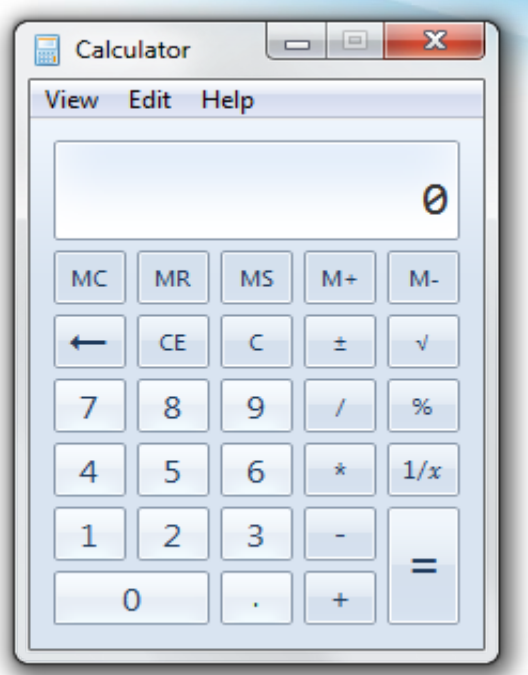
Overview of Distributed Computing

Agenda

- Trends of computing
  - Utility Computing
  - Cluster computing
  - Grid computing
- Next big thing
  - Cloud Computing

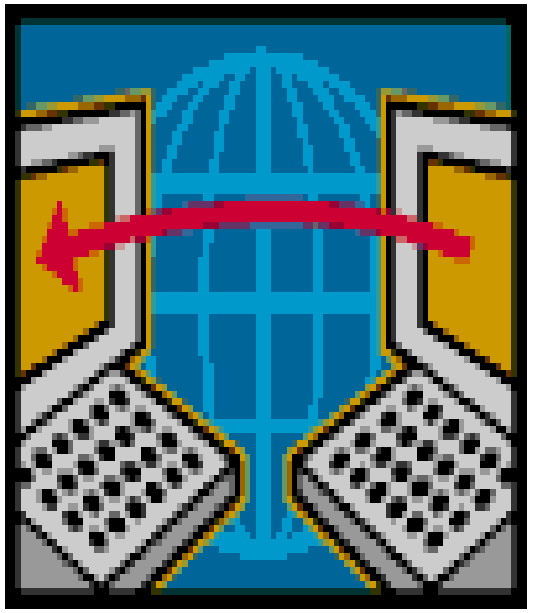
What's Computing

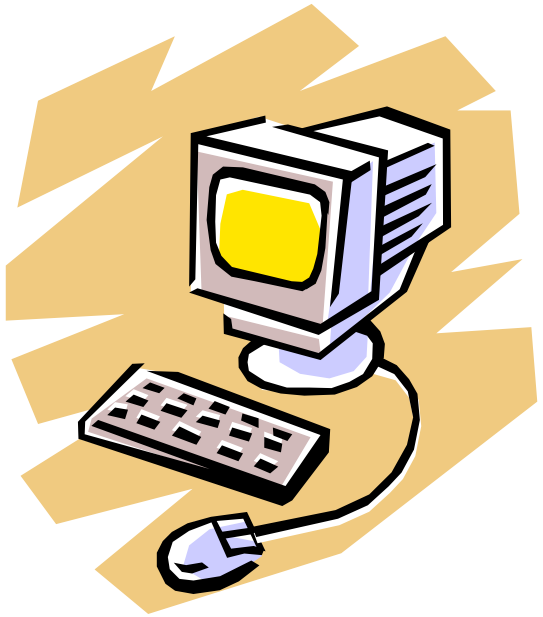
- Calculate
- Game theory
- Embattle
- Your thinking
- …



What's Computing

- In computer science
  - In a general way, we can define computing to mean any goal-oriented activity requiring, benefiting from, or creating computers.





Computing in Computer Science

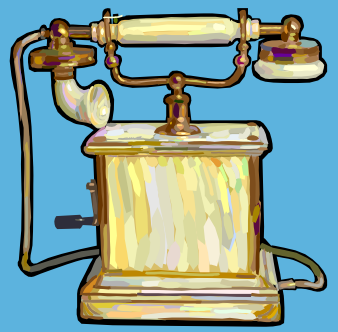
- Computing includes
  - Designing and building hardware and software systems for a wide range of purposes
  - Processing, structuring, and managing various kinds of information
  - Doing scientific studies using computers
  - Making computer systems behave intelligently
  - Creating and using communications and entertainment media
  - …

…computing may someday be organized as a public utility just as the telephone system is a public utility… The computer utility could become the basis of a new and important industry.

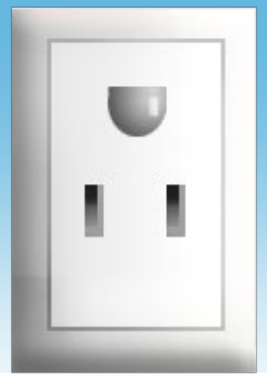
– John McCarthy (a professor of MIT) 1961.

As of now, computer networks are still in their infancy, but as they grow up and become sophisticated, we will probably see the spread of computer utilities which, like present electric and telephone utilities, will service individual homes and offices across the country.

– L. Kleinrock (one of the chief scientists of the original ARPANET project) 1969.



Computing will one day be…



The 5th Utility

The 5th Utility

- Traditional utilities
  - Water
  - Electricity
  - Natural gas
  - Telephone network

- *Computing* is being transformed to a model consisting of services that are commoditized and delivered in a manner similar to traditional utilities

➔ Utility Computing

Utility Computing

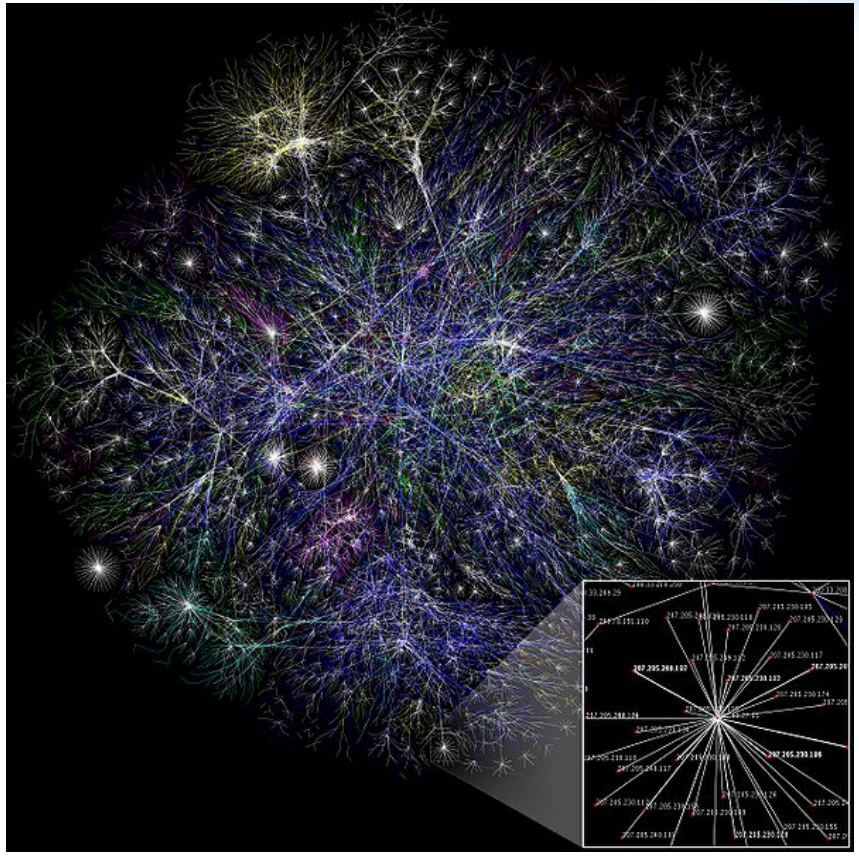
- Computing as a Utility
  - Provide the basic level of computing service that is considered essential to meet the everyday needs
  - Users access services based on their requirements without regard to where the services are hosted or how they are delivered

- Offing computing resources as a metered service

The Creation of The Internet

- The Internet is the foremost milestone

- Enables individual computers to communicate with any other computers located elsewhere in the world



Variety of Paradigms

- New computing paradigms have been proposed and adopted to edge closer toward achieving the vision of *computer utilities*

Paradigms

Utility Computing
Cluster Computing
Grid Computing
Cloud Computing
…

Attribute

Accessibility
Manageability
Autonomic
Performance
Scalability
Availability
QoS
SLA
…

The fundamental notion is…

Distributed Computing

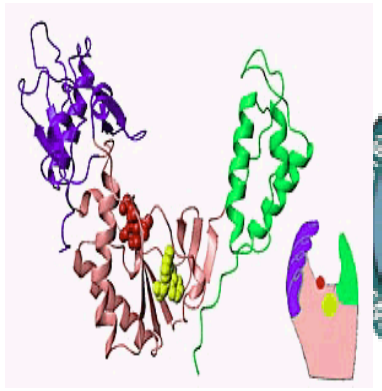
Distributed Computing

- A computer system in which several *interconnected computers* share the computing tasks assigned to the system

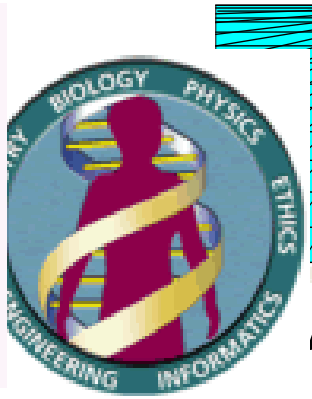
- Paradigms
  - Cluster computing
  - Grid computing
  - Cloud computing

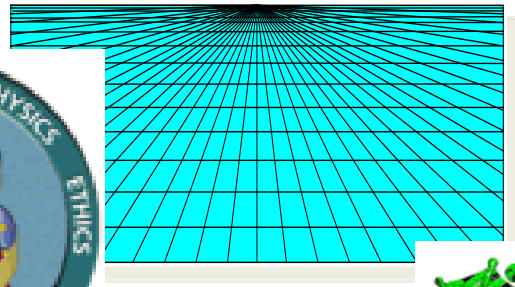
Demand for Computing Power

- Solving grand challenge applications using computer *modeling*, *simulation* and *analysis*

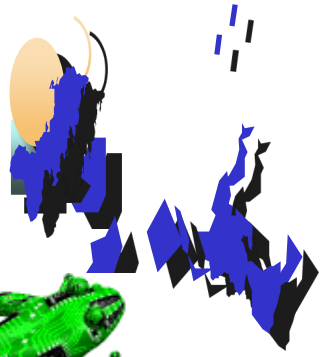


Life Sciences

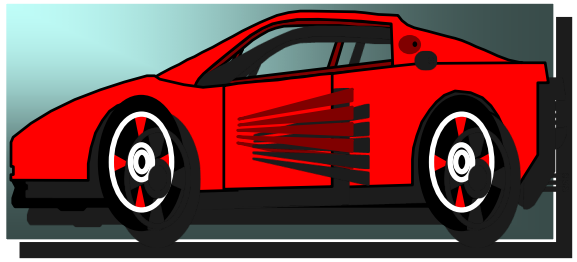




Aerospace



Internet & Ecommerce



CAD/CAM

Digital Biology

Military Applications

How to Run Applications Faster

- There are 3 ways to improve performance:
  - Work Harder
  - Work Smarter
  - Get Help

- Computer analogy
  - Using faster hardware
  - Using optimized algorithms and techniques to solve computational tasks
  - Using multiple computers to solve a particular task

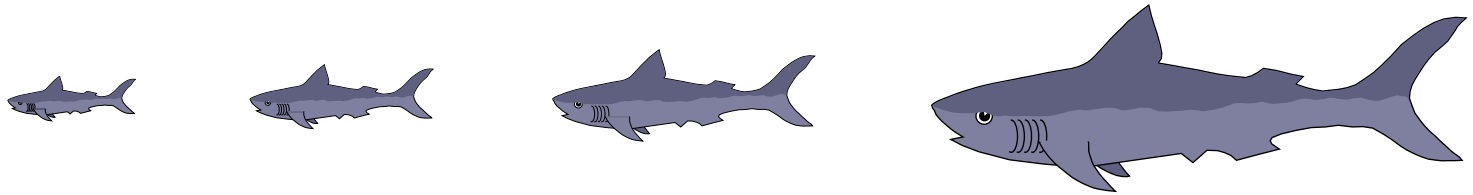
History

- In the 1980s
  - Computer performance was best improved by creating faster and more efficient processors
- In the early 1990s
  - An increasing trend to move away from expensive and specialized proprietary parallel supercomputers towards networks of workstations

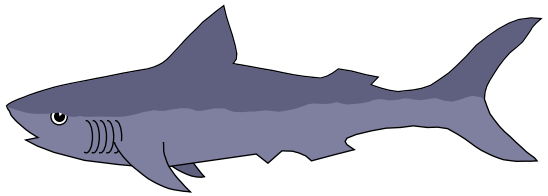
Towards Commodity Computing

- Trend of computing
  - From specialized traditional supercomputing platforms
  - To inexpensive, general purpose systems consisting of loosely coupled components built up from single or multiprocessor PCs or workstations
- Low-cost commodity supercomputing
  - Linking together two or more computers to jointly solve some computational problem
  - Providing high performance computational facilities for large-scale and grand-challenge applications

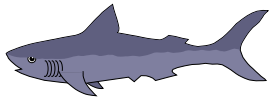
Traditional Food Chain



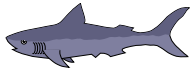
Food Chain of Computer



Mainframe



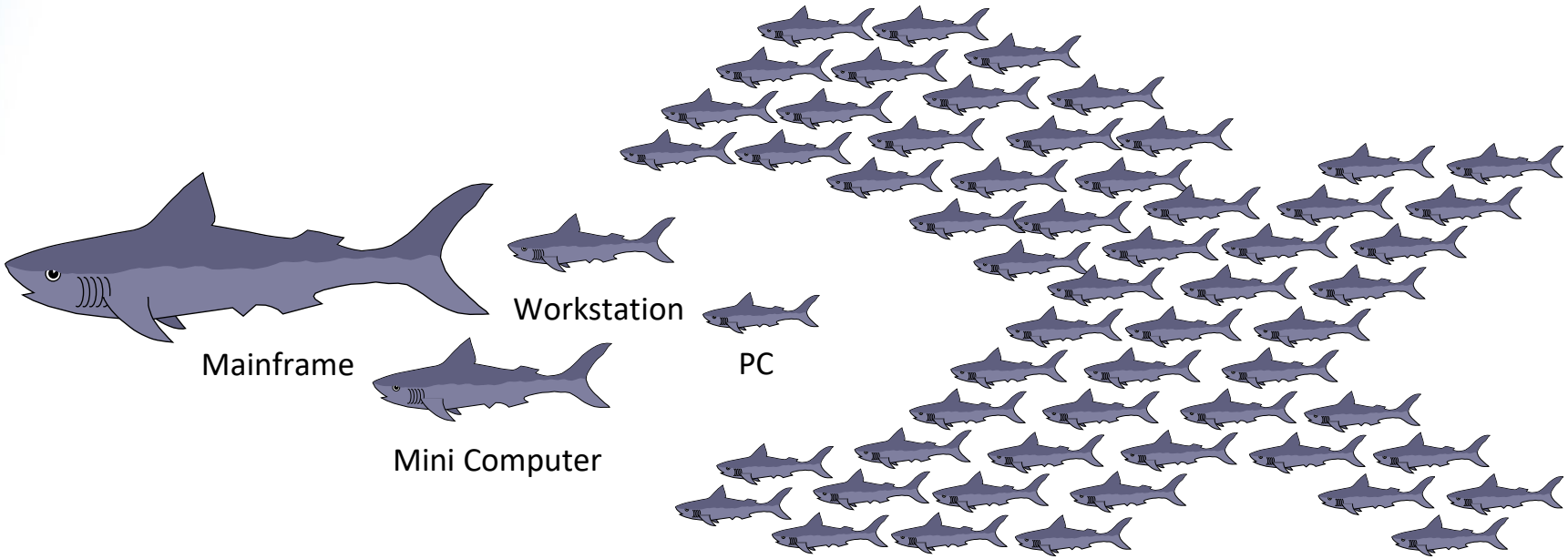
Mini Computer



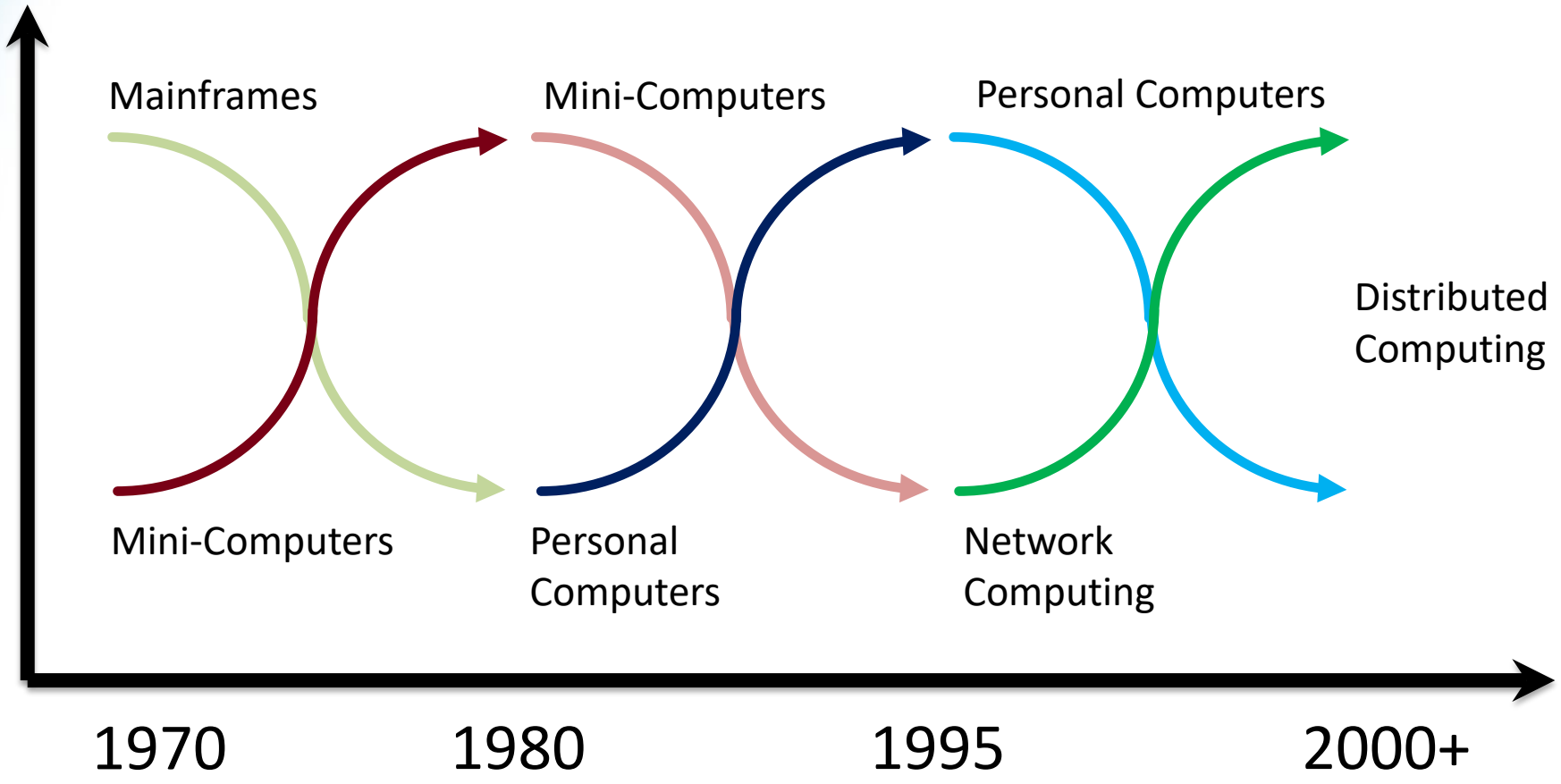
Workstation

PC

Food Chain of Distributed Computing



Rise & Fall of Computing Technologies



Cluster Computing

Grid Computing

Cloud Computing

DISTRIBUTED COMPUTING

Cluster Computing

- A cluster is a type of parallel and distributed system, which consists of a collection of *inter-connected stand-alone* computers working together as a *single* integrated computing resource

The Cluster

- A Node
  - A single or multiprocessor system with memory, I/O facilities, & OS
- A Cluster:
  - Generally two or more computers (nodes) connected together
  - In a single cabinet, or physically separated & connected via a LAN
  - Appear as a single system to users and applications
  - Provide a cost-effective way to gain features and benefits

Parallel Computing

- Parallel Computing
  - A form of computation in which many *calculations are carried out simultaneously*
  - Large problems can often be divided into smaller ones, which are then solved concurrently ("*in parallel*")

- Advantages
  - Cost efficient
  - High performance
  - Improve Utilization

Parallel Programming Models

- Parallel programming model
  - A set of software technologies to express parallel algorithms and match applications with the underlying parallel systems
- Flynn's taxonomy
- Shared-memory or Distributed-memory model

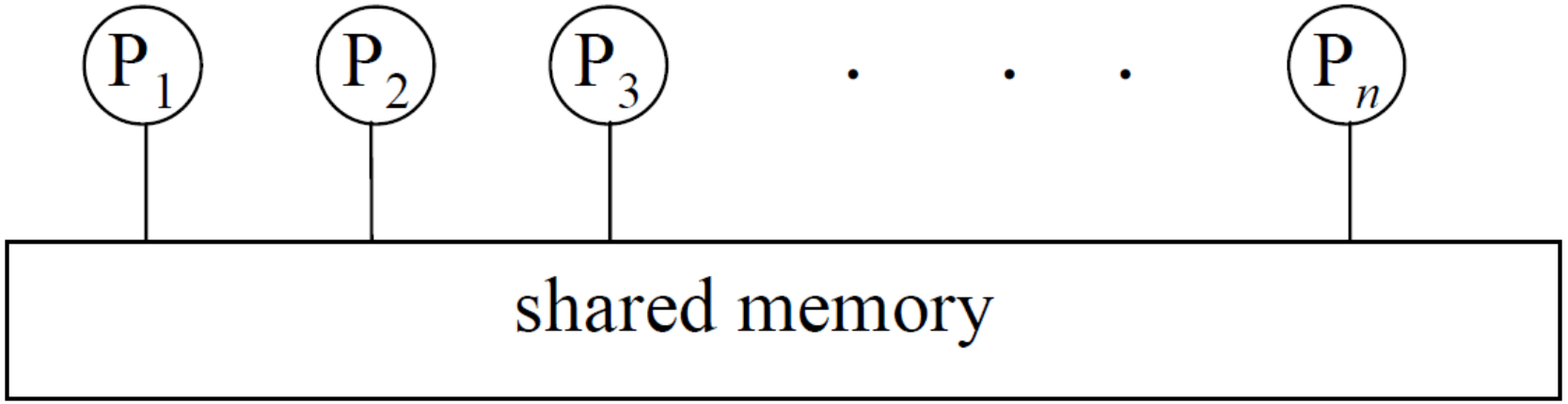
Flynn's Taxonomy

- Programs and computers are classified by
  - whether they were operating using a single set or multiple sets of instructions
  - whether or not those instructions were using a single or multiple sets of data

	Single Instruction	Multiple Instructions
Single Data	SISD	MISD
Multiple Data	SIMD	MIMD

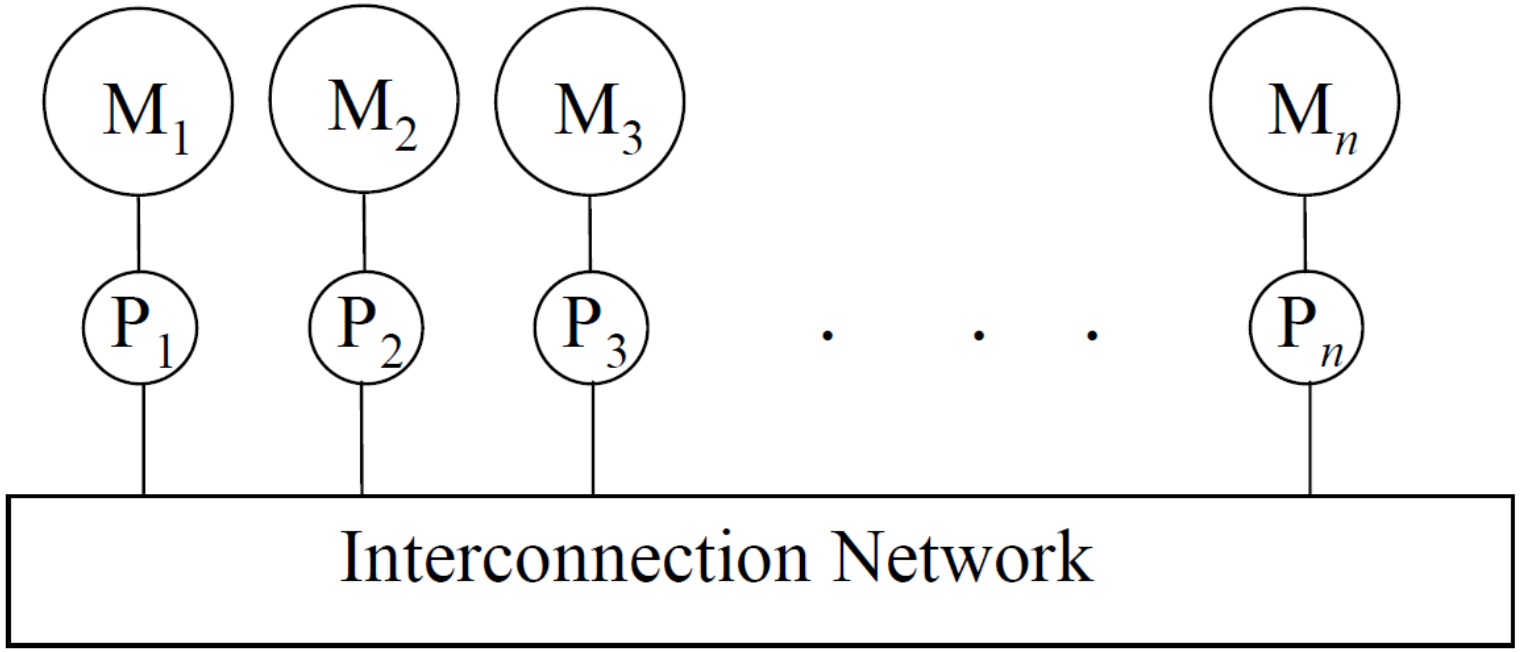
Two Basic Models

- Shared memory model
  - Memory can be simultaneously accessed by multiple process with an intent to provide communication among them or avoid redundant copies



Two Basic Models

- Distributed memory model
  - A multiple-processor computer system in which each processor has its own private memory
  - Computational tasks can only operate on local data, and if remote data is required, the computational task must communicate with one or more remote processors

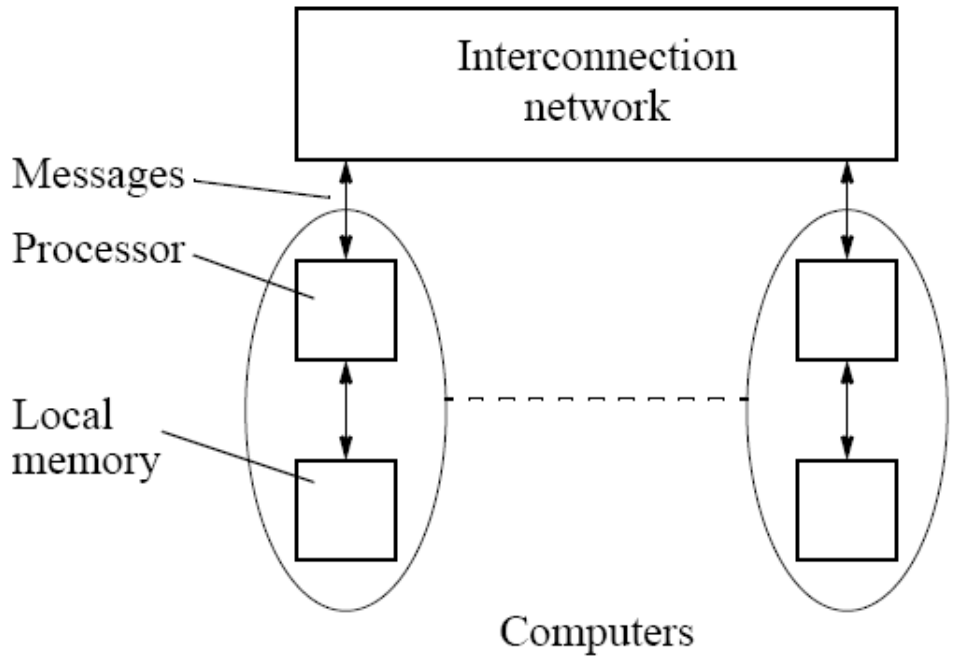


Computer Collaboration in Cluster

- How machines co-work in cluster?
  - Using MPI to inter-connect those stand-alone computers
- Massage Passing Interface (MPI)
  - A specification that allows computers communicate with each other
  - Use Message Passing to do synchronization

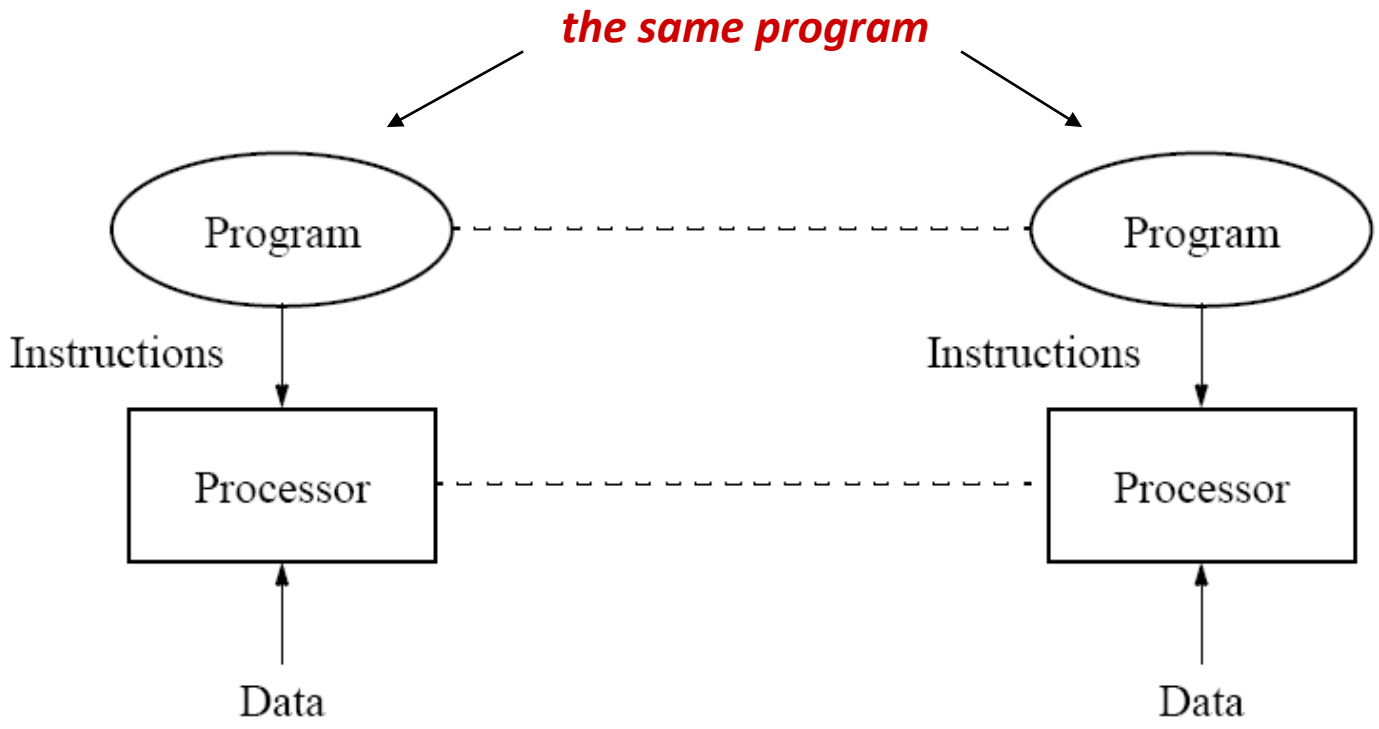
Massage Passing Interface (MPI)

- Distributed memory programming model
- Complete computers connected through an interconnection network



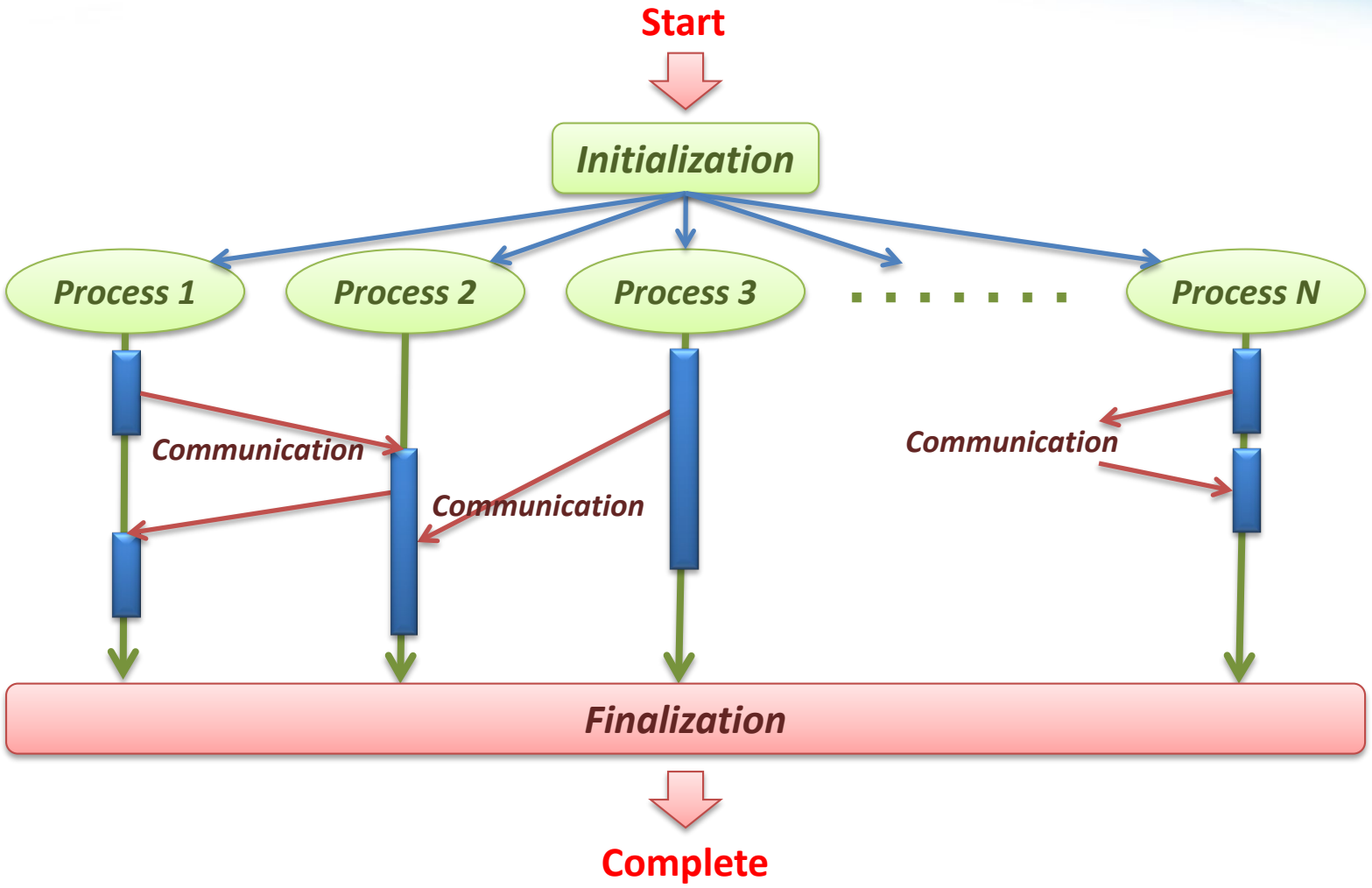
Massage Passing Interface (MPI)

- Single program with multiple data (SPMD)
  - Similar to SIMD (single instruction multiple data)



Massage Passing Interface (MPI)

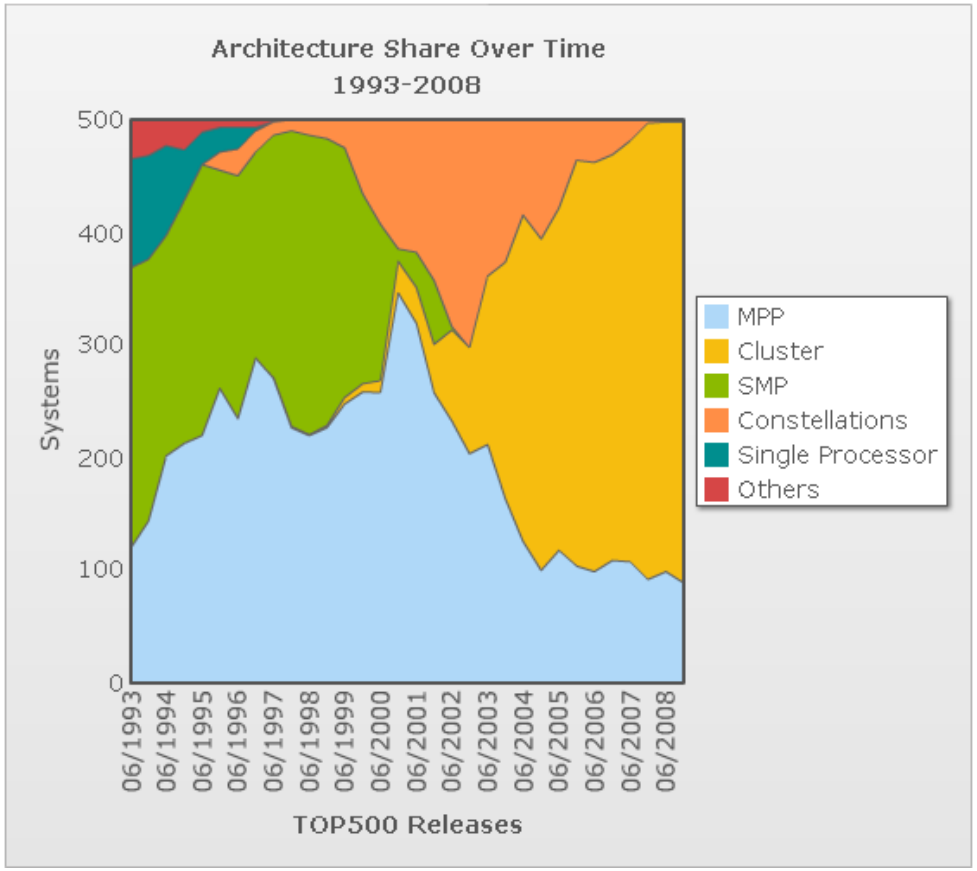
- Typical parallel execution flow :



Cluster Applications

- Cluster had become the mainstream computing system

- Apply parallel program to
  - Computing intensive
  - Data intensive
  - Timing critical system
  - … any time you are pleased



Cluster Computing

Grid Computing

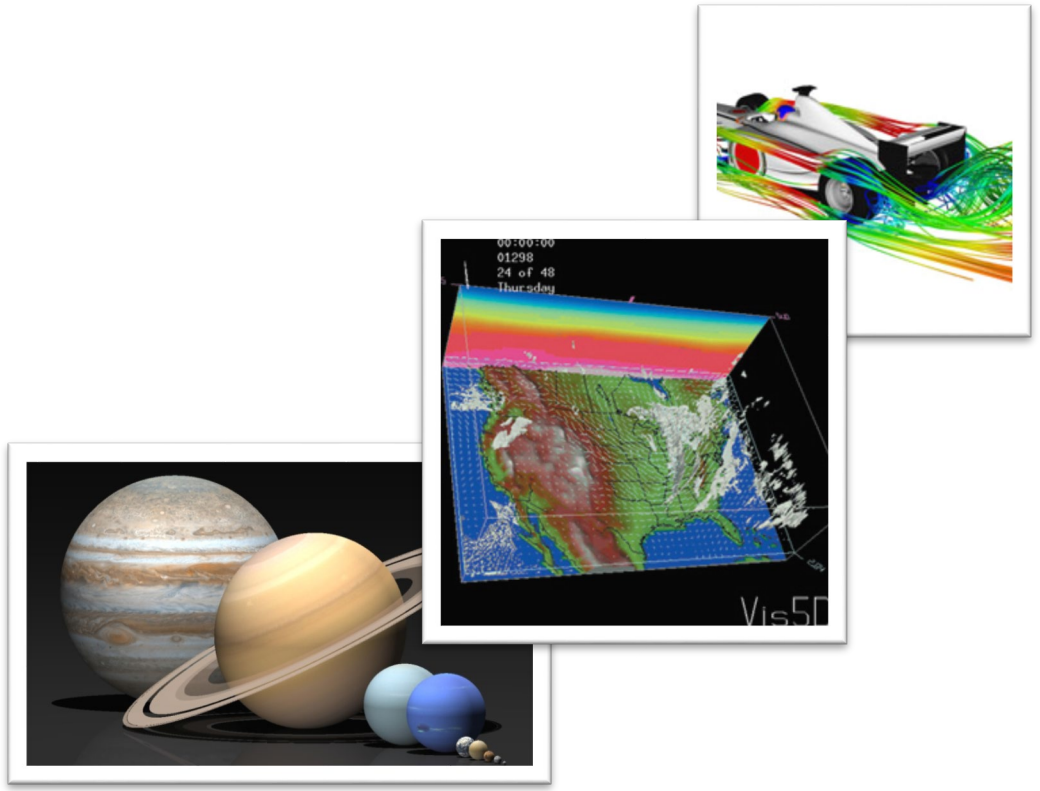
Cloud Computing

DISTRIBUTED COMPUTING

Demand for More Computing Power

- The large-scale, computational-/data-intensive scientific applications require more resources

- Applications
  - Scientific application
  - Computer animation
  - Computer games
  - Image processing
  - Data mining
  - … etc



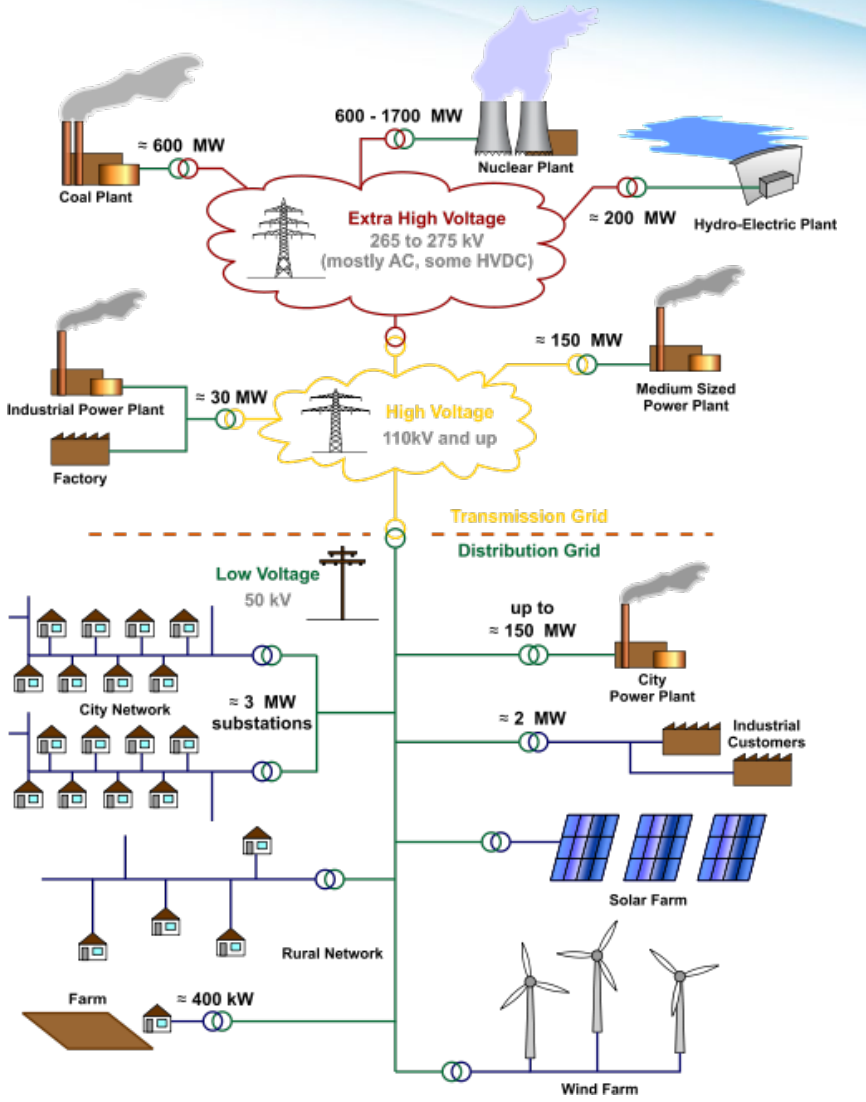
Grid Computing

- Grid computing
  - To coordinate resource sharing and problem solving in dynamic, multi-institutional virtual organization (VO)

- Provide the generic approach for a general resource-sharing framework that address the VO requirement
- Support the creation and use of computation- and data-enriched environments
- Uses open standards and interfaces

The Grid

- Grid
  - An analogy with the electric power grid around 1910
  - In the mid-1990s, this term is coined to denote a proposed *distributed computing infrastructure* for advanced science and engineering



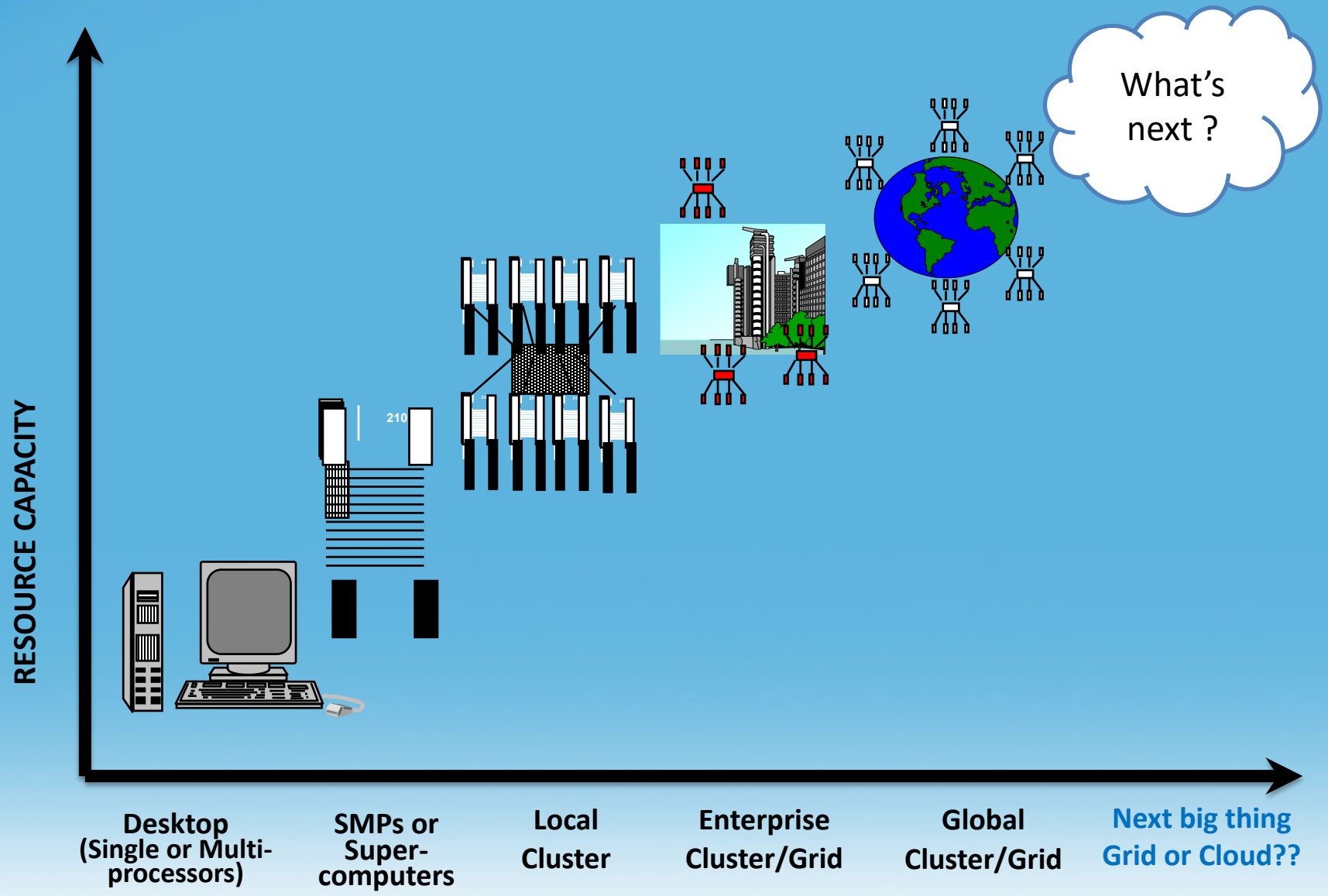
Resource Collaboration in Grids

- Virtual Organization (VO)
  - A set of individuals and/or institutions defined by such sharing rules form
    - what is shared
    - who is allowed to share
    - the conditions under which sharing occurs
- An actual organization can participate in one or more VOs by sharing some or all of its resources

Grid Environments

- Resources are heterogeneous
  - supercomputers, storage systems, data sources, and specialized devices owned by different administrative domains
- Enables the sharing, selection, and aggregation of a wide variety of geographically distributed resources
- To solve large scale resource-intensive problems in science, engineering, and commerce
- Hailed as the next revolution after the Internet and the World Wide Web

Computing Paradigm Evolution



Cluster Computing

Grid Computing

Cloud Computing – Next big thing

DISTRIBUTED COMPUTING

Long united, must divide
Long divided, must unite

Water pond

Carry bucket

Small bottle

Drinking fountain

Past

Now

Mainframe

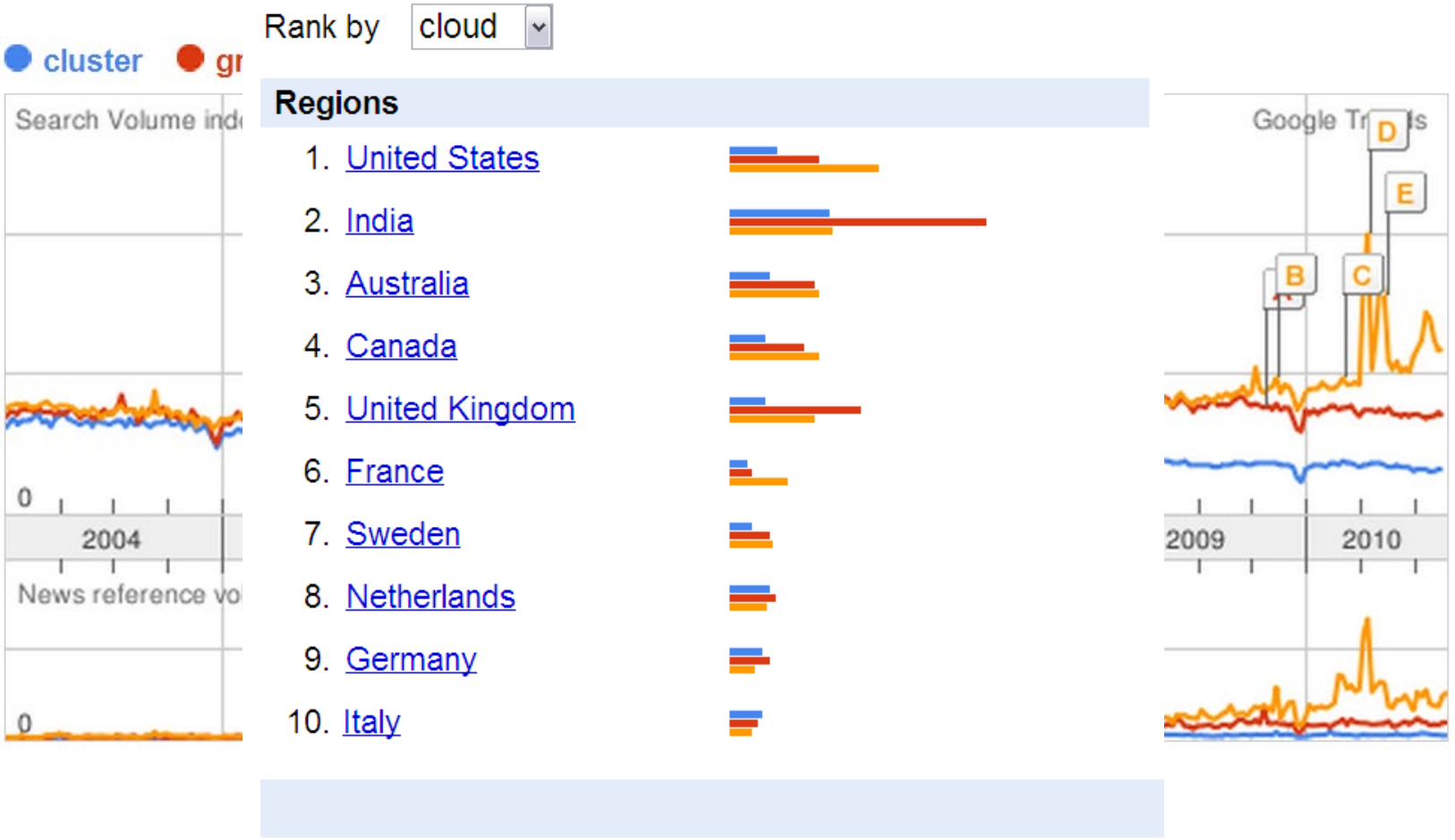
PC

Laptop & Mobile

Cloud Computing

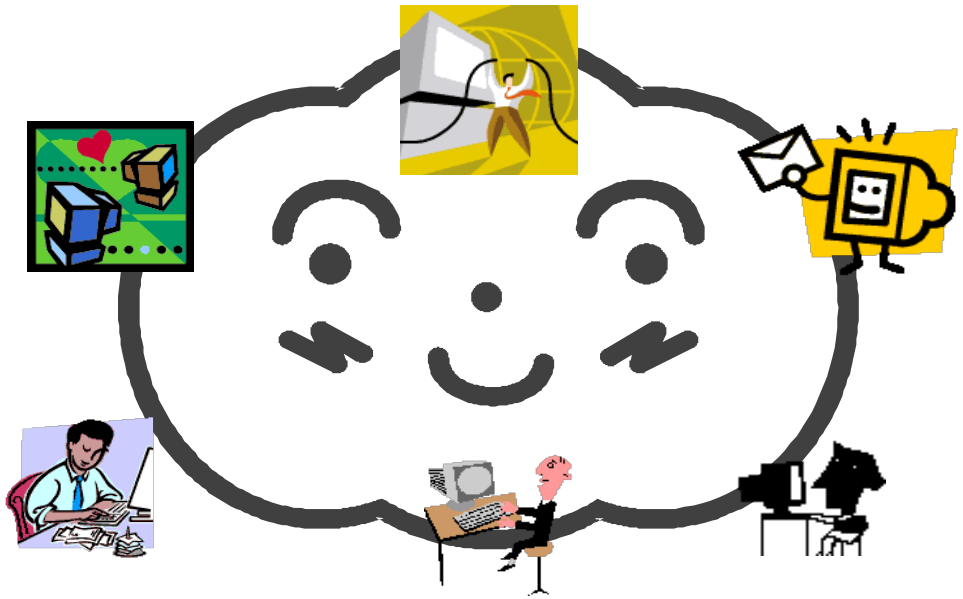
Next Big Thing

- Google search trends – all years



The "Cloud"

- The term "cloud" is often used as a metaphor for the Internet.
  - A simplified way to represent the complicated operations in the network
- Currently, the term "cloud" is further used as an abstraction of complexities
  - E.g., servers, applications, data, and heterogeneous platforms



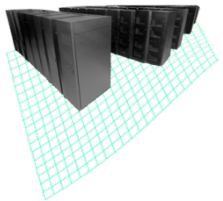
Cloud Computing – A New Paradigm

- An IT service delivered to users that provides:
  - A simple user interface that automatically provisions IT resources
  - Capacity on demand with massive scalability
  - Innovative service delivery models for applications

1990 → 2009

Grid Computing

- Solving large problems with parallel computing



Utility Computing

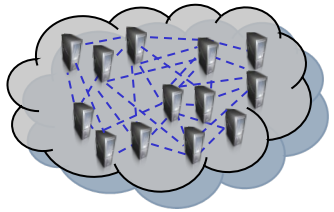
- Offering computing resources as a metered service

Software as a Service

- Network-based subscriptions to applications

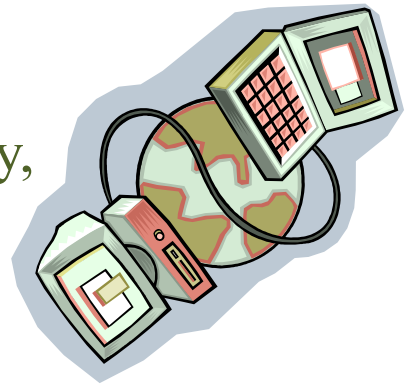
Cloud Computing

- Anytime, anywhere access to resources delivered dynamically as a service



Cloud Computing in Mathematics

- 1
  - One single integrated environment
  - A collection pool of resources and services
- 0
  - Zero management
  - Automatic management and resilience of resource or service up/down/fail
- ∞
  - Endless possibility
  - Scalability, Availability, Accessibility, Manageability, Performance

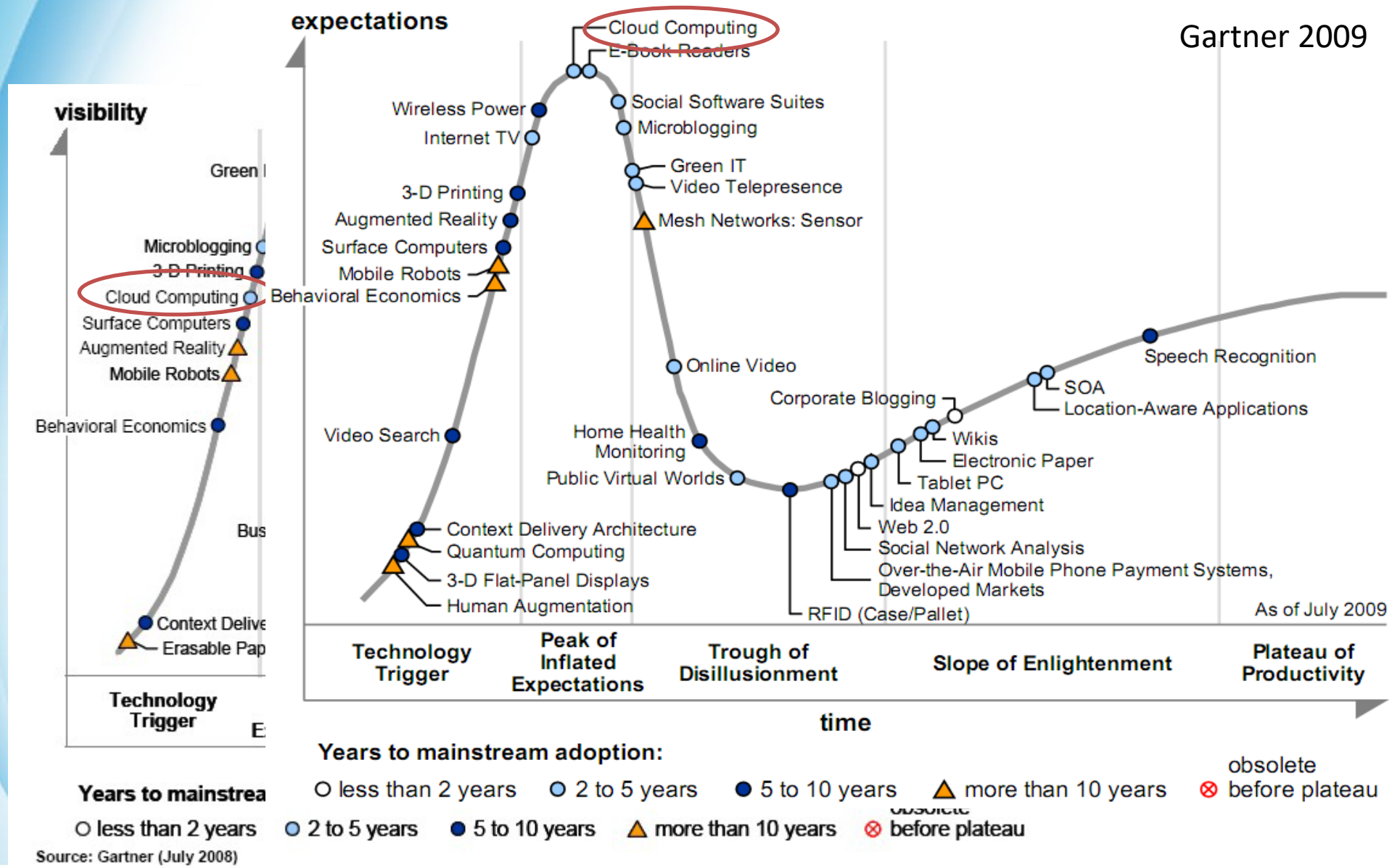


Cloud Computing in IT

- An acquisition and delivery model of IT resources
  - Help improve business *performance* and control the *costs* of delivering IT resources to the organization
- From a user perspective
  - Provides a means of acquiring computing services via the internet while making the technology beyond the user device almost *invisible*
- From an organization perspective
  - Delivers services for consumer and business needs in a simplified way, *providing unbounded scale* and *differentiated quality of service* to foster rapid innovation and decision making

Emerging Technologies Hype Cycle

Gartner 2009



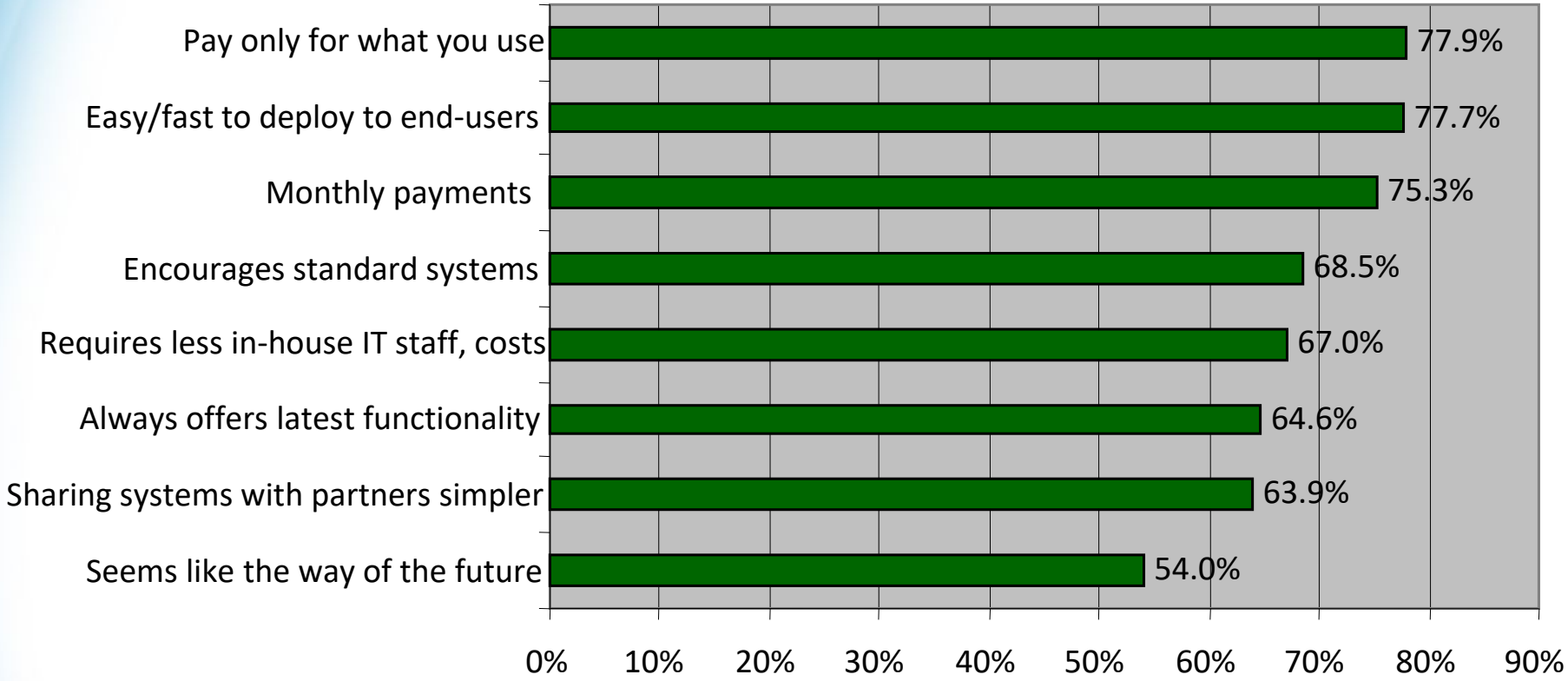
Emerging Technologies Priority Matrix

benefit	years to mainstream adoption			
	less than 2 years	2 to 5 years	5 to 10 years	more than 10 years
transformational	Web 2.0	Cloud Computing Internet TV Public Virtual Worlds SOA	3-D Printing Context Delivery Architecture RFID (Case/Pallet)	Human Augmentation Mobile Robots Quantum Computing
high		E-Book Readers Electronic Paper Green IT Location-Aware Applications Online Video Social Network Analysis Social Software Suites	Augmented Reality Home Health Monitoring Wireless Power	Behavioral Economics Mesh Networks: Sensor
moderate	Corporate Blogging	Idea Management Microblogging Over-the-Air Mobile Phone Payment Systems, Developed Markets Tablet PC Video Telepresence Wikis	3-D Flat-Panel Displays Speech Recognition Surface Computers Video Search	
low				

Gartner 2009

Benefits from Cloud Computing

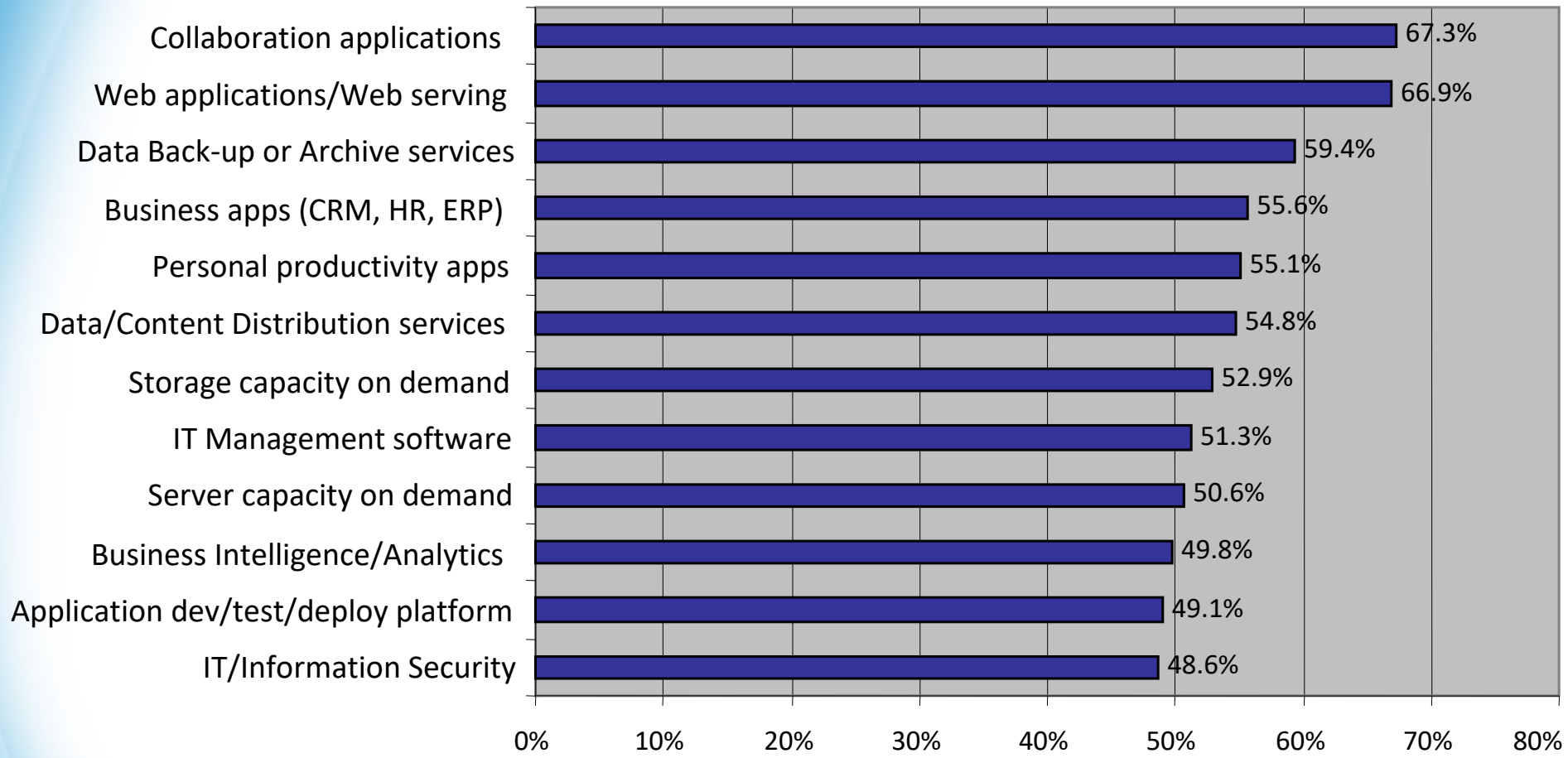
Q: Rate the benefits commonly ascribed to the 'cloud'/on-demand model



Source: IDC Enterprise Panel, 3Q09, n = 263, September 2009

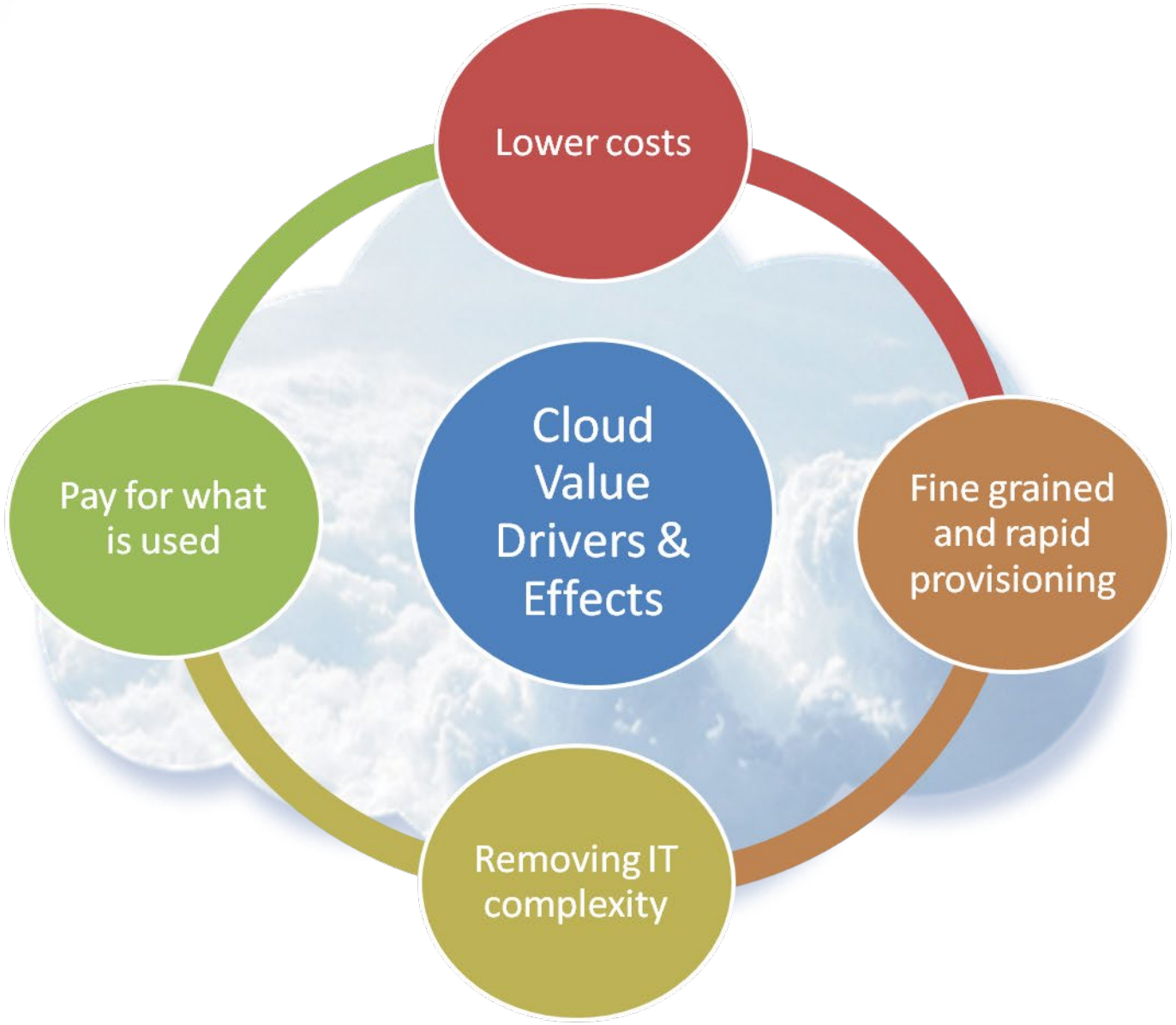
Adoption of Cloud Computing

Q: Rate your likelihood to pursue the cloud model for the following



Source: IDC Enterprise Panel, 3Q09, n = 263, September 2009

Cloud Value Drivers & Effects



Lower IT operating and capital costs

Lower costs

- The leading value driver is lower IT operating and capital costs

- Lower IT cost
  - Optimize, consolidate and reduce servers
  - Improve capital utilization & quality
  - Reduce energy costs
- Enables implementation of ideas or applications
  - Cheaper pilots encourages experimentation and innovation
  - Reduction in the costs for large, compute and storage intensive applications
  - A Pay for Use model and the lower cloud costs of large computing and storage resources

Fine grained and rapid provisioning

Fine grained and rapid provisioning

- Fine grained IT services with very rapid provisioning change the way IT can acquire capacity

	Traditional IT	Cloud
Servers	Today buy large capacities using multi-year leases/ capital	With cloud capacity on demand, pay-as-you-go
Software	Today multi-year Software Licenses by seat	With cloud SaaS model, pay by the month
Infrastructure capacity in very small increments	Traditional IT capacities come in large increments with up-front capital costs	Fine grained cloud services allow capacity to be obtained on just what is needed then and on a pay-as-you-go basis
Rapid provisioning and scaling up or down easily	Today routine provisioning 2 to 3 weeks	With cloud provisioning in minutes to hours

Removing IT complexity

Removing IT complexity

- Removing IT complexity from end users

- End users can easy to access services without worrying about technical details
  - Acquire computing services via the Internet
    - using web-based user interface
  - Cloud enhances user experience through faster and richer cloud services

Pay for what is used

Pay for what is used

- Cloud pricing models based on paying for what is used

- Avoid the upfront cost for infrastructure and the financial risk
  - Cloud pricing models allow pay for what is used
  - Scare capital needed to invest in infrastructure is replaced with an operating expense

Typical IT budget models :

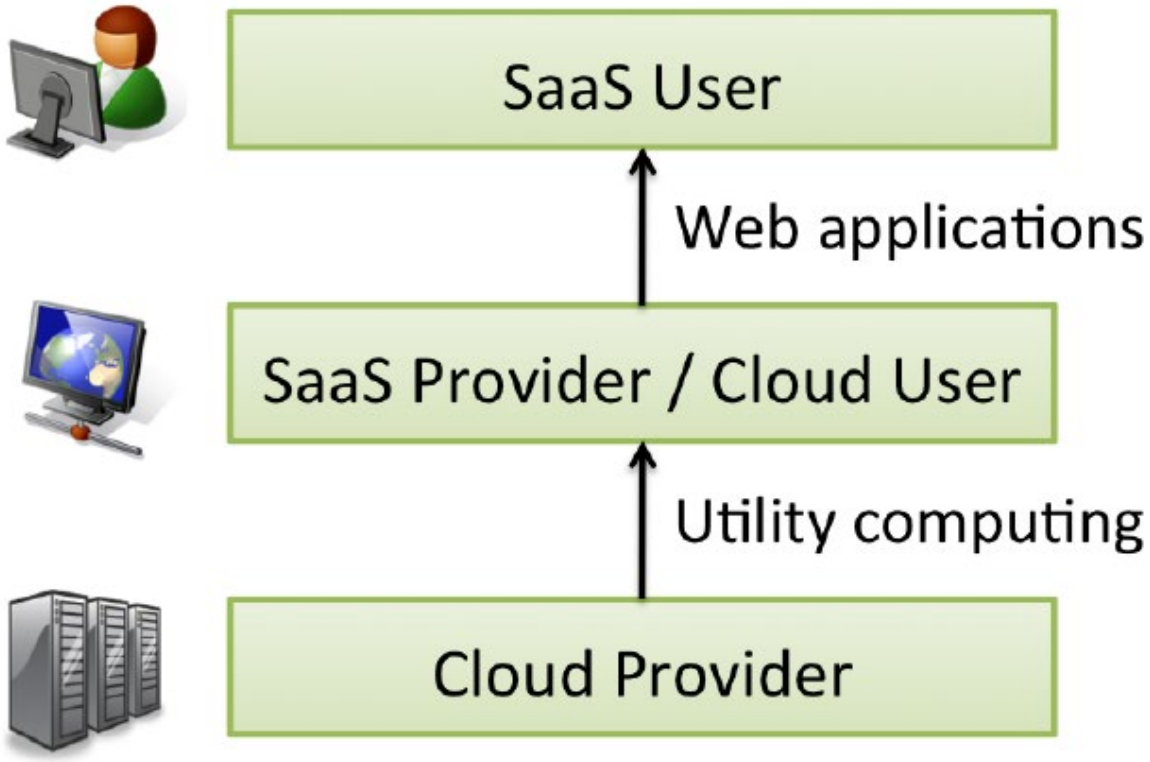
- Applications: 35%
- Infrastructure: 60%
- Other: 5%

Cloud Computing Players

more and more…

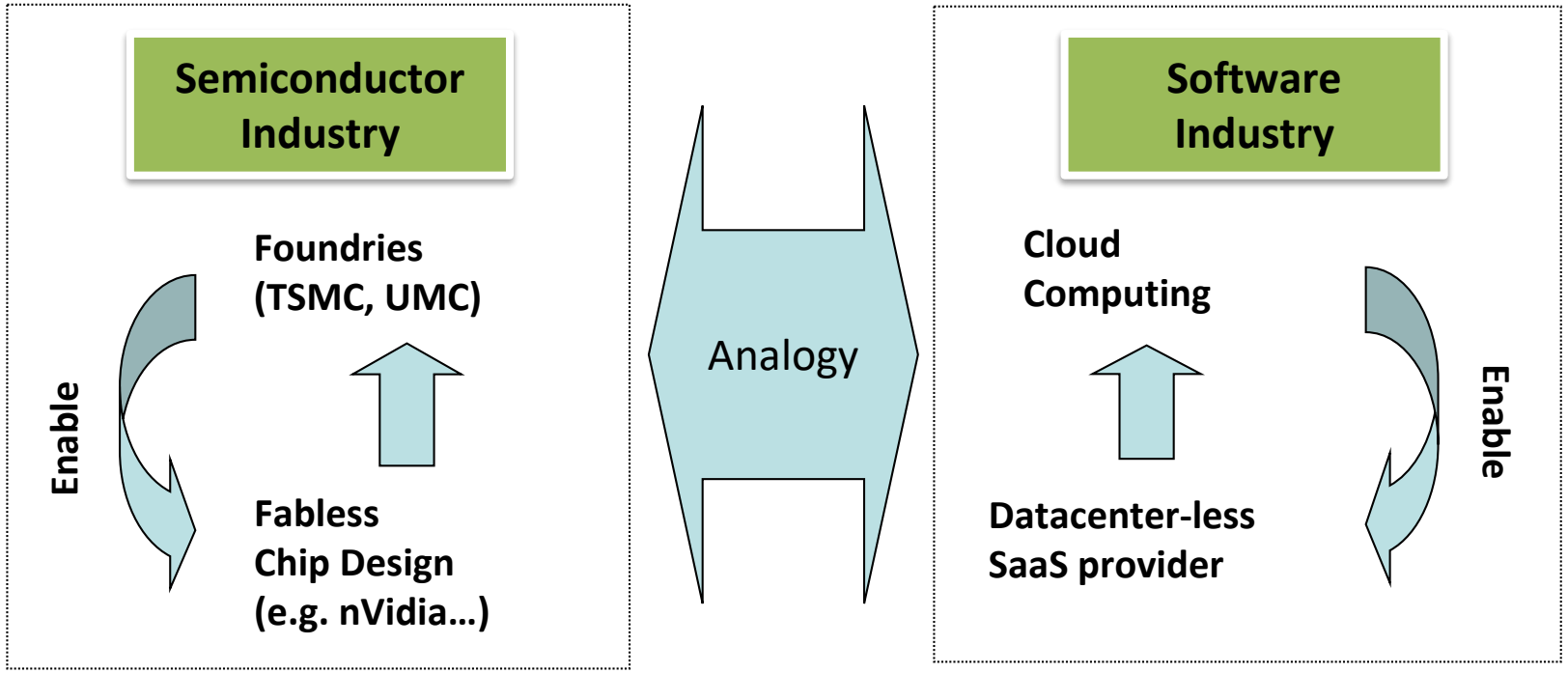
Players : Users (Consumers) or Providers

- Players can act as Users or Providers in the Cloud Ecosystem



Cloud Computing Economy

- Enable SaaS providers that do not own IT infrastructure



Industry Chain

Mobile Phones

- Upstream – IC design
  - Media Tech, Morning Star, etc.
- Midstream – foundry
  - TSMC, UMC, etc.
- Downstream – production
  - Asus, HTC, etc.
- End Users
  - Smart phone

Cloud Services

- Upstream – IaaS provider
  - Amazon EC2, CHT hicloud, ect.
- Midstream – PaaS provider
  - Google GAE, Windows Azure, etc.
- Downstream – SaaS provider
  - Saleforce.com, Google docs, etc.
- End Users
  - Thin client

Summary

- Long united, must divide; long divided, must unite
- Modern IT require
  - To increase capacity or add capabilities to their infrastructure dynamically
    - without investing money in the purchase of new infrastructure
  - All the while
    - without needing to conduct training for new personnel
    - without the need for licensing new software
- Given a solution to the above mentioned demands
  - Cloud computing is the next big thing in the world of IT

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