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How to decentralize Desktop Grid middlewares, lessons learned and future works

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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 Destop Grids

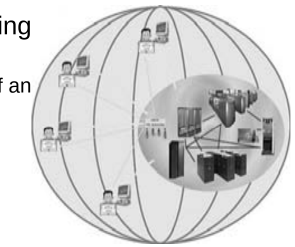
Introduction 1/3

- 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

Condor High Throughput Computing

SETI@HOME

BOINC

PLANETLAB

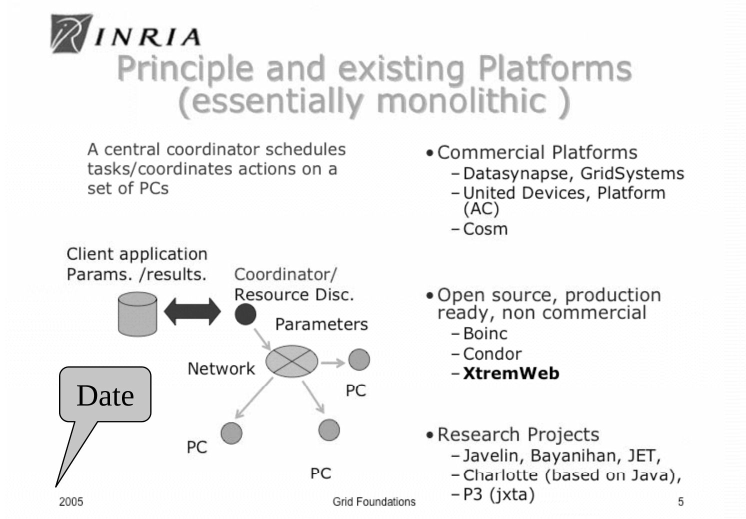
XtremWeb-CH

- 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

The history of Desktop Grids by Franck Cappello



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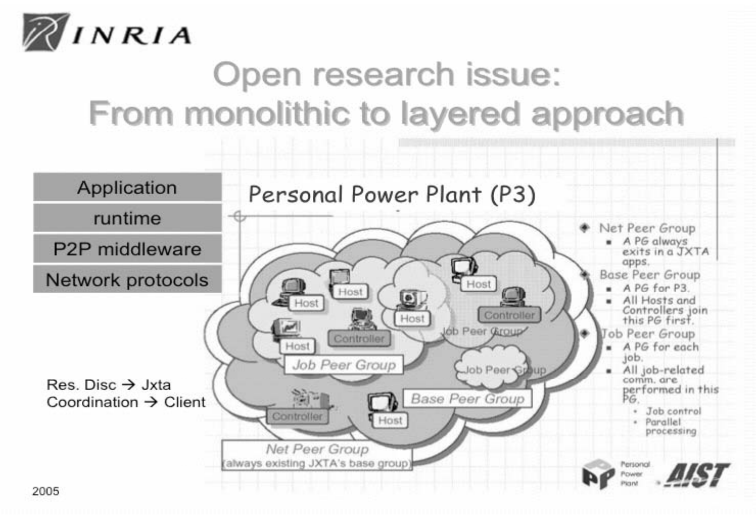

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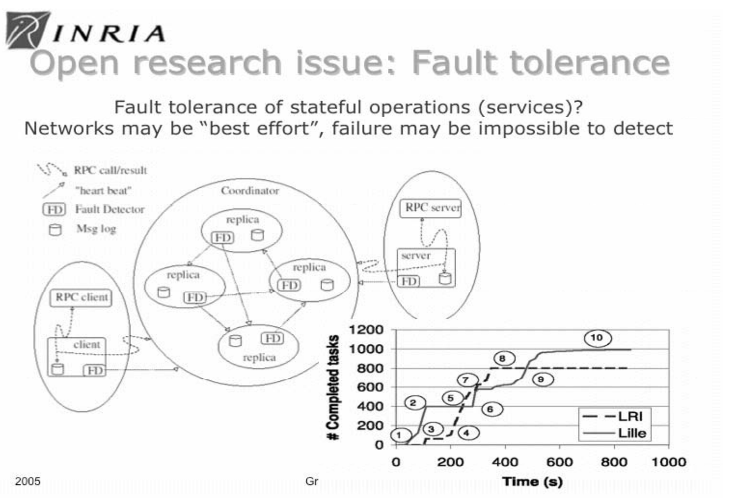


Objectives of this talk

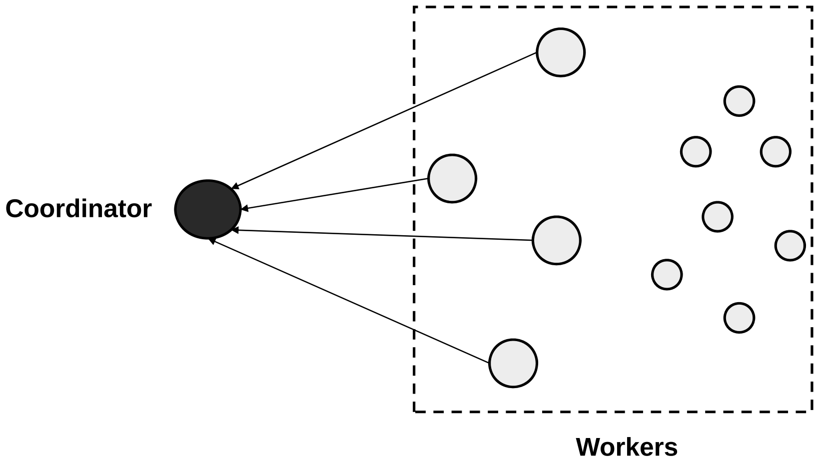
- To offer a comprehensive survey of (some) hot topics in Desktop Grids
- To illustrate with innovative middleware
- To explain views from other researchers
- To motivate people to join our community

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

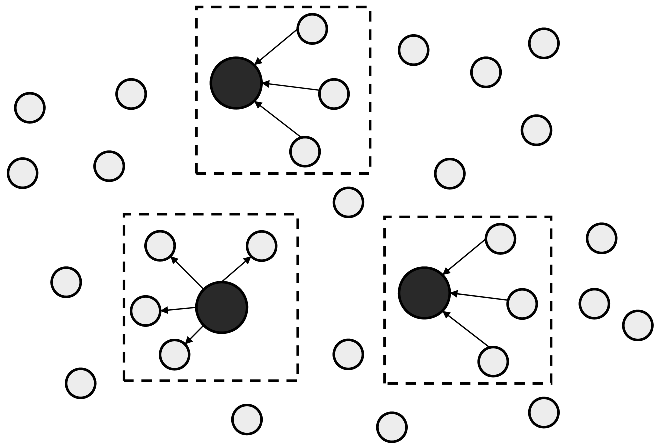
Collaborative Grid | Meta-Grid

BonjourGrid : Basic design (1/3)



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

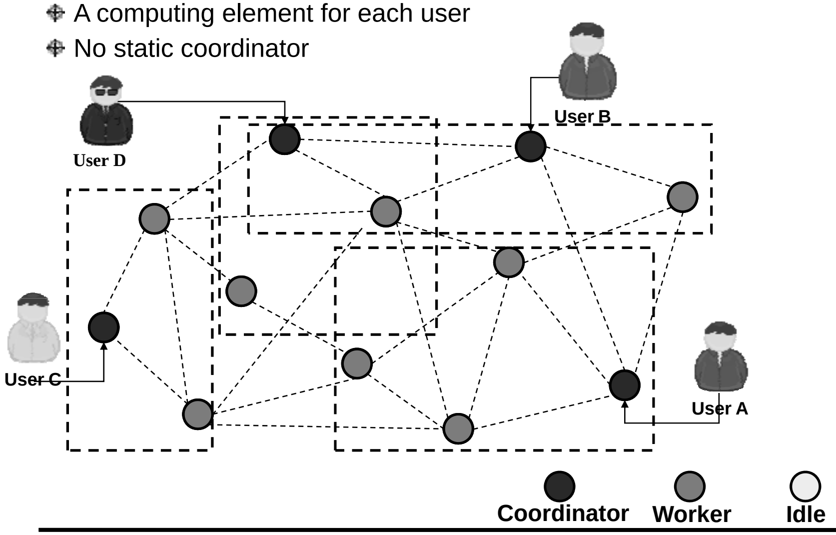
BonjourGrid : Basic design (2/3)



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

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

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)

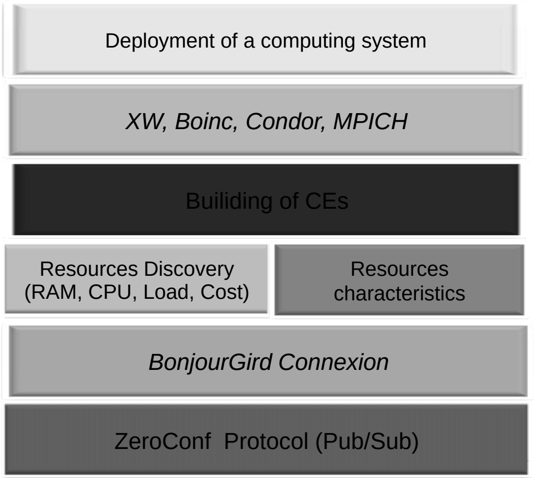
- Each user uses his machine as a coordinator
- Each coordinator creates dynamically its CE
  - ❑CE = Coordinator + set of workers
- CE functionalities
  - ❑To allocate workers
  - ❑To submit and run tasks on workers
  - ❑To schedule and get results
- Computing systems
  - *XtremWeb, Condor, Boinc, MPICH*

➡ Specific CE middleware for each user

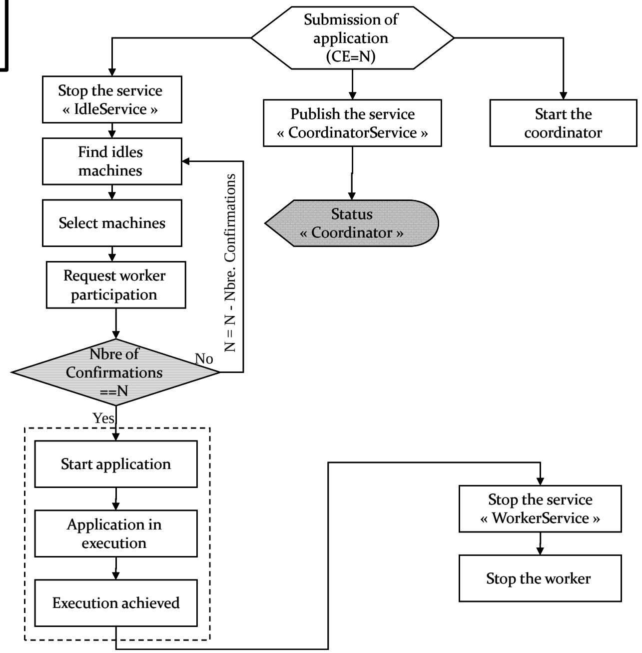
BonjourGrid node state

- Each machine can have one of the three states (Idle, Worker or Coordinator).
- A machine announces its state by publishing the <u>specific service</u> 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.

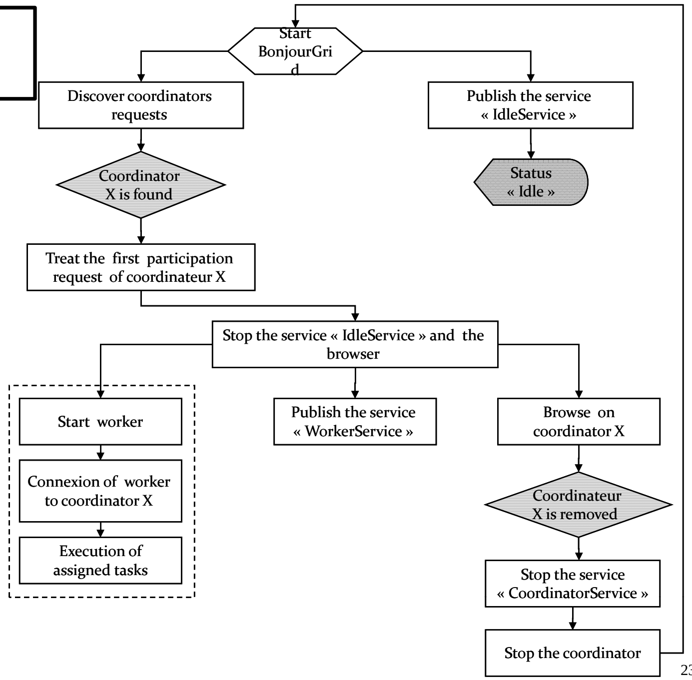
BonjourGrid's Layers



Idle into Coordinator



Idle into worker



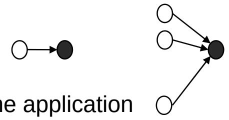
Experimentation

- 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

Application ID	Arrival Time	Execution Time	Nbre of parallel tasks
1	19	4	32
2	39	11	13
3	69	13	16
4	98	87	1
5	200	100	4

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



Experimentations

- 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

Experimentations

Grid'5000 *

A very brief overview

A nation wide Experimental Grid

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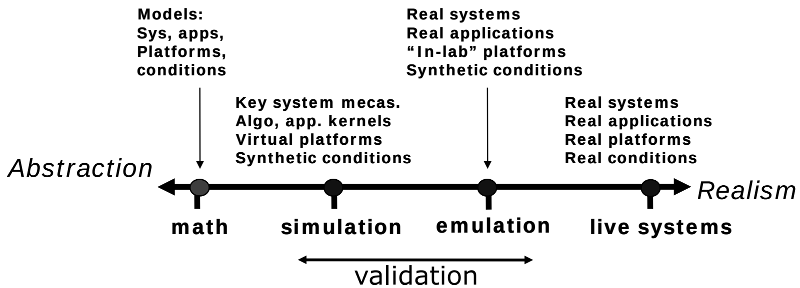
INRIA Renater

Experimentations

Tools for Distributed System Studies

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



2) Strong interaction between these research tools

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

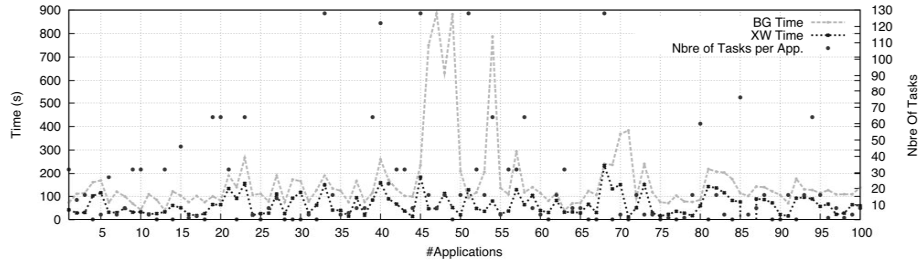
1st Setup

- ❑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

Experimentations

Results

- BonjourGrid generates an overhead of about 60 sec for 90 % applications
- Waiting time to find a free machine for a coordiantor (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) ➡ submission tasks may delay



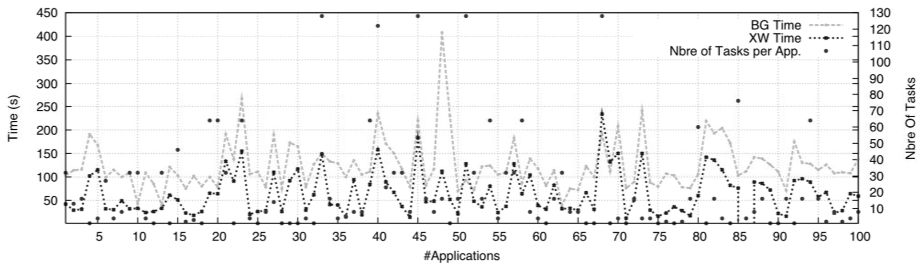
Experimentations

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

- 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 5VM*100 RM.

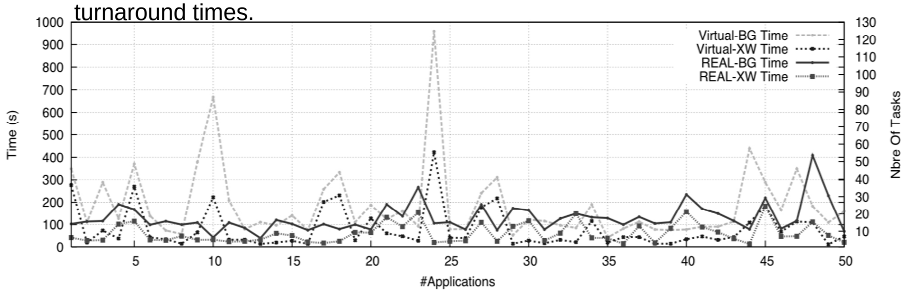
Experimentations

3rd Setup

- 500 VM = 4 VM x 125 RM
- 50 applications already executed on128 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 from128 RM to 500 VM did not enhance turnaround times.



Experimentations

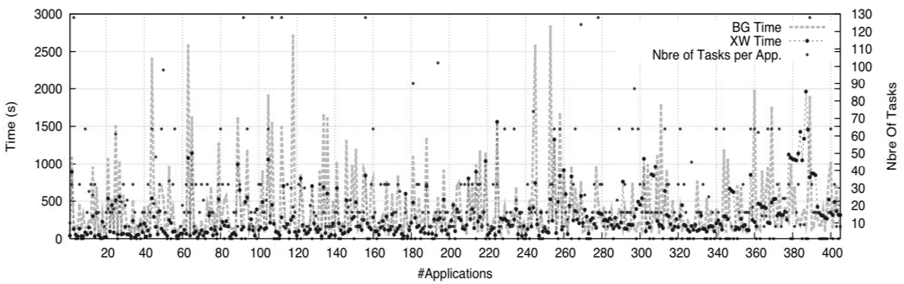
4th Setup

- 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 connexions of workers
  - ❑ 300 MB per each worker

Experimentations

Results

- Bonjour can manage more than 400 CEs
- BonjourGrid performs better around the application 380
  - ❑ The overload of XW-Coordinator
  - ❑ The lose of workers connexions
  - ❑ Back-off effect



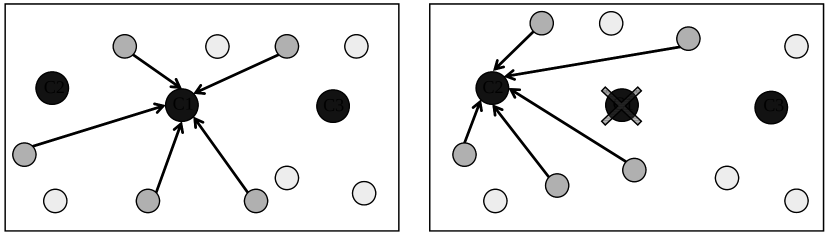
Fault tolerance in BonjourGrid

- 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

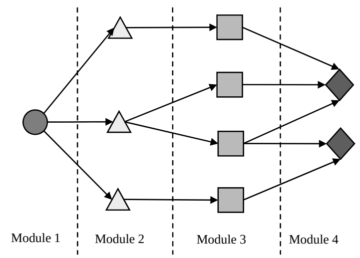
PastryGrid objectives

- 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)

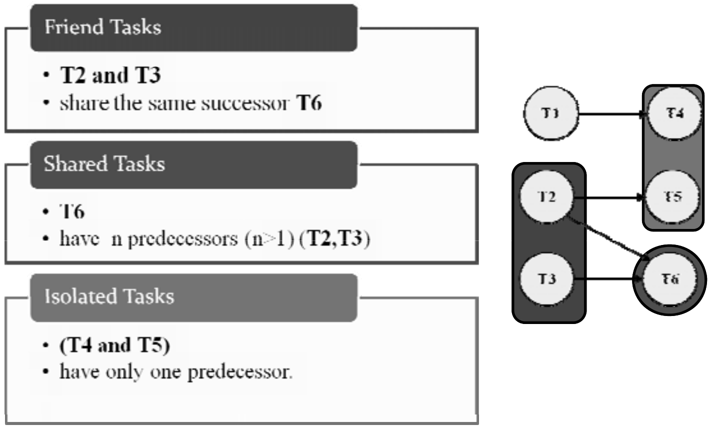
Chalenge : Distributed applications with precedence between tasks:

- 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



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.

SDAD

Design of PastryGrid

- PastryGrid is composed of four components:
  - Addressing scheme to identify machines and applications
  - RDV concept
  - Protocol of resources discovery
  - Coordination approach between machines carrying out a given application

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.

1. Addressing scheme

- 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

- How to localize a node without identifier (neither IP address neither 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→

2. Concept of RDV

Coord.

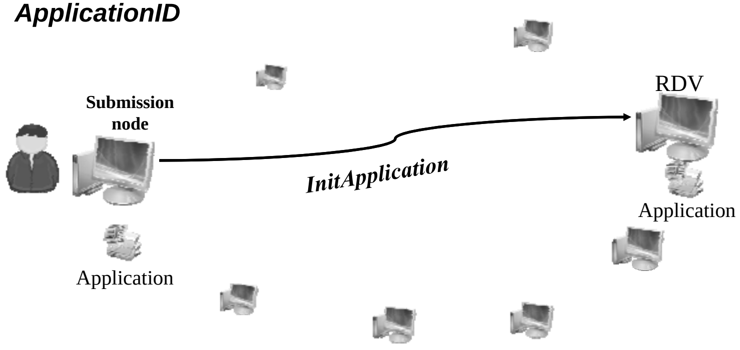
- Known and fixed
- Static central element
- In case of breakdown, the system collapses
- Centralised management of resources
- Management of all applications
- Simple
- Overload

RDV

- Unknown
- Variable
- In case of breakdown the system remain functional
- Decentralised resources management
- RDV for each application
  - no overload

RDV initialization

- RDV is the machine which ***nodeId*** is numerically closest to ***ApplicationID***



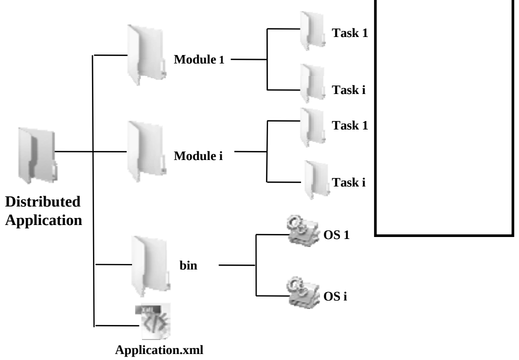
RDV initialization

Application

- Extracts the zip file to rebuild the initial tree structure of the application
- Generates ***Task.xml*** file for each task (Application.xml)

Info in ***Task.xml*** of **Ti:**

- Task name Ti
- successors of Ti (Succ(Ti))
- Requirements of Succ(Ti)
- Friends of Ti

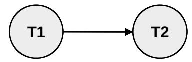


3. Resources discovery protocol

- 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)

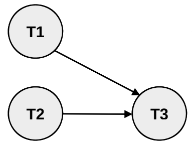
Notation: Mi execute the task Ti

<u>Case 1:</u>



M1 finishes **T1** then looks for **M2** for **T2**

<u>Case 2:</u>



Avoid the research redundancy
Only one machine, among M1 and M2, looks for M3
Optimization: the last that finishes, looks for M3

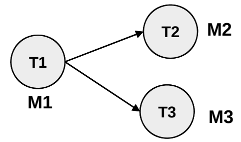
3. Resources discovery protocol

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

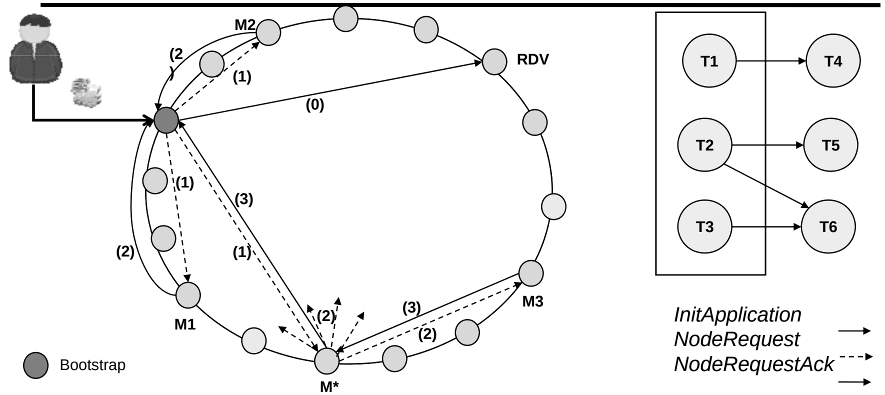
3. Resources discovery protocol

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



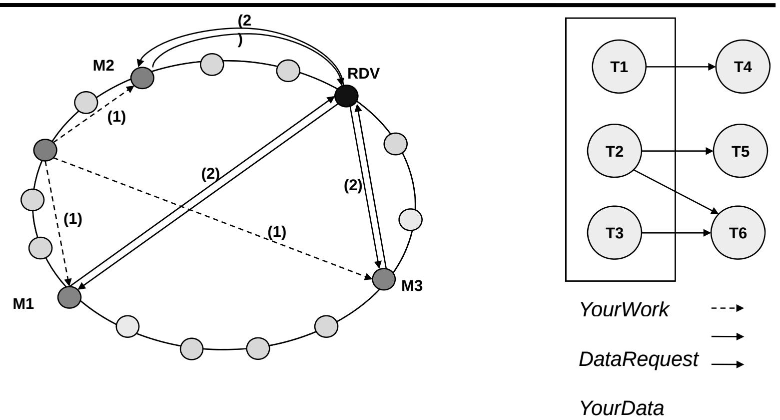
1. **M1** constructs a vector **Va (H,W,R)** :
   - **a** : application ID
   - **H** : list of nodes handles of **M1** leafset
   - **W** : list of tasks names (**T2**, **T3**)
   - **R** : execution requirement
2. **M1** sends **Va(H,W,R)** to **head(H)**
3. **M=head(H)** checks if it is free and fits **R**: if yes, **M** takes **T**=**head(W)** to execute it and deletes it from **W** (**W=W-T**).
4. If **W=∅**, then the discovery process is accomplished. Else, **M** deletes 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 **Va(H,W,R)** to the **head(H)**. Goto 2

Coordination and data transfer



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

Coordination and data transfer



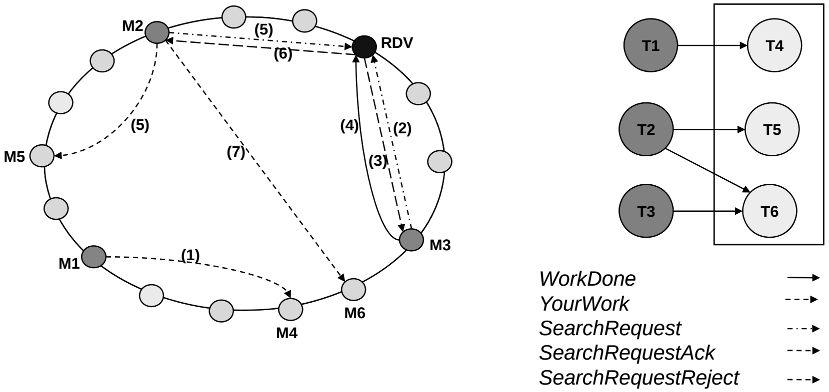
Assignment of tasks ***T1***, ***T2 and T3*** to ***M1***, ***M2*** and ***M3***

➔ ***YourWork*** message containing the task name and ***ApplicationId .***

Demand and recuperation of the data by ***M1***, ***M2*** and ***M3***

➔ ***DataRequest*** and ***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

Application ID	Arrival Time (s)	Execution Time (s)	Nbre of parallel tasks
1	19	4	32
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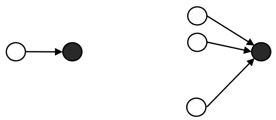
Implementation and experimentation

- Extension of the basic model by adding a fictitious "gather" task



- "gather" receive all results of the previous tasks.
- An application with k tasks means that k-1 friend tasks and the k^{th} is the gather one
- Stressful scenario (Big number of friend tasks)

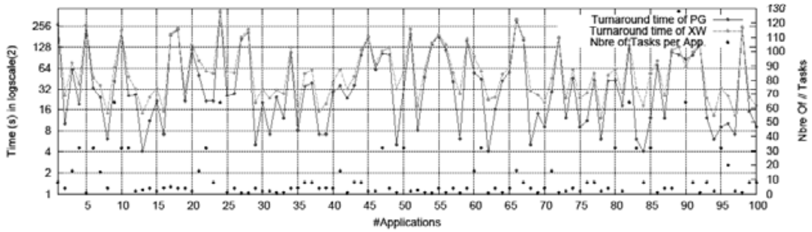
Experimentations

- 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

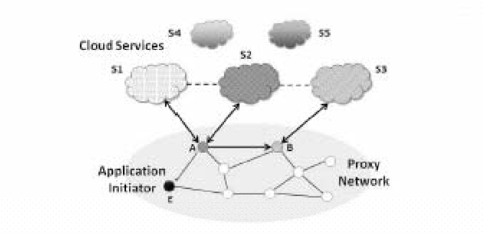


Figure 1: System Model: S_i are the cloud services, nodes A and B are proxies, and E is an initiator for an application that uses clouds S_1, S_2 and S_3. Solid arcs represent actual proxy-to-proxy and proxy-cloud interactions, and dotted lines represent logical cloud-to-cloud interactions.

Proxies may serve as:

Cloud service interaction:

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

Caching:

See : http://www-users.cs.umn.edu/~jon/

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?fID=569&rID=27420
- Mentioned (rank=2) the problem of result certification
- Certification is not the process that flotting 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?

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…)

Some others perspectives in our group

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)