University College Dublin
An Coláiste Ollscoile, Baile Átha Cliath

Distributed Operating Systems

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Technology Trends

	1981	2014	Factor
MIPS	1	106,924	100,000
Dollar per MIPS	$100	$0.003	3×10^{-5}
#Address bits	16	64 -- 128	4 -- 8
Clock frequency	8Mhz	4.0Ghz	500
DRAM capacity	128Kb	16Gb	128000
Disk capacity	10Mb	2500Gb	250000
Net Bandwidth	9600b/s	10Gb/s	104 0000
Cores	1	8	8

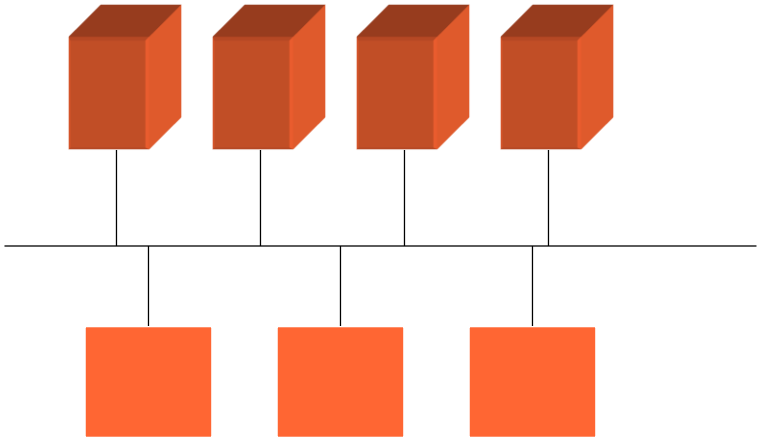
Distributed Hardware

- How are computers interconnected ?
  - via a bus-based
  - via a switch
- How are processors and memories interconnected ?
  - Private
  - shared memory

Distributed Hardware

- Bus-Based Technology

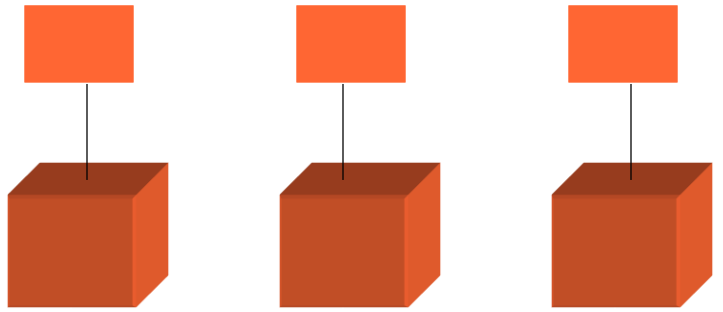
Scalability problem



Shared Memory

Scalability & bandwidth problems

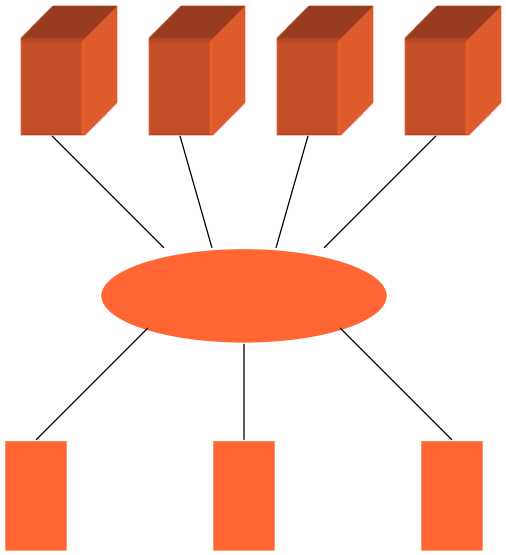
Private Memory



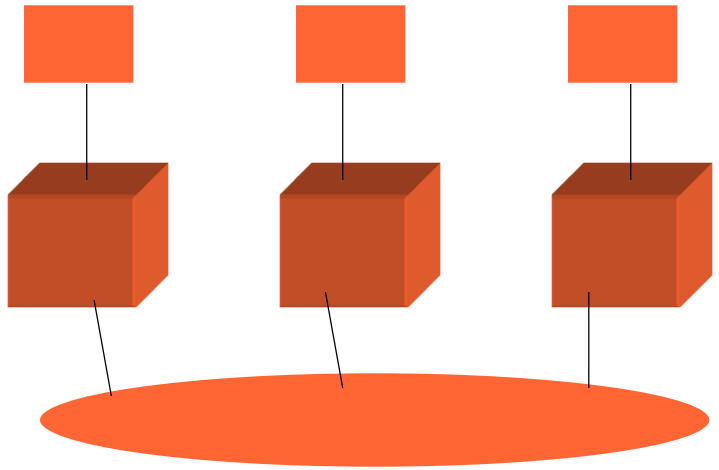
Distributed Hardware

- Switch-Based Technology

Expensive switch



Poor Communication support



The Network

- Definition
  - physical connection allowing two or more computers to communicate

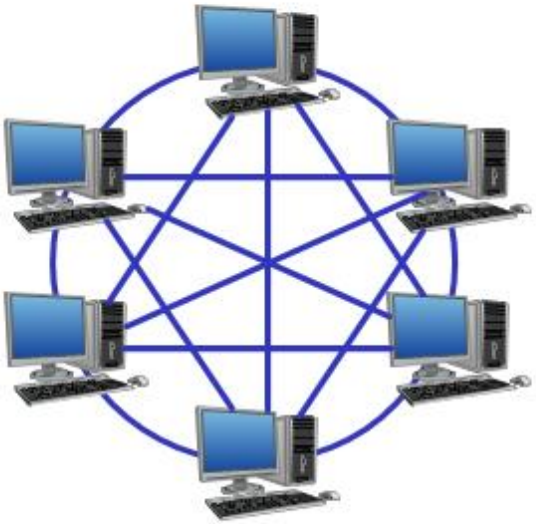
- There are various factors that can be taken into account to interconnect nodes
  - physical
  - topology
  - protocol

The Network

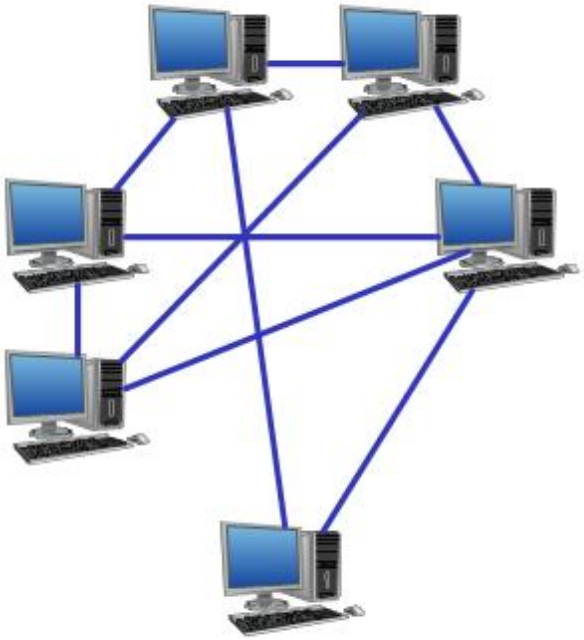
- LAN (Local Area Networks)
  - provide connection between computers geographically very close (e.g. within a building)
- MAN (Metropolitan Area Networks)
  - used across cities
- WAN (Wide Area Networks)
  - used across countries

Network Topologies

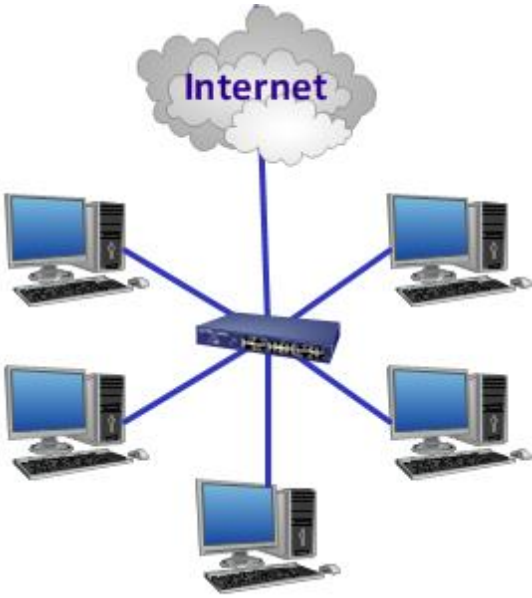
- Fully-connected network
- Star network
- Hypercube network
- Mesh network
- Tree network
- Ring network
- Linear bus network
- Hybrid network



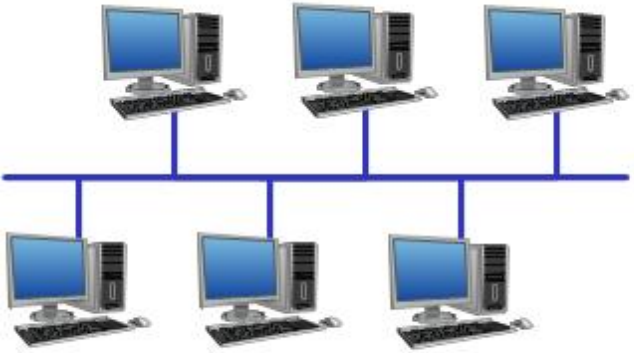
Fully Connected Network Topology



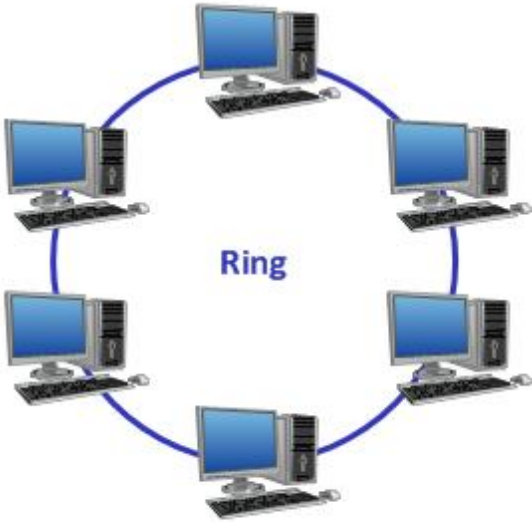
Mesh Network Topology



Star Network Topology



Common Bus Topology

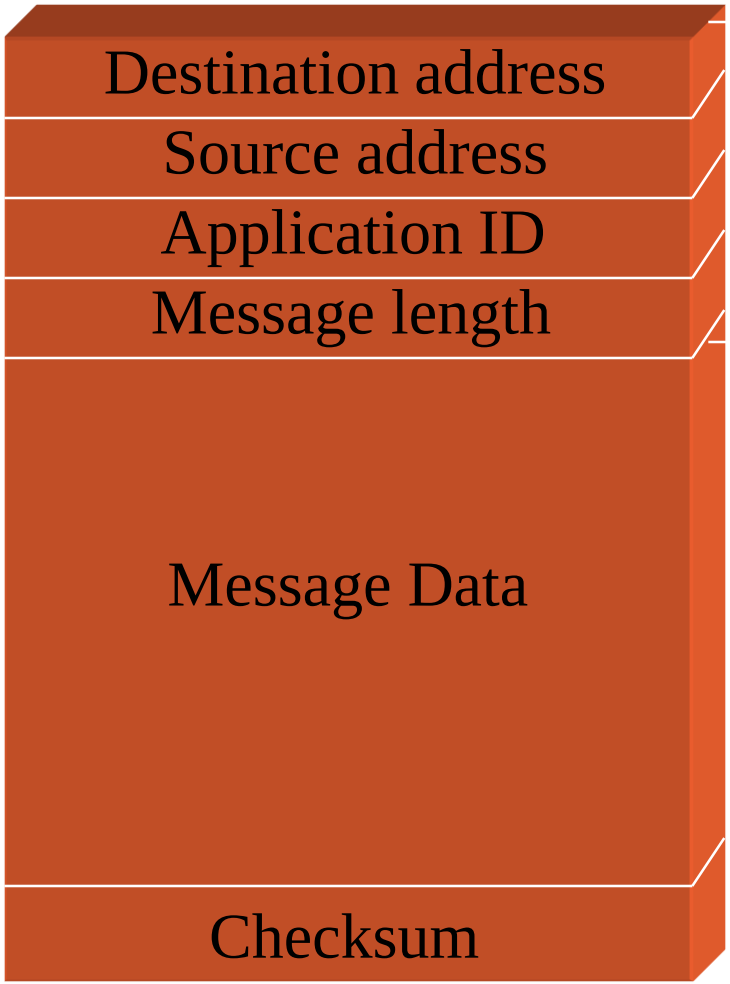


Ring Network Topology

Messages

- At the low level, the network communication is done via messages
- Messages
  - is simply typed byte string exchanged between two levels of the system (e.g. OS to OS, application to application)
  - usually contains a header describing it, followed by the data
- How to interpret bytes of a message?
  - Is an agreement between communicating parties (The Protocol)

Messages



Header

May contain a header and some data of another header of communication...

Today's Distributed Systems

- Today, nearly all systems are distributed "in some way":
  - they use e-mail
  - they access files over the network
  - they access printers over the network
  - they are backed up over the network
  - they share other physical or logical resources
  - they co-operate with other people on other machines
  - they receive video, audio, sound, etc

DS Properties

- Resource Sharing
  - Hardware (printers, disks, tapes, etc.) and software (files, windows, databases, etc.)
- Open System
  - can be adapted fairly easy (i.e. customized for specific needs)
- Scalable
  - To what extent can the system grow (number of nodes, accessibility, etc.)

DS Properties

- Fault Tolerant
  - having a lot of components is fine, but the effect of increased faults must be hidden
- Transparent
  - How visible is the distribution?

What Is a Distributed System?

- Definition
  - Distribution concerns processing, data and control

- DS -- Hardware
  - is a collection of independent computers interconnected by a network
- DS -- Software
  - is a distributed abstract machine or distributed resource manager

What is a DS?

- There are several levels of distribution
- Earliest systems use simple explicit network programs
  - FTP: File Transfer Program
  - Telnet (rlogin): remote login program (virtual terminal)
  - Mail
  - RSH: remote shell -- remote job execution
- Each system is a complete independent system and has an access to the network

Why We Need DS?

- Communication
  - need to communicate
- Resource Sharing
  - need to share physical devices, information, etc.
- Distributed Applications
  - many applications are, by their nature, distributed (bank teller machines, airline reservations, ticket purchasing, etc.)
- Parallel & Distributed Programming
  - need to solve very large problems by co-operation of a large collection of small computers

DS Issues

- Transparency
- Scalability
- Reliability
- Security
- Performance
- Programming Models
- Communication Models

Transparency

- A true distributed system with high transparency
  - appears as a single system
  - different nodes are invisible
  - jobs will migrate automatically from one node to another
  - a job located in one node is able to use resources of another node

Transparency

- Location transparency
  - The user doesn’t know where resources are located
- Migration transparency
  - the resources can migrate without changing their names
- Replication transparency
  - The user doesn’t know how many job copies exist in the whole system
- Concurrency transparency
  - Different users can share resources automatically
- Parallelism transparency
  - Activities can happen in parallel without user intervention

Scalability

- Definition
  - A system is scalable if it can handle additional users and resources without loss of performance or increase of administrative complexity

- Three basic strategies
  - Replication
  - Distribution
  - Caching

Scalability

- Replication
  - make copies of important resources and place them near their users
- Distribution
  - partition a large resource (e.g. database) into small parts and place them in different locations
- Caching
  - when you grab a resource, keep it in your own site for a while -- you may need it again shortly
- *The biggest problem is to keep the global state consistent*

Reliability

- Original goal of distributed systems
  - more reliable than single processor systems
  - if a node goes down another node takes over the job
- Availability
  - fraction of time that the system is usable
- Example
  - 4 file servers, each has a probability of 0.05 to go down
  - Probability[4 file systems down] = 0.05^4 = 0.00000625
  - Probability[at least 1 server is available] = 0.99999375

Reliability

- Fault Tolerance
  - If a server crashed and quickly reboots. What happens?
  - Does the server crash bring users down with it?
  - The server has tables containing important information about ongoing activities, recovery will be difficult

- Distributed systems can be designed to mask failures
- Solutions are based on group of closely co-operating servers

Reliability

- Failure Classification
  - Crash failure: processor crashes (and reboots)
  - Omission failure: loss of messages, …
  - Performance failure: overloaded operating system, network congestion
  - Timing failure: fast or slow clock, response comes too early or too late
  - Response failure: wrong response (2+2=5), message altered in the wire

Programming Models

- Message-Passing Model
  - processes communicate by exchanging messages
- Shared-Memory Model
  - processes communicate by reading and writing shared objects, queues, sets, …

Parallel & Distributed Systems

- Parallel System
  - a collection of processing elements that can communicate and co-operate to solve large problems faster
- Distributed System
  - multiple autonomous nodes that do not share the main memory, but co-operate and communicate by sending messages over the network

Parallel & Distributed Systems

- Not (Parallel & Distributed)
  - independent PCs or workstations (not connected)
- Parallel & Not Distributed
  - vector machines, array processor architectures
  - shared-memory multiprocessor systems
  - Example : modern day GPU's
- Distributed & not Parallel
  - wide-area network (communication too slow)
  - distributed database system (airline reservation system)
- Parallel & Distributed
  - collection of workstations connected by a LAN
  - Example SETI Online, Rosetta@home , Folding@home

Advantages of DS

- Economics
  - μ-processors offer better price/performance than mainframes
- Speed
  - DS may have more total computing power than mainframes
- Inherent Distribution
  - some applications involve spatially separated machines
- Reliability
  - if one machine crashes, the whole system can survive
- Incremental Growth
  - computing power can be added in small increments

Advantages of DS

- Data Sharing
  - Allow many users to access to a common database
- Device Sharing
  - Allow many users to share expensive peripherals
- Communication
  - Make user-to-user communication easier, (e.g. e-mail)
- Flexibility
  - Spread the workload over the available nodes

Disadvantages of DS

- Software
  - Little software exists for distributed systems
    - Cloud computing is changing this radically but for this course we will still consider direct software as limited
- Networking
  - The network can be saturated or can cause other problems
- Security
  - Easy access to secret data

Next week

- End of lectures so next two weeks will be revision lectures on previous topics

- Quizzes – We will make up for ‘lost’ quizzes
  - Week 13 → Processes (Quiz 3)
  - Week 14 → Process Synchronization (Quiz 4)
  - Week 15 → Quiz on all lectures!! Worth double marks!!

Finally:

- Best 8 quizzes (worst excluded) → 16%
- Week 15 quiz (all topics, double marks) → 4%