Distributed Systems

CS425/ECE428

Radhika Mittal

Today's agenda

- Course overview
- Logistics
- Distributed System Model (if time)
  - Chapter 2.4 (except 2.4.3), parts of Chapter 2.3

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Examples of distributed systems

- World Wide Web
- A cluster of nodes on the cloud (AWS, Azure, GCP)
- Multi-player games
- BitTorrent
- Online banking
- ……..

What is a distributed system?

Hardware or software **components** located at **networked** computers that communicate or **coordinate** their actions only by **passing messages**.

- *Your textbook*

(Coulouris, Dollimore, Kindberg, Blair)

What is a distributed system?

A collection of **autonomous computing elements**, connected by a **network**, which appear to its users as a **single coherent system**.

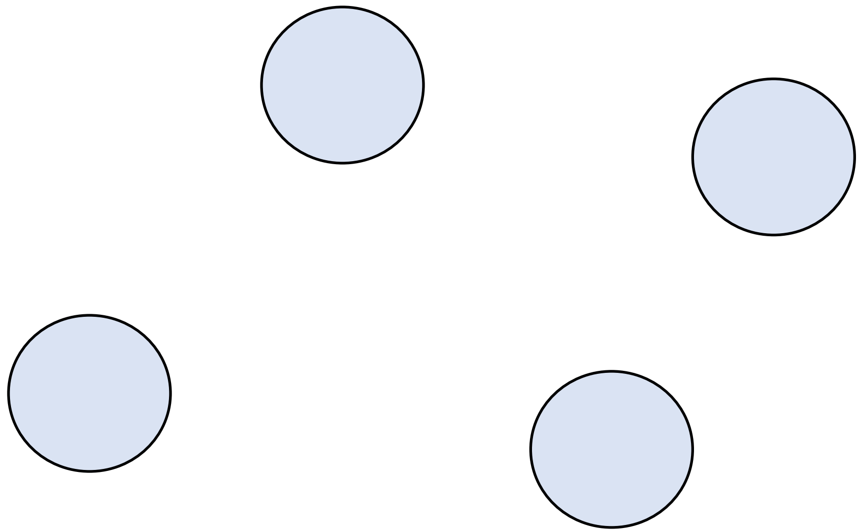
- *Steen and Tanenbaum*

What is a distributed system?

A system in which **components** located on **networked** computers communicate and **coordinate** their actions by **passing messages**. The components interact with each other in order to achieve a **common goal**.

- *Wikipedia*

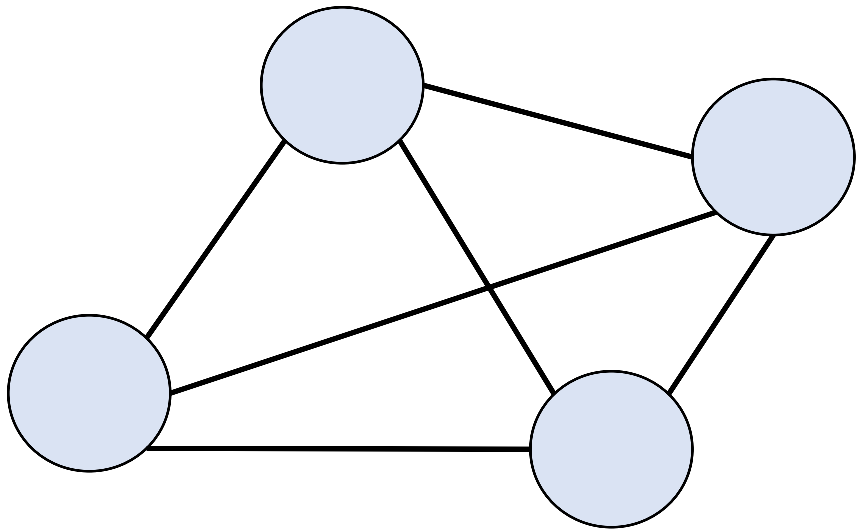
What is a distributed system?



Independent components or elements

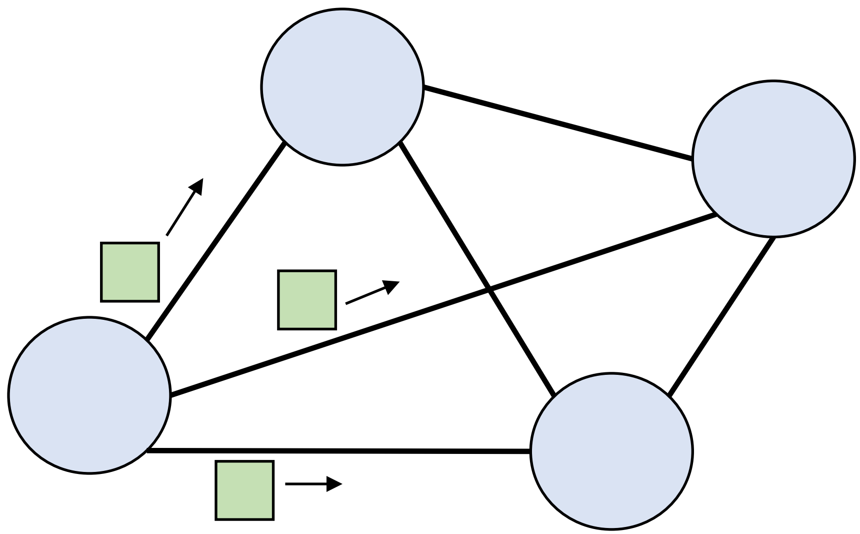
(software processes or any piece of hardware used to run a process, store data, etc)

What is a distributed system?



Independent components or elements that are **connected by a network**.

What is a distributed system?



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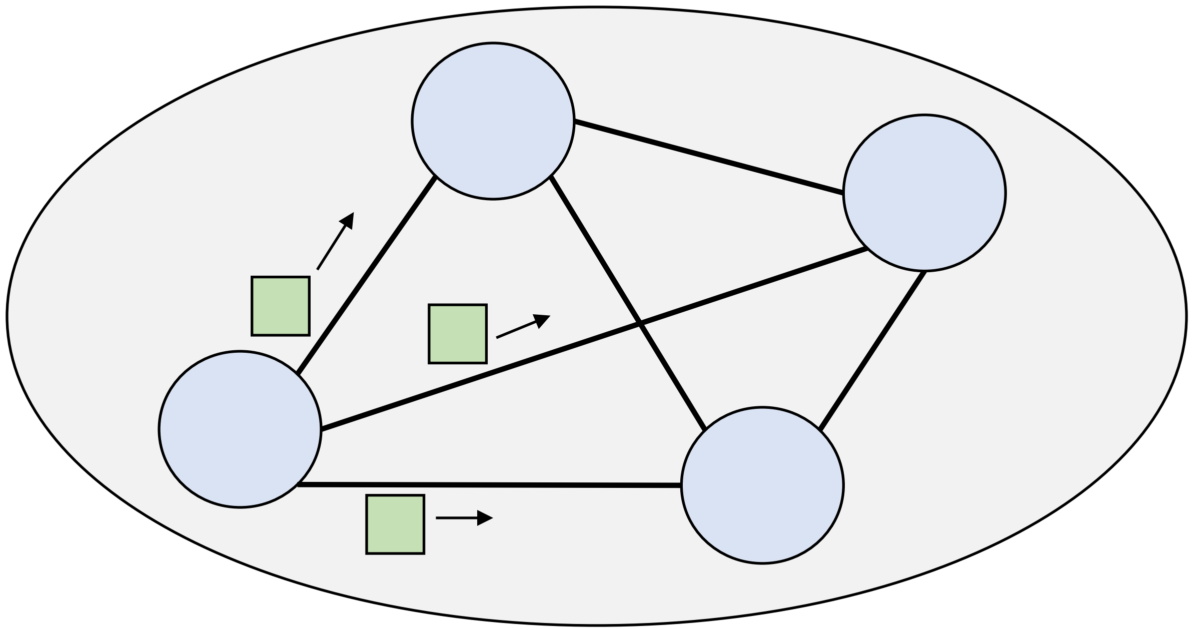
What is a distributed system?



Independent components or elements that are **connected by a network** and communicate by **passing messages** to achieve a **common goal**, appearing as a single coherent system.

What is a distributed system?

A distributed system is one in which the failure of a computer you didn't even know existed can render your own computer unusable.

- *Leslie Lamport*

Why distributed systems?

- Nature of the application
  - *Multiplayer games, P2P file sharing, client requesting a service.*
- Availability despite unreliable components
  - *A service shouldn't fail when one computer does.*
- Conquer geographic separation
  - *A web request in India is faster served by a server in India than by a server in US.*
- Scale up capacity
  - *More CPU cycles, more memory, more storage, etc.*
- Customize computers for specific tasks
  - *E.g. for storage, email, backup.*

Example: scaling up Facebook

- 2004: Facebook started on a single server
  - Web server front end to assemble each user's page.
  - Database to store posts, friend lists, etc.
- 2008: 100M users
- 2010: 500M users
- 2012: 1B users
- 2019: 2.5B users

How do we scale up?

Example: scaling up Facebook

- One server running both webserver and DB

- Two servers: one for webserver, and one for DB
  - *System is offline 2x as often!*

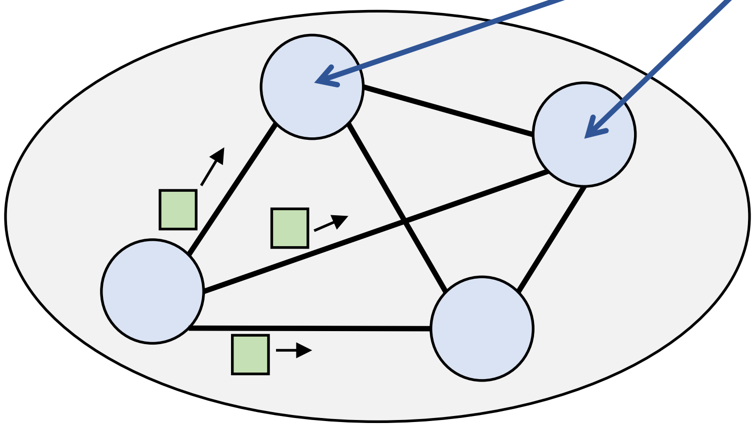
- Server pair for each social community
  - *E.g., school or college*
  - *What if server fails?*
  - *What if friends cross servers?*

Example: scaling up Facebook

- Scalable number of front-end web servers.
  - Stateless: if crash can reconnect user to another server.
  - Use various policies to map users to front-ends.

- Scalable number of back-end database servers.
  - Run carefully designed distributed systems code.
  - If crash, system remains available.

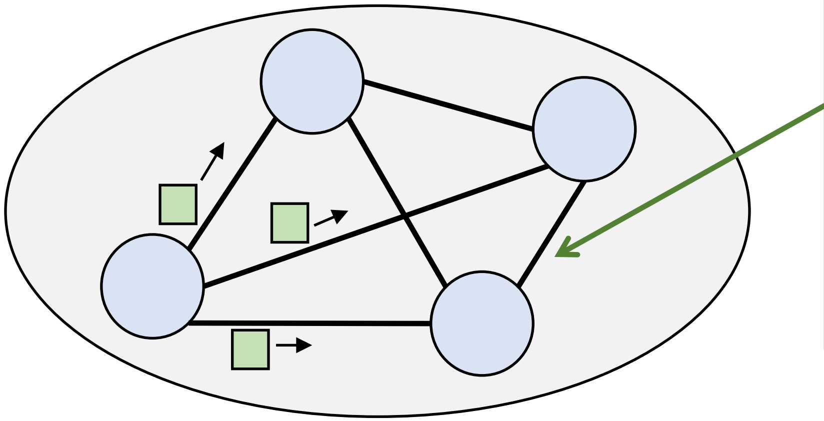
Challenging properties



Multiple computers

- Concurrent execution.
- Independent failure.
- Autonomous administration.
- Heterogeneous.
- Large numbers.

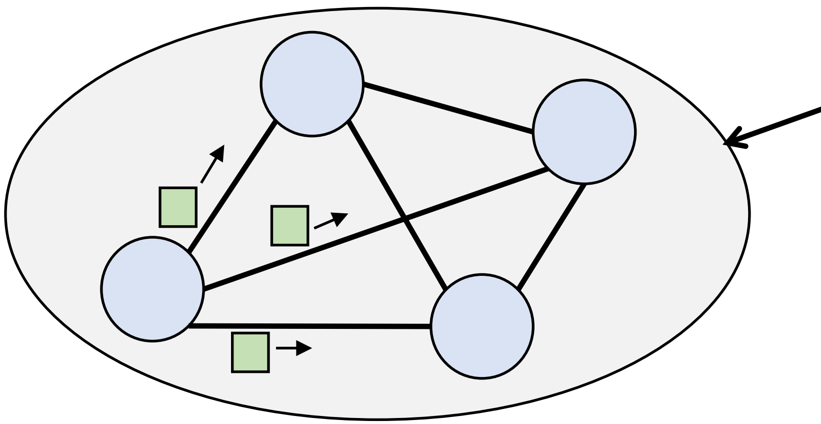
Challenging properties



Networked communication

- Asynchronous
- Unreliable
- Insecure

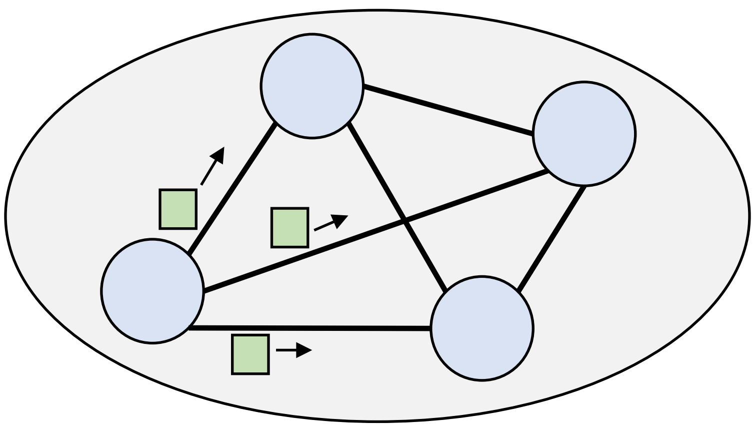
Challenging properties



Common goal

- Consistency
- Transparency

Challenging properties



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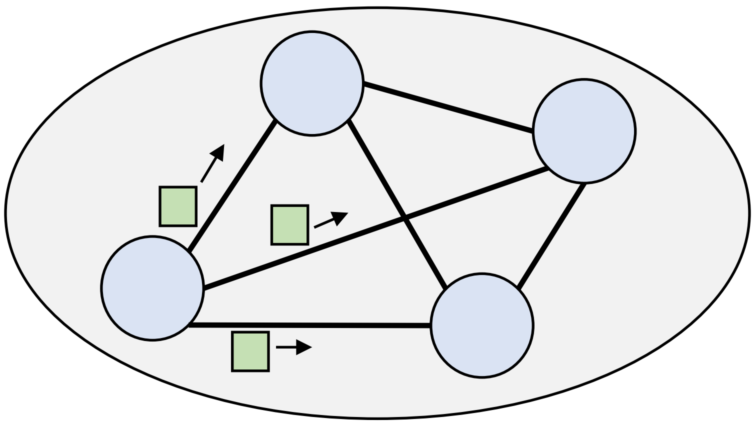

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What you will learn in this course

- **Distributed system concepts and algorithms**
  - How can failures be detected?
  - How do we reason about timing and event ordering?
  - How do concurrent processes share a common resource?
  - How do they elect a "leader" process to do a special task?
  - How do they agree on a value? Can we always get them to agree?
  - How to handle distributed concurrent transactions?
  - ….
- **Real-world case studies**
  - Distributed key-value stores
  - Distributed file servers
  - Blockchains
  - …

Related Courses

- CS 539 / ECE 526 Distributed Algorithms
- CS525: Advanced Distributed Systems

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- Logistics
- Distributed System Model (if time)
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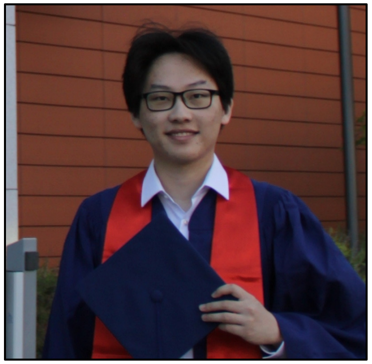
Course Staff

Radhika Mittal
Asst. Prof.
ECE and CS

Eashan Gupta, MS, CS



Jiangran Wang, MS, ECE

Sarthak Moorjani, MS, CS

Manoj Girija, MCS, CS

Sources of information

- **Course website**
  - https://courses.grainger.illinois.edu/ece428/sp2023/
    - https://courses.grainger.illinois.edu/cs425/sp2023/ also works.
  - Course Calendar
    - Time slots and locations for office hours
  - Homeworks, MPs
  - Lecture schedule, readings, and slides

- **CampusWire**
  - Announcements, questions, clarifications

Books

- *Distributed Systems: Concepts and Design*, Coulouris et al., 5th edition.
  - Earlier editions may be acceptable.
  - Your responsibility to find correct reading sections.

- Other texts
  - *Distributed Systems: An Algorithmic Approach*, Ghosh
  - *Distributed Systems: Principles and Paradigms,* Tanenbaum & Steen
  - *Distributed Algorithms*, Lynch

Mode of Lecture Delivery

- In person
  - 1320 Digital Computer Laboratory

- Mondays and Wednesdays, 2-3:15pm.

Relevant Online Platforms

- CampusWire
  - Link with access code has been shared over email.
  - Reach out to Manoj (netID: gmk6) if you need access to CampusWire.

- Gradescope
  - We will add students soon……stay tuned.

- PrairieLearn and CBTF for exams
  - More instructions to follow.

Lecture Videos

- Lecture videos will be uploaded to MediaSpace.
- Plan on attending classes for a better learning experience.
  - Use lecture videos only to fill in gaps in understanding.
- Students with conflicts during class timings:
  - Please make sure you view the lectures timely and regularly.
  - Ask clarifying questions on CampusWire or during office hours.

Grade components

- **Homeworks**
  - 5 homeworks in total.
  - Approx every 2-3 weeks.
  - Will be submitted using Gradescope.
  - Must be **typed** (hand-written diagrams are fine).
  - Must be done **individually**.

Grade components

- **Homeworks**

- **MPs (only for 4 credit version)**
  - 4 mini projects.
  - First (warm-up) MP0 will be released next Wednesday!
  - Groups of up to 2
    - Need to fill up a form to activate VM clusters.
  - MP0, MP1, and MP3 can be in any language
    - Supported languages: Python, Go, C/C++, Java
    - You can also use other languages (e.g. Rust), but might get limited help from course staff.
  - *MP2 must be implemented in Go.*

Grade components

- Homeworks
- MPs (only for 4 credit version)
- Exams
  - One midterm
    - Tentative dates: March 22-24 (more details to follow)
  - Comprehensive final.

Grade components

- Homeworks
- MPs (only for 4 credit version)
- Exams
- CampusWire + Class participation

Grade distribution

	3-credit	4-credit
Homework	33%	16% (drop 2 worst HWs)
Midterm	23%	17%
Final	43%	33%
MPs	N/A	33%
Participation	1%	1%

Late Policy

- For homeworks:
  - Can use a total of 48 late hours across the entire semester.

- For MPs
  - Can use a total of 168 late hours (1 week) across the entire semester.
  - Counted individually for each student, so keep your late hours in mind if you end up changing groups over the course of the semester.

Switching between credits

- Multiple sections:
    - *ECE428/CS425 T3*
    - *ECE428/CS425 TU4*
    - *ECE428/CS425 T4*

- If you'd like to switch between 3 and 4 credits, try to get on the wait list for the desired section.

- If you are unable to make the switch, reach out to Heather Mihaly (hmihal2) after the drop deadline.

Integrity

- Academic integrity violations have serious consequences.
  - Min: 0% on assignment
  - Max: expulsion
  - All cases are reported to CS, your college, and senate committee.
- **As students, it is your responsibility to uphold academic integrity.**
- Example of violations:
  - Sharing of code outside group.
  - Copying homework solutions (from colleagues, from previous years', from the web).
  - Collaborating in exams.
  - ……

Questions?

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- **Distributed System Model**
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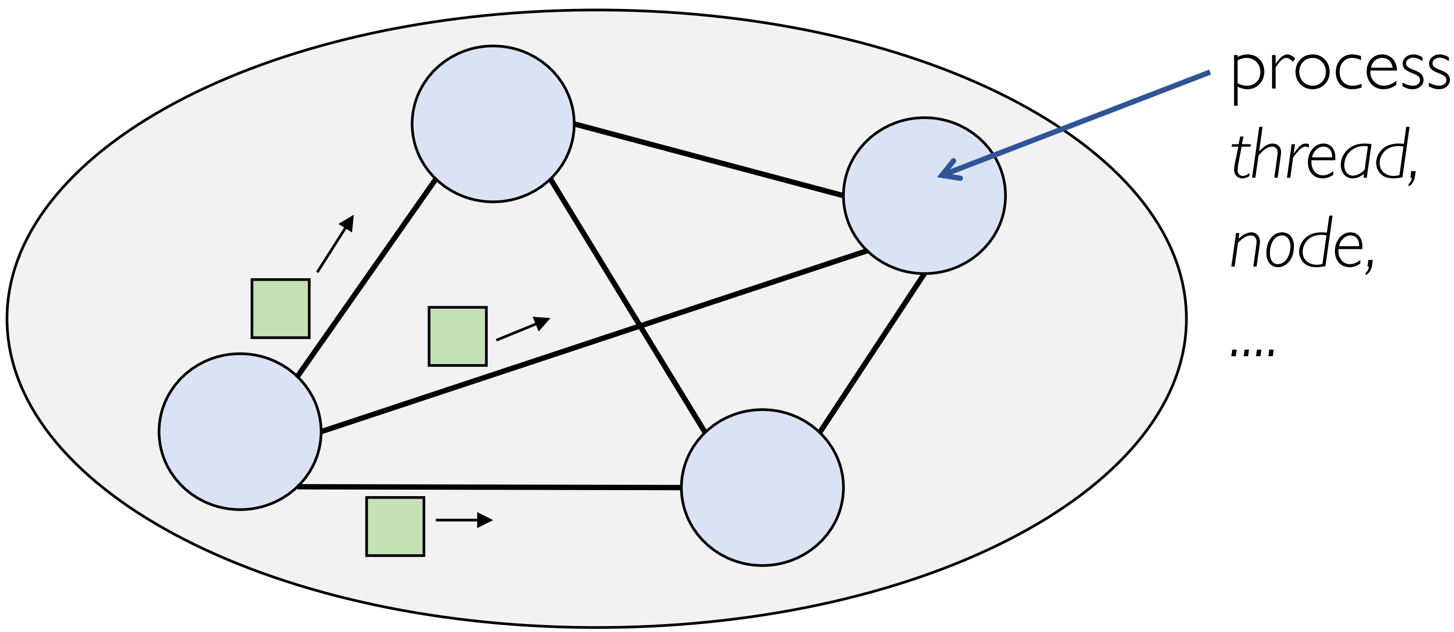
What is a distributed system?



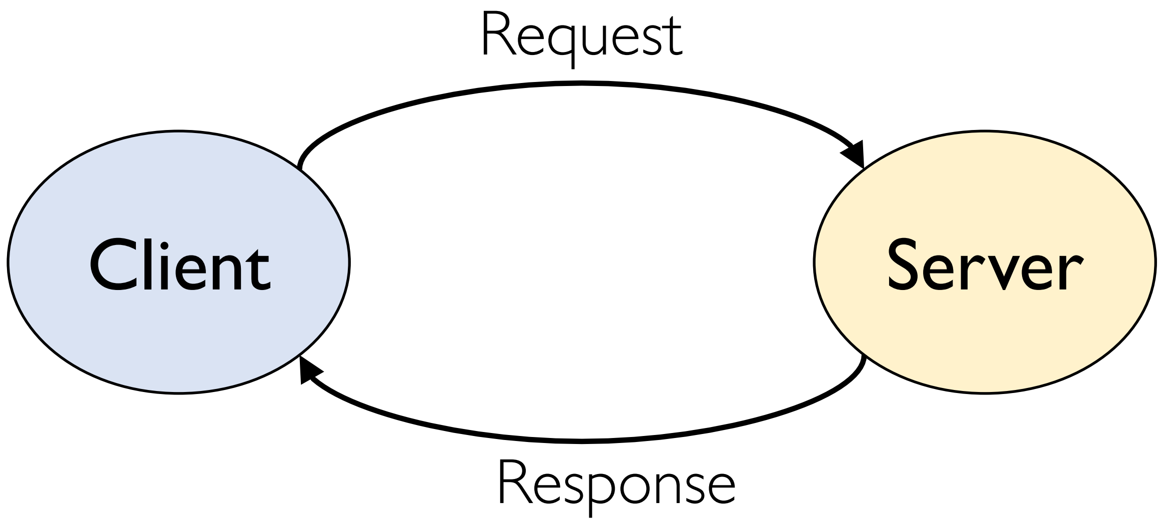
Independent components that are **connected by a network** and communicate by **passing messages** to achieve a common goal, appearing as **a single coherent system**.

Relationship between processes

- Two main categories:
  - Client-server
  - Peer-to-peer

Relationship between processes

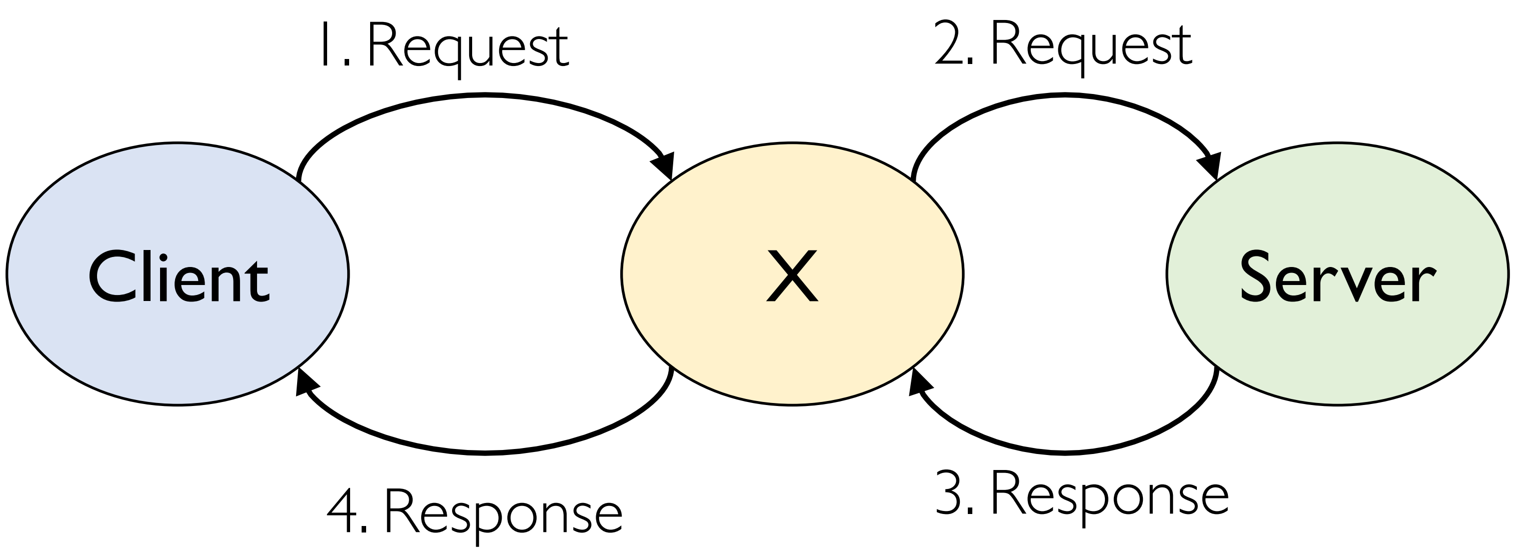
- Client-server



Clear difference in roles.

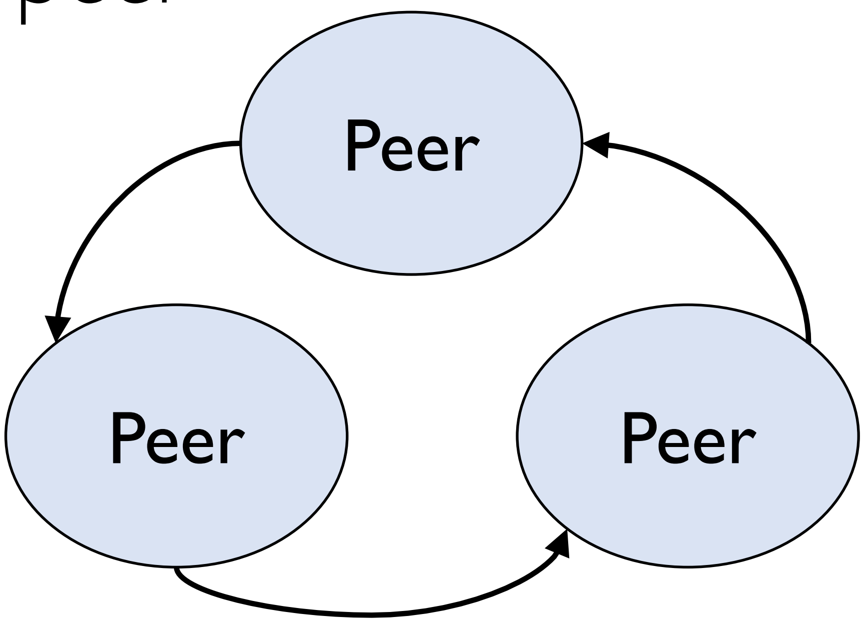
Relationship between processes

- Client-server



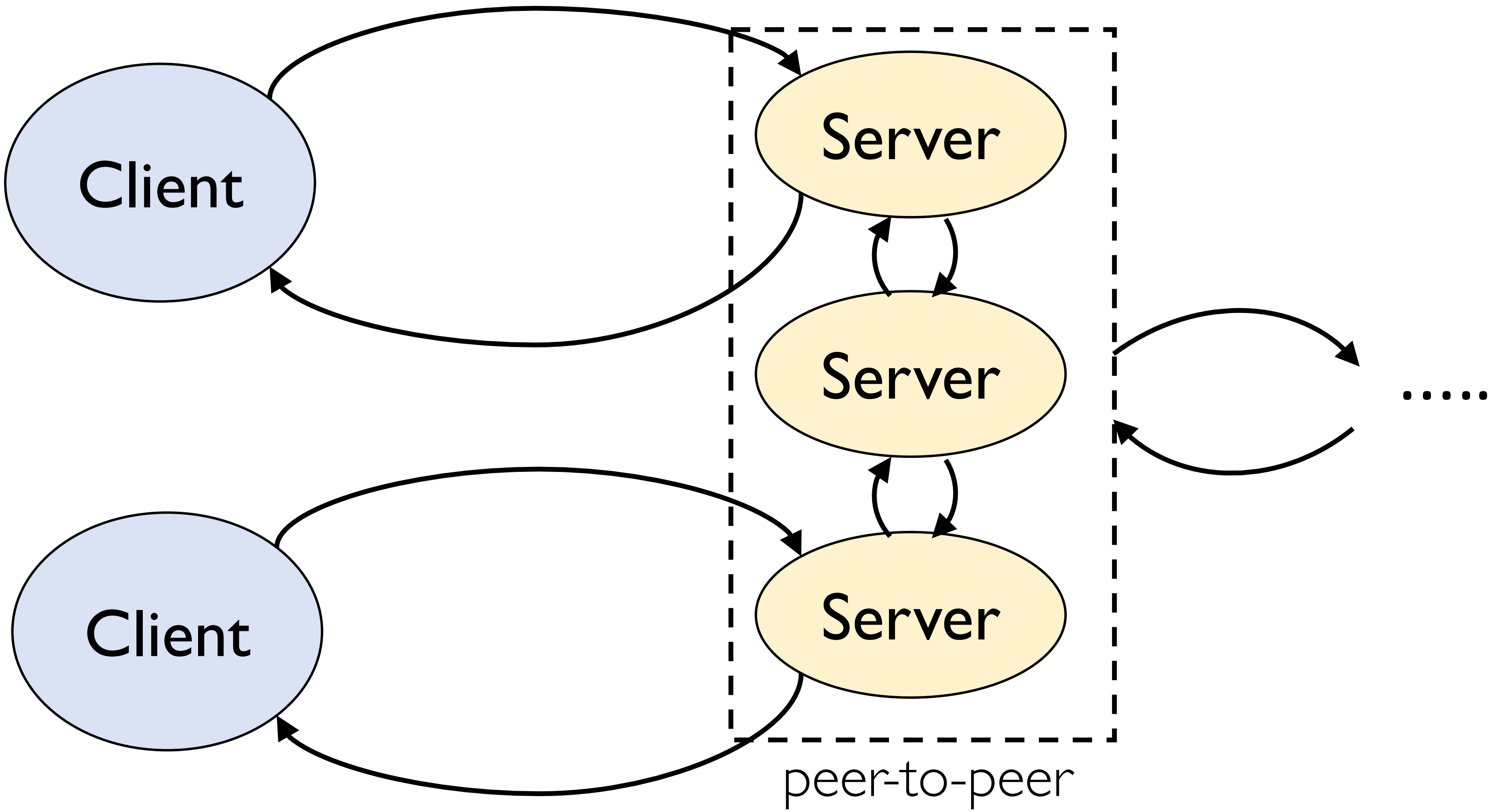
Relationship between processes

- Peer-to-peer



Similar roles.
Run the same program/algorithm.

Relationship between processes



Relationship between processes

- Two broad categories:
  - Client-server
  - Peer-to-peer

Distributed algorithm

- Algorithm on a single process
  - Sequence of steps taken to perform a computation.
  - *Steps are strictly sequential.*

- Distributed algorithm
  - Steps taken by each of the processes in the system (including transmission of messages).
  - *Different processes may execute their steps concurrently.*

Key aspects of a *distributed* system

- Processes must communicate with one another to coordinate actions. Communication time is variable.

- Different processes (on different computers) have different clocks!

- Processes and communication channels may fail.

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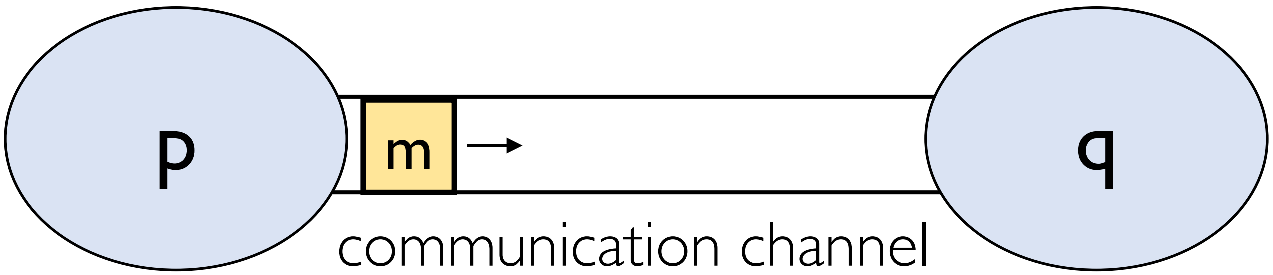
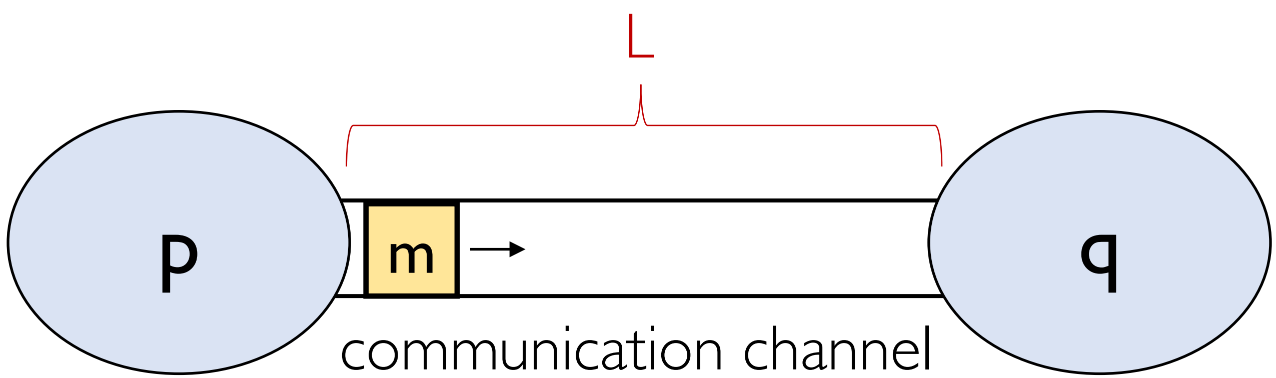
How processes communicate

- Directly using network sockets.
- Abstractions such as remote procedure calls, publish-subscribe systems, or distributed share memory.
- Differ with respect to how the message, the sender or the receiver is specified.

How processes communicate

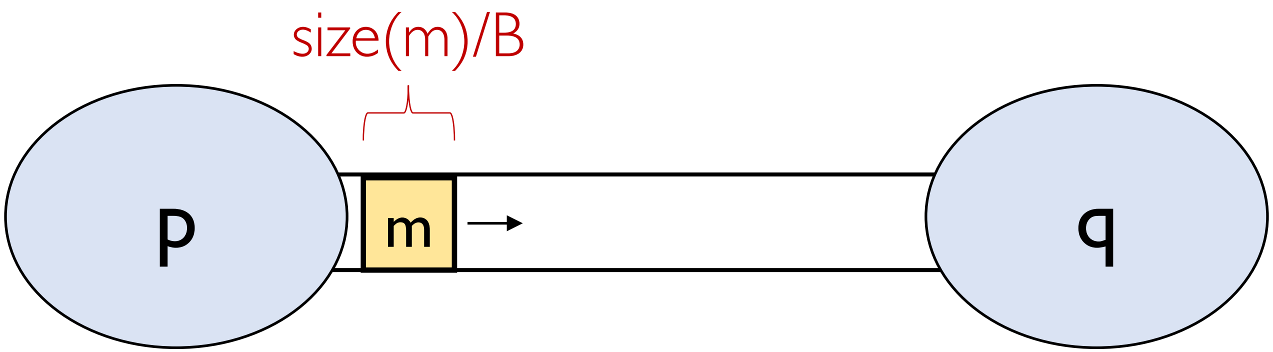


Communication channel properties



- Latency (L): Delay between the start of **m**'s transmission at **p** and the beginning of its receipt at **q**.
  - Time taken for a bit to propagate through network links.
  - Queuing that happens at intermediate hops.
  - Overheads in the operating systems in sending and receiving messages.
  - …..

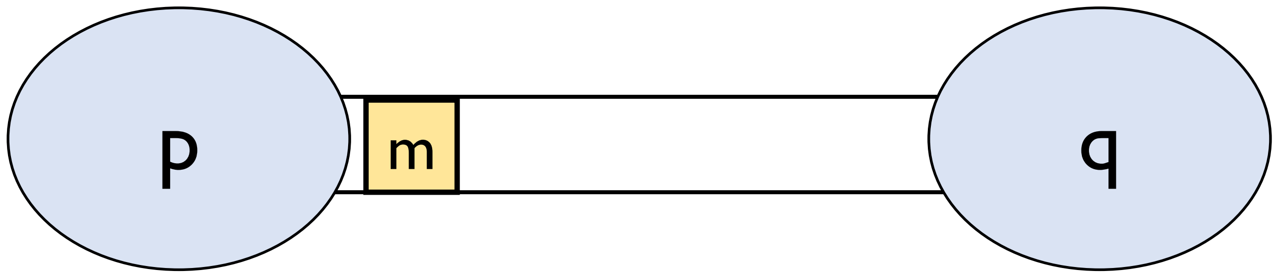
Communication channel properties



- Latency (L): Delay between the start of **m**'s transmission at **p** and the beginning of its receipt at **q**.

- Bandwidth (B): Total amount of information that can be transmitted over the channel per unit time.

Communication channel properties



- Total time taken to pass a message is governed by latency and bandwidth of the channel.
    - Both latency and available bandwidth may vary over time.

- *Sometimes useful to measure "bandwidth usage" of a system as amount of data being sent between processes per unit time.*

Key aspects of a *distributed* system

- Processes must communicate with one another to coordinate actions. Communication time is variable.
- Different processes (on different computers) have different clocks!
- Processes and communication channels may fail.

Differing clocks

- Each computer in a distributed system has its own internal clock.
- Local clock of different processes show different time values.
- Clocks *drift* from perfect times at different rates.

Key aspects of a *distributed* system

- Processes must communicate with one another to coordinate actions. Communication time is variable.
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Two ways to model

- Synchronous distributed systems:
  - Known upper and lower bounds on time taken by each step in a process.
  - Known bounds on message passing delays.
  - Known bounds on clock drift rates.

- Asynchronous distributed systems:
  - No bounds on process execution speeds.
  - No bounds on message passing delays.
  - No bounds on clock drift rates.

Lecture Summary

- Distributed System
  - Multiple computers (or processes)
  - Networked communication
  - Common goal
- Distributed systems are fundamentally needed.
- They are challenging to build.
  - Variable communication time, clock drifts, failures.
- Course goals: concepts, designs, case studies

Acknowledgements

- Arvind Krishnamurthy
- Nikita Borisov

Questions?