Advanced Operating Systems
Lecture notes

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Administration

- Class Home Page

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  - Announcements
  - Lecture Slides

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Administrative Information

- Text
  - Distributed Systems: Concepts and Design (5th edition)
    - By Coulouris, Dollimore, and Kindberg
  - Modern Operating System (5th edition)
    - By Anderws Tanenbaum and Herbert Bos

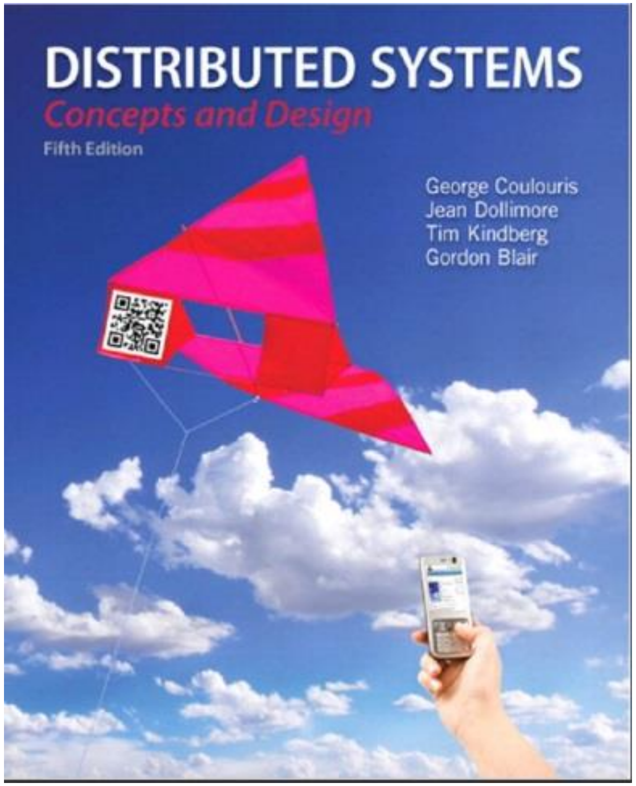
Syllabus

- CHARACTERIZATION OF DISTRIBUTED SYSTEMS
- SYSTEM MODELS
- Multiple Processor Systems
- INTERPROCESS COMMUNICATION
- REMOTE INVOCATION
- INDIRECT COMMUNICATION
- Security
- DISTRIBUTED FILE SYSTEMS
- TIME AND GLOBAL STATES
- COORDINATION AND AGREEMENT
- TRANSACTIONS AND CONCURRENCY CONTROL
- DISTRIBUTED TRANSACTIONS

Administrative Information

- Grading
  - 35%: Mid-Term
  - 35%: Final Exam
  - 30%: Projects, Seminar and Report

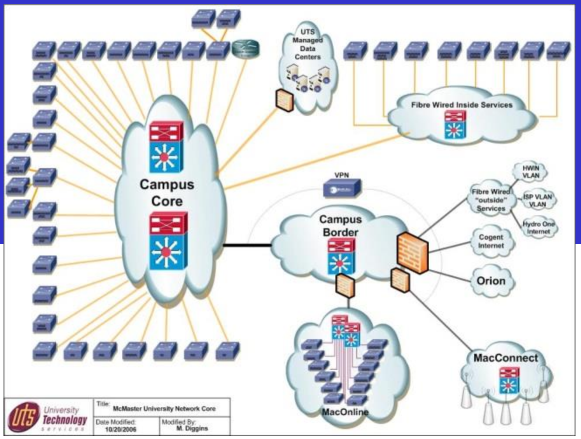
Introduction to Distributed Systems and Characterisation



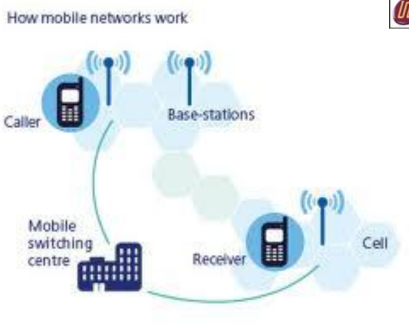
Presentation Outline

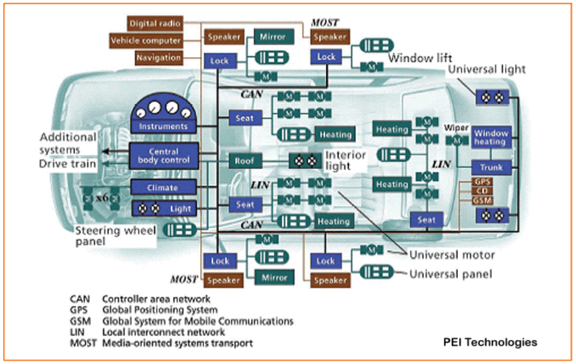
- Introduction
- Defining Distributed Systems
- Characteristics of Distributed Systems
- Example Distributed Systems
- Challenges of Distributed Systems
- Summary

Introduction

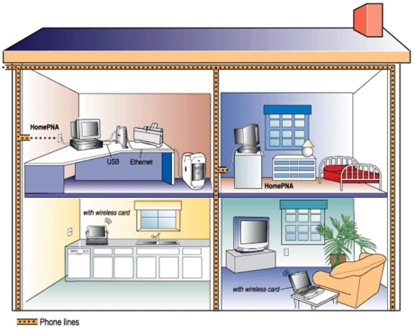


- Networks of computers are everywhere!
  - Mobile phone networks
  - Corporate networks
  - Factory networks
  - Campus networks
  - Home networks
  - In-car networks
  - On board networks in planes and trains





- The aims of this course are :
  - to explain the characteristics of networked computers that impact system designers and implementers
  - to present the main concepts and techniques that have been developed to help in the tasks of designing and implementing systems and applications that are based on them (networks).



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Defining Distributed Systems

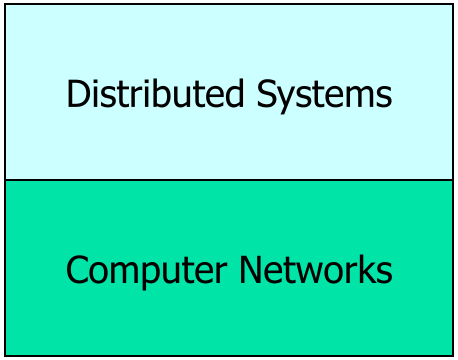
- *“A system in which hardware or software components located at networked computers communicate and coordinate their actions only by message passing.”* [Coulouris]
- *“A distributed system is a collection of independent computers that appear to the users of the system as a single computer.”* [Tanenbaum]
- *"A distributed system is one on which I cannot get any work done because some machine I have never heard of has crashed.“[Leslie Lampart]*

Defining Distributed Systems

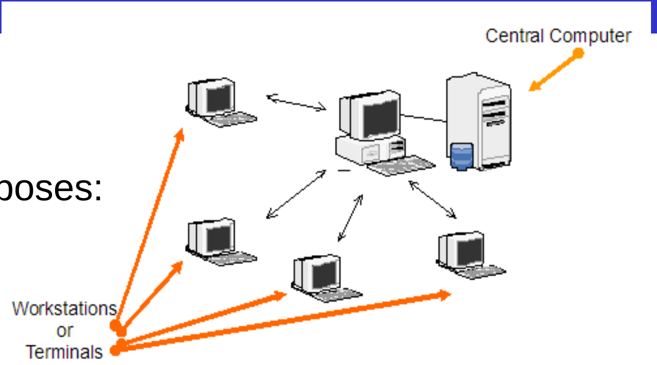
- Example Distributed Systems:
  - Cluster:
    - *"A type of parallel or distributed processing system, which consists of a collection of interconnected stand-alone computers cooperatively working together as a single, integrated computing resource" [Buyya].*
  - Cloud:
    - *"a type of parallel and distributed system consisting of a collection of interconnected and **virtualised computers** that are dynamically provisioned and presented as one or more unified computing resources based on service-level agreements established through negotiation between the service provider and consumers" [Buyya].*
  - Grid can consist of many clusters interconnected and shared.

Networks vs. Distributed Systems

- Networks: A media for interconnecting local and wide area computers and exchange messages based on protocols. Network entities are visible and they are explicitly addressed (IP address).
- Distributed System: existence of multiple autonomous computers is transparent
- However,
  - many problems (e.g., openness, reliability) in common, but at different levels.
    - Networks focuses on packets, routing, etc., whereas distributed systems focus on applications.
    - Every distributed system relies on services provided by a computer network.



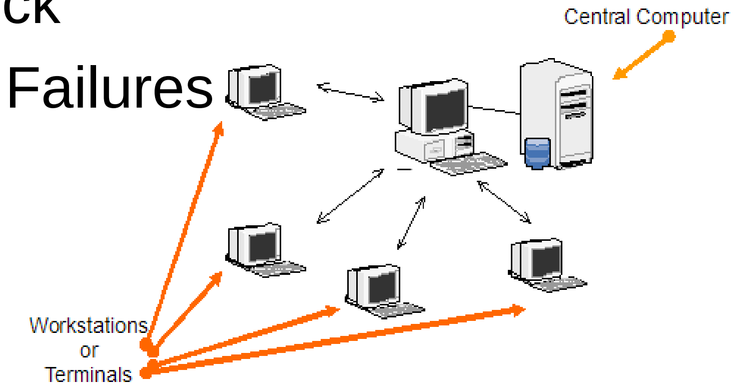
Reasons for Distributed Systems



- Functional Separation:
  - Existence of computers with different capabilities and purposes:
    - Clients and Servers
    - Data collection and data processing
- Inherent distribution:
  - Information:
    - Different information is created and maintained by different people (e.g., Web pages)
- Power imbalance and load variation:
  - Distribute computational load among different computers.
- Reliability:
  - Long term preservation and data backup (replication) at different locations.
- Economies:
  - Sharing a printer by many users and reduce the cost of ownership.

Consequences of Distributed Systems

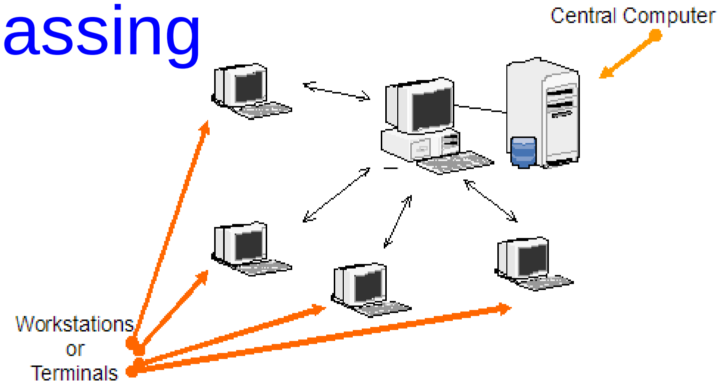
- Computers in distributed systems may be on separate continents, in the same building, or the same room. DSs have the following consequences:
  - Concurrency – each system is autonomous.
    - Carry out tasks independently
    - Tasks coordinate their actions by exchanging messages.
  - Heterogeneity
  - No global clock
  - Independent Failures



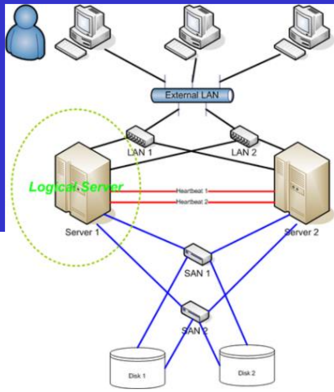
Grid Computing
Grid Computing is all about sharing, aggregating hosting, offering service across the world for the benefits of man kind.
"grid is need is a grid indeed"

Characteristics of Distributed Systems

- Parallel activities
  - Autonomous components executing concurrent tasks
- Communication via message passing
  - No shared memory
- Resource sharing
  - Printer, database, other services
- No global state
  - No single process can have knowledge of the current global state of the system
- No global clock
  - Only limited precision for processes to synchronize their clocks

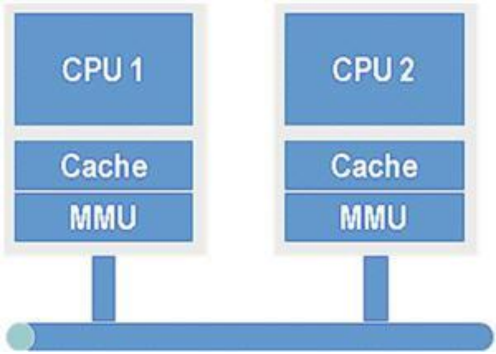


Goals of Distributed Systems



- Connecting Users and Resources
  - Ultimately we want out system made widely avail.
- Transparency
  - User should be unaware of complexity behind system, access it almost like local system.
- Openness
  - Use standards (like http/ftp, w3 standards) so anyone can interface with, understand and extend your system
- Scalability
  - Having near linear scaling is the ultimate goal, add capacity to deal with growth
- Enhanced Availability

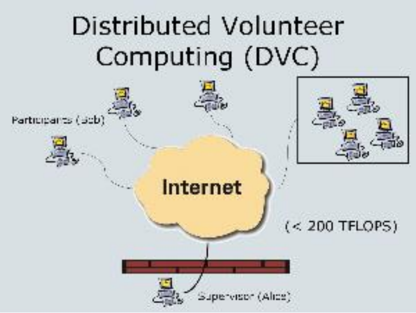
Differentiation with parallel systems



- Multiprocessor systems
  - Shared memory
  - Bus-based interconnection network or even switched based
  - E.g. SMPs (symmetric multiprocessors) with two or more CPUs

- Multicomputer systems / Clusters
  - No shared memory
  - Homogeneous in hard- and software
    - Massively Parallel Processors (MPP)
      - Tightly coupled high-speed network
    - PC/Workstation clusters
      - High-speed networks/switches-based connection.

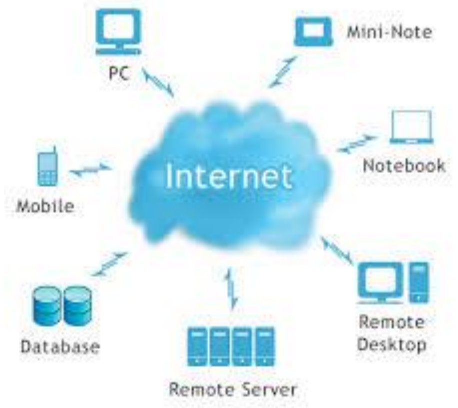
Differentiation with parallel systems is blurring



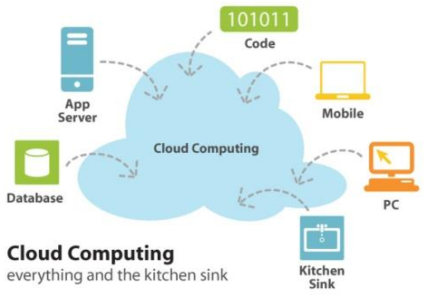
- Extensibility of clusters leads to heterogeneity
  - Adding additional nodes as requirements grow
- Extending clusters to include user desktops by harnessing their idle resources
  - E.g., SETI@Home, Folding@Home
- Leading to the rapid convergence of various concepts of parallel and distributed systems

Examples of Distributed Systems

- They (DS) are based on familiar and widely used computer networks:
  - Internet
  - Intranets, and
  - Wireless networks

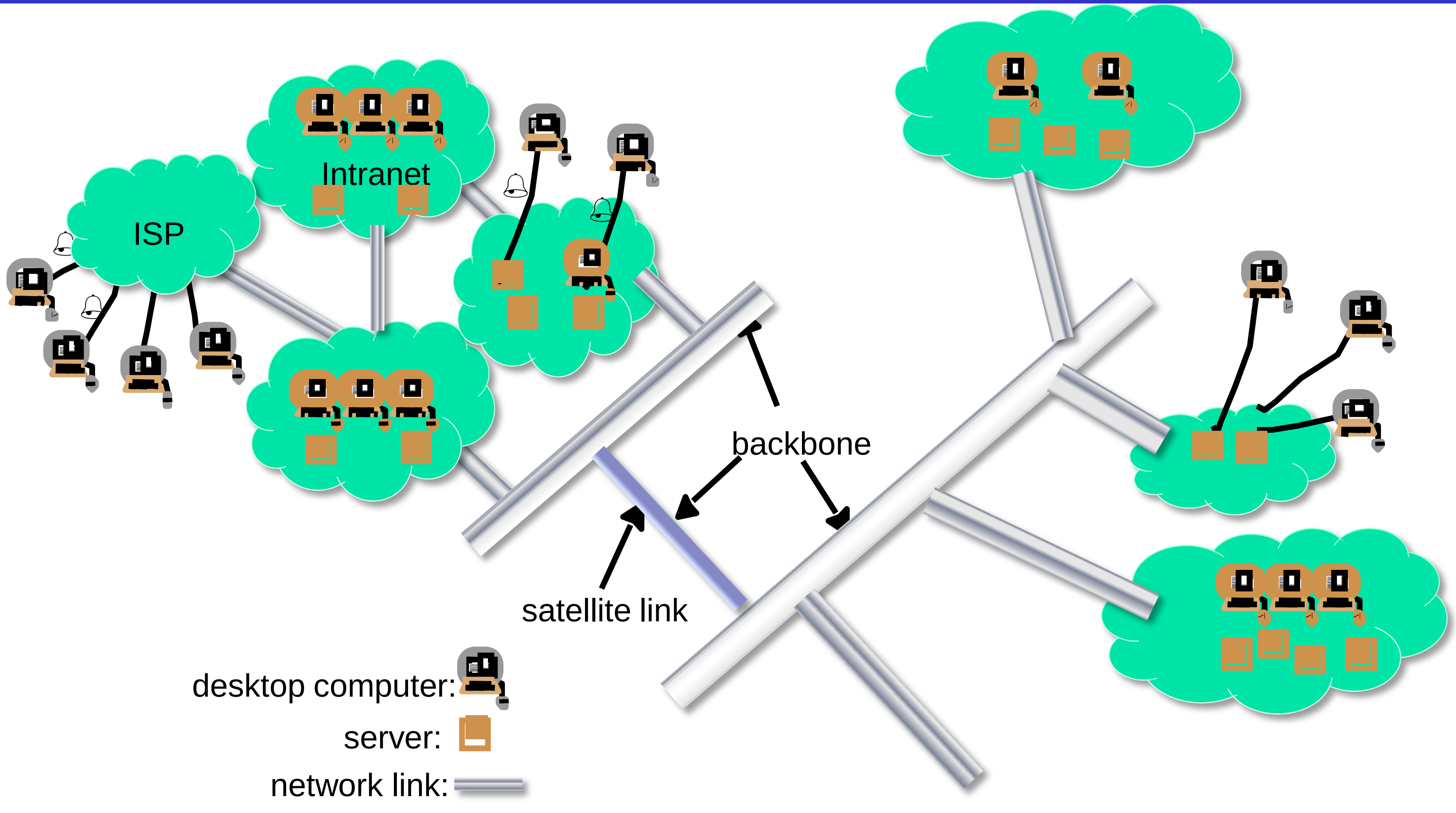


- Example DS:
  - Web (and many of its applications like Facebook)
  - Data Centers and Clouds
  - Wide area storage systems
  - Banking Systems



A typical portion of the Internet and its services:

Multimedia services providing access to music, radio, TV channels, and video conferencing supporting several users.



Intranet

ISP

backbone

satellite link

desktop computer:

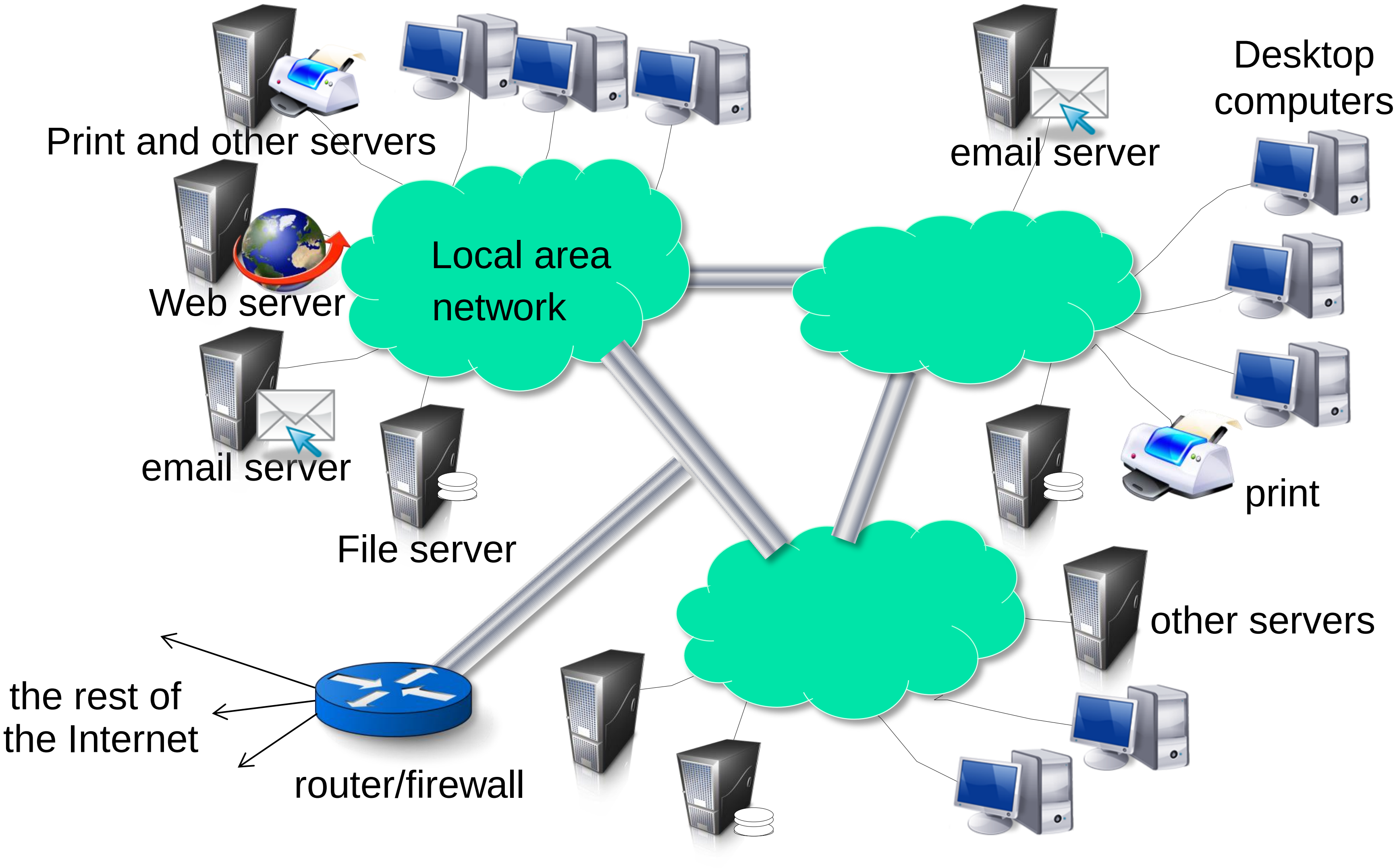
server:

network link:

- The Internet is a vast collection of computer networks of many different types and hosts various types of services.

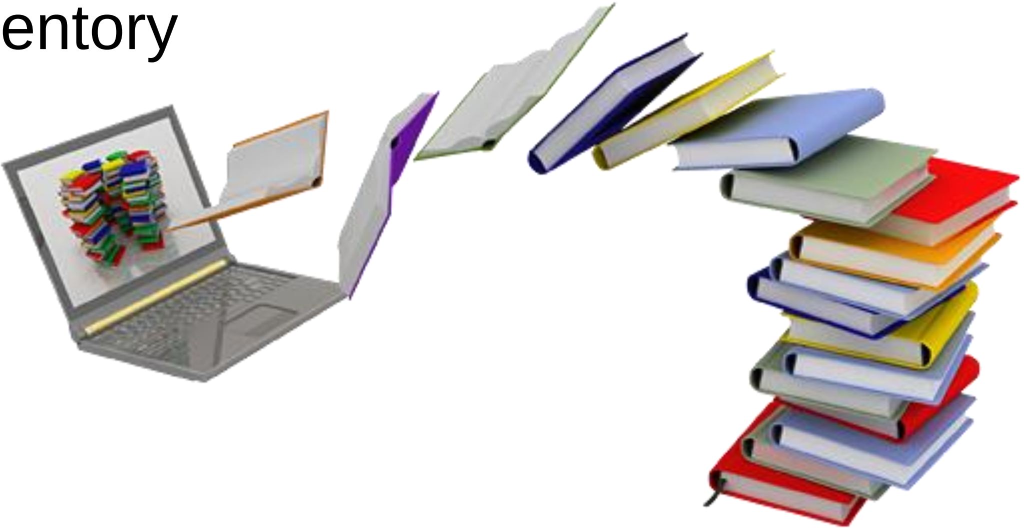
A typical Intranet:

A portion of Internet that is separately administered & supports internal sharing of resources (file/storage systems and printers)



Business Example and Challenges

- Online bookstore (e.g. in the World Wide Web)
  - Customers can connect their computer to your computer (web server):
    - Browse your inventory
    - Place orders
    - …



This example has been adapted from Torbin Weis, Berlin University of Technology

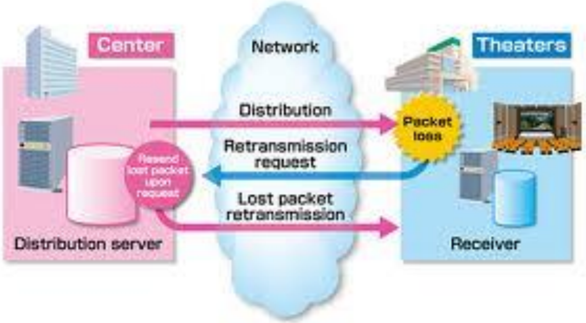
Business Example – Challenges I

- What if
  - Your customer uses a completely different hardware? (PC, MAC,…)
  - … a different operating system? (Windows, Unix,…)
  - … a different way of representing data? (ASCII, EBCDIC,…)
  - **Heterogeneity**
- Or
  - You want to move your business and computers to the Caribbean (because of the weather)?
  - Your client moves to the Caribbean (more likely)?
  - **Distribution transparency**

Business Example – Challenges II

- What if
  - Two customers want to order the same item at the same time?
  - **Concurrency**
- Or
  - The database with your inventory information crashes?
  - Your customer's computer crashes in the middle of an order?
  - **Fault tolerance**

Business Example – Challenges III



Reliable and secure distribution

- What if
  - Someone tries to break into your system to steal data?
  - … sniffs for information?
  - … your customer orders something and doesn’t accept the delivery saying he didn’t?
  - **Security**
- Or
  - You are so successful that millions of people are visiting your online store at the same time?
  - **Scalability**

Overview Challenges I

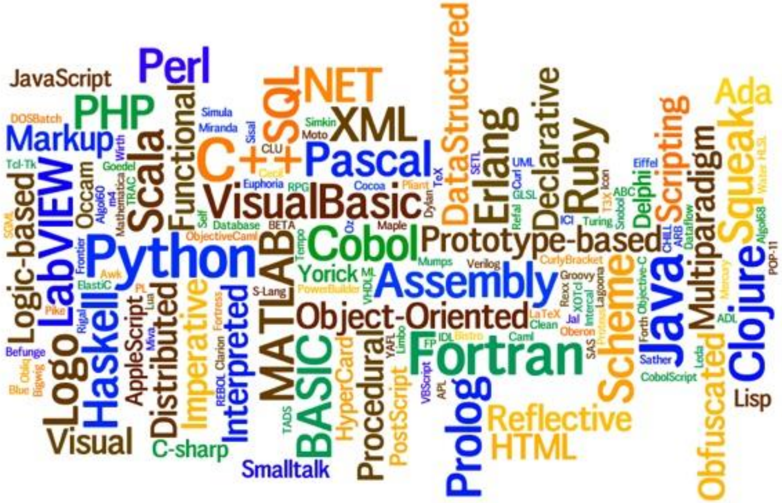
- Heterogeneity
  - Heterogeneous components must be able to interoperate
- Distribution transparency
  - Distribution should be hidden from the user as much as possible
- Fault tolerance
  - Failure of a component (partial failure) should not result in failure of the whole system
- Scalability
  - System should work efficiently with an increasing number of users
  - System performance should increase with inclusion of additional resources

Overview Challenges II

- Concurrency
  - Shared access to resources must be possible
- Openness
  - Interfaces should be publicly available to ease inclusion of new components
- Security
  - The system should only be used in the way intended

Heterogeneity

- Heterogeneous components must be able to interoperate across different:
  - Operating systems
  - Hardware architectures
  - Communication architectures
  - Programming languages
  - Software interfaces
  - Security measures



Distribution Transparency I

- ISO Reference Model for Open Distributed Processing (ODP) identifies the following forms of transparencies:
- Access transparency
  - Access to local or remote resources is identical
  - E.g. Network File System / **Dropbox**
- Location transparency
  - Access without knowledge of location
  - E.g. separation of domain name from machine address.
- Failure transparency
  - Tasks can be completed despite failures
  - E.g. message retransmission, failure of a Web server node should not bring down the website.

Distribution Transparency II

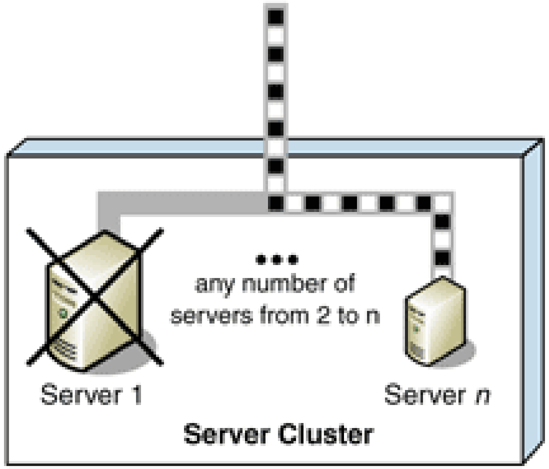
- Replication transparency
  - Access to replicated resources as if there was just one. And provide enhanced reliability and performance without knowledge of the replicas by users or application programmers.
- Migration (mobility/relocation) transparency
  - Allow the movement of resources and clients within a system without affecting the operation of users or applications.
  - E.g. switching from one name server to another at runtime; migration of an agent/process from one node to another.

Distribution Transparency III

- Concurrency transparency
  - A process should not notice that there are other sharing the same resources
- Performance transparency:
  - Allows the system to be reconfigured to improve performance as loads vary
  - E.g., dynamic addition/deletion of components
- Scaling transparency:
  - Allows the system and applications to expand in scale without changes in the system structure or the application algorithms.

Fault Tolerance

- Failure: an offered service no longer complies with its specification
- Fault: cause of a failure (e.g. crash of a component)
- Fault tolerance: no failure despite faults

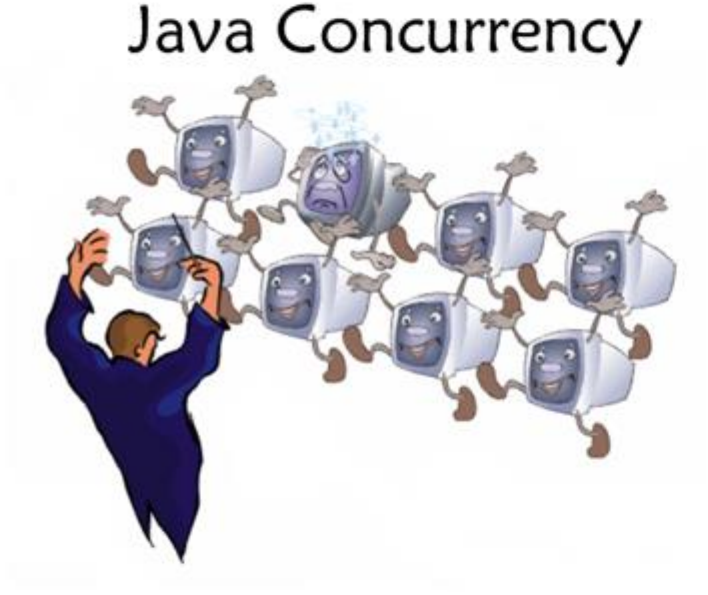


Fault Tolerance Mechanisms

- Fault detection
  - Checksums, heartbeat, …
- Fault masking
  - Retransmission of corrupted messages, redundancy, …
- Fault toleration
  - Exception handling, timeouts,…
- Fault recovery
  - Rollback mechanisms,…

Concurrency

- Provide and manage concurrent access to shared resources:
  - Fair scheduling
  - Preserve dependencies (e.g. distributed transactions)
  - Avoid deadlocks

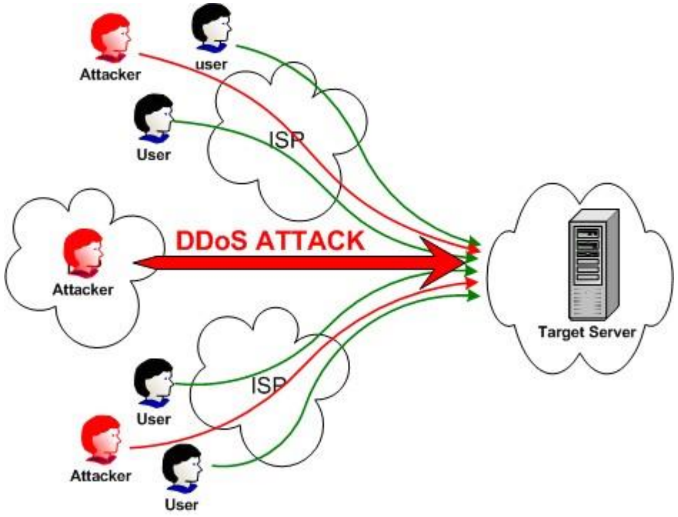


Security I

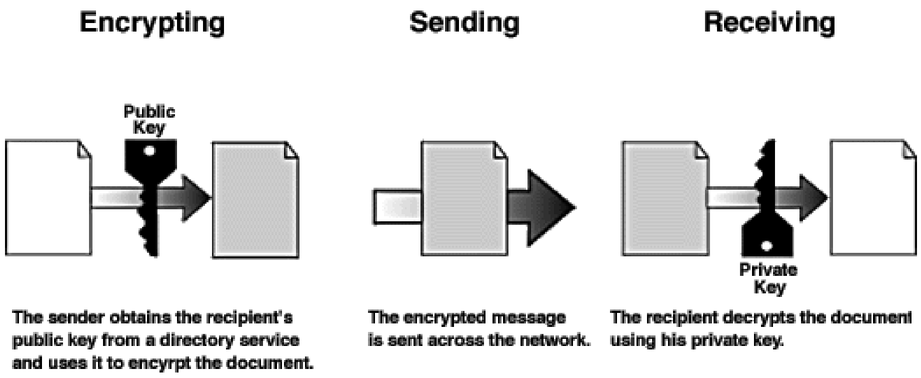
- Resources are accessible to authorized users and used in the way they are intended
- Confidentiality
  - Protection against disclosure to unauthorized individual information
  - E.g. ACLs (access control lists) to provide authorized access to information
- Integrity
  - Protection against alteration or corruption
  - E.g. changing the account number or amount value in a money order

Security II

- Availability
  - Protection against interference targeting access to the resources.
  - E.g. denial of service (DoS, DDoS) attacks
- Non-repudiation
  - Proof of sending / receiving an information
  - E.g. digital signature



Security Mechanisms


Encrypting
Sending
Receiving
Public Key
Private Key
The sender obtains the recipient's public key from a directory service and uses it to encyrpt the document.
The encrypted message is sent across the network.
The recipient decrypts the document using his private key.

- Encryption
  - E.g. Blowfish, RSA
- Authentication
  - E.g. password, public key authentication
- Authorization
  - E.g. access control lists

Summary

- Distributed Systems are everywhere
- The Internet enables users throughout the world to access its services wherever they are located
- Resource sharing is the main motivating factor for constructing distributed systems
- Construction of DS produces many challenges:
  - Heterogeneity, Openness, Security, Scalability, Failure handling, Concurrency, and Transparency