Advanced Operating Systems
Lecture notes
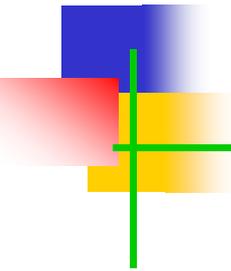
Dr. Ali Fanian

Dept. of Electrical and computer Engineering
Isfahan University of Technology
http://www.fanian.iut.ac.ir

Administration

- *Class Home Page*

  fanian.iut.ac.ir
  - *Announcements*
  - *Lecture Slides*

- *e-mail: a.fanian@cc.iut.ac.ir*

- *Text*
  - *Distributed Systems: Concepts and Design (5th edition)*
    - *By Coulouris, Dollimore, and Kindberg*
  - *Modern Operating Systems, (4th edition)*
    - *Andrew S. Tanenbaum*

- *What do you think about this course?*

- *What do you like to learn in this course?*

- *The purpose of this course*
  - *We take a top-down approach, addressing the issues to be resolved in the design of distributed systems and describing successful approaches in the form of abstract models, algorithms and detailed case studies of widely used systems.*

Syllabus

- *CHARACTERIZATION OF DISTRIBUTED SYSTEMS(2)*
- *SYSTEM MODELS (2)*
- *Multiple Processor Systems(2.5)*
- *INTERPROCESS COMMUNICATION (1.5)*
- *REMOTE INVOCATION (2)*
- *INDIRECT COMMUNICATION (2)*

  Midterm Exam
- *File Systems (2)*
- *DISTRIBUTED FILE SYSTEMS (1.5)*
- *OS Support for Building Distributed Application (1.5)*
- *TIME AND GLOBAL STATES (2.5)*
- *COORDINATION AND AGREEMENT (2)*
- *TRANSACTIONS AND CONCURRENCY CONTROL (3)*
- *DISTRIBUTED TRANSACTIONS (2)*
- *Final Exam*
- *Seminars*

- *Grading*
  - *35%: Mid-Term*
  - *45%: Final Exam*
  - *20%: Seminar and Report*

Introduction to Distributed Systems and Characterisation
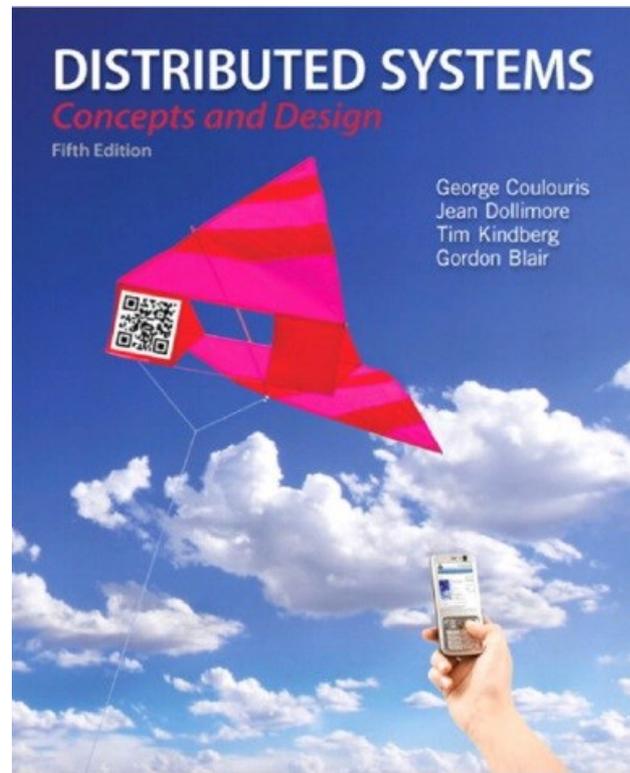
Presentation Outline

- *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).*

9
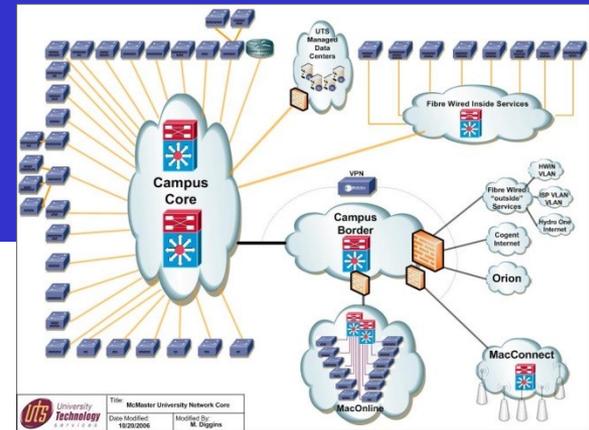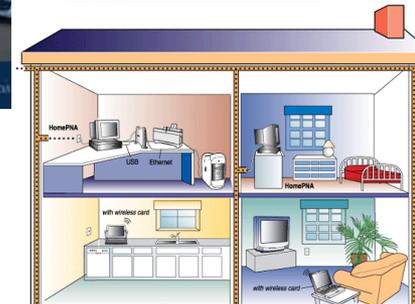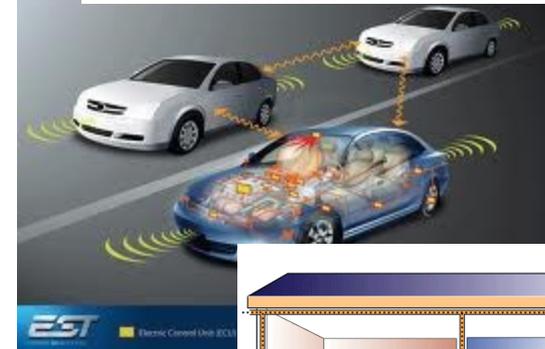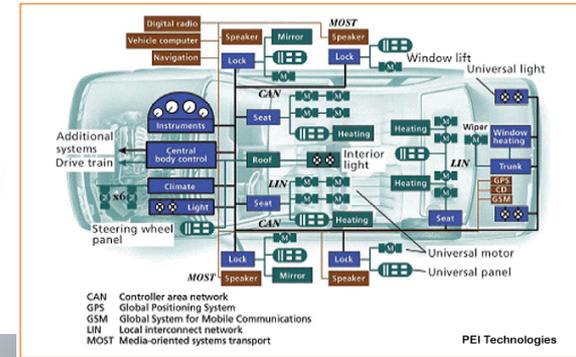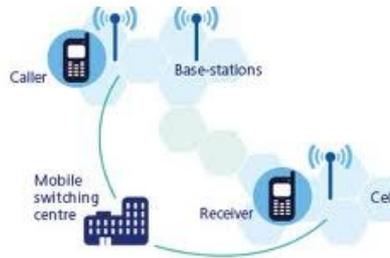
Defining Distributed Systems

- *"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].*

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.*

Distributed Systems
Computer Networks
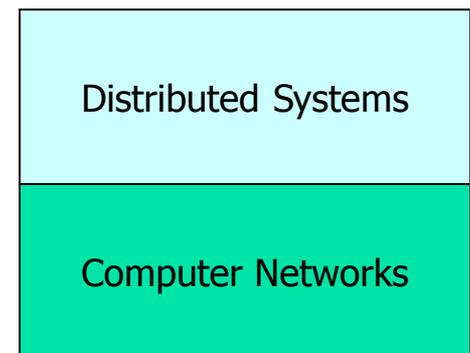
Reasons for Distributed Systems

- *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.*
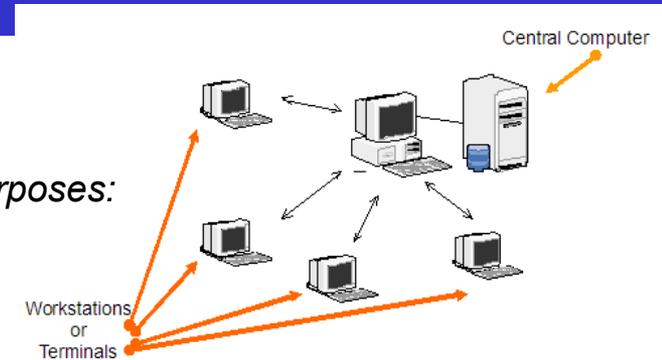
Consequences of Distributed Systems

- *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*
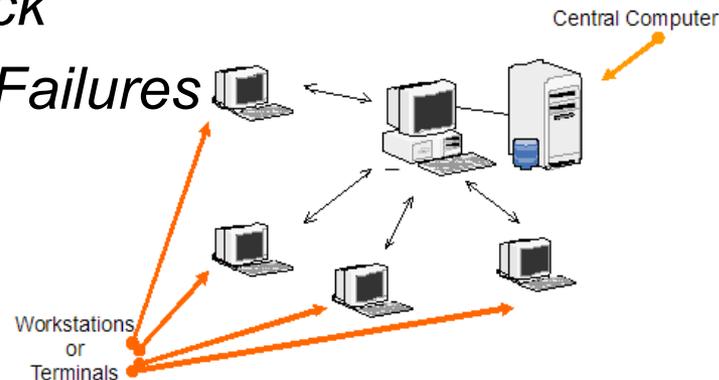
Characteristics of Distributed Systems

- *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*

Central Computer

Workstations or Terminals
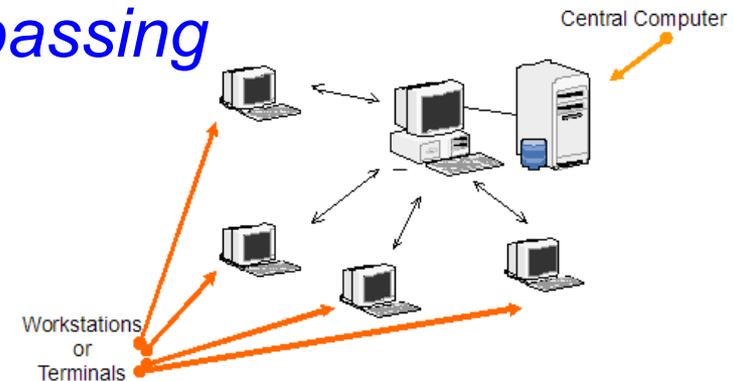
Goals of Distributed Systems

- *Connecting Users and Resources*
- *Transparency*
- *Openness*
- *Scalability*
- *Enhanced Availability*

16
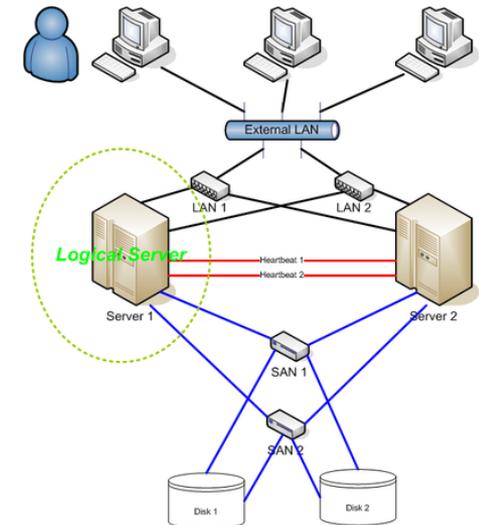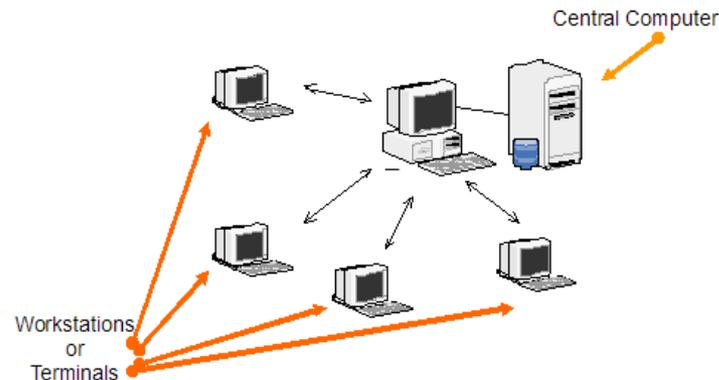
Differentiation with parallel systems

- *Multiprocessor systems*
  - *Shared memory*
  - *Bus-based interconnection network*
  - *E.g. SMPs (symmetric multiprocessors) with two or more CPUs*
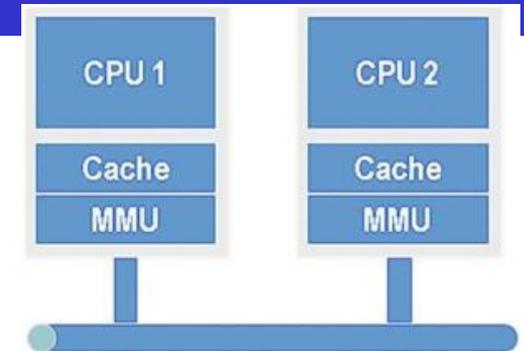
- *Multicomputer systems / Clusters*
  - *No shared memory*
  - *Homogeneous in hard- and software*
    - *Massively Parallel Processors (MPP)*
      - *Tightly coupled high-speed network*
    - *PC/Workstation clusters*
      - *High-speed networks/switches-based connection.*

Differentiation with parallel systems is blurring

Distributed Volunteer
Computing (DVC)

Participants (Bob)

Internet

(< 200 TFLOPS)

Supervisor (Alice)

- *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*
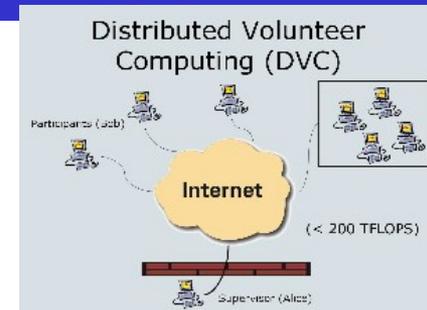
Examples of Distributed Systems

- *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*
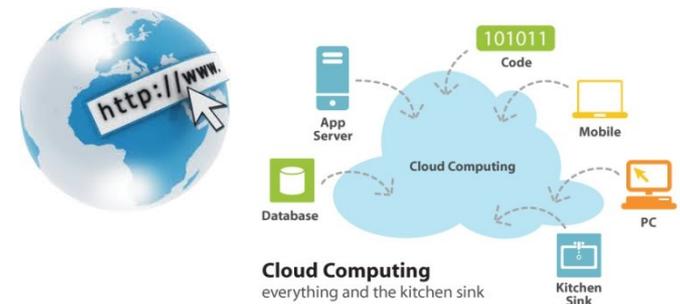
Intranet

ISP

backbone

satellite link

desktop computer:

server:

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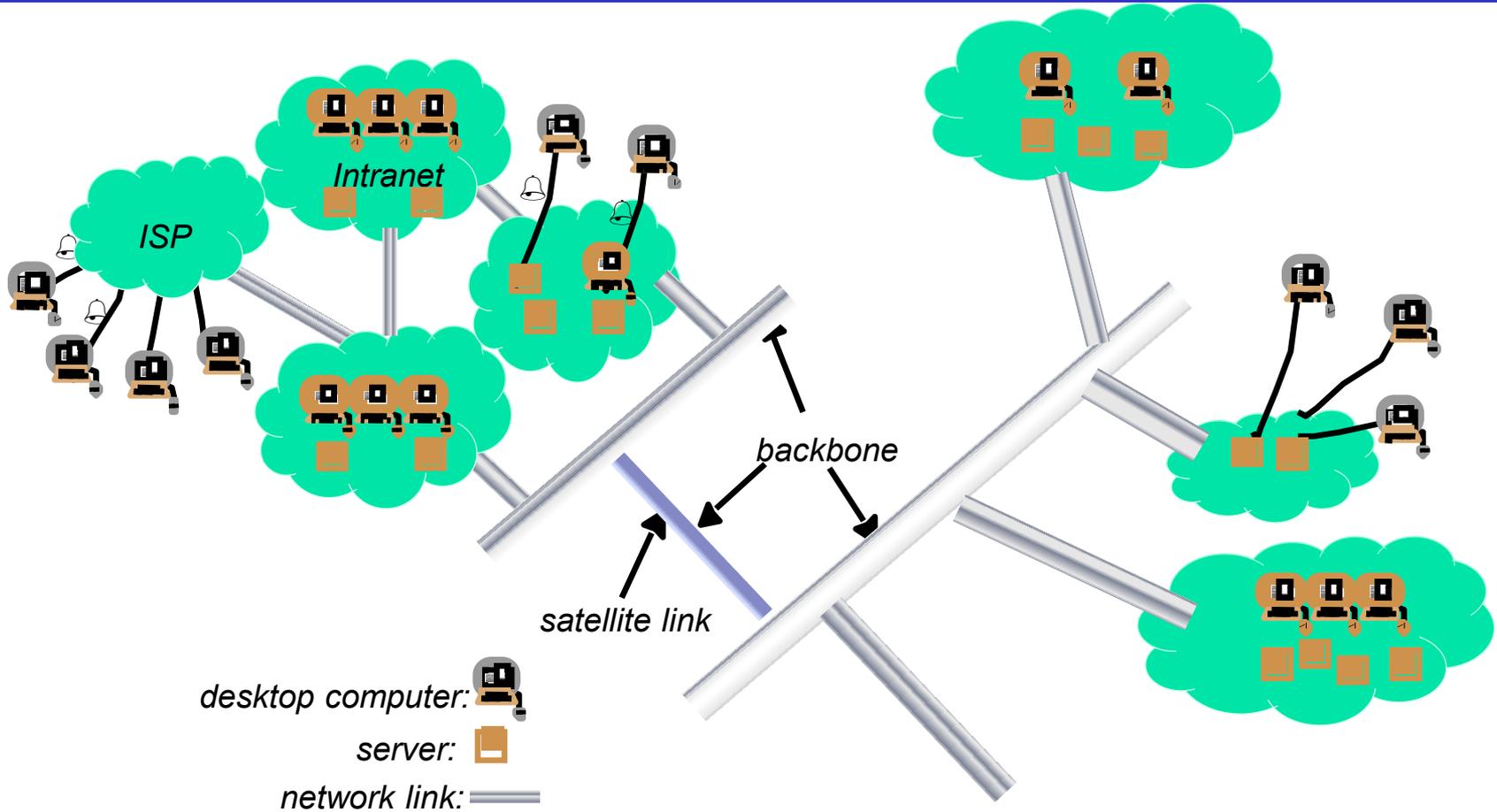
- **The Internet is a vast collection of computer networks of many different types and hosts various types of services.**

20

A typical Intranet:

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

Print and ... servers

Desktop computers

e... server

W...

Local area network

em... ...ver

Fil... ...ver

print

other servers

the rest of the Internet

router/firewall

21
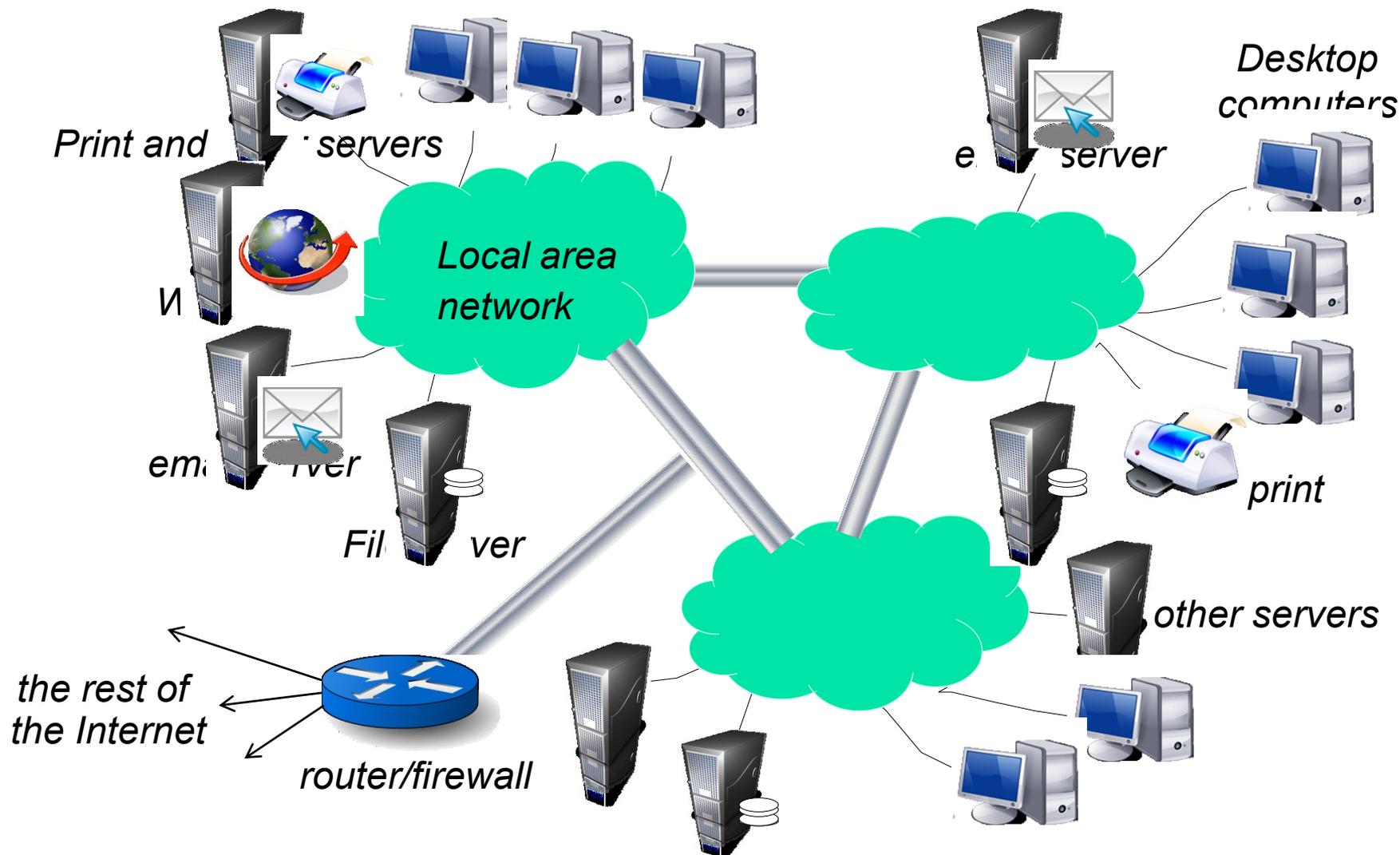
Business Example and Challenges

- *Online bookstore (e.g. in the World Wide Web)*
  - *Customers can connect their computer to your computer (web server):*
    - *Browse your*
    - *Place orders*
    - *…*
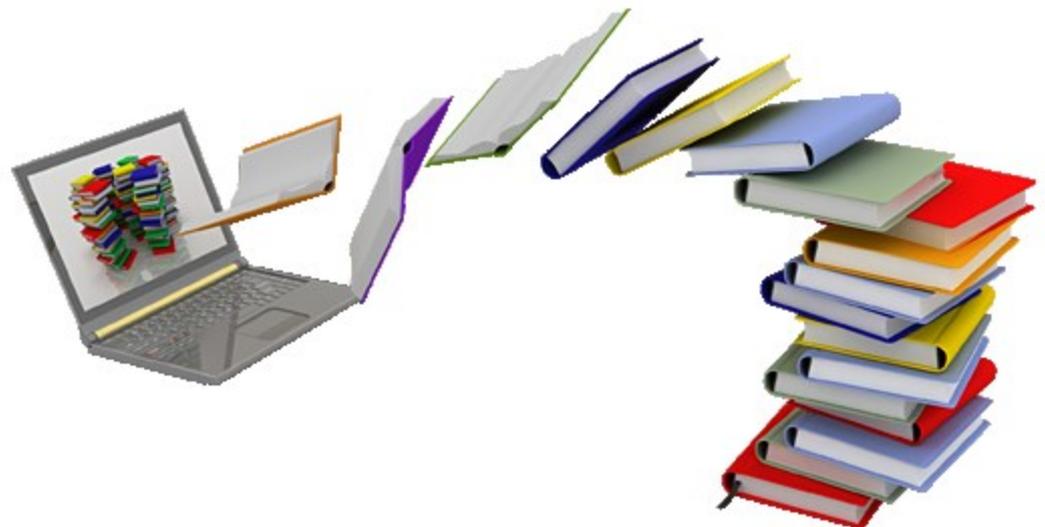
This example has been adapted from Torbin Weis, Berlin University of Technology

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

- *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**
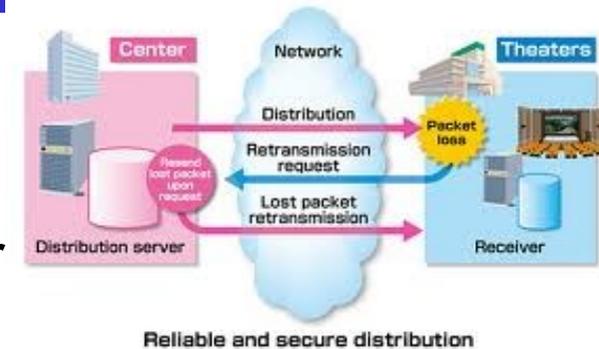
Overview Challenges I

- *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*
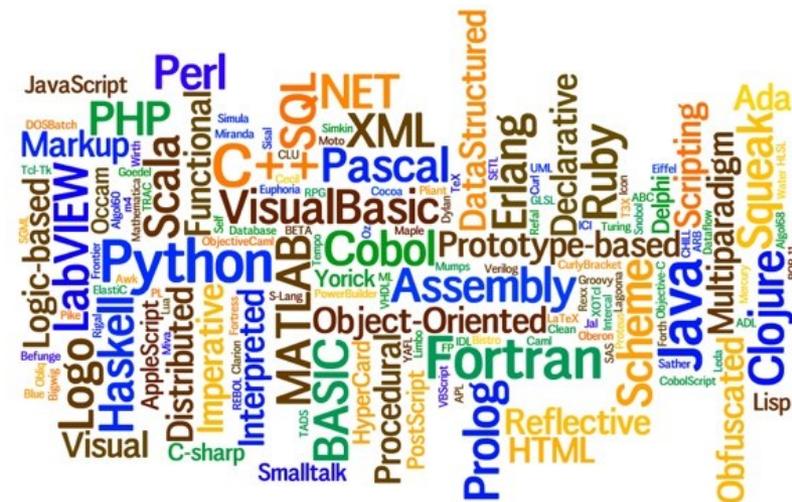
Distribution Transparency I

- *ISO Reference Model for Open Distributed Processing (ODP) identifies the following forms of transparencies:*
- *Access transparency*
  - *Access to local or remote resources is*
  - *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 failure*
  - *E.g. message retransmission, failure of Web server node should not bring down the website.*

29

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*

any number of
servers from 2 to n

Server 1   Server *n*

Server Cluster

32
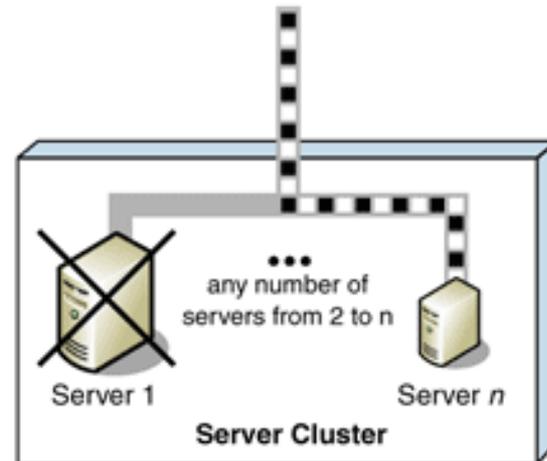
Fault Tolerance Mechanisms

- *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*

Java Concurrency
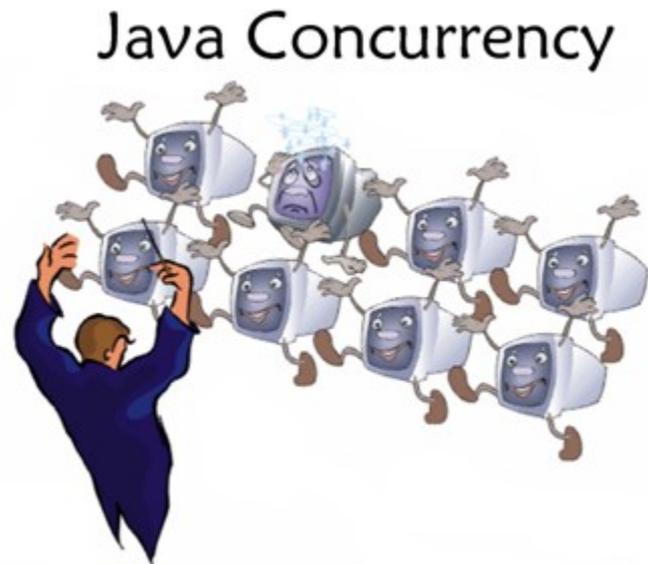
Security I

- *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*
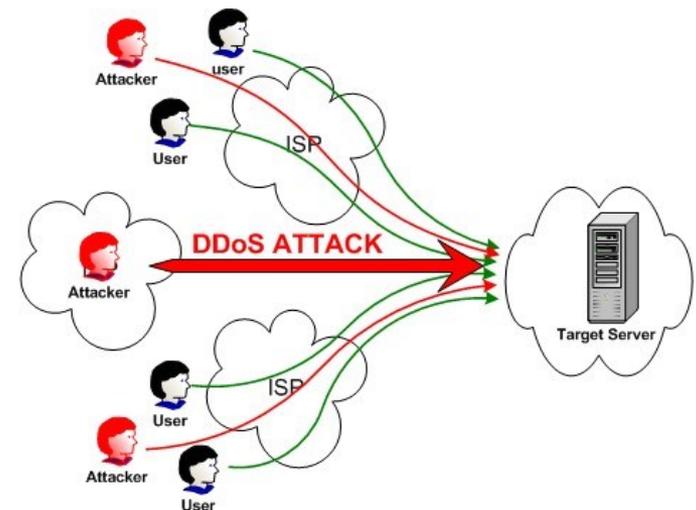
Security Mechanisms

Encrypting **Sending** **Receiving**

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*
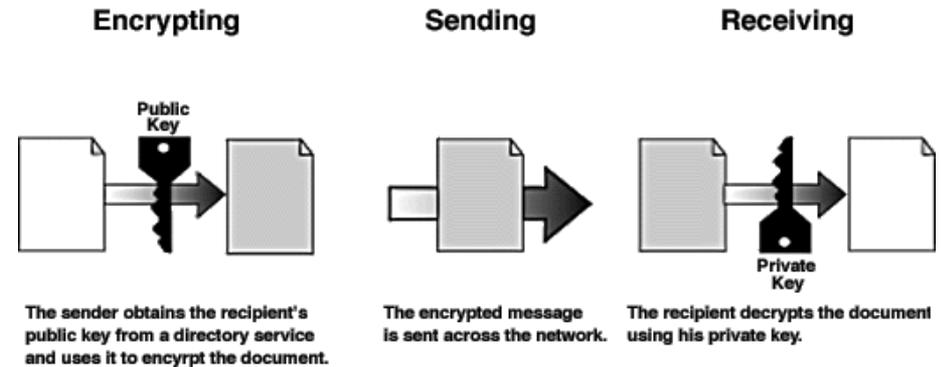
Summary

- *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*
- *Distributed systems enable globalization:*
  - *Community (Virtual teams, organizations, social networks)*
  - *Science (e-Science)*
  - *Business (e-Bussiness)*