Application of Petri Nets to Evaluation of Grid Applications Efficiency

Wojciech Rząsa\textsuperscript{1}, Marian Bubak\textsuperscript{2,3}

\textsuperscript{(1)} Rzeszow University of Technology, Poland
\textsuperscript{(2)} Institute of Computer Science AGH, Krakow, Poland
\textsuperscript{(3)} ACC Cyfronet, AGH, Krakow, Poland
Outline

- Motivation and the goal
- Related work
- Analysis method
  - The models
  - Enabling the simulation
- Results
- Conclusions and future work
Motivation

GT2 security overhead

[Baliś, Bubak, Rząsa, Szepieniec 2004]

- Secured connection enables
  - Authentication
  - Data integrity
  - Confidentiality
- Connection establishment

<table>
<thead>
<tr>
<th>Connections</th>
<th>Requested in 1 second</th>
<th>Established in 1 second</th>
<th>Failed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Secured</td>
<td>896</td>
<td>30</td>
<td>4</td>
</tr>
<tr>
<td>Clear</td>
<td>1692</td>
<td>1691</td>
<td>0</td>
</tr>
</tbody>
</table>

Data transmission

Transmission time for 100 B packets
Motivation

Communication overhead examples

- Secure communication
  - GT2 GSI
  - GT3/GT4 transport-level and message-level security
  - SSL/TLS
  - VPN

- Communication layers
  - TCP/IP
  - HTTP over TCP/IP
  - SOAP over HTTP over TCP/IP

- Network link parameters
Motivation
Distributed application efficiency

- Communication overhead
- Delay caused by the other resources
  - e.g. CPU
- Application logic and topology
  - implies resource usage
The goal

- Analyze efficiency of distributed application
- Depending on
  - Parameters of resources
  - Application design
- Method for application developers
Simulations of the Grid – examples

- Replica management simulators
  - OptorSim  DataGrid project, 2004
  - GridNet  [Lamehamedi, Shentu, Szymanski, Deelman 2003]
  - ChicagoSim  [Ranganathan, Foster 2001]

- Scheduling algorithms simulators
  - SimGrid  [Casanova, Legrand, Marchal 2003]
  - GridSim  [Buyya 2005]

- Grid security simulator – G3S  [Naqvi, Riguidel 2005]

- Grid application simulators
  - Performance Prophet  [Fahringer 2005]
Simulations of the Grid – tools and engines exploited

- General purpose discrete-event simulators
  - PARSEC
    - ChicagoSim
  - SimJava
    - GridSim
  - CSIM
    - Performance Prophet
- Network Simulator (ns)
  - GridNet
The method

- Model the environment and the application
- Perform simulation to obtain statistics
Parts of the model

- Model of the Grid resources
- Model of the application
The model

Nodes:
  • CPU(s)
The model

Parameters of the net segments:

- Bandwidth
- Delay
- Capacity (queues)
The model

**Link** – route between the nodes
The model

**Link** – route between the nodes
The model

*Elements* of the application located on the nodes
The model

Network connections established between the elements over the net segments
The model

Described using XML

- separate files
Parameters of the application element

- Network connection parameters
- Delay caused by processing
- Parameters of generated communication

All parameters described using expressions

```plaintext
if ($time<1000) { 100*$incomingVolume } else { pow($incomingVolume,3) }
```
Reliable simulation

• High level model – convenient for application developers

• Executable model for reliable simulation
  – Based on a formalism
  – Properly reflecting activities of concurrent, distributed applications

• Automatic transformation, transparent for the user
Enabling the simulation

Petri Nets

- Reliable formal model of concurrent processes
- Simulation
  - efficient
  - interactive

Concurrency  Synchronization  Conflict

Mutual exclusion

[Murata 1989]
Timed Colored Petri Net

[Jensen 1994] [Jensen 1995/96]

- Classical PN extended by
  - Color sets – data types
  - Colors of tokens – values
  - Guards defined for transitions
  - Arc expressions

- More compact and transparent model

- Time
  - Tokens with timestamps
  - Timestamps modified by transitions
  - Timestamps affect availability of tokens
Experiment

- At most one persistent connection between each two nodes
- Transmission of 100 packages of data
- No other data processing
- Measurement of wall time of whole experiment
- Nodes: AMD Athlon 64 1.8GHZ, 2GB RAM
Results (64kbps links)

Experiment and simulation
Raw TCP, 64kbps links
128 and 64kbps links

- Node 01 connected to Node 02 with 128kbps link.
- Node 02 connected to Node 03 with 64kbps link.
- Node 03 connected to Node 01 with 64kbps link.
Results (128 and 64kbps links)
64 and 128kbps links

Data

node01

64kbps

node02

128kbps

node03

Data

Data
Results (64 and 128kbps links)

Experiment and simulation
Raw TCP, 64,128, 64 kbps links

Simulation time [s]

Simulation time [s]

0 500 1000 1500 2000 2500 3000 3500

0 500 1000 1500 2000 2500 3000 3500

0 500 1000 1500 2000 2500 3000 3500

Package size [B]

Simulation time [s]

Simulation time [s]

Simulation time [s]

Package size [B]

Simulation time [s]

Simulation time [s]

Simulation time [s]

Simulation time [s]

Experiment
Simulation
Conclusions and future work

• Conclusions
  – Correct results if TCP model works correctly
  – The Petri net based model works correctly
  – Inaccuracy caused mostly by incorrect TCP flow control implementation

• Future work
  – Correct TCP model
  – Improve High-level application model
  – Feasibility study – ATLAS TDAQ soft real time system  [Korcyl, Szymocha, Kitowski, et al. 2008]