Condor and the Grid

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Slides based on those by Koh Kwangwon
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Grid Computing – Making the Global Infrastructure a Reality
Fran Berman, Geoffrey Fox, and Tony Hey
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Chapter 11

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Introduction

- Distributed computing would be difficult
  - When messages may be lost, corrupted, or delayed, precise algorithms must be used in order to build an understandable system
- *"Can we satisfy the needs of users who need extra capacity without lowering the QoS experiences by the owners of under utilized workstations?"*
  - Condor??

The Philosophy of Flexibility

- Flexibility is the key to surviving in a hostile environment
  - Large scale, Heterogeneous
- Let communities grow naturally
  - They aim to build structures that permit but do not require cooperation
- Plan without being picky
  - An over dependence on the correct operation of any remote device is a recipe for disaster
  - Spend more time contemplating the consequences of failure than the potential benefits of success
- Leave the owner in control
- Lend and borrow
- Understand previous research

The Condor Project Today

- Research
  - Harnessing the power of opportunistic and dedicated resources (*Condor*)
  - Job management services for grid applications (*Condor-G*)
  - Fabric management services for grid resources (*Condor, GlideIn*)
  - Resource discovery, monitoring, and management (*ClassAds*)
  - Problem solving environments (*MW, DAGMan*)
  - Distributed I/O technology (*Bypass, PFS, Kangaroo, Nest*)
- Participation in Community
  - GriPhyN, iVDGL, PPDG, NSF NMI, TeraGrid
- Engineering of Complex Software
  - Mission critical software
  - Each release subject to 200+ test automatic regression suite
- Maintenance of production environments
  - 1000 CPUs at CS dept in U. Wisconsin-Madison

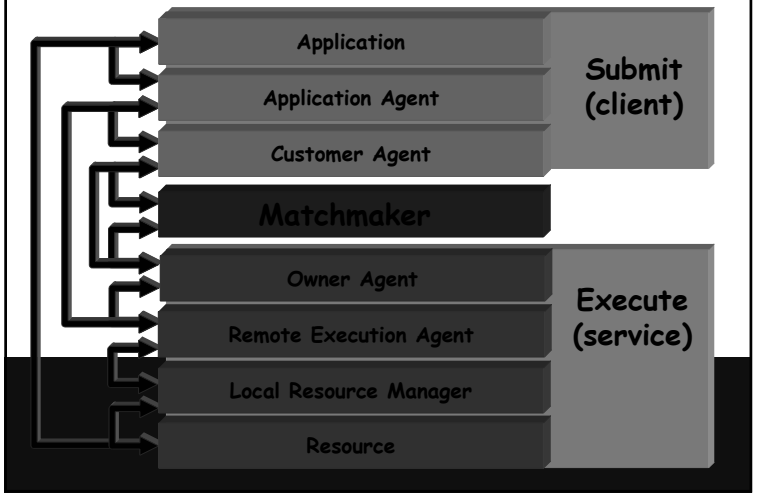
The Condor Software: Condor and Condor-G

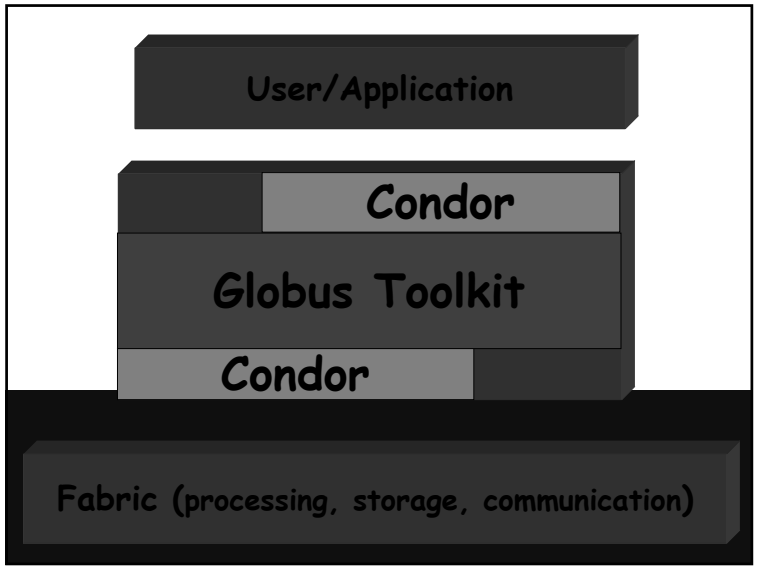
- *Condor: A System for High Throughput Computing*
  - A special job and *resources management system* (RMS) for compute-intensive jobs
    - Job queuing mechanism, scheduling policy, priority scheme, resource monitoring, and resource management
  - Condor's novel architecture and unique mechanisms allow it to perform well in environments where a traditional RMS is weak
    - *High-throughput computing:* large amounts of fault tolerant computational power over prolonged periods of time by effectively utilizing all resources available to the network
    - *Opportunistic computing:* the ability to utilize resources whenever they are available, without requiring one hundred percent availability

The Condor Software: Condor and Condor-G

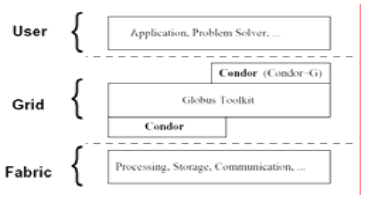
  - Some of the enabling mechanisms of Condor
    - ClassAds – to match resource requests with resource offers
    - Job Checkpoint and Migration
    - Remote System Calls
      - Part of the *mobile sandbox* environment for directing I/O to originating workstation
- *Condor-G: A Computation Management Agent for Grid Computing*
  - Represents the marriage of technologies from the Condor and Globus projects
    - From Condor: job submission, job allocation, error recovery, and creation of a friendly execution environment
    - From Globus: the use of protocols for secure inter-domain communications and standardized access to a variety of remote batch systems

The Layers of Condor



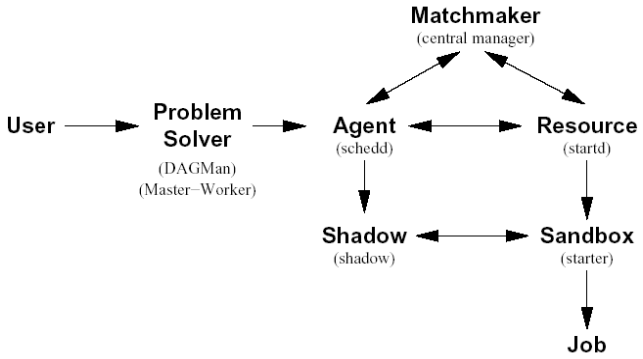


The Condor Software: Condor and Condor-G



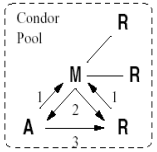
- Condor-G: the reliable submission and job management service for one or more sites
- Condor: the fabric management service (a grid "generator")
- Globus Toolkit: the bridge between Condor-G and Condor

A History of Computing Communities



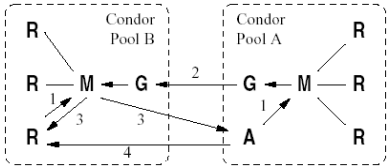
The Condor Kernel

A History of Computing Communities



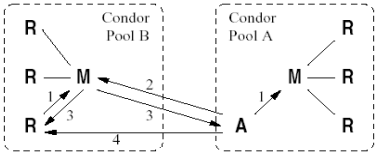
- Condor ca. 1987
  - Agents and resources independently report information about themselves to a well-known matchmaker, which then makes the same information available to the community
    - Both an agent and a resource daemon are running on the same machine
    - Agents and resources are logically distinct
    - *Did not answer need to share across organizational boundaries*

A History of Computing Communities



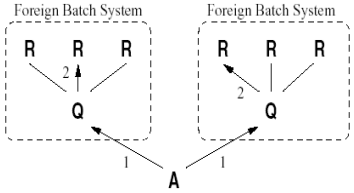
- Gateway Flocking ca. 1994
  - Gateways advertise idle resources to peers
  - Advantage: completely transparent to participants
  - Significant limitations
    - The accounting of use by individual remote users is essentially impossible because of represent through a single gateway machine
    - Only allow sharing at the organizational level

A History of Computing Communities



- Direct Flocking ca. 1998
  - To overcome the limitation that the gateway flocking only allows sharing at the organizational level
- Comparison
  - Gateway Flocking
    - Require agreement at the organizational level
    - Provides immediate and transparent benefit to all users
    - Gateway participates in every interaction in Condor kernel
  - Direct Flocking
    - Only requires agreement between one individual and another organization
    - Only benefits the user who takes the initiative

A History of Computing Communities



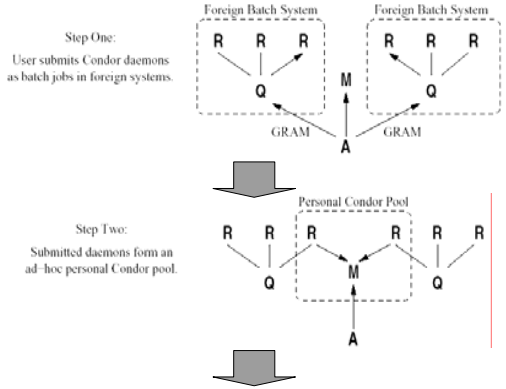
- Problem of Flocking
  - Gateway Flocking: complex
  - Direct Flocking: less powerful, but simple design
- Condor-G ca. 2000
  - To take advantage of GRAM – uniform interface to batch systems
  - Needed to add durability and two-phase commit to GRAM to prevent loss/repetition of jobs
  - If job fail, the system must analyze the failure and re-submit the job if necessary
    - Need queuing, prioritization, logging, and accounting

A History of Computing Communities

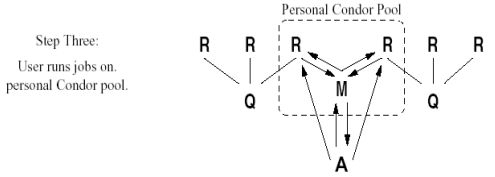
- Some disadvantage
  - Condor-G couples resource allocation and job execution
    - Jobs have to be submitted without knowledge of availability/load on resources
  - Condor-G does not support all of the varied features of each batch system underlying GRAM

A History of Computing Communities

Gliding In



A History of Computing Communities

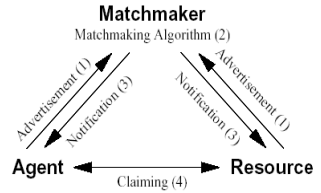


- Condor-G and Gliding In ca. 2001
  - To solve these problems
- I/O communities
  - Resources may group themselves together to express that they are "nearby" in measurable properties such as network latency or system throughput

Planning, Scheduling and Matchmaking

- Scheduling
  - Somebody must decide how to allocate resources to jobs because of more requests than available resources
- *Planning*: the acquisition of resources by users
  - Increasing personal metrics such as response time, turnaround time, and throughput of their own job within reasonable costs
- *Scheduling*: the management of a resource by its owner
  - Increasing system metrics such as efficiency, utilization, and throughput without losing the customers they intend to serve
- Feedback between *planning* and *scheduling,* is important!!
  - Matchmaker!!!!

Planning, Scheduling and Matchmaking



Job ClassAd

```
[
MyType = "Job"
TargetType = "Machine"
Requirements =
((other.Arch=="INTEL" &&
other.OpSys=="LINUX")
&& other.Disk > my.DiskUsage)
Rank = (Memory * 10000) + KFlops
Cmd = "/home/tannenba/bin/sim-exe"
Department = "CompSci"
Owner = "tannenba"
DiskUsage = 6000
]
```

Machine ClassAd

```
[
MyType = "Machine"
TargetType = "Job"
Machine = "nostos.cs.wisc.edu"
Requirements =
(LoadAvg <= 0.300000) &&
(KeyboardIdle > (15 * 60))
Rank = other.Department==self.Department
Arch = "INTEL"
OpSys = "LINUX"
Disk = 3076076
]
```

Planning, Scheduling and Matchmaking

- No specific schema
- Attributes may not be defined
- Class-Ads use 3-valued logic
  - True, false, undefined
- Special attributes
  - Requirements: indicate constraint and must evaluate to true
  - Rank: evaluates to fp number indicating rank among compatible choices

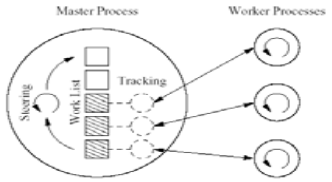
Planning, Scheduling and Matchmaking

- Matchmaking in Practice
  - More information on availability times and policies allow better planning of Condor job submissions
  - First implementation: *control expressions (1992)*
  - Second implementation : *ClassAds (1995)*
  - ClassAds is available in both Java and C++
  - Being replaced by new implementation (2000)
  - Other concepts
    - *Gang matching :* coallocation of resources
    - *Collections:* persistent storage for ClassAds with db features
    - *Set Matching:* claim large number of resources concisely
    - *Indirect reference :* to Class Ads

Problem Solvers

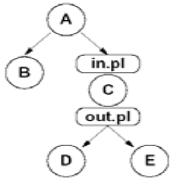
- Program Solver
  - A higher-level structure built on top of the Condor agent.
  - *master-worker, directed acyclic graph manager*
  - A program solver uses the agent as a service for reliably executing jobs
  - The program solver is presented as a normal Condor job which simply executes at the submission site

Problem Solvers



- Master-Worker (MW)
  - Work List: a record of all outstanding work the master wishes to be done
  - Tracking: accounts for remote worker processes and assigns them uncompleted work
  - Steering: directs the computation by examining results, modifying the work list, and communicating with Condor to obtain a sufficient number of worker processes

Problem Solvers



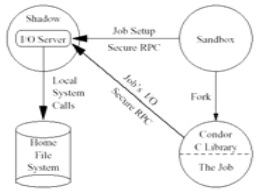

```
JOB A a.condor
JOB B b.condor
JOB C c.condor
JOB D d.condor
JOB E e.condor
PARENT A CHILD B C
PARENT C CHILD D E
SCRIPT PRE C in.pl
SCRIPT POST C out.pl
RETRY C 3
```

- Directed Acyclic Graph Manager (DAGMan)
  - A service for executing multiple jobs with dependencies in a declarative form
  - PRE and POST jobs not Condor jobs but run on submitting machine
  - A distributed, fault-tolerant version of the traditional make(?)
    - But it does not depend on the file-system
  - Read about multilevel error handling

Split Execution

- The techniques of getting a job to an appropriate execution site
- Shadow provides everything needed to specify the run-time job
  - Executable, environment, input files etc
- Sandbox responsible for creating a safe place to play
  - Asks shadow for details and creates environment

Split Execution

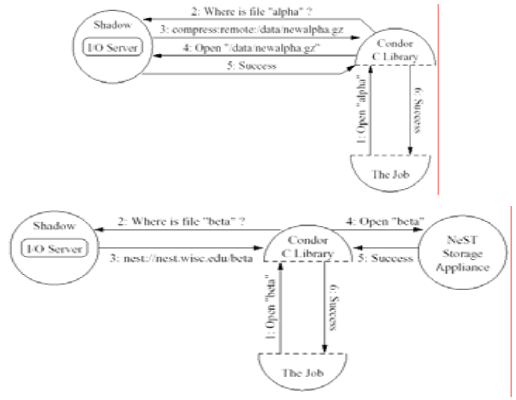


- Standard Universe – POSIX environment
  - Process creation & IPC not supported
  - provides *checkpointing*
  - *Sandbox* creates temp directory and fetches job details there
  - Job must be relinked with Condor libraries – same API as C library
    - SecureRPC, HTTP, GridFTP, Nest, and Kangaroo can be used
  - Shadow remains in control

Split Execution

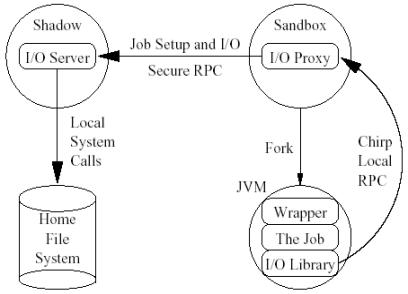
- The shadow remains in control of the entire operation
  - Neither the sandbox or the Condor library is permitted to simply open a file by name
  - Maximizes the flexibility of the user to make run-time decisions about exactly what runs where and when

Split Execution



Two-Phase Open

Split Execution

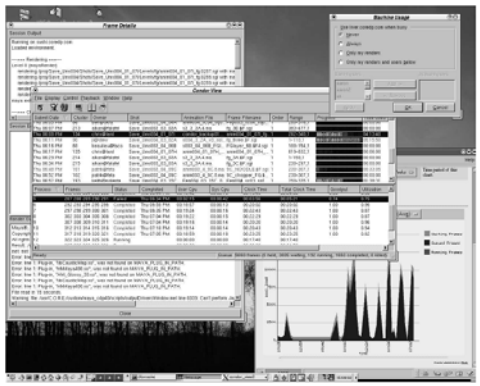


The Java Universe

- Location of JVM is provided by resource administrator
- I/O via proxy in sandbox
  - Also helps with firewall issues
- Wrapper helps to sort out environment errors (failure to find libraries etc) from ordinary exceptions

Case Study - Read

C.O.R.E. Digital Pictures Inc.



Conclusion

- They believe the key to lasting system design is to outline structure first in terms of *responsibility* rather than expected *functionality*
- *Look forward to the challenges ahead!*