The gLite Workload Management System

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Contents

- **Service definition**
- **Mechanisms for parallelism and workflow management**
  - MPI Jobs
  - Collections
  - Directed Acyclic Graphs (DAGs)
  - Petri Net-based workflows
- **WS Interface**

WMS Definition

- **Service responsible for the distribution and management of computational jobs on the resources made available on the Grid**
- **The goal is to provide a generic abstraction of the underlying system**
  - hide heterogeneity of the infrastructure
  - hide complexity of the infrastructure
  - prevent and recover from errors
  - support applications from largely different domains
    - flexible job description language (JDL) based on Condor ClassAds

MPI

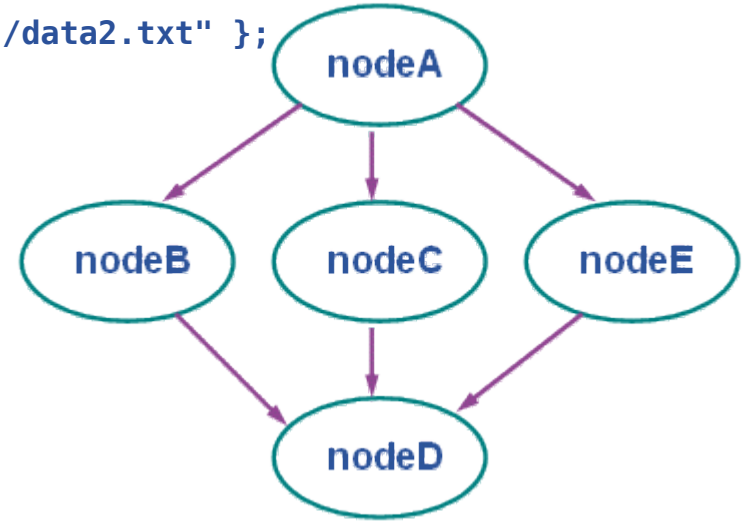
- **Intra-cluster MPI jobs**
  - normal job + specification of the *CPUNumber* attribute
  - the WMS submits the job to the CE asking to reserve the specified number of CPUs
  - the user's job has to determine the batch system type (LSF, PBS, ...) and call *mpirun* itself accordingly

```
[
  Type = "Job";
  CPUNumber = 4;
  Executable = "MPItest.sh";
  Arguments = "cpi 4";
  StdOutput = "test.out";
  StdError = "test.err";
  InputSandbox = {"exe/MPItest.sh", "exe/cpi"};
  OutputSandbox = {"test.err", "test.out", "executable.out"};
  requirements = Member("MPICH", other.GlueHostApplicationSoftwareRunTimeEnvironment)
                 && other.GlueCEInfoTotalCPUs >= 4;
]
```

DAGs

- **Group of jobs with dependencies between them**

```
[
  Type = "dag";
  InputSandbox = {"/home/data/data1.txt", "/home/data/data2.txt" };
  Nodes = [
    nodeA = [
      Description = [
        Executable = "/home/peppe/first.exe";
        InputSandbox = {root.InputSandbox[0]};
        OutputSandbox = {"/home/data/data3.txt"};
        ...
      ];
    ];
    nodeB = [
      Description = [
        Executable = "/home/peppe/second.exe";
        InputSandbox = {root.InputSandbox[1], root.nodes.nodeA.OutputSandbox[0]};
        ...
      ]
    ];
    nodeC = [ ... ];
    nodeD = [ ... ];
    nodeE = [ ... ];
  ];
  Dependencies = {{nodeA, {nodeB, nodeC, nodeE}}, {{nodeB, nodeC, nodeE}, nodeD}}
]
```



DAGs /2

- **Jobs can go to different Computing Elements (CEs) or be collocated on the same CE**
- **Job scheduling is done at run-time**
  - when a node's dependencies have completed successfully
- **The flow control relies on Condor DAGMan**

Collection

- **Group of jobs without dependencies between them**
  - possibly unrelated
  - degenerate DAG

```
[
  Type = "collection";
  Nodes = {
    [
      JobType = "normal";
      Executable = "job1.exe";
      ...
    ],
    [
      JobType = "normal";
      Executable = "job2.exe";
      ...
    ],
    ...
    [
      JobType = "normal";
      Executable = "jobn.exe";
      ...
    ]
  }
]
```

Collection /2

- **Allows *bulk submission***
  - many jobs submitted with one operation
  - reduces submission time
- **Originally implemented like a DAG**
  - source of instability, due to a potentially large number of nodes being scheduled at the same time
- **Now dedicated implementation**
  - allows *bulk matchmaking*: one match for many *equivalent* jobs
    - two jobs are equivalent if the values of their *SignificantAttributes* are literally the same

```
SignificantAttributes = {“requirements”, “rank”};
Requirements = Member("MPICH",other.GlueHostApplicationSoftwareRunTimeEnvironment);
Rank = -other.GlueCEStateEstimatedResponseTime;
```

Parametric

- **A group of almost equal jobs without dependencies**
  - the difference is in the value of some attributes

```
[
  Type = "job";
  JobType = "parametric";
  Executable = "sim.exe";
  StdInput = "input_PARAM_.txt";
  StdOutput = "output_PARAM_.txt";
  Parameters = 10;
  ParameterStart = 1;
  ParameterStep = 1;
  InputSandbox = {"file:///home/user/sim.exe", "file:///home/user/data/input_PARAM_.txt";
  OutputSandbox = {"output_PARAM_.txt"};
]

[
  Type = "job";
  JobType = "parametric";
  ...
  Parameters = {DC1, DC14, DC14bis, HRfixed};
  InputSandbox = {"gsiftp://neo.datamt.it:3344/home/cms/_PARAM_"};
]
```

- **Transformed in a collection**

Workflow Management

- **The goal is to provide a fully generic workflow management engine based on the (High-Level) Petri Net formalism**
  - turing-complete
  - can model any workflow (DAGs, loops, branches, ...)
- **Aim at interoperability between different engines/languages**
  - reference language is GWorkflowDL (with variations)

Workflow Management /2

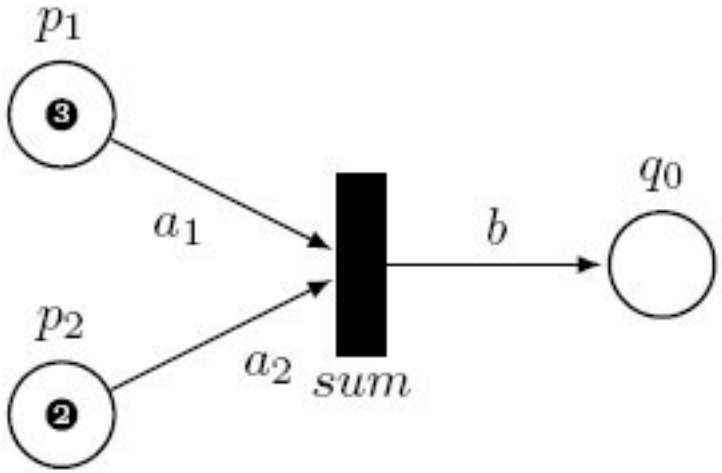
- **Developed within the CoreGrid project**
- **Independent of the underlying Grid infrastructure**
- **Work in progress but experimental prototype available**
  - implemented in C++ and python
  - tested on the EGEE infrastructure
  - translator from JDL available, e.g. for a DAG
- **More information available at**

https://twiki.cnaf.infn.it/cgi-bin/twiki/view/EgeeJra1It/WorkflowManagementSystem

WfMS: basic idea

1. Describe an operation with an abstract PN in GWorkflowDL

```
<workflow>
   <place ID="p1">
     <token><data><t1 xsd:type="xs:int">3</t1></data></token>
   </place>
   <place ID="p2">
     <token><data><t2 xsd:type="xs:int">2</t2></data></token>
   </place>
   <place ID="q0" />
   <transition ID="sum">
     <inputPlace placeID="p1" edgeExpression="a1"/>
     <inputPlace placeID="p2" edgeExpression="a2"/>
     <outputPlace placeID="q0" edgeExpression="b"/>
     <operation /> <!-- generic operation -->
   </transition>
</workflow>
```



WfMS: basic idea /2

2. Map the operation to a concrete one

- web service invocation

```
<operation>
    <wsOperation wsdl="http://localhost/plus?wsdl" operationName="plus">
        <in>n1</in>
        <in>n2</in>
        <out>q1</out>
    </wsOperation>
</operation>
```

- local operation (via python)

```
<operation>
    <pyOperation operation="b = a1 + a2" />
</operation>
```

- sub-workflow

```
<operation>
    <swOperation name="Sum" />
</operation>
```

WMS Interface

- **The current WMS interface is a Web Service**
  - the legacy *Network Server* interface is not supported anymore
- **Changes**
  - decoupling job registration from job start
  - improved performance
  - file perusal
- **Compliant with WS-I Basic Profile**
- **The complementary Logging & Bookkeeping Service also provides a WS interface**
- **For example the WfMS uses the WS interfaces of both WMS and LB**

Conclusions

- **The WMS aims at providing a reliable access point to the Grid for users running computational jobs, hiding the heterogeneity and complexity of the infrastructure**
- **The WMS supports several mechanisms for parallelism and workflow management**
  - intra-cluster MPI jobs, DAGs, collections, parametric jobs
- **A generic workflow management system is under development**
- **The WMS and the LB both provide a WS interface for an easier integration and interoperability with other Grid services**