Fundamentals of Distributed Computing

Course: Distributed Computing

Faculty: Dr. Rajendra Prasath

Spring 2019

About this Course

This course covers essential aspects that every serious programmer needs to know about **distributed algorithms**, **design principles and their analysis**, with emphasis on **real-time implementations** and **scalable applications development**

What do we learn?

- Some Important aspects of DC:
  - Reliable network
  - Zero Latency
  - Infinite Bandwidth
  - Secure network
  - Fixed Topology,
  - Only one administrator
  - Zero Transport cost
  - Homogeneous Network
- Remember these points when you first develop a distributed application

Reliable Network

- Hardware may fail! Power failures; Switches have a mean time between failures

The implications:

- Hardware: weight the risks of failure versus the required investment to build redundancy
- Software: we need reliable messaging: be prepared to retry messages, acknowledge messages, reorder messages (do not depend on message order), verify message integrity, and so on.

Zero Latency

Latency (not bandwidth): how much time do the data take to move from one place to another? → measures in time

- ➔ The minimum round-trip time between two points on earth is determined by the maximum speed of information transmission: the speed of light.
- ➔ At 300,000 km/sec, it will take at least 30msec to send a ping from Europe to the USA and back.

The implications:

- ➔ Strive to make as few calls over the network (other than LANs) as possible

Infinite Bandwidth

Bandwidth: how much data you can transfer over a period of time (may be measured in bits/second)

- It constantly grows
- Bandwidth may be lowered by packet loss: we may want to use larger packet sizes

The implications:

- Compression: simulate the environment to get an estimate for your needs

Secure Network

How to secure the underlying network?

The implications:

- You may need to build security into your applications from the beginning
- As a result of security considerations, you might not be able to access networked resources, different user accounts may have different privileges, and so on
- How to solve these issues efficiently?

Fixed Topology

Topologies do not change as long as you are in a closed environment

- In reality, servers may be added and removed often, clients (laptops, wireless ad hoc networks) are coming and going: the topology is changing constantly

The implications:

- Do not rely on specific endpoints or routes
- Abstract the physical structure of the network: the most obvious example is DNS names as opposed to IP addresses

Who is the Administrator?

Different Administrators may be associated with the network with different degrees of expertise

- Might make it difficult to locate problems
- Coordination of upgrades: will the new version of MySQL work as before with Ruby on Rails?
- Never underestimate the 'human' factor!

Zero Transport Cost

- Going from the application layer to the transport layer (2nd highest in the five layer TCP/IP reference model) is not free:
- Information needs to be serialized (marshalling) to get data onto the wire
- The cost (in terms of money) from setting and running the network is not zero.
- Have we leased the necessary bandwidth

Everything cost "Some money" !!

Homogeneous Network

Homogeneous = of the same kind; uniform

- Even a home network may connect a Linux PC and a Windows PC. A homogeneous network today is the exception, not the rule!

The implications:

- Interoperability will be needed
- Use standard technologies such as XML

FUNDAMENTALS OF DISTRIBUTED SYSTEMS

Can you parallelize all apps?

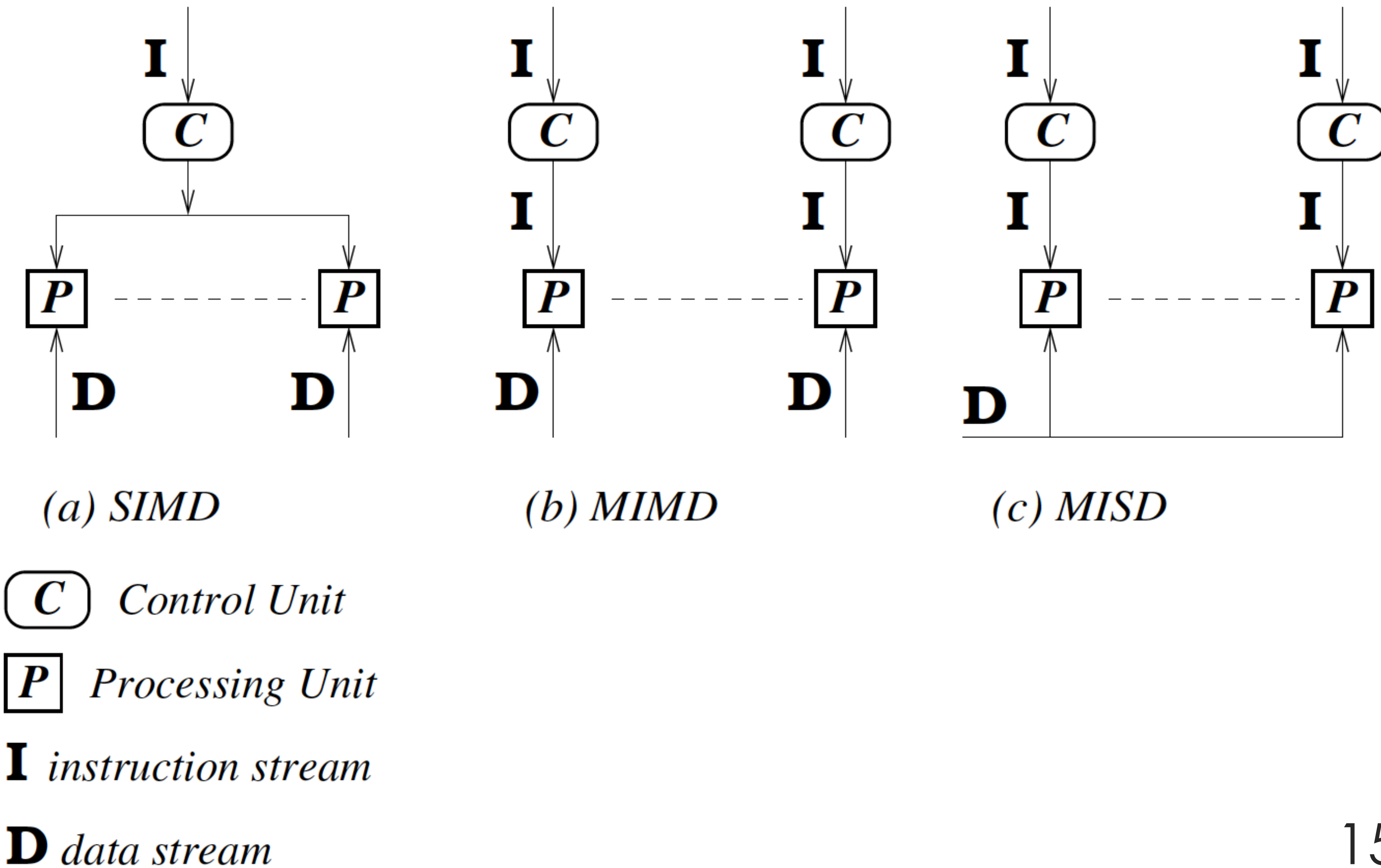
- What can you parallelize?
  - Identify Instructions that could execute in parallel?
- If the proportion of an application that you can parallelize is x ($0<x<1$),

  Maximum speed up = $1/(1-x)$
- Let us assume that a task needs ts time to run on one machine. How much time does it take to run the same task on p CPUs?
- Let running time be tp of a task running on p CPUs. Now $tp=to+ts*(1-x+x/p)$, where to is the overhead added due to parallelisation (communication, synchronization, etc)

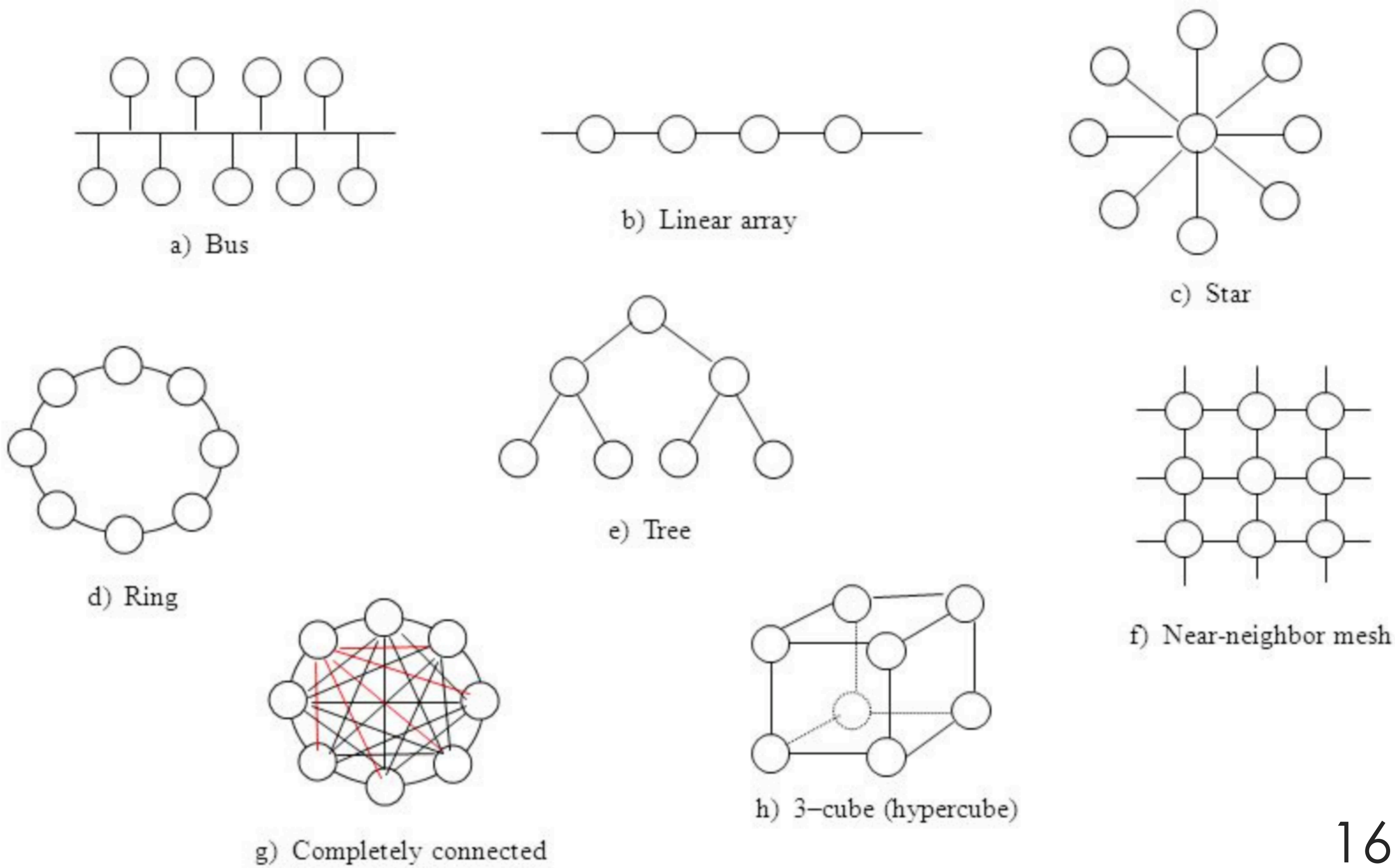
Flynn's Classification

- Single Instruction Single Data (SISD) Stream
  - Traditional von Neumann architecture
- Single Instruction Multiple Data (SIMD) Stream
  - Scientific Applications, Vector Processors, array processors and so on
- Multiple Instruction Single Data (MISD) Stream
  - Visualization is an example
- Multiple Instruction Multiple Data (MIMD) Stream
  - Distributed Systems

Flynn's Classification

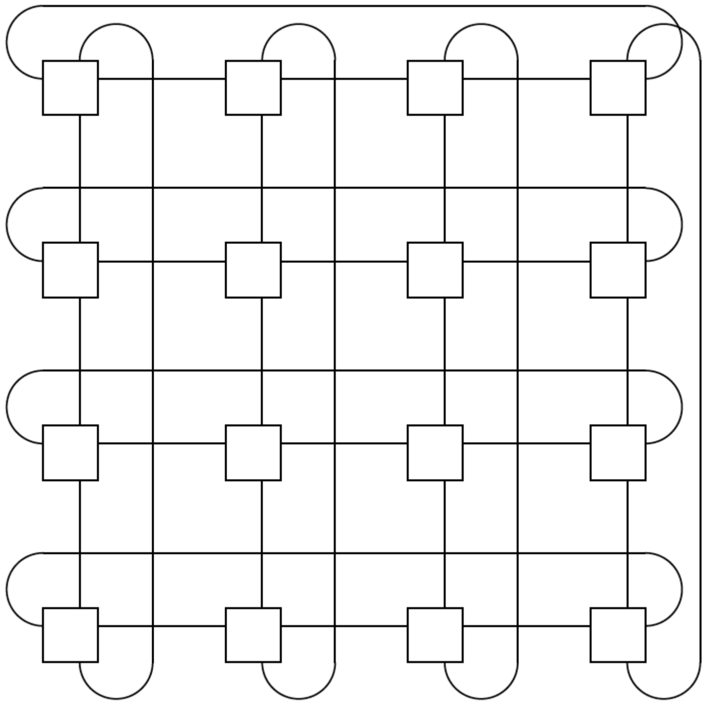


Interconnection Topologies



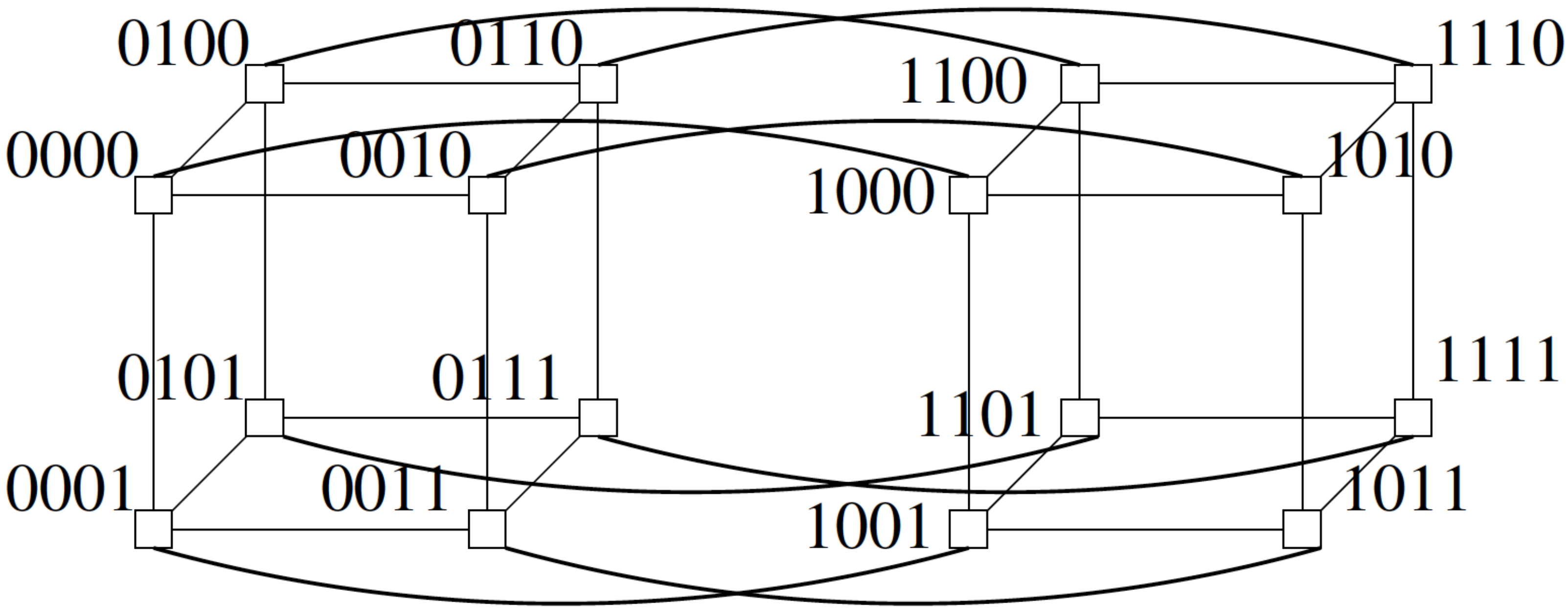
Interconnection Topologies (contd)

- ➔ **Wrap – around mesh (torus)**



k-ary d-cubes

- Hypercube of Dimension 4



- k-ary d-cudes (generalized version)

Message Passing Systems

Basic Primitive Operations

- Send
  - *send* message from process A to Process B

    A → B
- Receive
  - *receive* message at Process B from Process A

    B ← A

- Compute at A and / or B
  - do the specific computations at A and / or B

Message Passing vs. Shared Memory

- Emulate MP on SM
  - Partition the shared address space
  - Send / Receive messages via shared address space
- Emulate SM on MP
  - Model each shared location as a separate process
  - Send: Write to the shared object by sending messages to owner process for the object
  - Receive: Read from shared object by sending query to the owner process of the object

Synchronous vs. Asynchronous

- Synchronous (send / receive)
  - Handshake between sender and receiver
  - *send* completes only when *receive* completes
  - receive completes only when copying of the data to the buffer is over
- Asynchronous (send)
  - No need for handshake between sender and receiver
  - Control returns to the invoking process when data copied out of user-specified buffer

Blocking vs. non-blocking

- Blocking
  - Control returns to the invoking process after the the task completes
- Non-blocking
  - Control returns to the invoking process when data copied out of user-specified buffer
  - *send* completes even before copying the data to the user buffer
  - *receive* may happen even before data may have arrived from the sender
  - How to order EVENTs?

Applications

- Mobile Systems
- Sensor networks
- Pervasive Computing
  - Smart workplace
  - Intelligent Home
- Peer-to-peer computing
- Distributed Agents
- Distributed Data Mining
- Grid Computing
- Security aspects in Distributed Systems

Summary

- Focused aspects in this course:
  - Fundamental aspects while building distributed applications
  - Interconnection topologies
    - Number of Message exchanges
  - Primitives of Distributed Communications
    - Message Passing vs Shared memory systems
  - Properties of a distributed system
    - Many more to come up … stay tuned in …

How to reach me?

- ➔ Please leave me an email:
  rajendra [DOT] prasath [AT] iiits [DOT] in

- ➔ Visit my homepage @

  - ➔ http://www.iiits.ac.in/FacPages/index-rajendra.html

  OR

  - ➔ http://rajendra.2power3.com

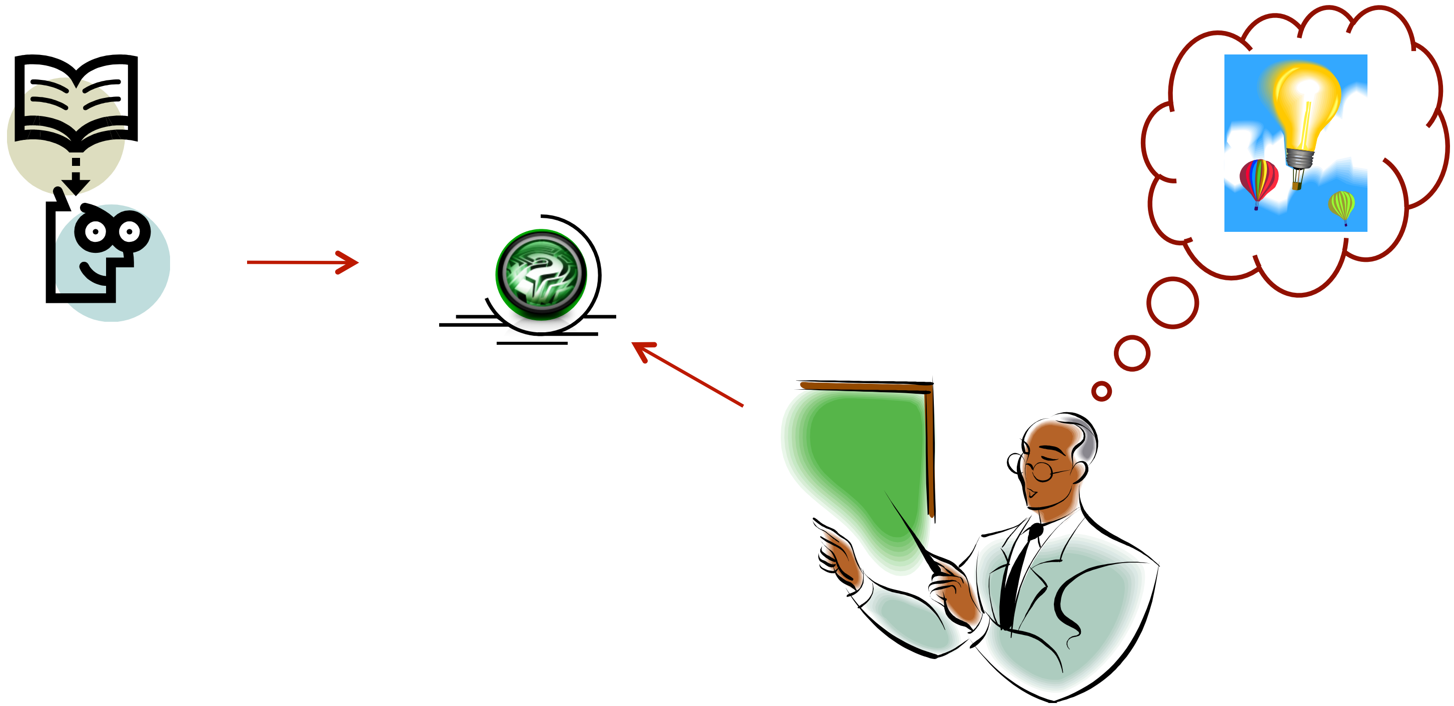
Help among Yourselves?

- **Perspective Students** (having CGPA above 8.5 and above)
- **Promising Students** (having CGPA above 6.5 and less than 8.5)

- **Needy Students** (having CGPA less than 6.5)
  - Can the above group help these students? (Your work will also be rewarded)

- You may grow a culture of **collaborative learning** by helping the needy students

Thanks …



… Questions ???