Massively Distributed Systems:

From Cluster/Grid to P2P/Cloud Computing over The Internet

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Presentation Outline:

- Enabling networking and virtualization technologies
- Emerging massively distributed System Models
- New Challenges in P2P/Grid and Cloud Computing

Presentation slides available in http://GridSec.usc.edu/Hwang.html

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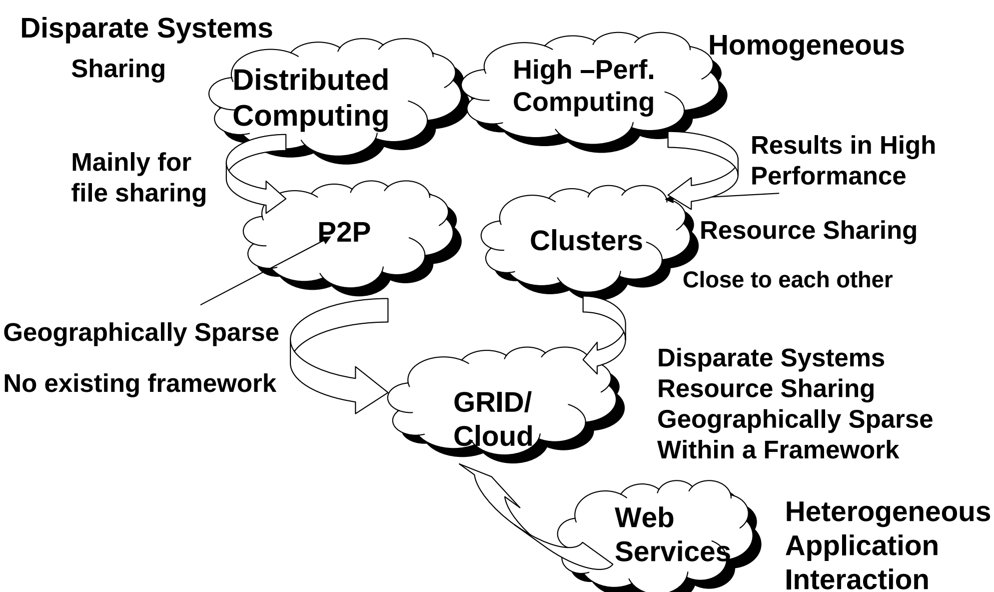
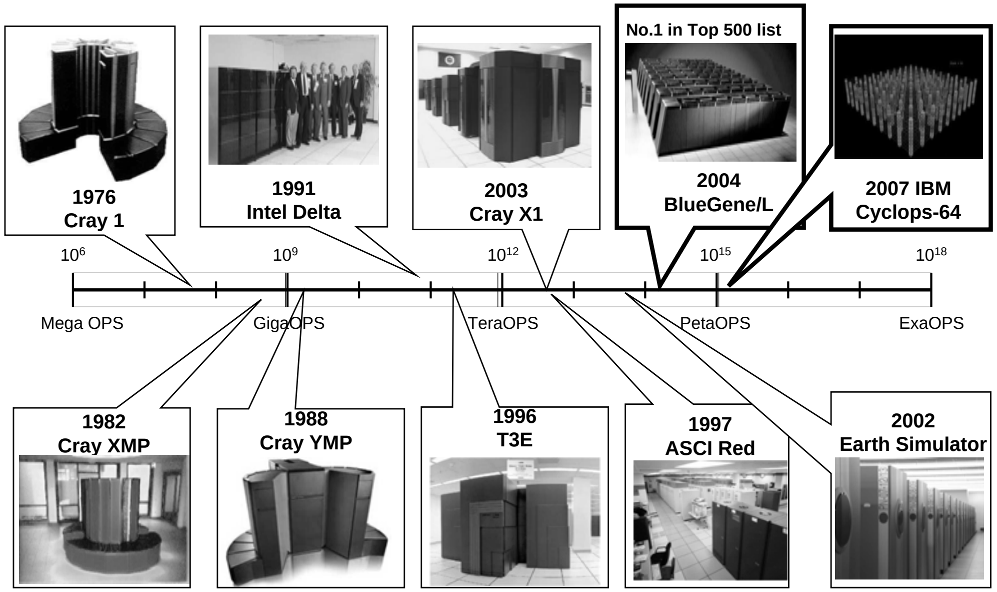
Evolution of HPC, Clusters, Distributed P2P/Grid/Cloud Computing, and Web Services

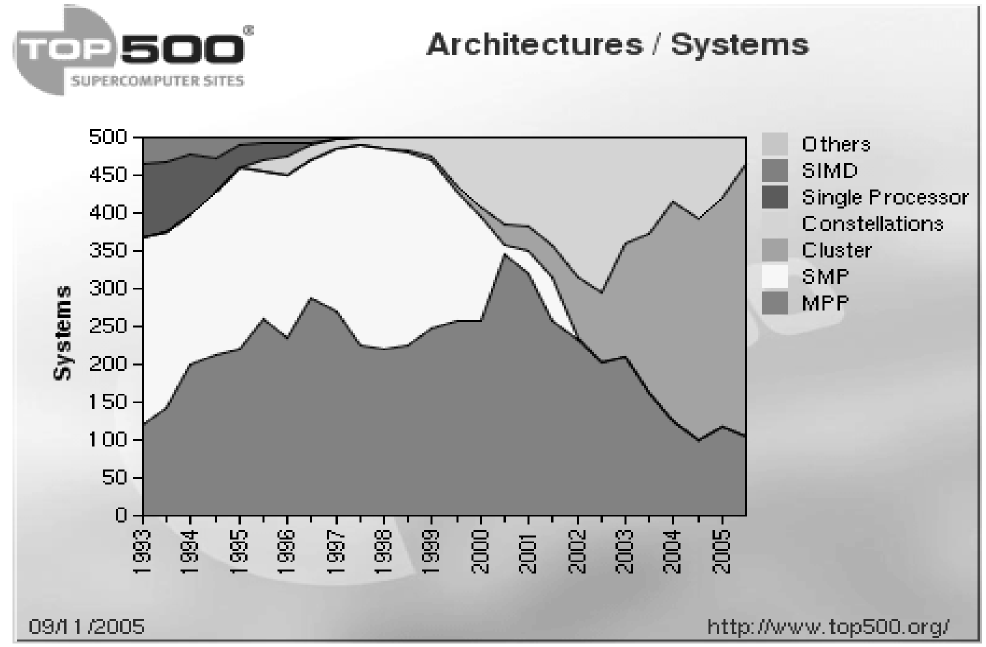


Applications of Massively Distributed Systems

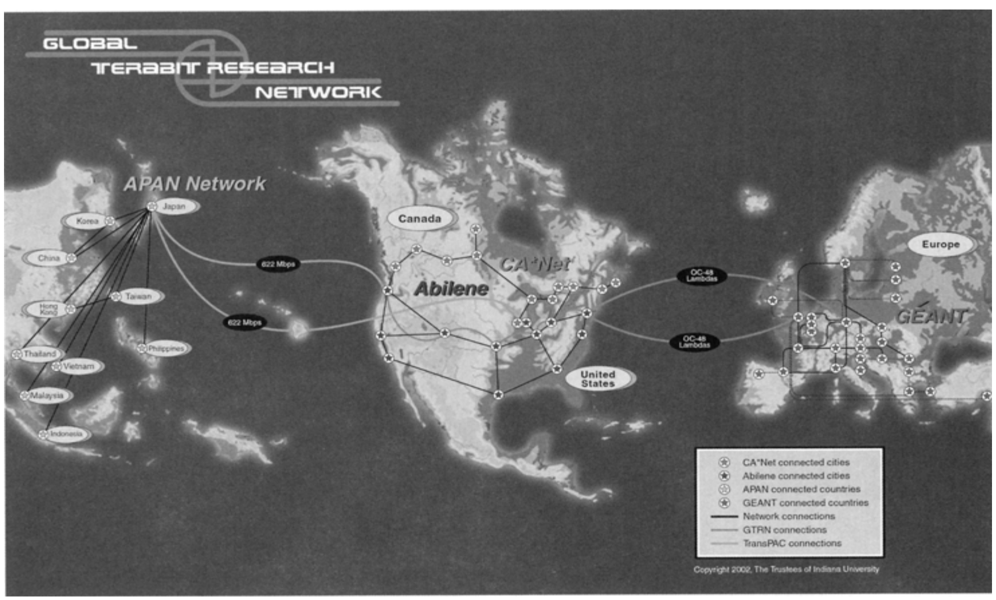
- Numerous Scientific & Engineering Applications.
- Scientific Simulations and Social Networking
- Business Applications
  - E-commerce Applications (Amazon.com, eBay.com ….)
  - Database Applications (Oracle on cluster)
  - Decision Support Systems
- Internet Applications
  - Web servicing / searching (google.com, hotbot.com)
  - Infowares (yahoo.com, AOL.com)
  - ASPs (application service providers)
  - eMail, eChat, ePhone, eBook, eCommerce, eBank, eSociety, eAnything !
- Mission Critical Applications
  - Command control systems, banking, nuclear reactor control, star-war, and crisis management, etc.

A Growth-Factor of a **Billion** in Performance in the past 30 Years





GTRN : Global Terabit Research Network

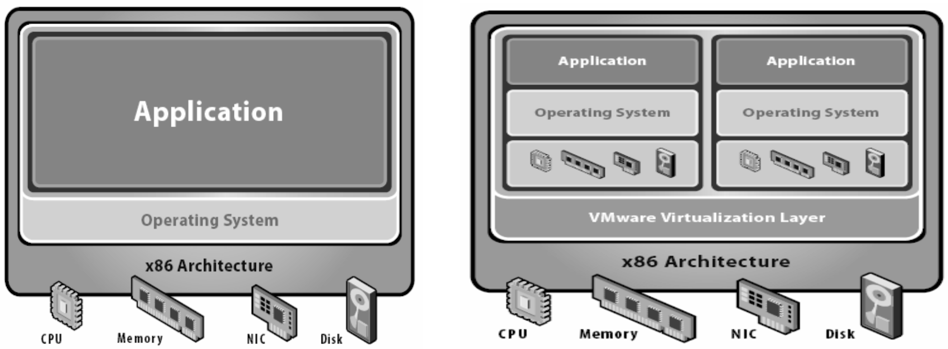


The fever of building national Grids is receding, progress very slow for lack of R/D funding in most countries.

Some Observations in Wide-Area Networking :

- **We have observed a 10: 1: 0.1 Gbps ratio in national, organization, and desktop links since 2003.**
- **By 2006, the GTRN development aimed at a 1000:1000:100:10:1 Gbps ratio in international backbone, national, organization, optical desktop, and copper desktop links.**
- **An increase factor of 2 per year on network performance, faster than Moore's law on CPU doubling in speed for every 1.5 year -- More computers to be used concurrently in the future.**
- **High-capacity networking increases the capability to support massively parallel and distributed applications.**
- **The current Grid connectivity down to desktop level will be extended to pervasive devices with wireless Internet and mobile connectivity.**

Machine Virtualization for Distributed Computing



Before Virtualization:

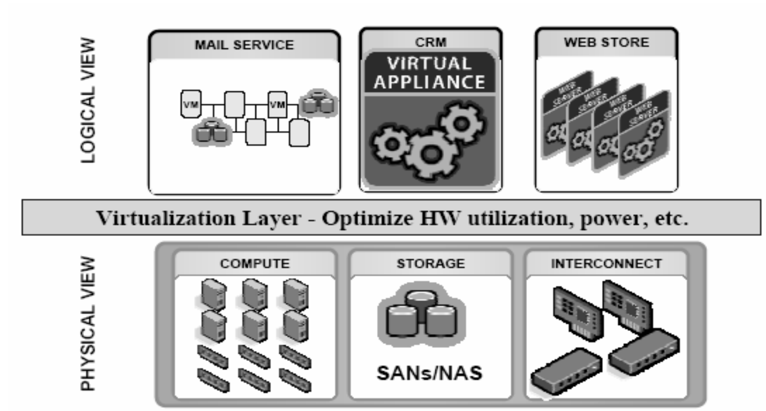
- Single OS image per machine
- Software and hardware tightly coupled
- Running multiple applications on same machine often creates conflict
- Underutilized resources
- Inflexible and costly infrastructure

After Virtualization:

- Hardware-independence of operating system and applications
- Virtual machines can be provisioned to any system
- Can manage OS and application as a single unit by encapsulating them into virtual machines

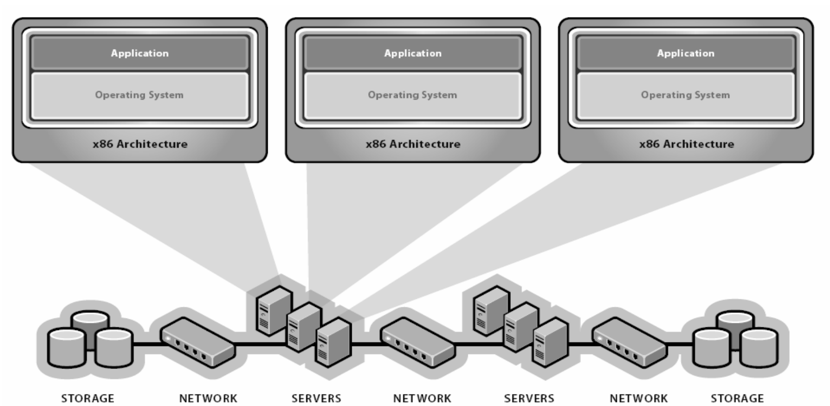
Source: VMWare, 2005

User's View on Virtualization



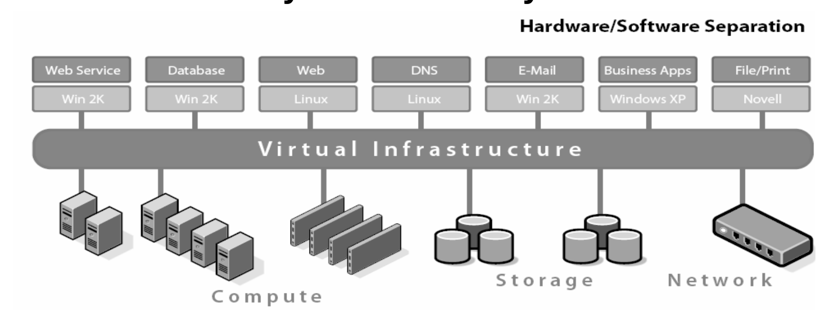
- VMWare, a subsidary of EMC, produces virtualization middleware for upgrading servers and desktops used in major enterprises.
- National 973 Project ($3.5M) launched in 2007 by 8 major Universities in China on Machine Virtualization that supports Grid/Cloud computing

Traditional Infrastructure:
Dedicated Servers for Dedicated Applications



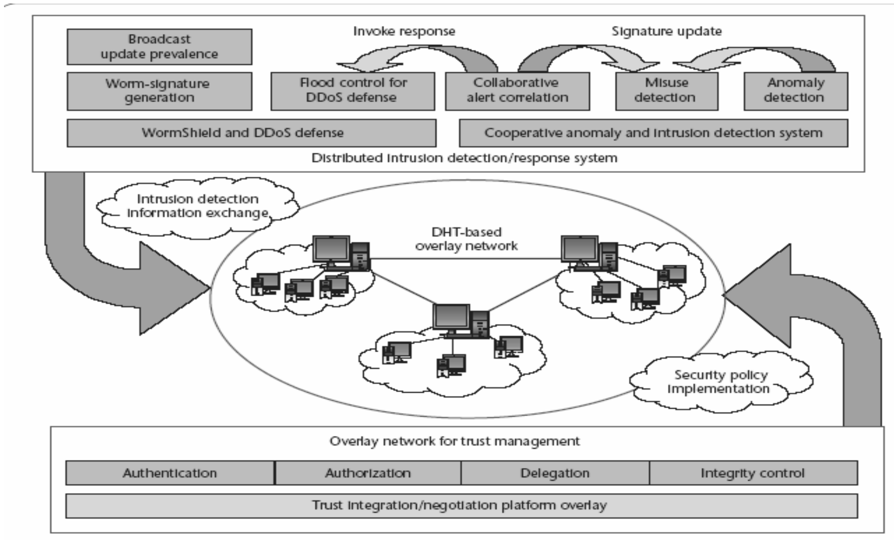
Virtualization enables server consolidation by providing more functionality with upgraded resource utilization, reliability, security, and manageability

Virtual Infrastructure for
Massively Distributed Systems



- Trend to use virtual machine as software distribution mechanism. (Virtual appliances)
  - Applications and OS bundled together.
  - Like Appliance Computing without hardware
- Many benefits for software vendor and customer:
  - Choose OS based on application needs, not what customer has.
    - Functionality, performance, reliability, security, manageability.

GridSec Project at USC Internet and Grid Computing Lab, supported by NSF



***IEEE Security & Privacy,* May 2006**

Relevant Publications from GridSec Project :

- Trust management and security-aware job scheduling in P2P and Grid Systems -- (*IEEE Internet Computing*, Nov. 2005, *IEEE-TC,* June 2006, *Journal of Grid Computing*, Sept. 2005)
- Collaborative intrusion detection and fast containment of Internet worm outbreaks -- (*IEEE Security & Privacy,* May 2006, two papers in *IEEE-TDSC, Jan. and April* 2007)
- Distributed change-point monitory and detection of DDoS attacks over multiple ISP domains (*IEEE-TPDS,* Dec. 2007)
- Reputation systems for structured and unstructured P2P networks (presented in *IPDPS-2006, IPDPS-2007*, Journal versions in *IEEE-TPDS* April 2007 and *IEEE-TKDE accepted to appear 2008*)
- Game-theoretic modeling of selfish grids, evaluated by simulated NAS/PSA benchmark results (presented in *cc-Grid 2005, IEEE-TPDS*, May 2007)
- Copyright protection in P2P networks using proactive content poisoning, secure file indexing, and reputation systems – (*IEEE-TRAM Workshop* with *ICDCS-2007, submitted to IEEE-TC, revised Dec. 2007)*

All papers are downloadable from **http://GridSec.usc.edu**

WormShield Built over a DHT Overlay Network

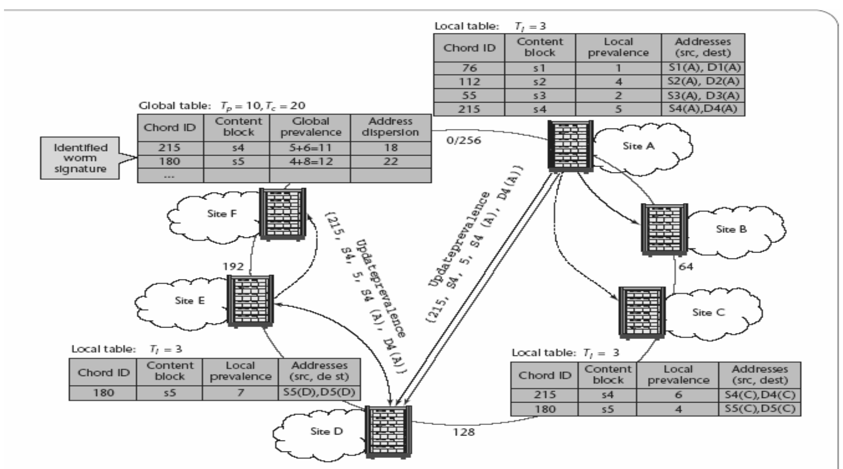
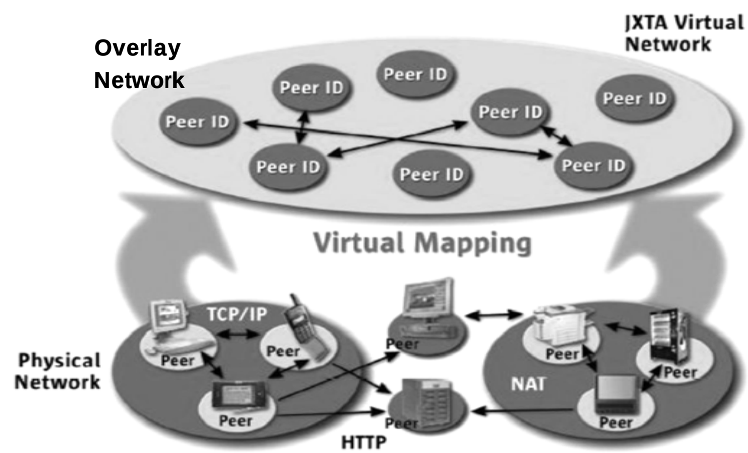


Figure 2. The WormShield architecture. In this example, six worm monitoring sites are deployed in six edge networks. This DHT-based overlay system performs distributed worm monitoring, anomaly detection, signature updating, alert correlation, and automated intrusion response.

(*IEEE Security & Privacy,* May 2006 and two papers on HIDS and WormShield appeared in *IEEE-TDSC*, April and May 2007)

Why peer-to-peer systems are popular ?



In P2P systems such as Gnutella, BitTorrent, eMule, JXTA, every node acts as both a client and a server – forming overall recourses in the system, collectively. No central coordination or no central database available. No peer has a global view of the entire system.

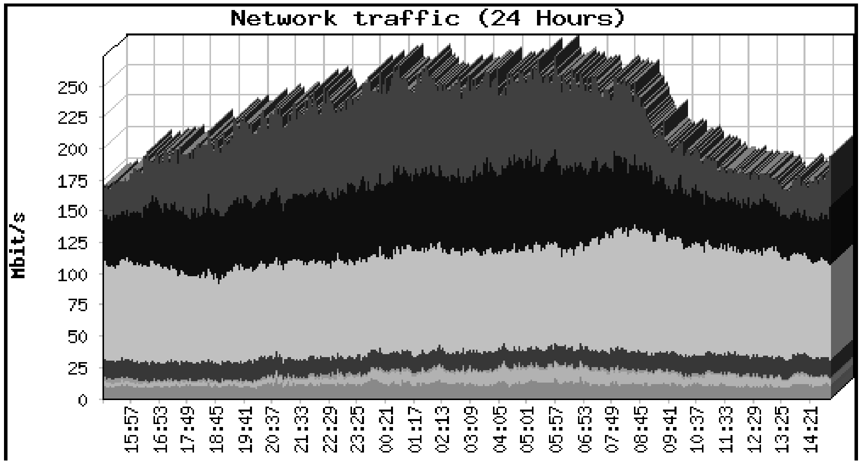
Internet Traffic Distribution (Jan. 31, 2005)

HTTP – red, Non-P2P – blue

BitTorrent – gray, eDonkey – purple

Gnutella – yellow, Other P2P – green ,

*** Source: CacheLogic http://www.slyck.com/news.php?story=649**

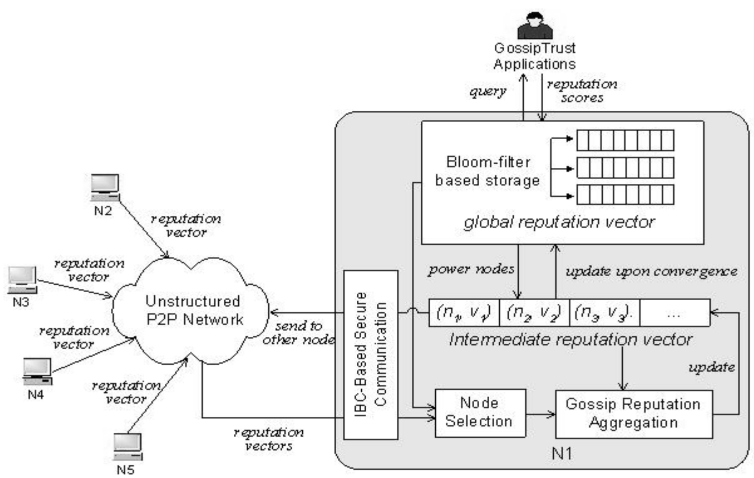


USC Challenges on P2P Systems :

- **Attribute-based naming to publish and discover objects (files) in a P2P system. Fast P2P information aggregation and dissemination (Cai and Hwang, *IEEE-TDSC* 2007)**
- **Effective reputation systems for supporting P2P applications (Zhou and Hwang, *IEEE TPDS* 2007 and *TKDE* 2008)**
- **Killer applications of P2P systems – Internet worm monitory, detection, and containment. (Security and Privacy, May 2006)**
- **Copyright protection in P2P content delivery networks (Proactive content poisoning to stop collusive piracy by Lou and Hwang, 2008)**
- **P2P Grid technology being explored by Hwang and collaborators at Chinese Academy of Science and Peking University -- The idea is to merge the advantages of both P2P and Grid technologies for web-scale services, distance education, and digital government applications.**

GossipTrust for P2P Systems

- **A Scalable, Robust and Secure reputation system for use in both structured and unstructured P2P networks**



Zhou and Hwang, IEEE-Transaction on Knowledge and Data Engineering, accepted to appear 2008

P2P Networks, Grids, and P2P Grids

Features	P2P Systems	Grids	P2P Grids
Architecture, Connectivity	Flexible topology, highly scalable, autonomous users	Static configuration with limited scalability	P2P flexibility with Grid resource sharing initiatives
Control and Resource Discovery	Distributed control, client-oriented, free in and out, and self-organizing peers	Centralized control, server or supercomputer -oriented with registered participants	Policy-based control, operating with both P2P and Grid resource management
Security, Privacy, Reliability	Distrusted peers, insecure P2P interactions, and anonymity	Guaranteed trust, more secure with federated users and accountability	Peer-layer reputation system and Grid-layer security infrastructure
Applications and Job Management	General, content delivery, file sharing, download services	Scientific computing, global problem solving, and hierarchical job management	Support desktop, Grid computing, community services, and cloud computing
Represen-tative Systems	Gnutella, Chord, CAN, Tapestry, SETI@home, etc.	TeraGrid , GriPhyN Grid, LHC Grid , e-Science, Vaga Grid	Entropia, P2P Grid, SETE@, Linger Longer

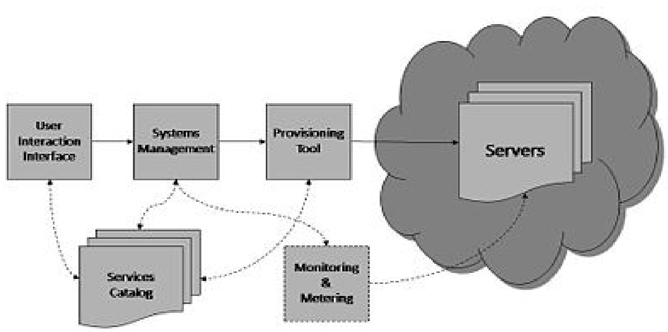
Advantages of P2P Grids over the Grids with Centralized Control

- **P2P Grid Advantages:** More efficient in the way that it broadcast its messages. System offers more scale, self-organizing data communities, and high performance data processing.
- **Security and Trust:** OGSA protocols have been partially developed under the assumption of uniform trust and reliability.
- **Connectivity:** P2P Grids typically have to deal with changing IP addresses (roaming users) and even unknown IP addresses (firewalls and nets).
- **Interactivity:** End-users are an essential element in large scale Grid computing, guiding the back-end computations dynamically.
- **Administrative Advantages :** Purely user-space based network. Require no system administrator. Easy to by-pass firewalls.

Emerging Cloud Computing

- The idea of upgrading Internet search and web-based applications with massively collected data set stored in a "cloud" somewhere over the Internet and processed at an edge network. (Edge computing).
- Need new web-based operating systems to support resource virtualization in global-scale distributed environment.
- Internet cloud is the computing equivalent of the evolution in electricity, when businesses and farmers shut down their generators and bought power instead
- Joint work among collaborators at USC, Tsinghua Univ., PKU, HUST, and CAS/ICT during Hwang's sabbatical visits of these universities in China, Spring 2008.

Architecture of Cloud Computing



- Clouds are giant clusters of computers that house immense sets of data – such as the receipts from 100 millions shoppers or troves of geological data.
- Grid technology is used to manage a cloud of Internet resources
- Virtualization of servers on a shared cluster can consolidate services
- Cloud computing applications expand rapidly as connectivity costs reduce
- Current major cloud applications are in upgraded web services, distributed data storage, raw computing, or access to specialized services.

R/D/A of Cloud Computing

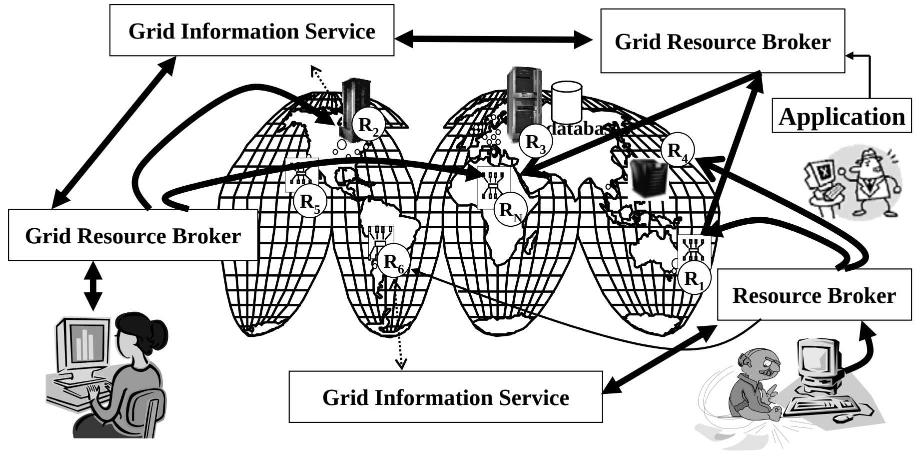
- DISC – Data-Intensive SuperComputing (Randal Bryant of CMU, 2007), opens up new research challenges
- Some Cloud/Utility Computing Applications
  - Inferring biological function from genomic sequences
  - Predicting and modeling the effects of earthquakes
  - Exploring the hugh resources in world's oceans (Neptune Project)
  - Understanding spatial and temporal patterns of brain behavior based on MRI data
- R/D towards Massively Distributed Cloud Computing
  - Hardware design and dystem software for DISC
  - New programming model in massively distributed systems
  - Resource management of massively distributed systems
  - Supporting program development for Internet clouds

Major Cloud Computing Challengers

- Major players (competitors): Google, IBM, Microsoft, Amazon, Yahoo, Red Hat, EMC, CMU, NSF, and academic research efforts at CMU, Stanford, Berkeley, Washington (where Google 101 is taught) , USC, etc.
- Cloud computing is evolved from distributed superclusters, transaction processing systems, computational Grids, and P2P network services.
- Alex Szalay and Jim Gray (*Nature* 440, March 23, 2006)

  "In the future, working with large data sets will typically mean sending the computations (programs) to the data, rather than copying the data to your workstations."

Global Resource Aggregation using Grid Computing Services



Google's New Dream on Internet Clouds

- Google's new challenge offers personalized search operations by upgrading their web-based applications and global network of low-cost servers.
- Google server infrastructure built with low-cost commodity hardware and networks : Several million processors, spread over 25+ data centers worldwide -- maintaining 20 billion documents and responding to each user query in 0.1 sec.
- Google's MapReduce and BigTable are being upgraded over Internet clouds to support web-scale search, research, and computing services -- Investing $2 billion a year in data centers Schmidt, Google's CEO, compares the data centers to cyclotrons used to advance particle physics.

Cloud Computing at IBM and Yahoo

➔ IBM wanted to deploy clouds to provide data and services to business customers.

➔ IBM teams up with Google to get a foothold in clouds, launching a pilot project in Vietnam

➔ Collaboration services get IBM clients started with "blue cloud" offerings for massive-scale computing in Spring 2008.

➔ Yahoo leads in the patron of Hadoop for parallel workload scheduling in cloud computing services

Internet Clouds : Microsoft and Amazon

- ➔ Tony Hey, VP of Microsoft, views clouds as hugh virtual laboratories, with a new generation of librarians – some of them human- curating troves of data and open them to researchers with right credentials.
- ➔ Microsoft building massive data centers in Illinois and Siberia and aiming cloud science
- ➔ Amazon offers Elastic Compute Cloud (EC2) to enable "compute" in the cloud and Simple-Storage Service (S3) to enable storage in the cloud.
- ➔ Amazon EC2 and S3 are the very first industrial sell of cloud to create a more reliable, secure, and inexpensive web service environment.

Conclusions: Clusters and Grids will continue flourishing. P2P networks and Internet Clouds are becoming very hot R/D topics in both industry and academia for many years to come.

- ➔ All massively distributed systems demand scalability, security protection, fault-tolerance, and hacker-proof operations, which are crucial to their acceptance in a digital society.
- ➔ Distributed storage systems demands hardware or software support of a single I/O space and a global file management system.
- ➔ Many innovative applications exist in personalized web services, telemedicine, distance education, P2P content delivery, and digital entertainment, etc.
- ➔ Business Grids/Clouds are under development by Google, IBM, EMC, Microsoft, Yahoo, Amazon, etc. Their acceptance could be hindered by selfish user behavior and security concerns.