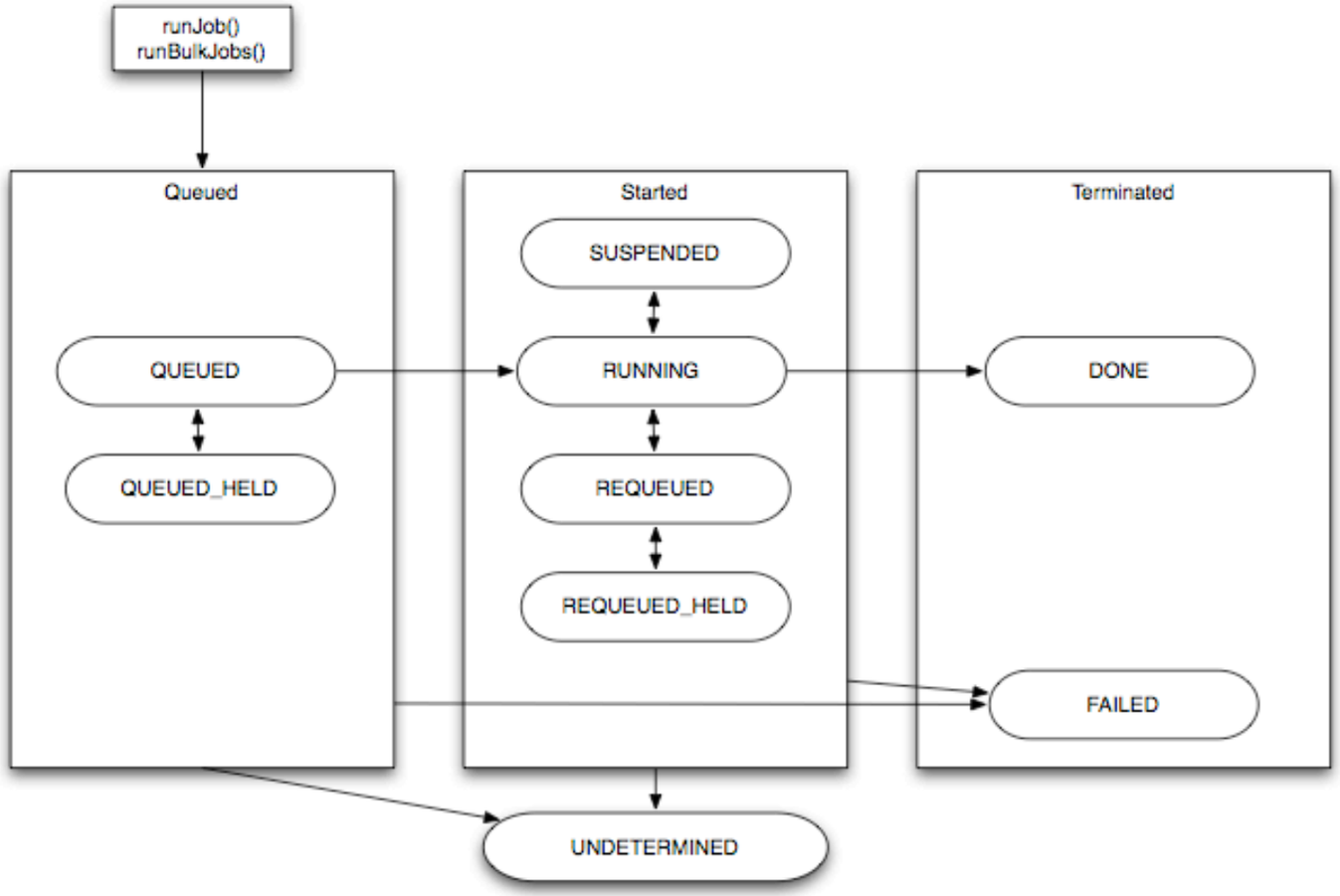
- Number of states reduced
- New sub-state concept
  - Similar to OGSA-BES
  - Allows simple DRMAAv1 mapping
- Wait functions work only on class level (timing issues)
- No more different hold modes



DRMAA JobState	SAGA JobState [4]	OGSA-BES Job State [3]
UNDETERMINED	N/A	N/A
QUEUED	Running	Pending (Queued)
QUEUED_HELD	Running	Pending (Queued)
RUNNING	Running	Running (Executing)
SUSPENDED	Suspended	Running (Suspended)
REQUEUED	Running	Running (Queued)
REQUEUED_HELD	Running	Running (Queued)
DONE	Done	Finished
FAILED	Cancelled, Failed	Cancelled, Failed

DRMAAv2 Job Template

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- Basic rules
  - DRM systems manage machines, which have a CPU and physical memory
  - Machines can be booked in advance reservation
  - DRM systems manage **queues** and **slots** as resources, **opaque** to DRMAA
- Jobs can be submitted ...
  - ... to specified candidate machines or a queue
  - ... to machines matching an OS type, architecture type, or memory requirement
  - ... as ‚classified‘ job with special treatment by the DRMS (jobCategory)
    - Examples: MPICH2 job, OpenMPI job, OpenMP job

DRMAAv2 Job Template

- Most things remain the same, but:
  - Relative start / end times are gone, switched to RFC822
  - Only copying between submission and exception machine, no host names
  - Standardized job category names (based on GFD.115, see web page)
  - Standardized resource limit types (*setrlimit*)
  - Several new resource specification attributes

```
struct JobTemplate {
      string remoteCommand;
      OrderedStringList args;
      boolean submitAsHold;
      boolean rerunnable;
      Dictionary jobEnvironment;
      string workingDirectory;
      string jobCategory;
      StringList email;
      boolean emailOnStarted;
      boolean emailOnTerminated;
      string jobName;
      string inputPath; string outputPath;
      string errorPath; boolean joinFiles;
      string reservationId;
      string queueName;
      long minSlots; long maxSlots;
      long priority;
      OrderedStringList candidateMachines;
      long minPhysMemory;
      OperatingSystem machineOS;
      CpuArchitecture machineArch;
      AbsoluteTime startTime;
      AbsoluteTime deadlineTime;
      Dictionary stageInFiles;
      Dictionary stageOutFiles;
      Dictionary resourceLimits;
      string accountingId;
};
```

DRMAAv2 Job / JobArray

- Heavy cleanup
  - Dedicated control methods
  - Explicit job information fetching
- `waitStarted()` and `waitTerminated()` as on `JobSession` level
- Support for the new job sub-state model
- `JobArray` offers control operations on bulk jobs
- Rejected: Signaling, modifying running jobs, ...

```
interface Job {
      readonly attribute string jobId;
      readonly attribute string sessionName;
      readonly attribute JobTemplate jobTemplate;
      void suspend();
      void resume();
      void hold();
      void release();
      void terminate();
      JobState getState(out any jobSubState);
      JobInfo getInfo();
      Job waitStarted(in TimeAmount timeout);
      Job waitTerminated(in TimeAmount timeout);
}
interface JobArray {
   readonly attribute string jobArrayId;
   readonly attribute JobList jobs;
   readonly attribute string sessionName;
   readonly attribute JobTemplate jobTemplate;
   void suspend();
   void resume();
   void hold();
   void release();
   void terminate();
}
```

DRMAAv2 JobInfo

- No surprises with `JobInfo`
  - Used for both filtering and job status representation
  - Snapshot semantics
  - No promises for terminated jobs
- Implementations can give a meaning to the reported list of machines being used

```
struct JobInfo {
   string jobId;
   long exitStatus;
   string terminatingSignal;
   string annotation;
   JobState jobState;
   any jobSubState;
   OrderedSlotInfoList allocatedMachines;
   string submissionMachine;
   string jobOwner;
   long slots;
   string queueName;
   TimeAmount wallclockTime;
   long cpuTime;
   AbsoluteTime submissionTime;
   AbsoluteTime dispatchTime;
   AbsoluteTime finishTime;
};
```

DRMAAv2 Advance Reservation

DRMAA
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- Completely new
- Fits nicely to the rest of the spec

```
interface ReservationSession {
   readonly attribute string contact;
   readonly attribute string sessionName;
   Reservation getReservation(in string reservationId);
   Reservation requestReservation(in ReservationTemplate reservationTemplate);
   ReservationList  getReservations ();
};
interface Reservation {
   readonly attribute string reservationId;
   readonly attribute string sessionName;
   readonly attribute ReservationTemplate reservationTemplate;
   ReservationInfo getInfo();
   void terminate();
};
```

DRMAAv2 Advance Reservation

DRMAA
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- Reservation template
  - Different combinations of `startTime`, `endTime`, and `duration` are allowed
  - Sliding window + time frame support
  - Support for authorization setup

```
struct ReservationTemplate {
   string reservationName;
   AbsoluteTime startTime;
   AbsoluteTime endTime;
   TimeAmount duration;
   long minSlots;
   long maxSlots;
   string jobCategory;
   StringList usersACL;
   OrderedStringList candidateMachines;
   long minPhysMemory;
   OperatingSystem machineOS;
   CpuArchitecture machineArch;
};
struct ReservationInfo {
   string reservationId;
   string reservationName;
   AbsoluteTime reservedStartTime;
   AbsoluteTime reservedEndTime;
   StringList usersACL;
   long reservedSlots;
   OrderedSlotInfoList reservedMachines;
};
```

```
struct SlotInfo {
   string machineName;
   long slots;
};
...
typedef sequence<SlotInfo> OrderedSlotInfoList;
...
```

DRMAAv2 Monitoring

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- Completely new
  - Global view on resources
  - Stateless session instance
  - Implementation has freedom to leave out information
- Resource information model matching to SAGA
- Virtual memory = physical memory + swap space
- Load = 1-min average load
- Snapshot semantics

```
typedef sequence <Reservation> ReservationList;
typedef sequence <Job> JobList;
typedef sequence <QueueInfo> QueueInfoList;
typedef sequence <MachineInfo> MachineInfoList;
...
interface MonitoringSession {
   ReservationList getAllReservations();
   JobList getAllJobs(in JobInfo filter);
   QueueInfoList getAllQueues(in StringList names);
   MachineInfoList getAllMachines(in StringList names);
};
struct QueueInfo {
   string name;
};
struct MachineInfo {
   string name;
   boolean available;
   long sockets;
   long coresPerSocket;
   long threadsPerCore;
   double load;
   long physMemory;
   long virtMemory;
   OperatingSystem machineOS;
   Version machineOSVersion;
   CpuArchitecture machineArch; };
```

More Stuff

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- `DRMAA_INDEX_VAR`
  - Implementations should set the environment variable `DRMAA_INDEX_VAR`
  - Contains the name of the DRMS environment variable providing the job index
    - `TASK_ID` (Grid Engine), `PBS_ARRAYID` (Torque), `LSB_JOBINDEX` (LSF)
  - Jobs are enabled to get their own parametric index

Notes: Job Specification Is Hard

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A	B	C	D	E	F	G	H
	JSDL		**SGE**				
Resource requirement for job	**JSDL Name**		**SGE Queue Properties**	**SGE Description**		**Condor Machine ClassAd**	**Condor submission file**
	CandidateHosts					MACHINE	
	TotalResourceCount		slots	Number of processes (allowed) to run			machine_count
	FileSystem					-- (no free choice of FS)	
	ExclusiveExecution		(This is accomplished through a special complex as of 6.2u3.)				
	OperatingSystem		(arch built-in complex)			OPSYS	
	CPUArchitecture		(arch built-in complex)			ARCH	
	IndividualCPUSpeed					KFLOPS	
	IndividualCPUTime						
	IndividualCPUCount		(num_proc built-in complex)			CPUS	
	IndividualNetworkBandwidth						
	IndividualPhysicalMemory		(mem_total built-in complex)			MEMORY	
	IndividualVirtualMemory		(virtual_total built-in complex)			VirtualMemory	
	IndividualDiskSpace					DISK	
	TotalCPUTime		s_cpu / h_cpu	Soft / hard limit for CPU time of all processes			
	TotalCPUCount						
	TotalPhysicalMemory						
	TotalVirtualMemory		s_vmem / h_vmem	Soft / hard limit for job virtual memory			
	TotalDiskSpace		s_fsize / h_fsize	Soft / hard limit for bytes on disk			
				Minimum time between			

Notes: Job Submission Is Hard

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	LSF	Torque	PBS Pro
Wildcard Support	no	not recommended	yes
Other than submission host	no	yes	yes
Appending file	yes	no	no
Directory Staging	no	not by default	yes

- Ensuring true application portability with a unified API is REALLY hard
  - Interoperability (OGSA, JSDL) does not provide portability
  - Profiles (!) with „SHOULD“ and „UnsupportedFeatureFault“ are not helpful
- DRMAA tries to define **mandatory** job template attributes and API functions that are **implementable** in **most** DRM systems
  - This is why DRMAA will never by exhaustive -> use SAGA !

Notes: Other OGF Specs

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- JSDL is partially exhaustive, GLUE is conservative

DRMAA `OperatingSystem`	JSDL `jsdl:OperatingSystemTypeEnumeration`	GLUE v2.0
HPUX	HPUX	
LINUX	LINUX	OSFamily_t:linux
IRIX	IRIX	
TRUE64	Tru64_UNIX, OSF	
MACOS	MACOS	OSFamily_t:macosx
SUNOS	SunOS, SOLARIS	OSFamily_t:solaris
WIN	WIN95, WIN98, Windows_R_Me	OSFamily_t:windows
WINNT	WINNT, Windows_2000, Windows_XP	OSFamily_t:windows
AIX	AIX	OSName_t:aix
UNIXWARE	SCO_UnixWare, SCO_OpenServer	
BSD	BSDUNIX, FreeBSD, NetBSD, OpenBSD	

DRMAA `CpuArchitecture`	JSDL `jsdl:ProcessorArchitectureEnumeration`	GLUE v2.0
ALPHA	other	
ARM	arm	
CELL	other	
PARISC	parisc	
X86	x86_32	Platform_t:i386
X64	x86_64	Platform_t:amd64
IA64	ia64	Platform_t:itanium
MIPS	mips	
PPC	powerpc	Platform_t:powerpc
PPC64	powerpc	Platform_t:powerpc
SPARC	sparc	Platform_t:sparc
SPARC64	sparc	Platform_t:sparc

DRMAAv2 Implementations ?

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- C language binding discussion in the next session
- Implementations announced
  - Fork-based reference implementation (DRMAA Working Group)
  - Univa Grid Engine (Daniel Gruber)
  - Torque / PBS Pro (Mariusz Mamonski)
  - GridWay (Eduardo Huedo)
- Collection type handling in C should be re-usable
- Interfacing the DRM system is already part of the DRMAAv1 library
  - Just add more stuff (job arrays, session persistency, reservation, monitoring)
  - Restructure according to the new header file

Thanks to the Core Team !

DRMAA
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- Roger Brobst - Cadence Design Systems, Inc.
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- Daniel Templeton - Cloudera Inc.
- ... plus ...
- Andre Merzky - SAGA Working Group
- Thijs Metsch - Platform Computing / OCCI Working Group