Outline

- Introduction (the concept of Desktop Grids)
- Objectives of the talk
- Two visions in our research group
  - BonjourGrid
  - PastryGrid
- Other visions for the future of Desktop Grids

Introduction 1/3

- P2P systems have allowed large improvements in the field of file sharing over Internet.
- Gnutella, Kazaa and Freenet

Decentralized architecture

No coordination between machines

Introduction 2/3

- Grid computing: obtaining an infrastructure offering computing power for users applications.
  - Coordination between machines during the execution of an application.
  - Centralized or hierarchical architectures (Globus, GLite, Condor).

  - No scalability
  - Complicated procedure of installation
  - Complicated configuration phase for an ordinary user

Examples: TeraGrid, EGEE and OpenScience Grid (OSG):
Introduction 3/3

- Desktop Grid led the community to build computing systems based on voluntary machines.
- Current systems use Master/Worker model
- United Devices, BOINC, PLANETLAB, XtremWeb, Condor

- Applications domain
  - Global climate prediction (BOINC)
  - Search for extraterrestrial intelligence (SETI@Home)
  - Cosmic rays study (XtremWeb).

- Demonstrate the potential of Desktop Grid
- To suffer from being hardly scalable due to centralized control
- To rely on permanent administrative staff who guarantees the master operation
Objectives of this talk

- To offer a comprehensive survey of (some) hot topics in Desktop Grids
- To illustrate with innovative middleware
- To explain views from other researchers
- To motivate people to join our community

BonjourGrid Middleware

- To offer a collaborative, decentralized and multi-coordinators platform
- To build an infrastructure which does not depend on a central element.
- No static coordinator
- To create coordinators in a dynamic, automatic way and without system administrator intervention
- Each coordinator asks and seeks, in a decentralized way, idle machines to participate to the execution of a given application
- Pluggable computing systems

**BonjourGrid : Basic design (1/3)**

- Computing Element (CE) = 1 Coordinator + N Workers

**BonjourGrid : Basic design (2/3)**

- Control and coordinate multiple instances through Pub/Sub system
**BonjourGrid : Basic design (3/3)**

- A computing element for each user
- No static coordinator

**Advantages in using pub/sub systems**

- Only 3 primitives in the toolbox: publish, subscribe, browse
- Notions of global state and global/multicast operations
- Easy to develop applications

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**BonjourGrid’s vision**

- A user requests for a computation
- He provides tasks graph and codes implementing his distributed application
- He deploys locally a coordinator node and requests for participants
- The coordinator node selects a subset of idle nodes (CPU, RAM, Cost)
- When the coordinator node finishes application tasks it becomes free and returns to the idle status
  - Its worker nodes become idle

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**Fundamental Parts**

- BonjourGrid is composed of three fundamental parts:
  - A resources discovery protocol
    - Fully decentralized protocol
  - A “computing elements” constructor
    - Executes and handles the various tasks of an application (XtremWeb, Condor, Boinc, MPICH)
  - A global coordination protocol
    - Manages and controls all resources, services and computing elements
    - Does not depend on any specific machine or centralized element
**Discovery protocol**

- Based on Bonjour protocol
- Bonjour is an implementation by Apple of the ZeroConf protocol
- To obtain a functional IP network without DHCP or DNS servers

Bonjour is structured around three functionalities:
- Dynamic allocation of IP addresses without DHCP
- Resolution of names and IP addresses without DNS
- Services discovery without directory server

**Analysis of Pub/Sub systems**

- Questions?
  - Can a system based on publish/subscribe be scalable?
  - What is the response time to publish a service?
  - What is the discovery time of a service?

- Experiments on Bonjour protocol, on the Grid5000 platform using more than 300 nodes (Orsay site)
  - Bonjour is reliable and very powerful in resources discovery.
  - It discovers all the services (100%)
  - It succeeds to discover more than 300 services published simultaneously in less than 2 seconds

**A computing element (CE)**

- Each user uses his machine as a coordinator
- Each coordinator creates dynamically its CE
  - CE = Coordinator + set of workers
- CE functionalities
  - To allocate workers
  - To submit and run tasks on workers
  - To schedule and get results
- Computing systems
  - XtremWeb, Condor, Boinc, MPICH

- Specific CE middleware for each user

**BonjourGrid node state**

- Each machine can have one of the three states (Idle, Worker or Coordinator).
- A machine announces its state by publishing the specific service to this state
  - IdleService for Idle state
  - WorkerService for worker state
  - CoordinatorService for coordinator state.
- When a machine state changes:
  - It publishes the according service to advertise this new state,
  - after having deactivated the old one.
- Every machine can discover machines that are in a given state.
BonjourGrid’s Layers

- Deployment of a computing system
- XW, Boinc, Condor, MPICH
- Building of CEs
- Resources Discovery (RAM, CPU, Load, Cost)
- BonjourGrid Connexion
- ZeroConf Protocol (Pub/Sub)

Idle into Coordinator

1. Submission of application (CE=N)
2. Status « Coordinator »
3. Request worker participation
4. Select machines
5. Find idle machines
6. Publish the service « CoordinatorService »
7. Start the coordinator
8. Stop the service « IdleService »
9. Publish the service « CoordinatorService »
10. Start the coordinator

Experimentation

- Evaluate a system
  - based on a set of specific applications?
  - based on a specific arrival pattern (Poisson’s Law)?

- Workload model very close to the reality
  - Feitelson and Lublin
  - Inputs of the workload model
    - Number of nodes (system size)
    - Arrival time of applications
    - Maximum number of parallel tasks
    - Tasks execution times

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</tr>
</tbody>
</table>

ZeroConf Protocot (Pub/Sub)
Experimentations

- To emulate a set of users with a set of applications
- An application is submitted by a user
- To create CEs to carry out all submitted applications
- A python generator which creates a set of applications using a workload model
- An application is created for each entry in the workload with different parameters
  - Binary and data files
  - A data flow graph (in XML format)
  - Gather: fictitious task to detect the final date of the application
- Size of an application varies from 2 to N tasks
  - N may be equal to the maximum number of available machines in the network

1 CE is created dynamically for each application

Emulator
- List of machines
- List of applications
- Workload model
- Submit an application following the arrival pattern of applications in the workload
- Look for free machine on which a coordinator will start to initiate the application tasks execution
- The CE is released when application tasks finish

Tools for Distributed System Studies

To investigate Distributed System issues, we need:
1) Tools (model, simulators, emulators, experi. Platforms)

- Models: Sys, apps, Platforms, conditions
- Real systems
- “In-lab” platforms
- Synthetic conditions
- Key system mecas. Algo, app. kernels
- Virtual platforms
- Synthetic conditions
- Real systems
- Real applications
- Real conditions

2) Strong interaction between these research tools

Abstraction

- Validation

Realism

- Math
- Simulation
- Emulation
- Live systems

Grid’5000

A nation wide Experimental Grid

Franck Cappello
(with all project members)
INRIA
fci@iri.fr
Experimentations

Comparative study of BonjourGrid and XW

- Execution time = Final date – Submission date
- Same set of applications
- Same workload model
- N machines for BonjourGrid = 1 Coordinator + N-1 workers for XW

1st Setup
- 128 machines on Grid5000 (Orsay’s node).
- Creation of 100 applications with // tasks (1 à 128) (2150 tasks)
- 3 hours of execution (arrival dates are elapsed within this period)
- Management of 100 instances of CE

Results
- Execution time = Final date – Submission date
- Same set of applications
- Same workload model
- N machines for BonjourGrid = 1 Coordinator + N-1 workers for XW

2nd Setup
- 1st setup with 20 (15%) machines more for BonjourGrid.
- Relaxing the previous scenario
- Give more chance to BonjourGrid to find a free machine for the coordinator.

Results
- The difference between BonjourGrid and XW turnaround times is decreased
- 1 single peak with a diminution of 140 sec (3 applications which have requested more than 120 workers)
- BonjourGrid can provide better performance with other more relaxed scenarios.

Experimentations

Results
- BonjourGrid generates an overhead of about 60 sec for 90% applications
- Waiting time to find a free machine for a coordinator (delay the end time of an application with BonjourGrid) + CE building Time
- BonjourGrid can give, in some cases, better turnaround times than XW
  - XW-Coordinator: access to mysql DB, task assignment, workers allocation
  - Overload of the coordinator
  - Loss of workers connections (same port on the central server to maintain connections)
  - XW-Coordinator must wait for WorkRequest to submit a task (back-off effect)

Experimentations

Results
- To make more experiments over a large number of machines
- To check if BonjourGrid scale well? Can it orchestrate a great number of CEs?
- To use virtual machine to increase the experiment scale
- To use the virtual system Vgrid

- Vgrid provides a mechanism to create several virtual machines on the same host
- The different virtual machines communicate through a virtual Hub created on each physical machine (or real machine denoted by RM).
- 500 virtual machines means:
  - 10 VM * 50 RM or 5 VM * 100 RM.
Experimentations

3rd Setup
- 500 VM = 4 VM x 128 RM
- 50 applications already executed on 128 real machines (RM)
  - To observe the impact of virtual machines (VM) use.

Results
- Virtual machines lacked sufficient RAM to manage many opened sockets at the same time and to allocate necessary memory for the Java virtual machine.
- The increase in machines number from 128 RM to 500 VM did not enhance turnaround times.

Experimentations

4th Setup
- 405 applications ===> 405 CE managed by BonjourGrid
  - The parallel tasks number varies from 2 to 128
- BonjourGrid : 1000 VM (4 VM x 250 RM)
  - 300 MB per each VM
- XW: 1 coordinator + 480 workers
  - special VM with 1500 MB for the coordinator to reach 480 connexion of workers
  - 300 MB per each worker

Fault tolerance in BonjourGrid
- A CE is managed by a computing system (XtremWeb, Boinc, Condor)
  - A computing system handles fault inside a CE (faults of workers)
  - BonjourGrid must tolerate the coordinator fault
  - A replication approach of coordinator states
Fault tolerance in BonjourGrid

- Replication approach:
  - Create dynamically replicas (C2 and C3) of the principal coordinator (C1)
  - Use virtual machines (Xen) to save the state (checkpoints) of the principal coordinator
  - Send periodically checkpoints to replicas (C2 and C3)
  - Use publish/subscribe infrastructure to exchange information and detect failure
  - Redirect workers to the new coordinator (C2)

Conclusion about BonjourGrid

- BonjourGrid: A novel approach for making a collaborative and decentralized Desktop Grid systems.
- Publish/Subscribe protocol
- Orchestrate the participants
- A computing system (e.g., XW, Boinc, Condor, MPICH) for the execution level of an application
- BonjourGrid makes a distributed control over resources and does not depend on a central element.
- BonjourGrid favors collaborative execution and Meta-Grids orchestration

PastryGrid objectives

- Decentralize the execution of distributed applications with precedence between tasks
- New approach:
  - PastryGrid: a fully decentralized system based on DHT which decentralizes the execution of distributed applications.
  - Decentralize the resources management in the Desktop Grid (DG)

Distributed Application (1/4)

**Challenge**: Distributed applications with precedence between tasks:
DA is composed of several modules
A module is a set of tasks, using the same binary and, generally, different input files.
Tasks of the same module can be carried out in a parallel way.
Distributed Application (2/4)

Terminology

- **Friend Tasks**
  - T2 and T3
  - share the same successor T6

- **Shared Tasks**
  - T6
  - have a predecessors (T2, T3)

- **Isolated Tasks**
  - (T4 and T5)
  - have only one predecessor.

Distributed Application (3/4)

How a user can describe his application?

- He provides a compressed package: binary, data, data flow graph.
- Data flow graph: nodes are tasks, edges are precedence between tasks
- *Application.xml* to describe his application
- Data flow graph
- Execution requirement
- Path of binary file and data
  - NOT easy to write it by hand

Distributed Application (4/4)

**SDAD : System for Distributed Applications**

**Description**

- Help user to prepare his package
- A tool with graphical mode for simple applications and an advanced mode for complex ones
- User has just to draw the data flow graph for simple applications or follow special wizard for complex ones.
- SDAD generates the *Application.xml*, puts data and binary files in a directory tree, and compresses all these data in a zip file.
Design of PastryGrid

PastryGrid is composed of four components:

1. Addressing scheme
   - Withdraw the master/worker model → Decentralized style
   - Modern P2P networks: Pastry, CAN, CHORD
   - Based on DHT (Distributed Hash Table)
   - Nodes can join/leave the network
   - DHT is updated and mapped to new physical nodes
   - Fully decentralized routing algorithm
   - Delivery of lookup messages to the appropriate physical node in at most $O(\log(N))$ ($N =$ number of alive physical nodes)
   - Pastry: overlay network for the PastryGrid system

2. Concept of RDV
   - How to localize a node without identifier (neither IP address nor Hostname)?
   - From where can I get my data (binary + data)?
   - Where should I store my results?

   Solution
   - RDV created according to the application identifier ApplicationID
   - Communication with RDV via ApplicationID

Node: is assigned with a 128-bit nodeID to each physical node when it joins the network.
Application: is assigned with a 128-bit ApplicationID hashed using application and user name and current date on the submission machine
Unique identifier for each application
2. Concept of RDV

- Known and fixed
- Static central element
- In case of breakdown, the system collapses
- Centralised management of resources
- Management of all applications
- Simple
- Overload

RDV initialization

- RDV is the machine which \textit{nodeId} is numerically closest to \textit{ApplicationID}

3. Resources discovery protocol

- Each node M participates in the execution of a task T, is susceptible to look for free machines for the successors of M.
- No machine dedicated for research (to avoid centralisation)

\textbf{Notation:} M_i execute the task T_i

\textbf{Case 1:} M_1 finishes T_1 then looks for M_2 for T_2

\textbf{Case 2:} M_1 and M_2 look for M_3

\textbf{Optimization:} the last that finishes, looks for M_3
3. Resources discovery protocol

New discovery protocol

- Implementation: simplicity of grafting and controlling the discovery module
- Existing: a machine sends its local information (CPU, RAM, OS, Cost) to one or many servers ➔ Not real information (real time)
- Proposal solution: to access to the machine and to check directly its characteristics

M1 executes T1 and search available and suitable machines for T2 and T3

1. M1 constructs a vector \( V_a(H,W,R) \):
   - a: application ID
   - H: list of nodes handles of M1 leafset
   - W: list of tasks names (T2, T3)
   - R: execution requirement
2. M1 sends \( V_a(H,W,R) \) to \( \text{head}(H) \)
3. \( M=\text{head}(H) \) checks if it is free and fits R; if yes, M takes T=\( \text{head}(W) \) to execute it and deletes it from W (W=W-T).
4. If W=∅, then the discovery process is accomplished. Else, M updates its node handle from H (H=H-M). Goto 2
5. If H=∅, M updates it with a new leaf set: H leaf set of M. M forwards the new \( V_a(H,W,R) \) to the \( \text{head}(H) \). Goto 2

Coordination and data transfer

- Hash (Application + User + Date) ➔ Unique Identifier: \( \text{ApplicationId} \)
- Initialization of RDV ➔ machine which node is numerically closest to \( \text{ApplicationId} \)
- Lookup for free machines for T1, T2 et T3 ➔ M1, M2 and M3

Assignment of tasks T1, T2 and T3 to M1, M2 and M3

➔ \( \text{YourWork} \) message containing the task name and \( \text{ApplicationId} \).

Demand and recuperation of the data by M1, M2 and M3
➔ \( \text{DataRequest} \) and \( \text{YourData} \)
Coordination and data transfer

- M1 assigns T4 to M4 which it has just found
- M3 finishes T3 but do not search a machine for T6
- M2 searches M5 and M6 and affect them to T5 and T6

Implementation and experimentation

PastryGrid is entirely developed in JAVA
FreePastry API to create the overlay network and implement DHT functionalities
Comparison study between a central model, XW-CH, and PastryGrid
To validate and evaluate PastryGrid workload model very close to the reality
Feitelson and Lublin
Inputs of the workload model
Number of nodes (system size)
Arrival time of applications
Maximum number of parallel tasks
Tasks execution times

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<td>4</td>
</tr>
</tbody>
</table>

Grid’5000 platform using Orsay’s node
205 machines Amd Opterons, 2Go RAM, connected via 1GB/s network
“Python” based applications generator
Setup:
- PastryGrid : 205 machines
- XtremWeb : 1 coordinator + 204 workers
- 100 applications (2 to 129 // tasks), 2500 tasks
- Task turnaround time varies from 1 to 450 sec.
- 3 hours as period for arrival pattern
Experimentations

PastryGrid gives turnaround times < XW ones:
- XW-Coordinator: access to mysql DB, task assignment, workers allocation → overload of the coordinator
- Loss of workers connections (same port on the central server to maintain connections)
- XW-Coordinator must wait for WorkerRequest to submit a task → submission tasks may delay

Fault tolerance in PastryGrid

RDV fault tolerance
Active replication of RDV
Maintain a fixed replication coefficient
Last state (checkpoint) saved on replication machines
Migration on a new RDV copy, numerically closest to the old one in case of fault

PastryGrid vs Vigne

Vigne (Christine Morin, INRIA, Rennes (2007))
App. manager is also created according to the application ID
App. Manager makes "ALL", controls the tasks, looks for resources, sends data...
App. Manager supervises participants nodes.
PastryGrid
RDV: primordial function: a simple storage point of results and data
RDV does not make research
A direct data exchange may take place between the nodes without crossing by the RDV
A different research strategy: collaborative research.
Participants, permanently, share information between themselves via the RDV.

Conclusion about PastryGrid

PastryGrid
- Executes distributed applications with precedence between tasks in a decentralized way
- Collaborative resources and tasks management between participating nodes.
- No overhead caused by decentralization
Views from other researchers

Jon Weissman, University of Minnesota, USA, (PCGrid’2009 talk in Rome)

Promote proxy network comprised of volunteer nodes and how proxies accelerate applications spanning one or more clouds.

Describe how several classes of cloud applications might be better suited to an on-demand cloud comprised of distributed volunteer resources.

Views from other researchers

David Anderson, University of Houston, USA, Keynote Talk at GPC’2009 (Geneva): Exa-Scale Volunteer Computing

Also available on http://www.researchchannel.org/prog/displayevent.aspx?fD=569&rID=27420

Mentioned (rank=2) the problem of result certification

Certification is not the process that floting points operations are 'good' but refers to certify that the result is correct and not falsified.

Views from other researchers

Techniques for result certification

Redundancy + votes (consensus in distributed systems is hard)

Probabilistic certification (massive attacks):

http://moais.imag.fr/membres/jean-louis.roch/perso_html/publications.html

Without any specific secure system is the architecture: see http://www.loria.fr/~ejeannot/aleae-doc/Canon-Collusion.pdf

Use TPM?

Proxies may serve as:

Cloud service interaction:

Computing: A proxy may carry out computations on data via a set of data operators.

Caching:
Some others perspectives in our group

Short term

- Production versions of BonjourGrid and PastryGrid
- Rich user interface that helps users of BonjourGrid and PastryGrid to deploy their applications
- Extended evaluation of BonjourGrid and PastryGrid
  - Real applications deployment
  - Collaboration of other research teams (physics, numeric simulation, bio-informatics…)

Mean and long term

- Fault tolerance
  - PastryGrid: checkpoints to not re-execute long tasks
  - BonjourGrid: optimization of data exchange between virtual machines
- Dynamic infrastructure of services using BonjourGrid
  - Create services on demand (storage, computing, …)
- Reservation rules to share, optimally, resources between users (BonjourGrid)
- Resource authentication in BonjourGrid and PastryGrid
- Interaction between computing elements in BonjourGrid
  - Negotiations to exchange workers between coordinators (XW, Condor, Boinc)