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?

Independent components or elements that are connected by a network and communicate by passing messages.
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

Common goal
- Consistency
- Transparency

Multiple computers
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Networked communication
- Asynchronous
- Unreliable
- Insecure
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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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
• Homworks, MPs
• Lecture schedule, readings, and slides

• CampusWire
  • Announcements, questions, clarifications
Books

  • 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

<table>
<thead>
<tr>
<th></th>
<th>3-credit</th>
<th>4-credit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homework</td>
<td>33%</td>
<td>16% (drop 2 worst HWs)</td>
</tr>
<tr>
<td>Midterm</td>
<td>23%</td>
<td>17%</td>
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<tr>
<td>Final</td>
<td>43%</td>
<td>33%</td>
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<tr>
<td>MPs</td>
<td>N/A</td>
<td>33%</td>
</tr>
<tr>
<td>Participation</td>
<td>1%</td>
<td>1%</td>
</tr>
</tbody>
</table>
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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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

Client

Server

Server

Server

......

Client

peer-to-peer
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.
Key aspects of a *distributed* system

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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

\[ p \xrightarrow{m} q \]

communication channel
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.

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

- Processes and communication channels may fail.
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?