Disconnected Operation Service in Mobile Grid Computing

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Contents

Introduction to Grid

- **What is Grid?**
  - Large scale distributed computing on Internet
  - Designed for effectively solving complicated problems
  - Various kinds of resources are autonomously managed at distributed sites
- **Effects of Grid**
  - To increase job throughput (performance)
  - To increase utilization rate of resources
  - Enabling cooperative work
- **Grid Software**
  - Grid middleware (Ex: Globus Toolkit, Unicore)
  - Standardization efforts (OGSA)
  - Application toolkits (AppLes, Nimrod-G, Ninf-G, etc)
  - Parallel computing (MPICH-G)

Wireless Mobile Environment

- **Characteristics**
  - Users can freely move with heterogeneous mobile devices
  - Wireless communication is mainly used to access information, not to compute the information
- **Main Constraints**
  - Scarce host resources : computational capability, small amount of memory, limited battery life
  - Scarce network resources : narrow bandwidth, increased latency, small coverage
  - Weak security over wireless communication
  - Intermittent connectivity and frequent node failures
  - Heterogeneous systems (Hardware, O/S, Applications)

Two Possible Scenarios in Mobile Grid

- **Mobile Interface to Grid**
- **Mobile Resources for Grid**

Mobile device as grid interface

- Job submission, monitoring, result acquisition through mobile devices
- Grid users can manage their jobs anytime, anywhere, conveniently
- Grid promises the performance and reliability

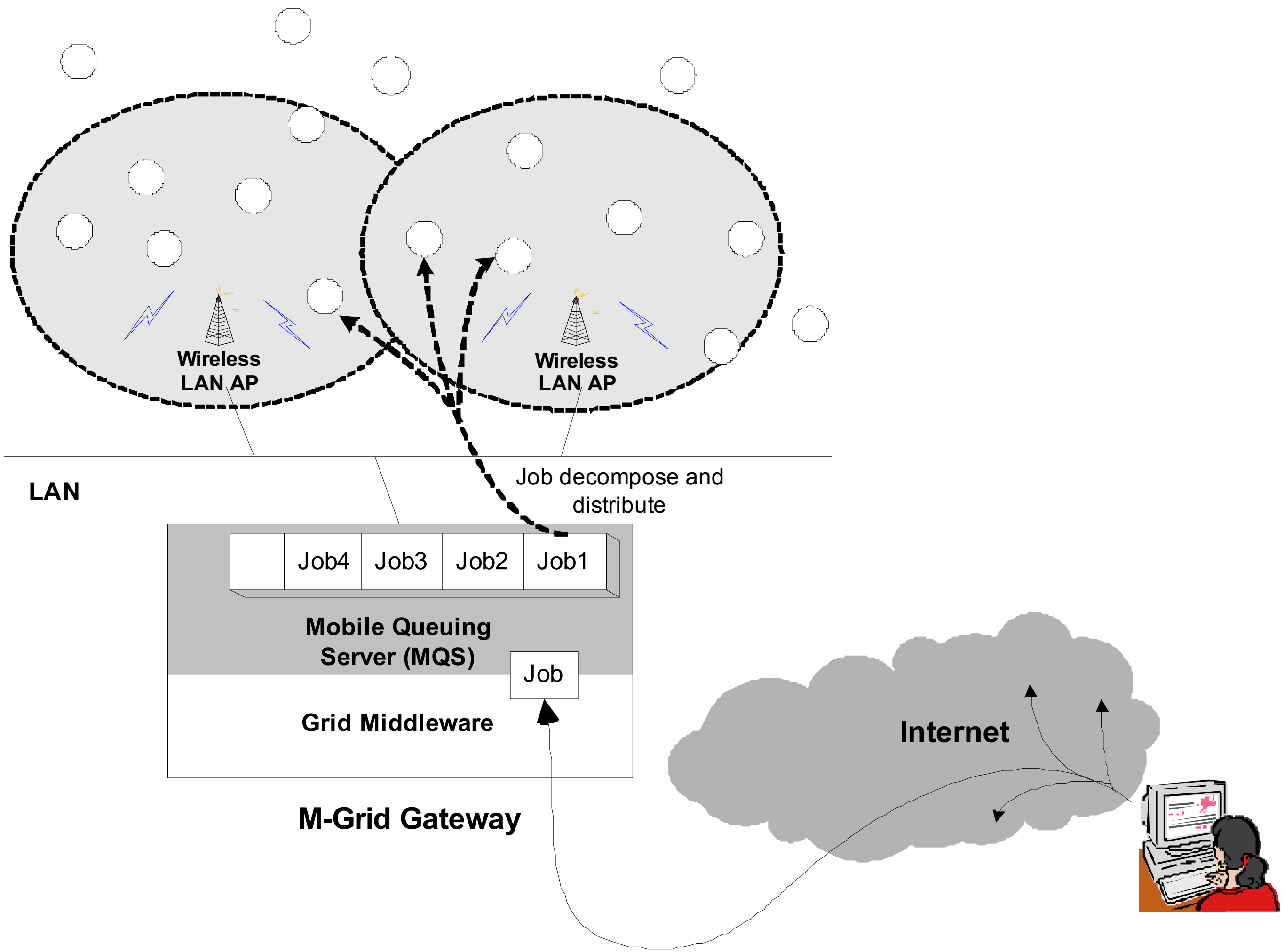
Issues

- **Adapting to various interfaces of mobile devices**
  - Laptops operated by Microsoft windows
  - PDAs having very small display and no keyboards
  - But, we need to sustain same functionalities
- **Reliable job management**
  - Mobile devices are exposed to frequent failures
  - The resources are scarce
  - How can we manage the job reliably?
- **Agent-based Job Management**
  - An Agent on a static system performs job management on behalf of the mobile user
  - Job initiation, interaction, monitoring, and completion process could be performed by this Agent
  - The process of this Agent would be dependent on the condition of mobile user

Mobile Device as Grid Resource

- **Scenarios**
  - Mobile devices serve their computing capability, memory space, network resource for the grid jobs
  - A group of mobile devices may form an actual grid site
  - A grid job submitted from static grid site run on the mobile devices
- **Why we should consider these thin devices as grid resources?**
  - A performances of mobile devices are increasing, significantly
    - Laptop has similar computing performance, memory size, storage amount
    - A PDA can have a 400Mhz CPU, 128 MB memory, wireless Internet capability
  - Wireless networking technologies are rapidly developing
  - The number of mobile users grow fast
  - A boundary of grid resource will be broadening

Proposed Architecture



Issues

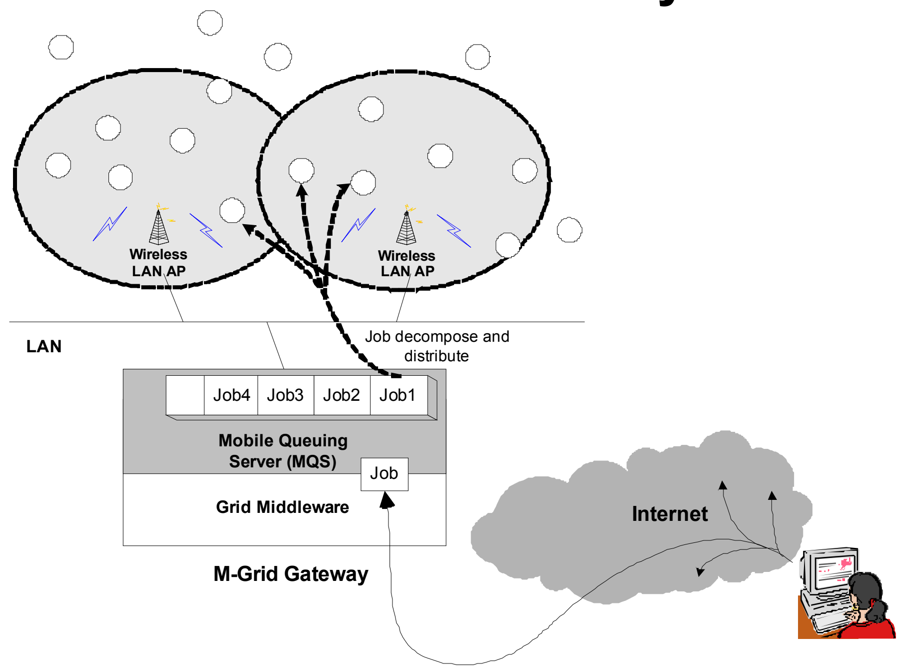
- **Fault tolerance**
  - Frequent disconnections, exhausted battery…
  - Even though a single mobile device is prone to failures, a collection of resources should be reliable and powerful
- **Dealing with Platform Heterogeneity**
  - A large portion of grid applications is based on the Unix-like OS
  - Microsoft Windows, Pocket PC, Palm OS are dominating mobile OS
- **Job Decomposition**
  - The normal grid job is too heavy to be executed on a single mobile device
- **Job Scheduling**
  - How can we distribute jobs to mobile resources? What principle should be applied for?

Job Scheduling Algorithm in Mobile Grid

- **Why we should deal with this scheduling problem?**
  - Scheduling algorithms in static grid: FCFS (based on Machine Speed)
  - Disconnections and failures are common in wireless networks
  - The number of mobile nodes participating in computing is NOT necessarily proportional to the performance of Grid.
- **Our proposed job scheduling algorithm**
  - To consider disconnection and reconnection rates of mobile resources, in addition to the job execution speed
  - To figure out the number of mobile nodes which are expected to produce the best performance

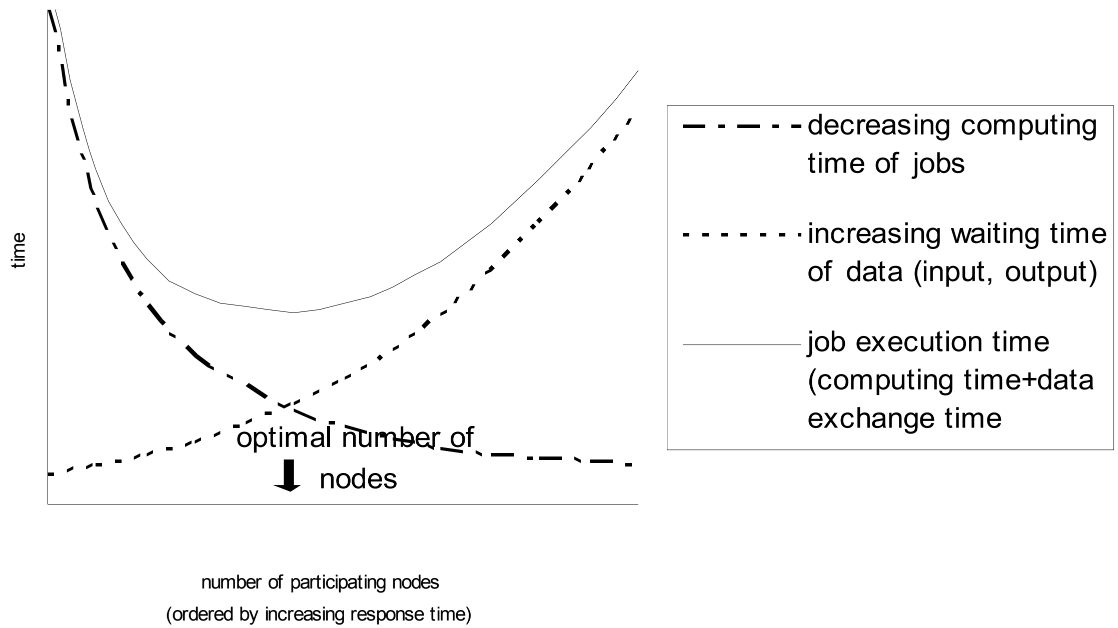
Job Scheduling Algorithm in Mobile Grid

- **Job Execution Process in Mobile Grid System**



Job Scheduling Algorithm in Mobile Grid

- **Three steps to construct the algorithm**
  - Calculate the expected time to transfer input and output data
  - Determine the job completion time of every mobile node (Job execution time + input and output transfer time)
  - Find out the optimal number of mobile nodes for the best job performance



Job Scheduling Algorithm in Mobile Grid

- **First step: Calculate the expected input and output data transfer time (to and from the mobile node)**

$$f(t) = P_c \cdot f_c(t) + P_d \cdot f_d(t)$$

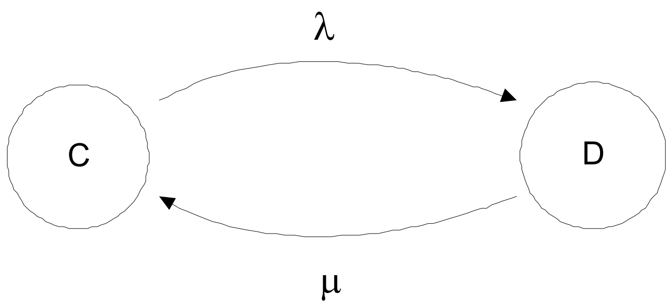
$f_c(t)$: Time required to transfer '*t*' time unit of data when the node is initially **in connection state**

$f_d(t)$: Time required to transfer '*t*' time unit of data when the node is initially **in disconnection state**

Then, how to determine the values of $f_c(t)$ and $f_d(t)$?

First Step (Cont’d)

Detailed Procedures



$$P_C = \frac{\mu}{\mu + \lambda}$$

$$P_D = \frac{\lambda}{\mu + \lambda}$$

Probability of connection and disconnection state

$$C(t, \varepsilon) = f_c(t + \varepsilon) - f_c(t)$$

Time required to perform ‘ε ’ time units of transfer

- **No disconnection occurs during data transfer:**

  Probability : $e^{-\lambda\varepsilon}$ **(Poisson process)**

  Transfer time : ε

- **Disconnection occurs during data transfer:**

  Probability : $1 - e^{-\lambda\varepsilon}$ **(Poisson process)**

  Transfer time : $\frac{1}{\mu}$

$$C(t, \varepsilon) = f_c(t + \varepsilon) - f_c(t)$$

$$= e^{-\lambda\varepsilon}\varepsilon + (1 - e^{-\lambda\varepsilon})\left(\varepsilon + \frac{1}{\mu}\right)$$

First Step (Cont'd)

Detailed Procedures

$$f_c(t) = \frac{\partial f(t)}{\partial t} = \lim_{\varepsilon \to 0} \frac{f(t+\varepsilon) - f(t)}{\varepsilon}$$

$$= \lim_{\varepsilon \to 0} \frac{e^{-\lambda\varepsilon}\varepsilon + (1 - e^{-\lambda\varepsilon})\left(\varepsilon + \frac{1}{\mu}\right)}{\varepsilon} = \frac{\lambda}{\mu} + 1$$

$$= \left(\frac{\lambda}{\mu} + 1\right)t$$

$$f_d(t) = \frac{1}{\mu} + f_c(t)$$

$$= \frac{1}{\mu} + \left(\frac{\lambda}{\mu} + 1\right)t$$

First Step (Cont'd)

- **Detailed Procedures**

$$f(t) = P_c \cdot f_c(t) + P_D \cdot f_d(t)$$

$$= \frac{\mu}{\lambda+\mu} \cdot \left(\frac{\lambda}{\mu} + 1\right) t + \frac{\lambda}{\lambda+\mu} \cdot \left\{ \frac{1}{\mu} + \left(\frac{\lambda}{\mu} + 1\right) t \right\}$$

$$f(t, \lambda, \mu) = \left(\frac{\lambda}{\mu} + 1\right) t + \frac{\lambda}{\lambda+\mu} \cdot \frac{1}{\mu}$$

⇨ **Here, we can get the expected time to transfer the data for which needs *t* time unit of connection**

Job Scheduling Algorithm in Mobile Grid

- **Second step**: Determine job completion time in every mobile nodes and sort them

$$g_i(t_{in}, t_{job}, t_{out}) = f_i(t_{in}) + t_{job} + f_i(t_{out})$$

⇨ **Job completion time in a mobile node**

t_{job} **depends on the number of mobile node participating in the computing**

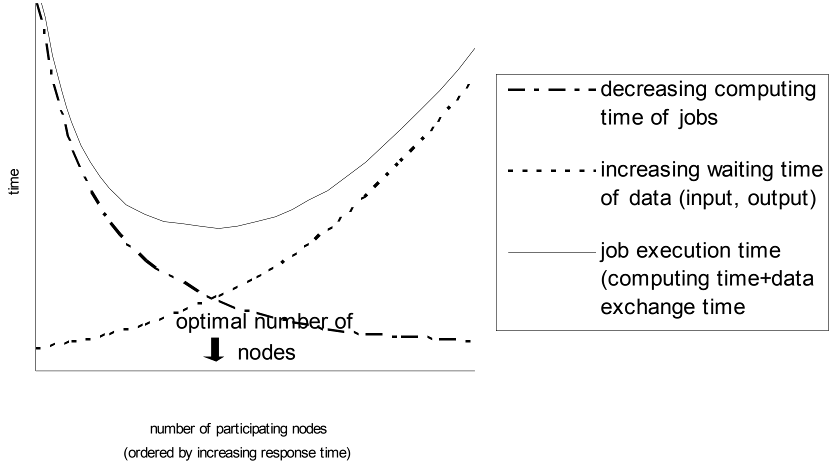
Job Scheduling Algorithm in Mobile Grid

- **Third step: Find the optimal number of participating nodes which makes the best job performance**
  - When we add a node in the computing

    + : the amount of job that a single mobile node perform decreases

    - : we may need to wait so long for the reconnection of the newly added mobile node, especially if the node remains disconnected long

⇨ **So, we determine whether adding a node to the computing will result in better job execution time or not, in the sorted list**



Performance Evaluations

- **Methods**
  - Mathematical analysis, simulations, and implementations
- **Implementation Method**
  - Simple prototype of MQS (Mobile Queuing Server)
  - Performs mobile node management, job distribution, monitoring, and result gathering process
  - Disconnection and reconnection is regarded as a normal activity
  - Considers the connection state of the node when executing the job

Performance Evaluations

- **Input Variables for assumed mobile environments**

Mobile environments	Max λ	Min λ	Max μ	Min μ
Stable	0.003	0.001	0.003	0.001
Highly disconnected	0.027	0.009	0.003	0.001
Unstable	0.027	0.009	0.027	0.009
Highly connected	0.003	0.001	0.027	0.009

λ: disconnection rate of mobile node

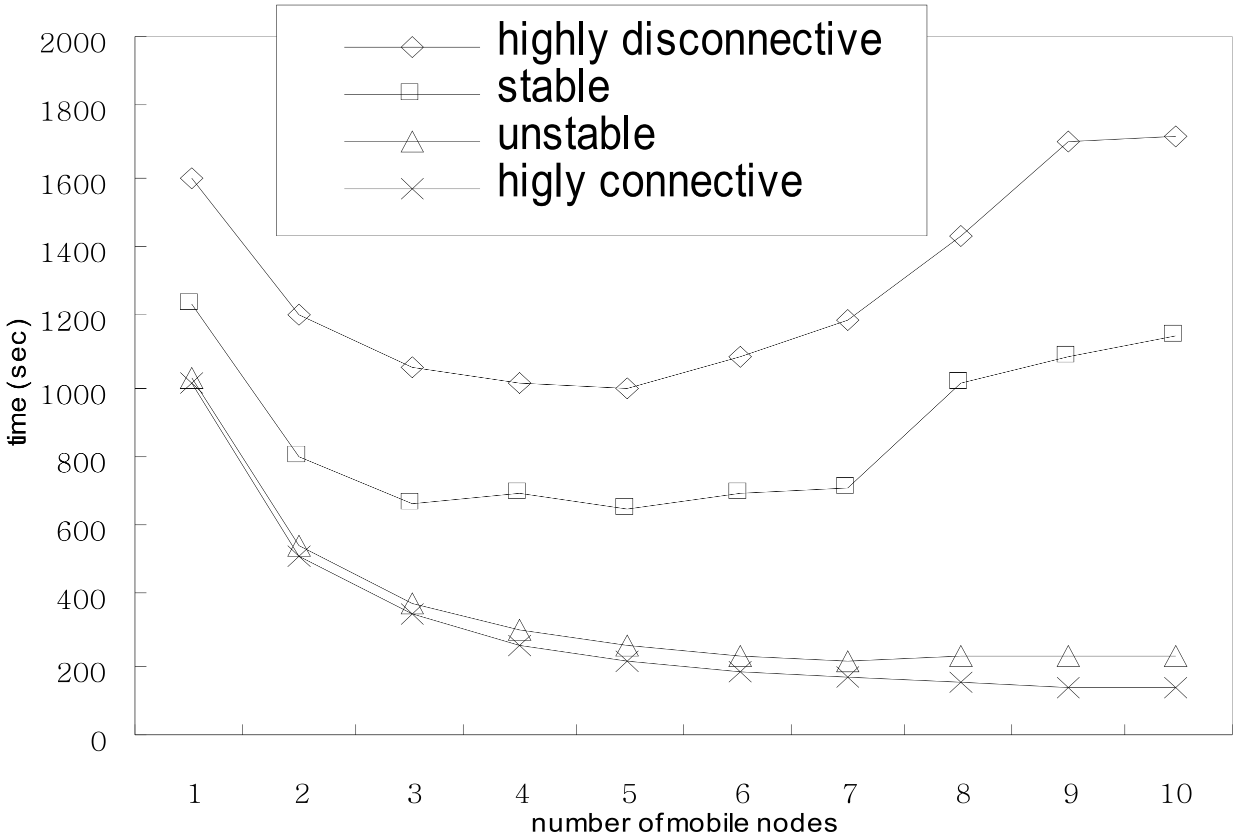
μ: reconnection rate of mobile node

Performance Evaluations

- **Experimental environments**

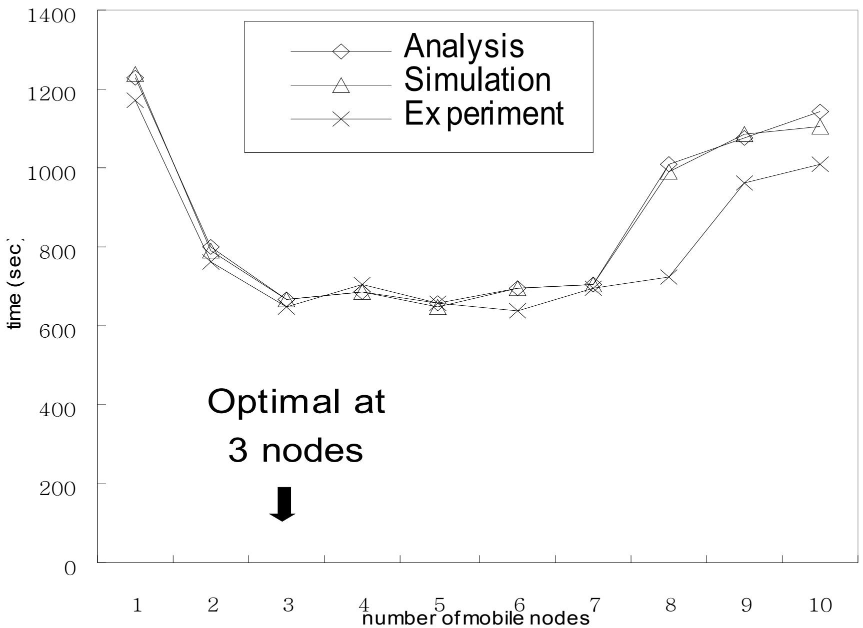
Mobile Node Specification (10 Machines)	CPU	P4 1.6 GHz
	Memory	256 MB
	Network Connection	802.11b wireless LAN
Application	Blast (Bioinformatics)	
Workload amount	Number of protein sequences needed for 1000 seconds of processing	
Network disconnection & reconnection	Exponentially random value with respect to the λ and μ of mobile node. Manually configured the disconnection and reconnection of mobile node	
Data	Input	Decomposed protein sequences (5 KB/*number of nodes*)
	Output	Information achieved from protein (200 KB/*number of nodes*)

Performance Evaluations

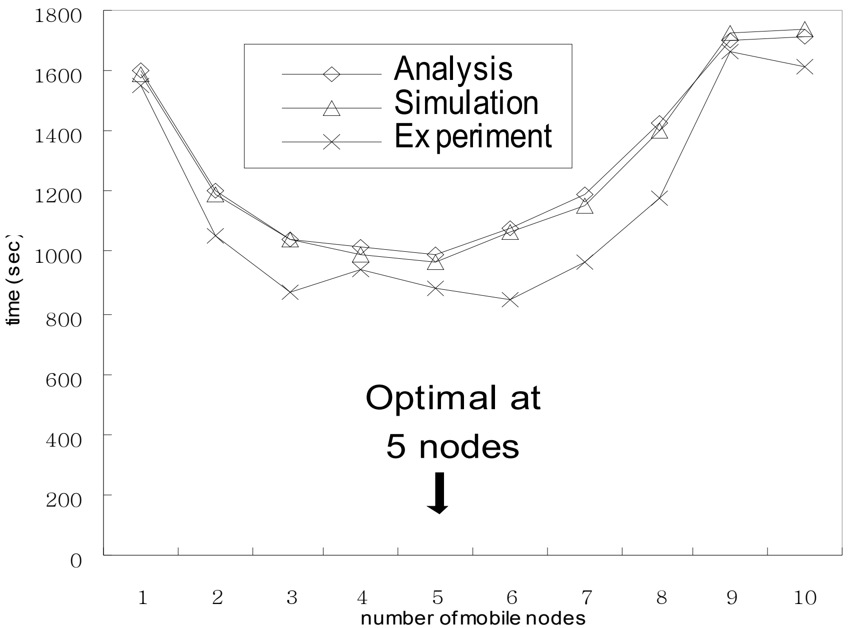


Analytical results in four difference environments

Performance Evaluations

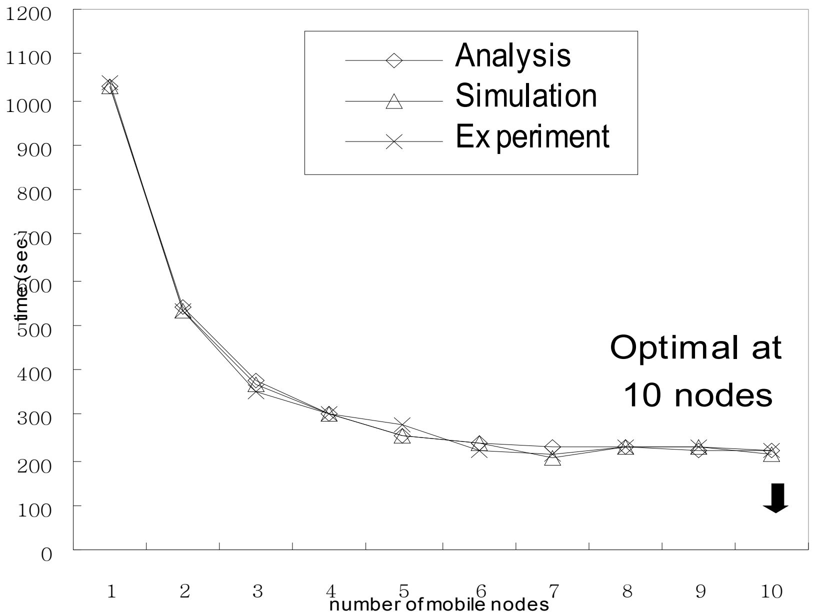


Job completion time in a stable environments

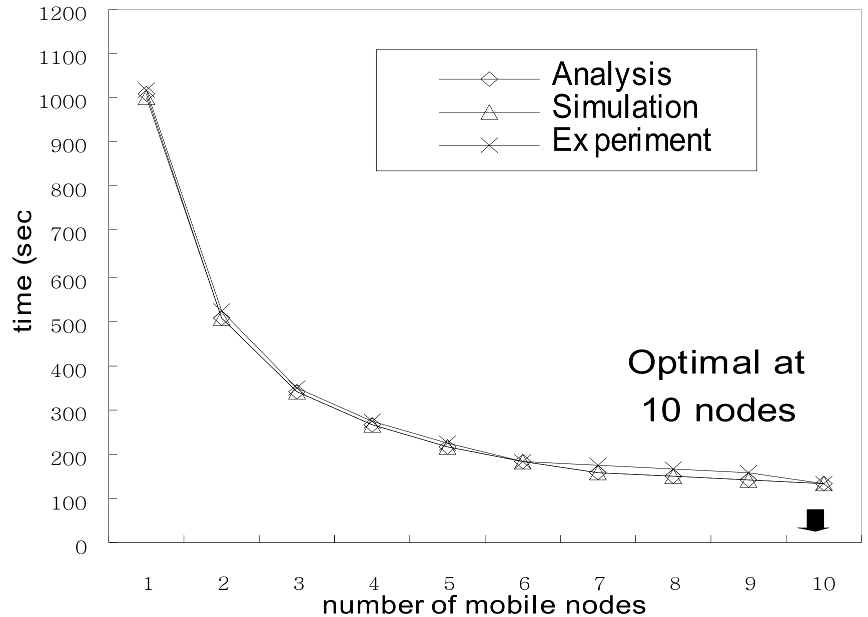


Job completion time in a highly disconnected environments

Performance Evaluations



Job completion time in an unstable environments



Job completion time in a highly connected environments

Performance Evaluations

- **What we learn from these results?**

  The proposed job scheduling algorithm is suitable to be adapted to mobile environments, especially when the mobile nodes tend to remain in disconnection state long

Conclusions

- **Discussed on the issue of integrating wireless mobile environments into Grid**
- **Proposed gateway-based architecture where the mobile nodes play two roles: grid interfaces and resource providers**
- **Presented several technical issues to be solved for the future Mobile Grid system**
- **Proposed job scheduling algorithm which take accounts of the connection/disconnection rate and the execution performance of mobile node**
- **The experimental results show that the proposed scheduling algorithm could be viable approach to deal with performance degradation of Mobile Grid system**

Thank you!