PluS: An Advance Reservation Plug In for Sun Grid Engine

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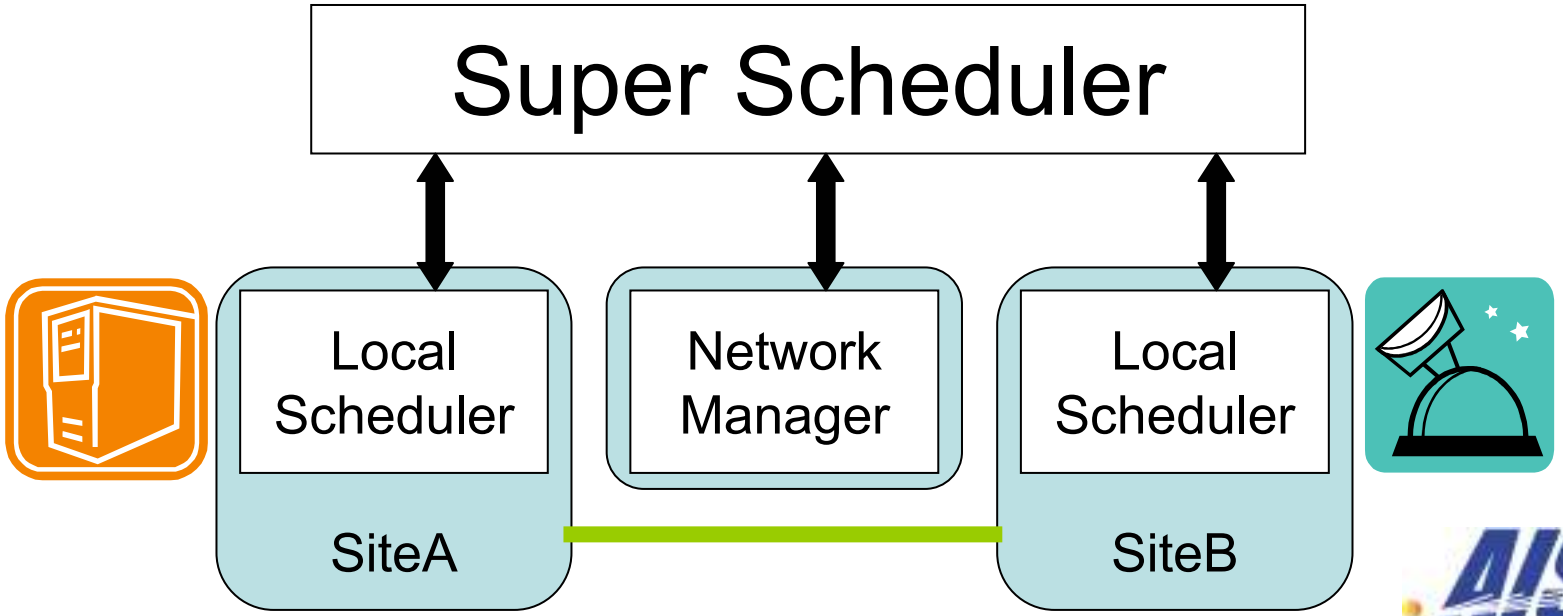
Background

- Large scale computation with Grid technology
  - Resources are spanning on several sites
  - Co-allocation of multiple resources is essential
- Resources might include
  - Network
  - Appliances, such as Telescopes, Microscopes, Storages



Background, cont.

- Advance Reservation is one of the easiest way to accomplish resource co-allocation
  - Specify a time slot and make reservations on all the resource in advance
- Note:
  - Computational resources might not be important as other resources
    - Appliances are more rare resources
    - Computers are cheap

    -> Preemption of existing jobs is required to fully utilize the more rare (important) resources

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What is PluS?

- A plug-in module to enable advance reservation
  - Preemption based
    - Reserved jobs will kick out running non-reserved jobs
  - Two implementations
    - Queue-based
    - Scheduling module replacement
- It also provides a toolkit to write your own scheduler

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Why PluS ?

- Q: SGE natively supports AR, finally, why PluS?
- A:
  - Still missing functionalities
    - Job preemption
      - Computation resources are cheaper than other resources
    - Modification with 2 phase-commit
    - Policy enforcement on reservation request
  - Two years ago, it did not. ☹

Overview of the talk

- How PluS looks Like
  - CLI
- PluS implementation
  - Scheduling module replacement
  - Queue control
- Policy enforcement in PluS
- PluS as a scheduler toolkit

CLI: Reservation Related Commands

- **plus_reserve**
  - Requests for a reservation
  - In: start/end time, # of Nodes
  - Out: Reservation ID
- **plus_cancel**
  - Cancel a reservation
  - In: Reservation ID
- **plus_status**
  - Query status of the reservation
  - In: Reservation ID
  - Out: Status of the reservation
- **plus_modify**
  - Modify the reservation
  - In: Reservation ID, start/end time, # of Nodes

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Reservation Usage Scenario

- Make a reservation

```
> plus_reserve -s 12:00 -e 14:00 -n 1
Reserve succeeded: reservation id is 14
```

- Confirm the reservation with the reservation ID

```
> plus_status
 id owner          start             end     duration state
 R14 nakada     Feb 20 12:00  Feb 20 14:00     2h00m Confirmed
```

- Submit a job with the reservation ID

```
> qsub -q R14 script
```

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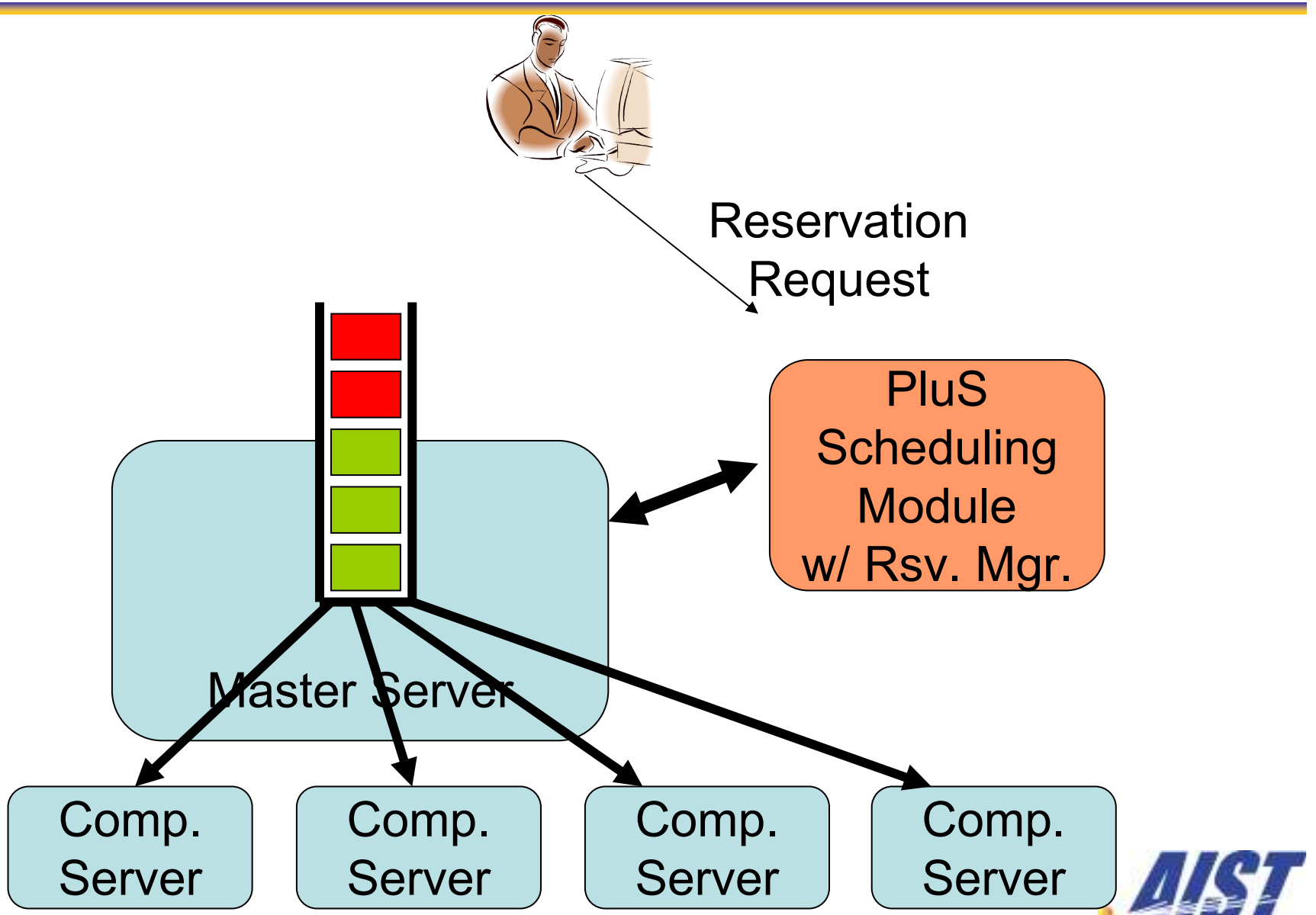
Implementation

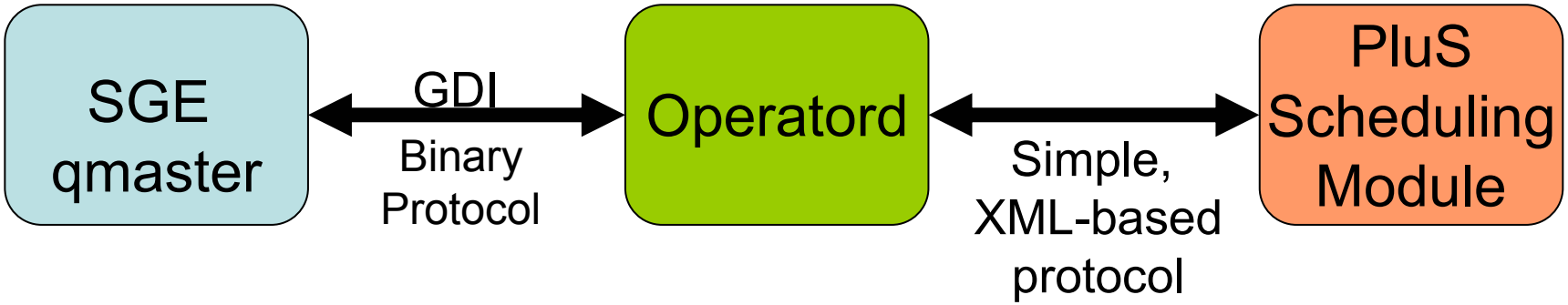
- PluS has two styles of implementation
  - Scheduling module replacement
    - Completely replaces the scheduling module of SGE
  - Queue control
    - Enables advance reservation using job queues.

Scheduling Module Replacement



PluS operatord

- **Operatord: a proxy module that translate the binary protocol into plain text protocol**
  - Sits between the scheduling module and the master module
  - Operatord is implemented in C, to leverage GDI (GridEngine Database Interface) implementation
  - Scheduring module can be implemented in any language, since the operatord can talk plain text protocol.



not working for 6.2, now ☹

Advance Reservation with Queue Control

- **What are queues?**
  - Abstract ‘submit point’ for jobs
  - Can be allocated for specific group of users
  - Can be allocated for specific set of nodes
- **Advance Reservation by Queue Control**
  - Create Advance Reservation as a queue
  - Activate the queue for specific time of period
- **Key Characteristics of the Method**
  - ○ (Relatively) Easy to implement
  - ○ No need to understand internal protocol of the target system - means easy to catch up updates.
  - × Requires multiple invocations of command to control queues - overhead

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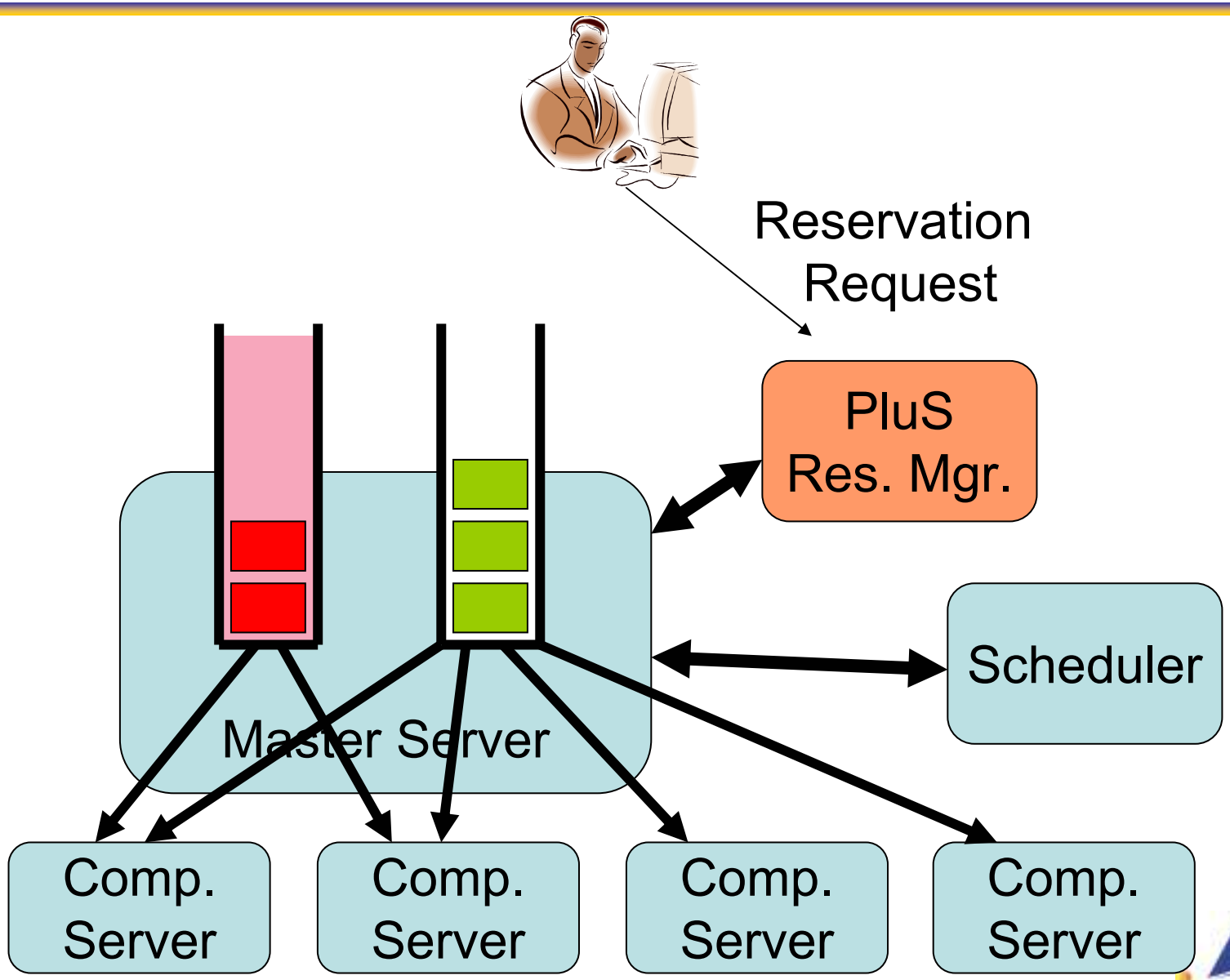
Advance Reservation by Queue Control



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Reservation Acceptance Policy

- Reservation once accepted should not be canceled or delayed by the system
  - Cancel or delay will screw up co-allocated resources
  - Acceptance is the only chance to enforce site-specific policy
- What are needed
  - User priority
  - Resource affinity

Policy Implementation

- Employ Condor ClassAd for policy description
  - Administrators define site-specific policies in ClassAds.
  - PluS provides node status and job status information as ClassAds
  - Client requests are translated into ClassAds
  - Evaluate all the ClassAds and determine whether to accept request or not.

What is ClassAd

- Developed for Condor Project by Univ. Wisconsin
  - Classified Advertisement
  - Condor uses ClassAd for ‘matchmaking’, i.e. allocation of resources for jobs
    - Jobs advertise resource requirements as ClassAds
    - Resources advertise their status as ClassAds
    - Negotiator make match with jobs and resources
- Employed by other projects
  - EGEE gLite
  - CoG kit

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ClassAd as a policy language

- Declarative, not imperative
  - Side-effect free
- Evaluation cost is linearly proportional to the length of the expression

- Primitives
  - Integer, floating, string, boolean, time, time period
  - Error, Undefined
- Structured
  - Record : Dictionary with keys and values
  - List: enumeration
  - Can be nested

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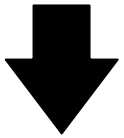
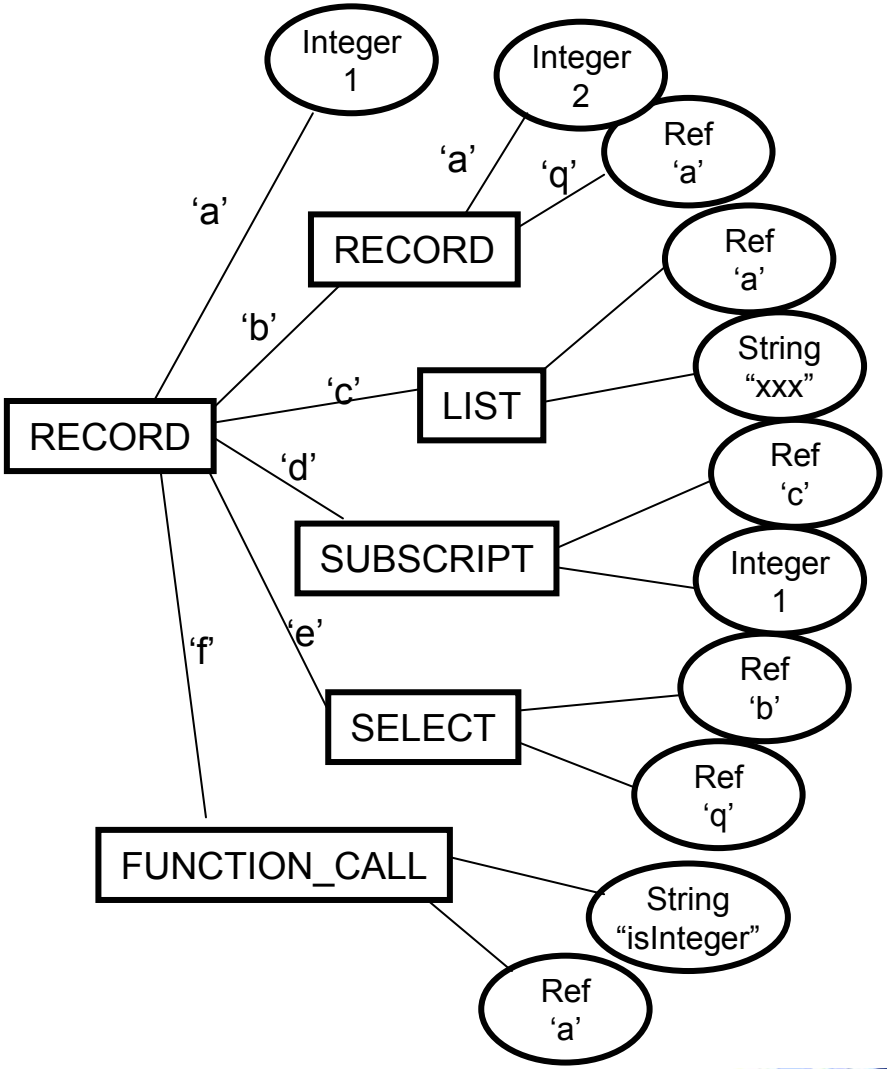
ClassAd Evaluation

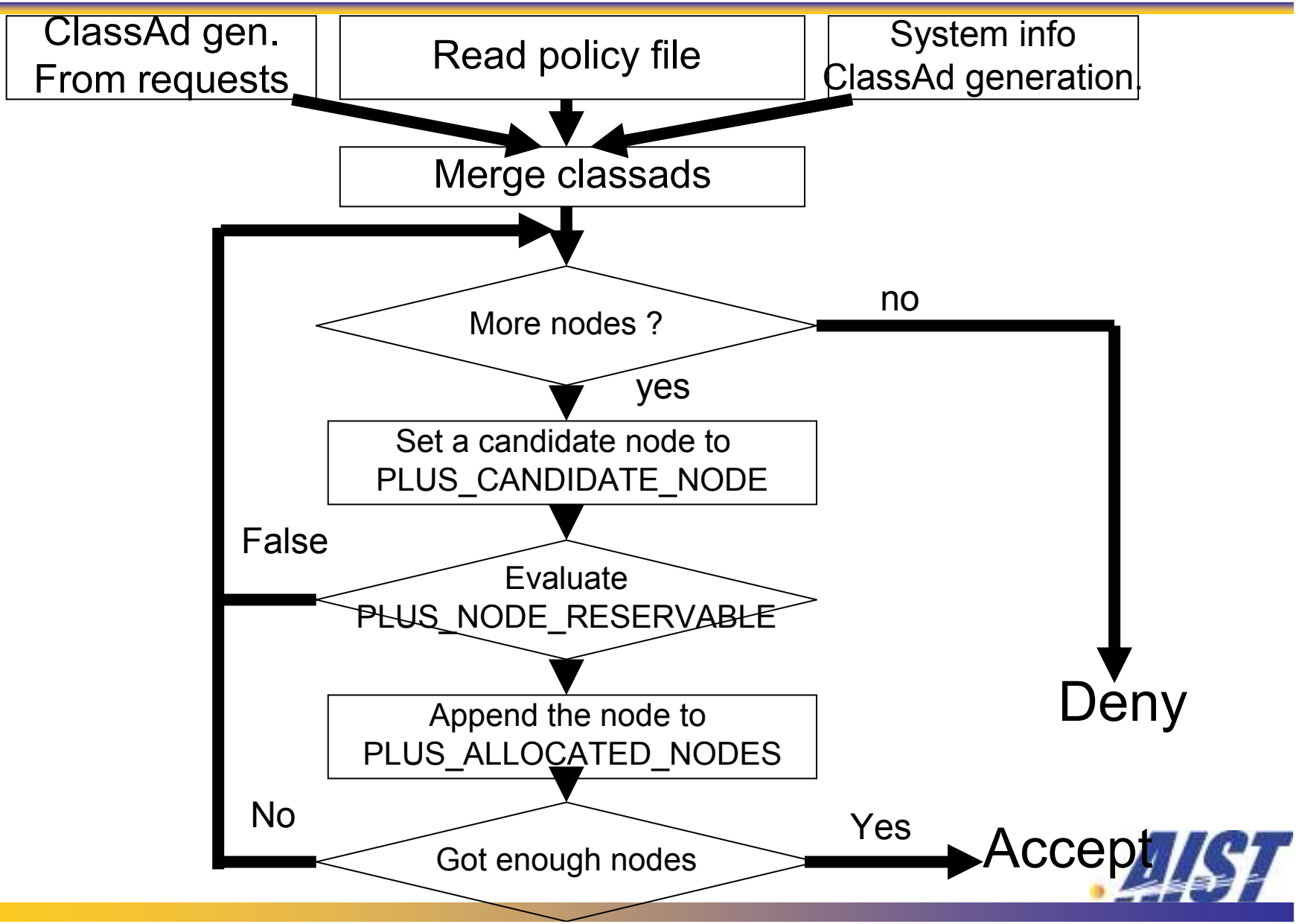
```
[
  a = 1;
  b = [a = 2; q = a;]
  c = {a, "xxx"};
  d = c[0];
  e = b.q;
  f = isInteger(a);
]
```



```
[
  a = 1;
  b = [a = 2; q = 2;]
  c = {1, "xxx"};
  d = 1;
  e = 2;
  f = true;
]
```



Policy decision flow



System provided information for policy decision

- **Request information**
  - PLUS_RSV_OWNER: string： requesting user
  - PLUS_RSV_START: time：reservation period start time
  - PLUS_RSV_END: time： reservation period end time
- **System internal status**
  - PLUS_ALL_NODES: List of node records： all the nodes
  - PLUS_CANDIDATE_NODE: node record ：policy target node
- **Node selection information**
  - PLUS_ALLOCATED_NODES: List of node records： nodes already allocated during the current reservation cycle

Node record and Job record

- **Node Record**
  - name — string : name of the node
  - isAlive — boolean : execution daemon status
  - loadavg — float : load average
  - nRunJobs — integer : number of running jobs
  - jobs — list of job records : running jobs status
- **Job Record**
  - id — string : job ID
  - owner — string : job owner
  - state — string : job status
    - Queued, Running, Exiting, Held, Suspend
  - priority — integer : priority
  - starttime — time : job start time
  - walltime — time period : walltime

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Policy Example 1

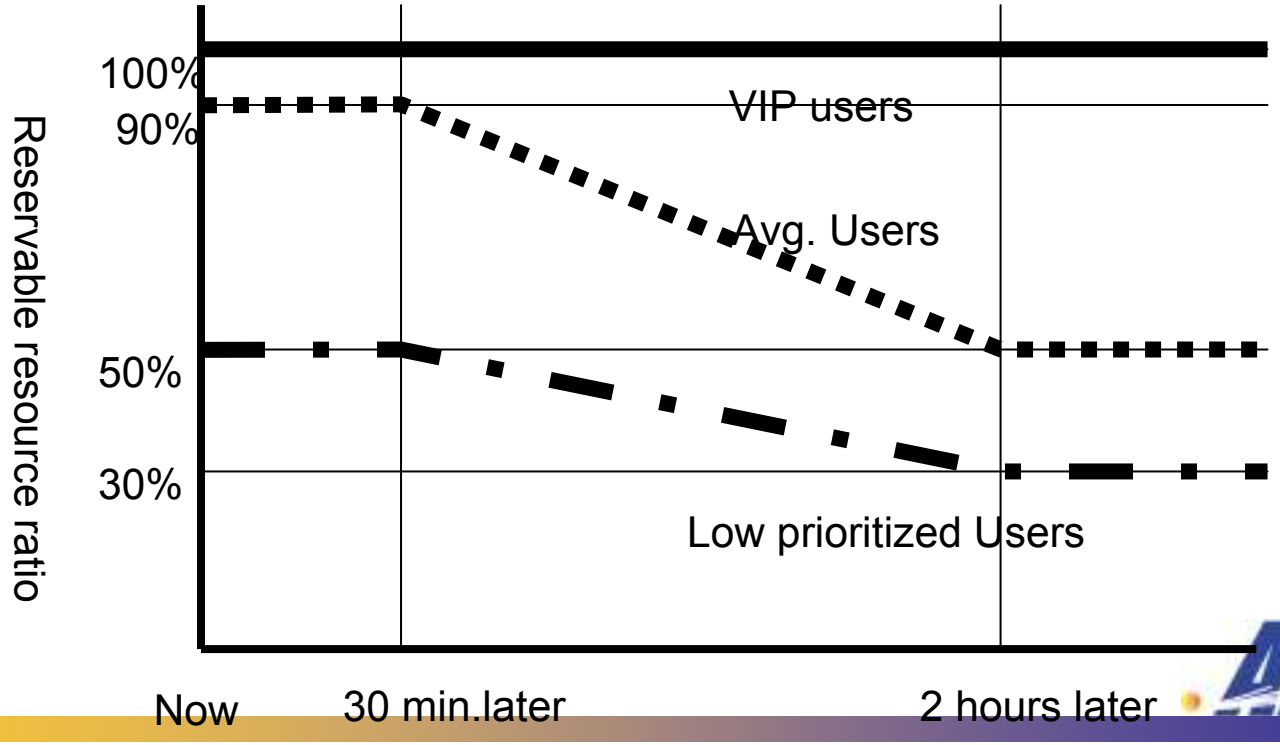
- Simple Policy
  - Provides nodes, which does not have running job, is alive, with low load average, and is not in the UnusableNode list.

```
[
  UnusableNodes = {"unusableA","unusableB" };

  PLUS_NODE_RESERVABLE =
     (PLUS_CANDIDATE_NODE.nRunJobs == 0   &&
      PLUS_CANDIDATE_NODE.isAlive         &&
      PLUS_CANDIDATE_NODE.loadavg <= 0.3 &&
      !member(PLUS_CANDIDATE_NODE.name,
              UnusableNodes));
]
```

Policy example2

- Specifies maximum ‘allocatable resource ratio’, depends on user ‘rank’
- The maxim ratio changes along with time
  - The restriction is loosened just before the time.



Policy example2

```
[ MaxPeriod = relTime("00:30:00");
  MinPeriod = relTime("02:00:00");
  LimitPeriod = relTime("7d");
  MaxReserveDuration = relTime("2d");
  VIPs = { "userA", "userB", "userC" };
  Users = { "userX" };
  VIPRatio = 100.0;
  UsersMaxRatio = 90.0;
  UsersMinRatio = 50.0;
  OthersMaxRatio = 50.0;
  OthersMinRatio = 30.0;

  MaxRatio = member(PLUS_RSV_OWNER, Users) ?  UsersMaxRatio : OthersMaxRatio;
  MinRatio = member(PLUS_RSV_OWNER, Users) ?  UsersMinRatio : OthersMinRatio;
  now = absTime(time());
  prev = PLUS_RSV_START - now;
  duration = PLUS_RSV_END - PLUS_RSV_START;
  ratioFunc = linear(prev, MaxPeriod, MaxRatio, MinPeriod, MinRatio);
  rsvRatio = (prev<=relTime("0") || LimitPeriod<=prev || duration>=MaxReserveDuration)?0:
        member(PLUS_RSV_OWNER, VIPs) ? VIPRatio :
           (prev <= MaxPeriod) ? MaxRatio :
              (prev >= MinPeriod) ? MinRatio : ratioFunc;

  nAllocate =    size(PLUS_ALLOCATED_NODES) + 1;
  nAllocatable = size(PLUS_ALL_NODES) * 0.01 * rsvRatio;
  PLUS_NODE_RESERVABLE = (nAllocate <= nAllocatable);
]
```

Policy example3

- History based policy
  - Refer previous reservations from the requesting user
  - Special built-in function ‘plus_rsv_util’
    - Returns history information

```
[ UtilCheckPeriod = relTime("7d");
  MaxReserveCount = 100;
  MaxReserveDuration = relTime("2d");
  MaxReserveHourNode = 1000.0;
  now  = absTime(time());
  util = plus_rsvutil(PLUS_RSV_OWNER,
          now - UtilCheckPeriod, now + UtilCheckPeriod);
  PLUS_NODE_RESERVABLE =((util[0] <= MaxReserveCount)     &&
                         (util[1] <= MaxReserveDuration)  &&
                         (util[2] <= MaxReserveHourNode));
]
```

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PluS as a scheduling module toolkit

- PluS provides Java API to write your own scheduling modules for Sun Grid Engine
  - Every organization has its own policies and requirements for scheduling. PluS makes it easy to implement your own scheduler
    - Provide Java API to talk with qmaster
  - C.f. TORQUE (OpenPBS)
    - There are several 3rd party schedulers include Catalina from SDSC, Maui from Cluster Resources, inc.
    - TORQUE uses simple text base protocol between the master module and scheduling module, encouraging third party implementation of the scheduling module

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PluS Scheduling Module API

```
public interface MainServer {
    void runJob(JobID jobID, NodeStatus node);
    void runJob(JobStatus job, Collection<NodeInfo> nodes);
    void deleteJob(JobID jobID);
    void suspendJob(JobID jobID);
    void resumeJob(JobID jobID);
    void holdJob(JobID jobID);
    void releaseJob(JobID jobID);
    void rerunJob(JobStatus job);
    void signalJob(JobID jobID, SignalType signal);
// status collector
    Collection<NodeStatus> getNodeStatus();
    Collection<QueueStatus> getQueueStatus();
    Collection<JobStatus> getJobStatus();
}
```

Ex. Simple FIFO Scheduler

```
Collection<NodeStatus> nodes = srv.getNodeStatus();
for (JobStatus job : srv.getJobStatus()) {
        if (job.getState() == JobStateType.Queued) {
                for (NodeStatus node : nodes) {
                        // run this job on a first found node
                        srv.runJob(job.getJobID(), node);
                        return;
                }
        }
}
```

Not working for 6.2, now ☹

- In 6.2, scheduler is embedded in the qmaster as a thread
- We'll find some workaround

Current Status

- PluS is available from

  http://www.g-lambda.net/plus

  - Works with Sun Grid Engine, TORQUE, and Condor (experimental)

Summary

- PluS provides Sun GridEngine with advance reservation capability
  - Pre-emptive
  - Policy specification with ClassAds
- PluS also works as a toolkit to implement your scheduler
  - Provides Java API to implement scheduler that works with GridEngine

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http://www.g-lambda.net/plus

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