CMPS 4760/6760

Distributed Systems

Prof. Zizhan Zheng

Spring 2021

Agenda

- Administrative trivia’s
- An Overview of Distributed Systems

Personal

- Instructor: Prof. Zizhan Zheng
  - Office: Stanley Thomas 307B
  - Email: zzheng3@tulane.edu
  - Office hours (virtual): Wed 2-3 pm and by appointment

Meeting Plan

- Hybrid class (60% on ground, 40% online)
  - Jan & Feb: Tu – on-ground (ST 302), Th – online
  - Will meet more in person in Mar and Apr
- Class meeting time: Tu & Th 2:05pm-3:15pm
  - All classes will be recorded

Attendance Policy

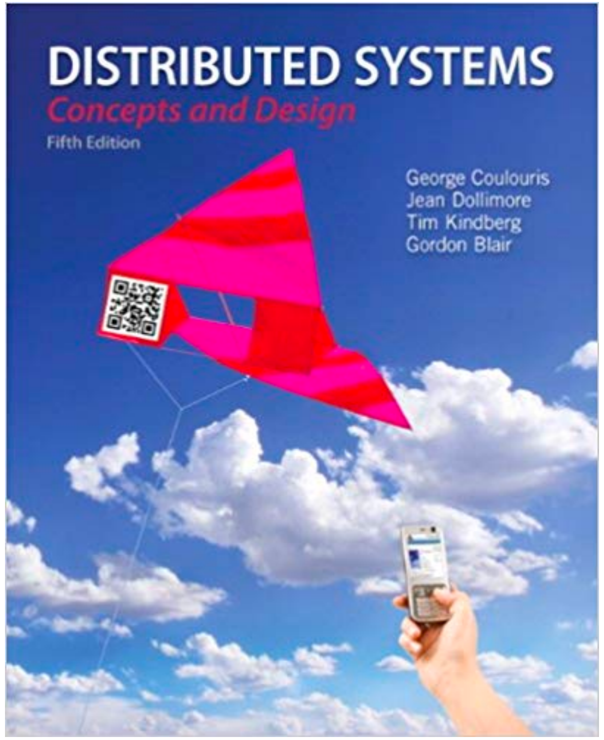
- All students should follow the hybrid class meeting schedule unless
  - you don’t feel well or have COVID symptoms
  - you have been approved for remote learning
- If you cannot attend class for any reason, you are responsible for communicating with me to make up any work you may miss
- If you are sick or told to quarantine, you can contact your case manager, and have your case management contact me directly

Course Overview

- Objective: understand the key concepts and fundamental principles in the design and analysis of distributed systems and distributed algorithms
- Course Webpage
  - http://www.cs.tulane.edu/~zzheng3/teaching/cmps6760/spring21
  - Used to post weekly schedule, assignments, lecture slides, reading assignment, etc.
- Prerequisites
  - Knowledge of systems, networking, and algorithms
  - Comfortable with rigorous mathematical reasoning
  - Programming skills

Textbook and References

- Textbook: George Coulouri, Jean Dollimore, Tim Kindberg, and Gordon Blair, *Distributed Systems: Concept and Design (5th edition)*, Pearson, 2012
- References
  - Sukumar Ghosh, *Distributed Systems: An Algorithmic Approach (2nd edition)*, Chapman and Hall/CRC, 2014
  - V. K. Garg, *Elements of Distributed Computing*, John Wiley & Sons
- Research papers, tutorials, etc.



Grading Policy

- Homework - 25%
- Labs - 15%
- Presentation - 5%
- Midterm - 20%
- Final Exam - 25%
- Class participation - 10%

A >= 93% A- >= 90%

B+ >= 87%, B >= 83%, B- >= 80%

C+ >= 77%, C >= 73%, C- >= 70%

D >= 60%

F < 60%

- All grades will be posted on Canvas

Homework and Labs

- Homework assignments (4-5)
  - Written problem sets
  - Graduate level students will be given extra questions that require advanced algorithmic and/or analytic techniques.
- Labs: programming assignments (2-3)
  - Java, Python
- Requests for a homework/lab assignment extension (with a valid reason) must be given to the instructor before the assignment is due

Late Policy

- 6 grace days that may be applied to homework/lab assignments
- No more than 2 grace days on any single assignment
    - assignment submitted > 2 days past the deadline (or no late day credit left) will get zero credit
- No late days for presentations and exams

Paper Presentation

- Each student will give a presentation
  - At the end of the semester
  - Two undergraduate students can work together
  - A suggested paper list will be posted on the course webpage
  - You can also suggest paper(s) you want to present

Exams

- One midterm and one final exam
  - Online exam on Zoom
  - Open-book and open-notes
- Missing an exam will result in a grade of zero. A request for a make-up exam must be given to the instructor prior to the exam date (documentation may be required).

Class Participation

- Class attendance
- Q&A in class & during office hours
- Homework solution presentation
- Online discussions

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  - http://www.cs.tulane.edu/~zzheng3/teaching/cmps6760/spring21/
  - Used to post weekly schedule, assignments, lecture slides, reading material, etc.
- Canvas
  - Used to post grades, discussions, and reading material, etc.

An Overview of Distributed Systems

CMPS 4760/6760: Distributed Systems

Outline

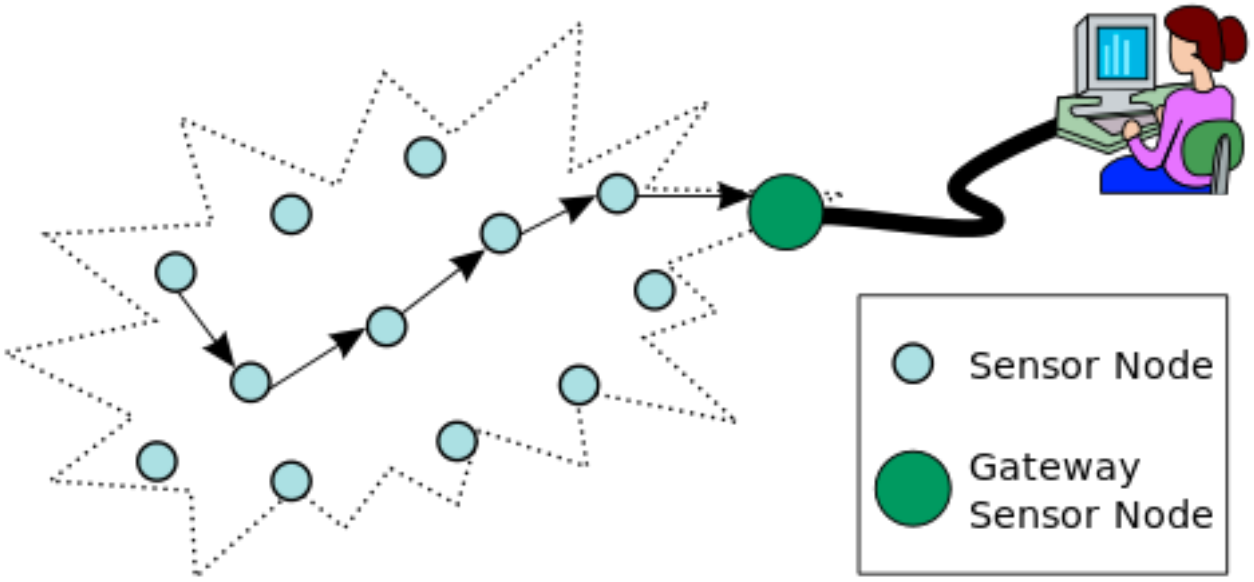
- What Is a Distributed System?
- Examples of distributed Systems
- Challenges
- Architectural models
- Fundamental models

What is a distributed system

- A system in which hardware or software components at networked computers communicate and coordinate their actions only by passing messages

- A network of processes: the processes interact with one other to achieve a goal

What is a distributed system



The **nodes** are processes, and the **edges** are communication channels

What is a distributed system

- Multiple processes
  - Concurrency
  - No global clock
  - Fail independently
  - No global knowledge
  - Disjoint address space
  - Collective objective

- Interprocess communication
  - Message passing vs. shared memory
  - Communication channels: delays, packet error/loss, reordering
  - Dynamic network topology

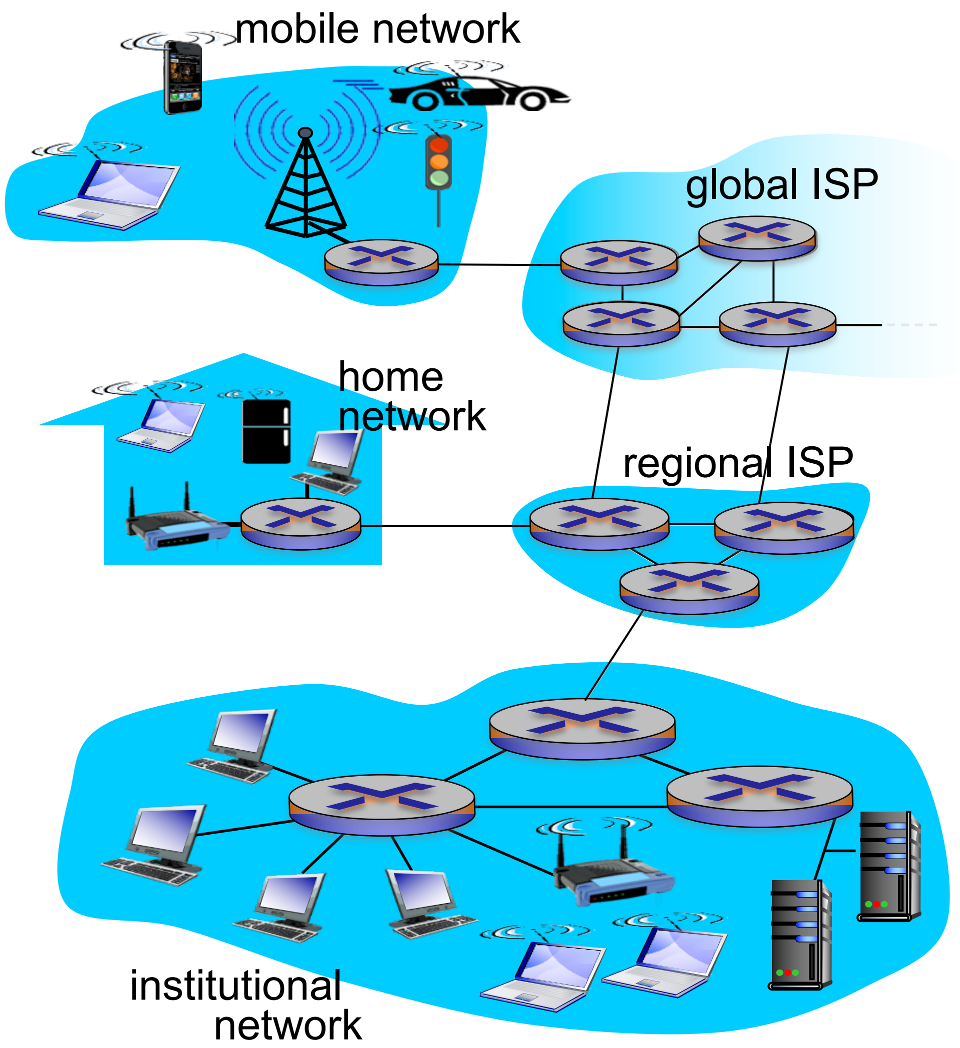
Why Distributed Systems

- Geographically distributed environment
- Speed up
- Resource sharing
- Fault tolerance

Examples of Distributed Systems

- The Internet
- World Wide Web
- Social networks: Facebook, Twitter, …
- Peer-to-peer networks: BitTorrent, Skype, …
- Cloud computing
- Internet of Things
- Smart Grid
- Blockchains
- …

The Internet

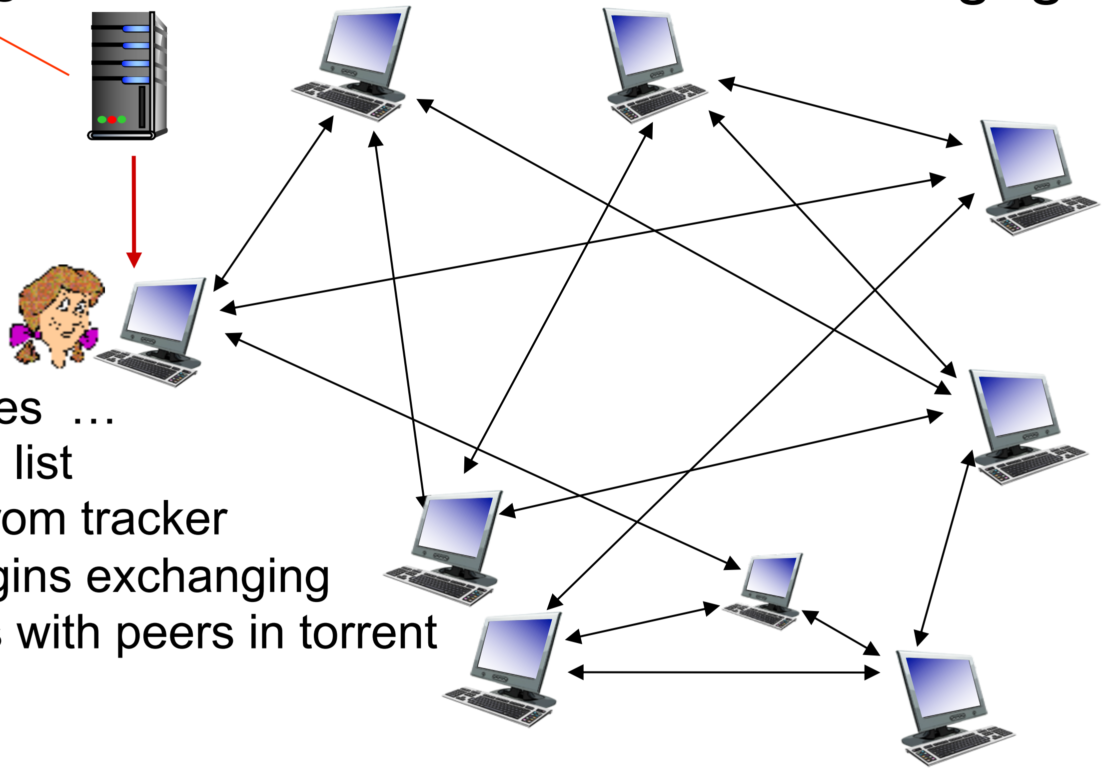


P2P file distribution: BitTorrent

- file divided into 256KB chunks
- peers in torrent send/receive file chunks

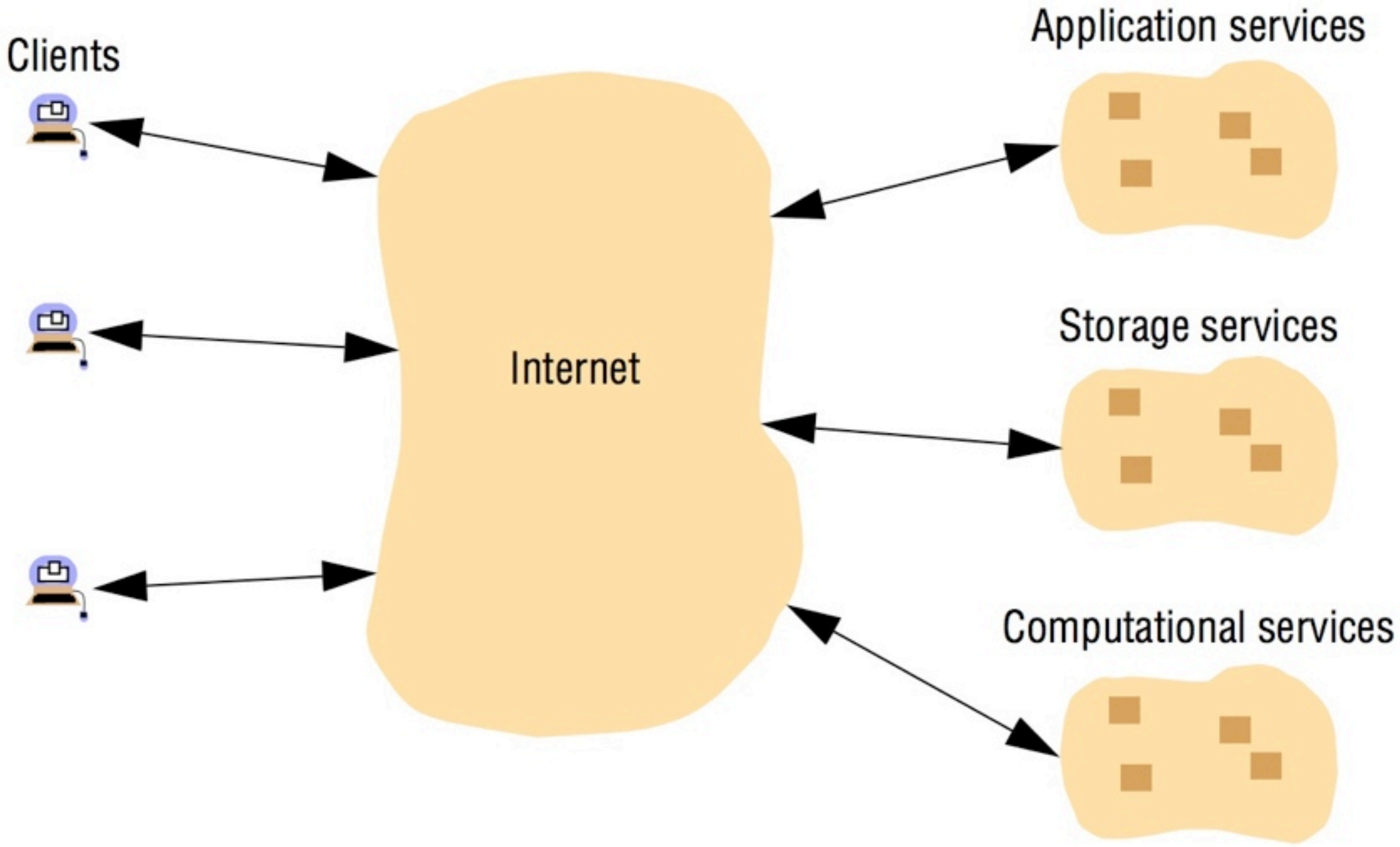
tracker: tracks peers participating in torrent

torrent: group of peers exchanging chunks of a file



Alice arrives …
… obtains list
of peers from tracker
… and begins exchanging
file chunks with peers in torrent

Cloud Computing



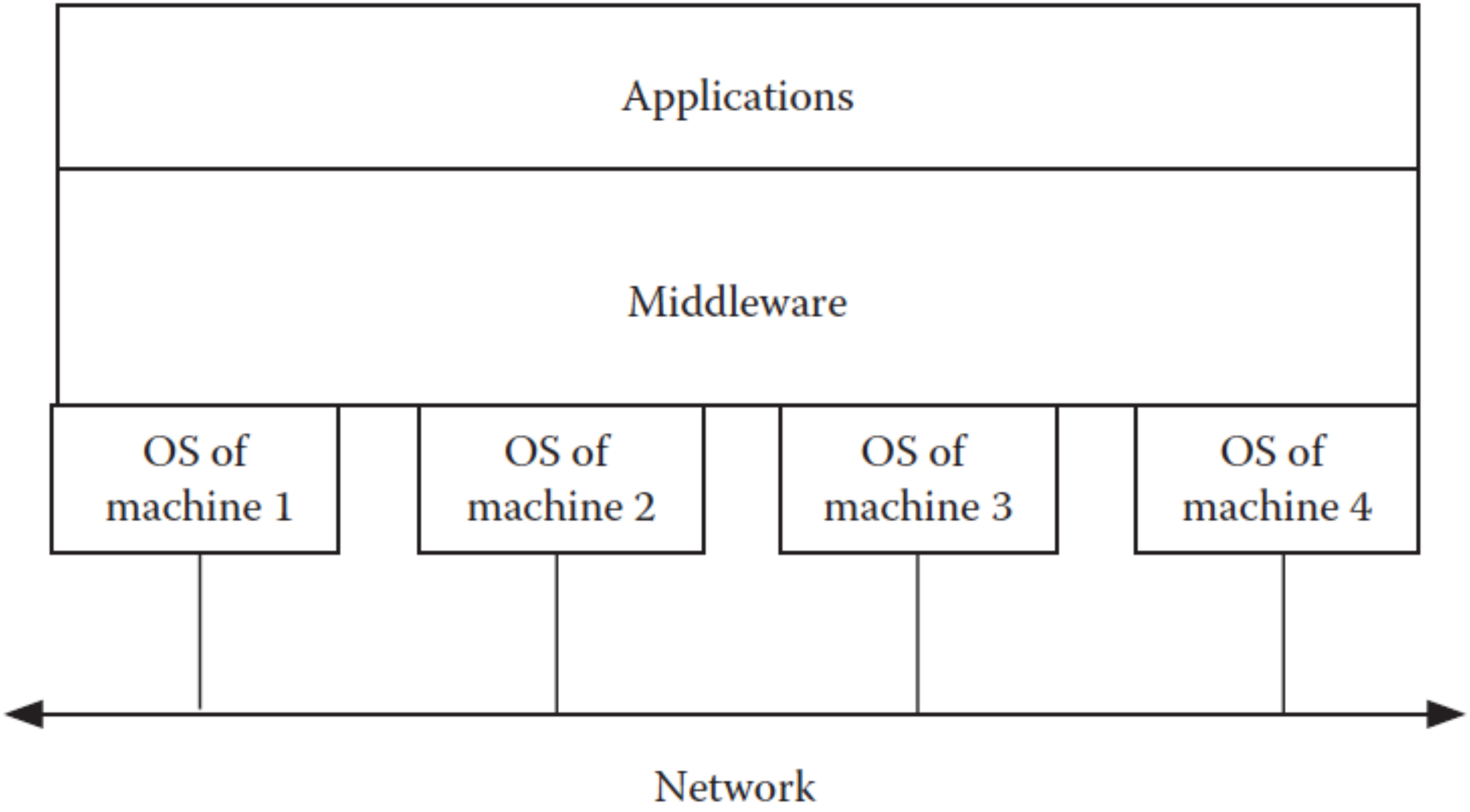
Challenges

- Heterogeneity
- Openness
- Security
- Scalability
- Failure handling
- Concurrency
- Transparency
- Quality of service

Heterogeneity

- Networks: masked by the Internet protocols
- Computer hardware: big-endian vs. small-endian
- Operating systems: programming interface
- Programming languages: data representation
- Implemented by different developers

Middleware


Applications
Middleware
OS of machine 1
OS of machine 2
OS of machine 3
OS of machine 4
Network

Scalability

- A system is scalable if it remains effective when there is a significant increase in the scale of the system (e.g., number of processes)
- For a system with n processes to be scalable
  - quantity of physical resources should be $O(n)$ or lower
  - Space or time complexity should be $O(\log n)$ or lower
- Preventing software resources running out: e.g., IP addresses

Common measures of complexity

Space complexity

How much space is needed per process to run an algorithm? (measured in terms of n, the size of the network)

Time complexity

What is the max. time (number of steps) needed to complete the execution of the algorithm?

Message complexity

How many messages are exchanged to complete the execution of the algorithm?

Transparency

- *Access transparency*: enables local and remote resources to be accessed using identical operations.
- *Location transparency*: enables resources to be accessed without knowledge of their physical or network location (for example, which building or IP address).
- *Concurrency transparency*: enables several processes to operate concurrently using shared resources without interference between them.
- *Replication transparency*: enables multiple instances of resources to be used to increase reliability and performance without knowledge of the replicas by users or application programmers.

Transparency

- *Failure transparency*: enables the concealment of faults, allowing users and application programs to complete their tasks despite the failure of hardware or software components.
- *Mobility transparency*: allows the movement of resources and clients within a system without affecting the operation of users or programs.
- *Performance transparency*: allows the system to be reconfigured to improve performance as loads vary.
- *Scaling transparency*: allows the system and applications to expand in scale without change to the system structure or the application algorithms.

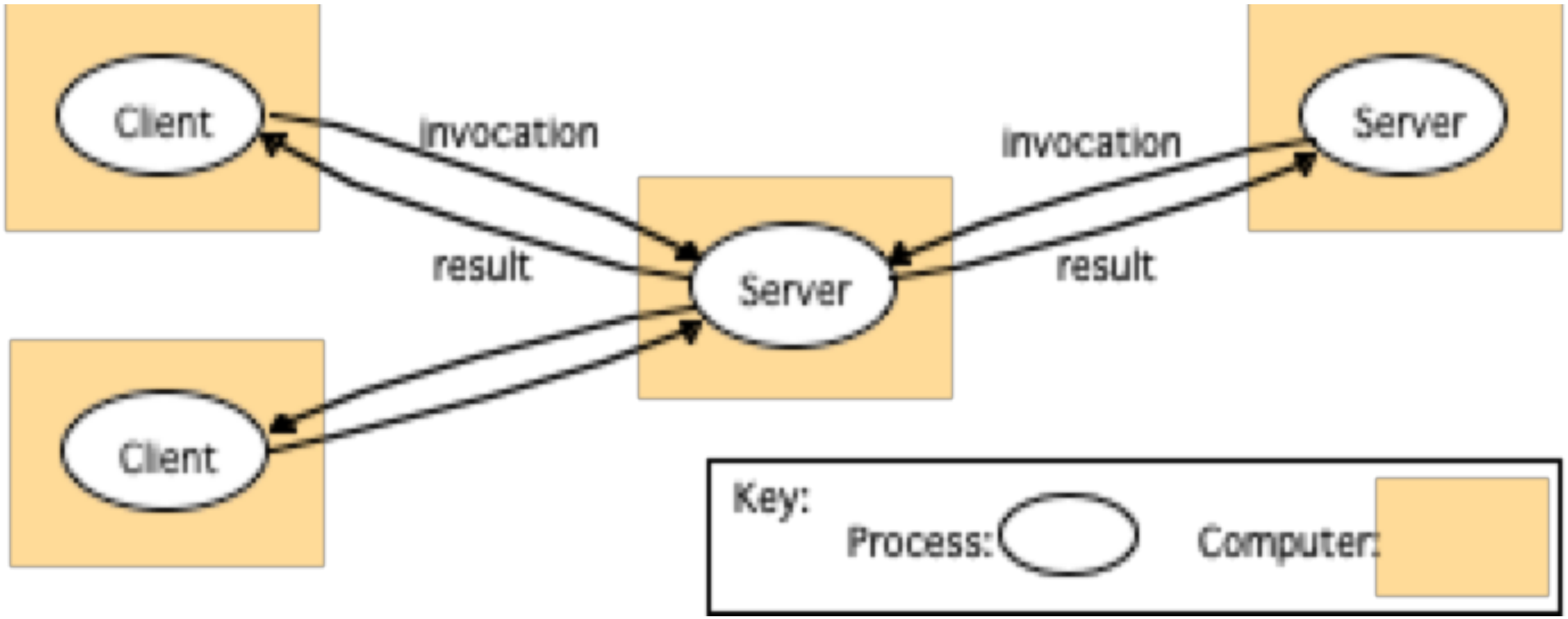
Outline

- What Is a Distributed System?
- Examples of distributed Systems
- Challenges
- Architectural models
- Fundamental models

Architectural elements

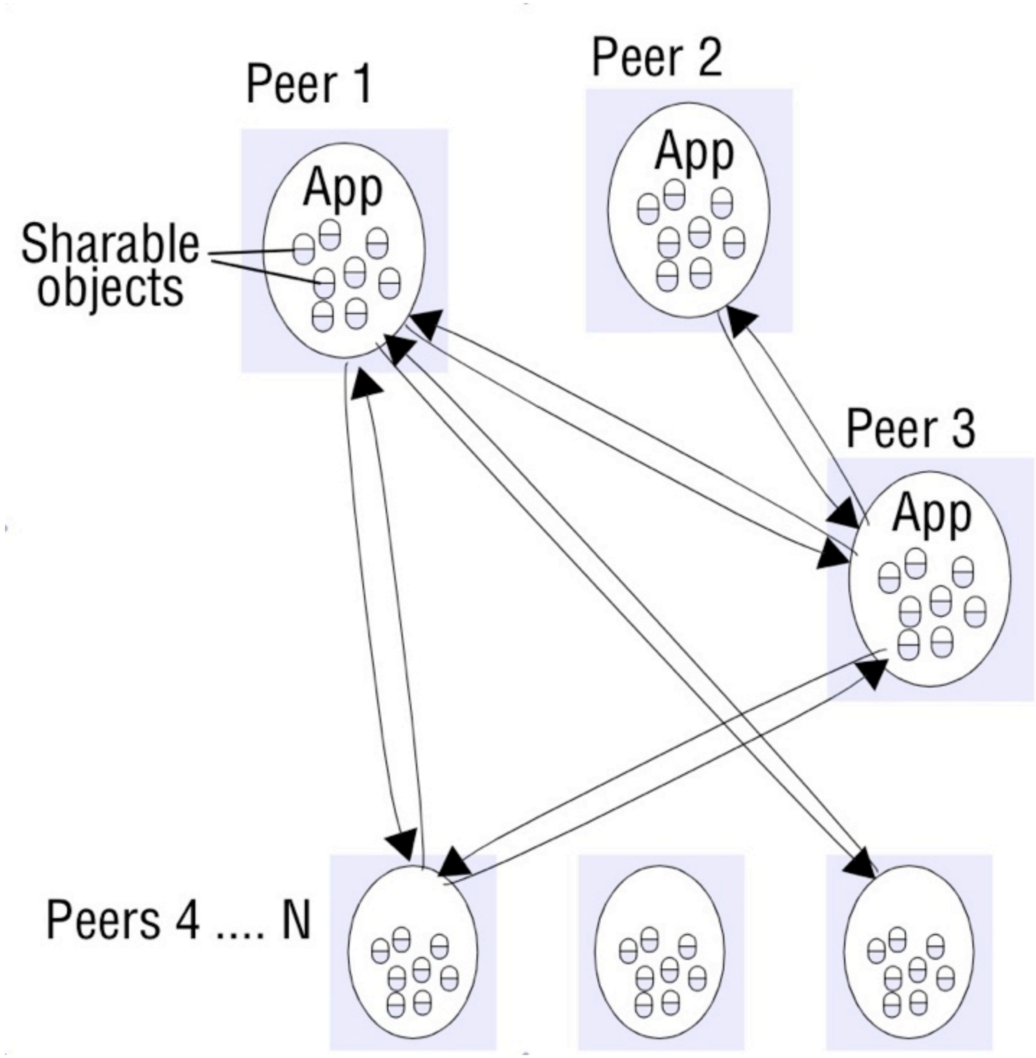
- Communication entities
  - Processes, threads, nodes
  - Objects: Java RMI (5.5), CORBA (8.3)
  - Components: EJB (8.5), CORBA component model
  - Web services: URI, XML-based message passing (chapter 9)
- Communication paradigms
  - interprocess communication: message passing and multicast
  - RPC (5.3), RMI (5.4-5.5)
  - Group communication (6.2), publish-subscribe systems (6.3), …

Client-server vs. peer-to-peer architectures



Client-server model

Client-server vs. peer-to-peer architectures



Peer-to-peer model

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Synchronous vs. Asynchronous Systems

- Two limiting factors
  - Communication performance
  - Lack of a single global notion of time
- A synchronous system is one with the following bounds defined:
  - Time to execute each step of a process has known upper and lower bounds
  - Each message transmitted over a channel is received within a known bounded time
  - Each process has a local clock whose drift rate from real time has a known bound
- An asynchronous system is one in which there are no bounds on processing execution speeds, message transmission delays, and clock drift rates.

Synchrony vs. Asynchrony

Synchronous clocks	Physical clocks are synchronized
Synchronous processes	Lock-step synchrony
Synchronous channels	Bounded delay
Synchronous message-order	First-in first-out channels
Synchronous communication	Communication via *handshaking*

- **Any constraint defines some form of synchrony**

Common Failure Types

- Crash failure = the process halts
  - a form of “nice” failure. In a synchronous system, it can be detected using timeout, but in an asynchronous system, crash detection becomes tricky.
- Omission failure: Message lost in transit
  - e.g., buffer overflow, software errors at the sender or the receiver, link errors, collisions at the MAC layer
- Byzantine failure
  - any type of erroneous behavior, including malicious ones
  - Most difficult to deal with