Recent Advances in Internet, Cluster, Grid, and Pervasive Computing

Kai Hwang

Internet and Pervasive Computing Laboratory
University of Southern California

Email: kaihwang@usc.edu
Web site: http://ceng.usc.edu/~kaihwang
Information Technology: Today and the Future

What are hot in Year 2001?

1.5 GHz microprocessors, 256 Mb RAM, Gigabit Ethernet, Unix/Linux, Windows NT, Clusters, Java, Internet, digital TV, Smart Network Devices, Pervasive Computing, etc.

How about 3 years from now?

2-4 GHz microprocessors, 1-4 Gb RAM, flash memory (NVSM), 1 Tbps LAN, Satellite-based WWW, Petaflops Supercomputers, Cluster OS, Grid Metacomputing, etc.
a billion people interacting with a million E-Businesses with a trillion intelligent devices interconnected

Lou Gerstner,
IBM Chairman and CEO

Mainframe Computing (50 - 70’s)

→ Personal Computing (80 - 90’s)

→ Cluster Computing (90 - 00’s)

→ Pervasive Computing (00 - ??)

→ Grid Metacomputing (10 - ??)
## Network-Based Computing Paradigms

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Cluster Computing</th>
<th>Grid Computing</th>
<th>Pervasive computing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Networking</td>
<td>System Area Network</td>
<td>Internet or Wide Area Network</td>
<td>Wireless LAN, IrDA</td>
</tr>
<tr>
<td>Operating system support</td>
<td>Most UNIX and Windows variants</td>
<td>Most UNIX, Windows variants</td>
<td>Pocket PC (CE), Palm OS, Inferno, Chorus OS</td>
</tr>
<tr>
<td>Environment and tool sets</td>
<td>MPI, PVM, Score, Codine</td>
<td>GLOBUS, GSI, LEGION, CONDOR</td>
<td>JINI, UPnP, Bluetooth,</td>
</tr>
</tbody>
</table>

**May 20, 2003**

K. Hwang at USC
Scalable clusters providing SSI services are gradually replacing the SMP, cc-NUMA, and MPP in Servers, Web Sites, and Database Centers.
Issues in Cluster Design

- Size Scalability (physical & application)
- Enhanced Availability (failure management)
- Single System Image ( Middleware, OS extensions)
- Fast Communication (networks & protocols)
- Load Balancing (CPU, Net, Memory, Disk)
- Security and Encryption (clusters and Grids)
- Distributed Environment (User friendly)
- Manageability (Jobs and resources)
- Programmability (simple API required)
- Applicability (cluster- and grid-awareness)
Trojans Linux Cluster
with Middleware for Security and Checkpoint Recovery

Programming Environments
(Java, EDI, HTML, XML)

Web Windows User Interface

Other Subsystems
(Database, OLTP, etc.)

Single-System Image and Availability Infrastructure

Security and Checkpointing Middleware

Linux

Pentium PC

Linux

Pentium PC

Linux

Pentium PC

Gigabit Network Interconnect

May 20, 2003
K. Hwang at USC
Scaled Workload leads to Linear Speedup on The Trojan Cluster
Distributed RAID Embedded in a Cluster or in a Storage-Area Network:

- I/O Bottleneck in Cluster Computing
  - CPU/ Memory and disk-I/O speed gap widens as μP doubles in speed every year
  - Pervasive applications are often I/O-bound

- Disks connected to hosts are often subject to failure by hosts themselves. Distributed RAID has much higher availability by fault isolation, rollback recovery, and automatic file migration.

Distributed RAID-x Architecture

Cluster Network

Distributed RAIDDistributed RAID--x Architecturex Architecture

Node 0

P/M
CDD

D0

B0
B12
B24
B25'
B26'
B27'

B4
B16
B28
B29'
B30'
B31'

B8
B20
B32
B33'
B34'
B35'

Node 1

P/M
CDD

D1

B1
B13
B25
B14'
B15'
B24'

B5
B17
B29
B18'
B19'
B28'

B9
B21
B33
B22'
B23'
B32'

Node 2

P/M
CDD

D2

B2
B14
B26
B3'
B12'
B13'

B6
B18
B30
B7'
B16'
B17'

B10
B22
B34
B11'
B20'
B21'

Node 3

P/M
CDD

D3

B3
B15
B27
B0'
B1'
B2'

B7
B19
B31
B4'
B5'
B6'

B11
B23
B35
B8'
B9'
B10'

CCD: Cooperative Disk Drivers
Remote Disk Access using a Central NFS vs. using Cooperative Disk Drivers in a Distributed RAID

(a) Parallel disk I/O using the NFS in a server/client cluster.

(b) Using CDDs to achieve a SIOS in a serverless cluster.

May 20, 2003  K. Hwang at USC
Parallel Write Performance of four Distributed RAIDs on USC Linux Cluster

![Graph showing performance comparison between RAID-x, Chained Declustering, RAID-10, and RAID-5.](image-url)

- RAID-x
- Chained Declustering
- RAID-10
- RAID-5
Parallel Polygon Rendering with Adaptive Supersampling

Speedup Performance of Two Parallel Renderer on the SGI SMP Server and Unix WS Cluster at HKU High-Performance Computing Research Lab.

![Graph showing speedup performance comparison between different renderers on SMP and Cluster. The x-axis represents machine size (n), and the y-axis represents speedup (S). The graph includes two sets of data: one for our renderer on SMP and Cluster, and another for Crow's renderer on SMP and Cluster.](image-url)
Securing Clusters, LANs, Intranets, WANs, Grids, and Internet Resources

with intrusion detection and automatic recovery from malicious attacks

Design Goals: A distributed network architecture with Dynamic Security and Privacy (DSP) supporting fine-grain resources access with automatic intrusion prevention, detection and responses, based on dynamic security policies, multicast protocols, and adaptive cryptographic engines in a scalable network environment.
Security Threats in Mobile Agent-Based Systems

- Masquerading - Identity misuse
- Denial of Service - Resource occupation
- Unauthorized Access - Intrusions
- Repudiation - Dispute services provided
- Eavesdropping - Secrecy interception
- Alteration - Data/code integrity
- Copy and Reply - Clone of agents
Security Component Technologies

- Firewalls and Cryptography
- Cluster Middleware for Security
- Anti-virus and Immune Systems
- Intrusion Detection and Response
- Distributed Software RAIDs
- Security & Assurance Policies
Distributed Micro-Firewalls for Dynamic Security supported by IPChains, Mobile Agents, RMI, or CORBA.

Adaptive Security Control

Agents detect threats, learn from intrusion patterns, and update security safeguards

Adaptive Security

= Security Safeguards
  • Micro-Firewalls
  • Authentication
  • Access control
  • Cryptography

= Detect network and threat conditions

= Detect software vulnerabilities

Adaptive Responses
Distributed Firewall Architecture
built in Trojans Cluster at USC

Nodes with Micro-Firewall

Switch
Network

Policy Manager
Gateway Firewall

Demilitarized Zone

Internet

Router

May 20, 2003
K. Hwang at USC
Implementing Micro-Firewall in The Linux Kernel

Adaptive Cryptographic Engine for IPSec

## Comparison of Agents, CORBA, and RMI for Security-Policy Update on Intranets or Clusters

<table>
<thead>
<tr>
<th>Capabilities</th>
<th>Mobile Agents</th>
<th>CORBA Middleware</th>
<th>RMI Middleware</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central policy coordination</td>
<td>Autonomous and require no coordination once dispatched</td>
<td>The policy manager coordinates all communications</td>
<td>The policy manager acts as the RMI registry to coordinate among all nodes</td>
</tr>
<tr>
<td>Reaction time to policy change</td>
<td>The time increases with the number of agents dispatched.</td>
<td>Faster than agents or RMI to react to a policy change</td>
<td>RMI slower than CORBA and faster than agent based system for policy update</td>
</tr>
<tr>
<td>Hosts fortified with micro-firewalls</td>
<td>Agents carry most mechanisms required to update security policy</td>
<td>Requires the ORB middleware support on all hosts in the Intranet</td>
<td>Requires JVM to be present on all the hosts.</td>
</tr>
<tr>
<td>Security Mechanisms</td>
<td>Use authentication and encryption. Still prone to attacks from hosts/agents.</td>
<td>Security implemented with the CORBA Sec.</td>
<td>Security is the best among all three, implemented with the Java sandbox model.</td>
</tr>
<tr>
<td>Update Process Termination</td>
<td>Multiple agents used autonomously, Policy update always completes</td>
<td>Implemented at application level using RPC-like semantics</td>
<td>Implemented at application level using RPC-like semantics</td>
</tr>
</tbody>
</table>
Distributed Intrusion Detection and Response in a Linux Cluster

1. Attack penetrated through the gateway firewall
2. Intrusion detected by the mobile agent
3. Response through RMI policy updates
Pervasive Computing

- Small inexpensive computers and sensors in every device and appliance - handheld or portable in offices, homes, cars, stores, classrooms, and factories, etc.

- These smart devices are networked to each other and the Internet (3 trillion devices). They can sense and react intelligently to the environment changes.

- Information appliances, integration into Internet through phone lines, cables, or wireless LANs (HomeRF, Bluetooth) using protocols Jini, Inferno, etc.

- Neworked household, automobile, personal assistants, smart spaces (offices, classrooms, etc), and express delivery (BodyLAN) services, etc.
Information Appliances vs Personal Computers

US Shipments, Consumer Devices, In Millions

Source: US/NIST Information Technology Lab.
Investing in Infrastructure Today for Tomorrow

Active badges

Smart phones
13 million in 2006

palm-size computers
28 million in 2006

Screen phones

E-Commerce
$300 billion in 2001

May 20, 2003

K. Hwang at USC

Source: NIST/IT Lab.
The Rome Architecture for Pervasive Job Scheduling at Stanford University

Scanner

Web Form

Semantic Translator

Trigger Manager

Unit Manager

Auto PC

PDA

Internet
Computing and Information
Grid for The Future?

A metacomputing infrastructure that couples

- computers, information appliances, (PCs, WSs, servers, clusters, supers, laptops, notebooks, PDA, etc.,)
- mobile software (e.g., renting expensive applications on demand),
- distributed databases (e.g., transparent access to human genome database),
- smart network devices (e.g., Internet cars, express services, etc.),
- and People (You, me, and every one).
Basic Concept of Grid Computing

(Courtesy of Foster and Kesselman, 2000)

The Grid: The Web on Steroids

Web: Uniform access to HTML documents

Grid: Flexible, high-perf access to all significant resources
Grid Application-Drivers

- New applications enabled by coupling computers, databases, people, etc.
  - (distributed) Supercomputing
  - Collaborative engineering
  - Data-miming in E-commerce
- Computing Power as an Utility Industry
  - Renting Software
  - Renting CPU Cycles
  - On-demand computing
Security Issues in Computational Grids

- Grid components can insulate themselves from security breaches elsewhere.
- Only authorized principals are allowed to use the available resources.
- Detection and Recovery from intrusions that occur from outsiders and compromised insiders.
- All communications among grid components should be immune to tampering and tapping.
- The grid should establish the identity of a principal using the resources reliably across the system.
Underlying Technologies for E-Commerce, Digital Government, and E-Everything

Core Technologies
- Data Warehousing
- Unix/Linux/NT
- Networking
- Open Standards
- CORBA/IIOP
- RDBMS

Enabling Technologies
- OLAP
- HTML/XML
- Fast Messaging
- Scalability
- COM/DCOM/DNA

Decision-Support Technologies
- Relationship Management
- Personalization
- Billing/Payment Systems
- Advertising/Promotions
- Data Mining
- Supply Chain Management
- Performance Measurement
- Knowledge Management

Increasing Demand of Secure Cluster, Grid, and Pervasive Applications:

- LANs, clusters, Intranets, WANs, Grids, and the Internet all demand security protection, fault-tolerance, and hacker-proof operations, which are crucial to a digital society and economy.

- Distributed storage-area networks demands HW/SW support of a single I/O space and global file and database management in all network-based computing applications.

- Many innovative applications exist in remote network services, E-commerce, telemedicine, distance education, collaborative design, pervasive computing, digital entertainment, etc.
Charles Darwin (1809 - 1882)

“It is not the strongest of species that survive, nor the most intelligent, but the one most adaptable to change.”