CS 425 / ECE 428
Distributed Systems
Fall 2023

Indranil Gupta (Indy) and Aishwarya Ganesan

August 23 – December 6, 2023

Lecture 1-29

Our First Goal in this Course was…

(First lecture slide)

To Define the Term Distributed System

Can you name some examples of Distributed Systems?

(First lecture slide)

- Client-Server (NFS)
- The Web
- The internet
- A wireless network
- DNS
- Gnutella or BitTorrent (peer to peer overlays)
- A "cloud", e.g., Amazon EC2/S3, Microsoft Azure
- A datacenter, e.g., NCSA, a Google datacenter, AWS

What are other examples you've seen in class?

What is a Distributed System?

(First lecture slide)

FOLDOC definition

(First lecture slide)

A collection of (probably heterogeneous) automata whose distribution is transparent to the user so that the system appears as one local machine. This is in contrast to a network, where the user is aware that there are several machines, and their location, storage replication, load balancing and functionality is not transparent. Distributed systems usually use some kind of client-server organization.

Textbook definitions

(First lecture slide)

- A distributed system is a collection of independent computers that appear to the users of the system as a single computer.

  [Andrew Tanenbaum]

- A distributed system is several computers doing something together. Thus, a distributed system has three primary characteristics: multiple computers, interconnections, and shared state.

  [Michael Schroeder]

A working definition for us

(First lecture slide)

A distributed system is a collection of entities, each of which is autonomous, programmable, asynchronous and failure-prone, and which communicate through an unreliable communication medium.

- Entity=a process on a device (PC, PDA)
- Communication Medium=Wired or wireless network
- Our interest in distributed systems involves
  - design and implementation, maintenance, algorithmics
- *What Evidence/Examples have we seen?*

Problems we have seen since then

- Time and Synchronization
- Global States and Snapshots
- Failure Detectors
- Multicast
- Mutual Exclusion
- Leader Election
- Consensus and Paxos
- Gossiping
- Peer to peer systems – Napster, Gnutella Chord, BitTorrent
- Cloud Computing and Hadoop
- Sensor Networks
- Structure of Networks
- Datacenter Disaster Case Studies

Basic Theoretical Concepts

Cloud Computing

What Lies Beneath

Problems we have seen since then (2)

- RPCs & Distributed Objects ← Basic Building Blocks
- Concurrency Control
- 2PC and Paxos
- Replication Control
- Key-value and NoSQL stores

Distributed Services (e.g., storage)

- Stream Processing
- Graph processing
- Spark
- ML

New Emerging Distributed Systems

- Scheduling
- Distributed File Systems
- Distributed Shared Memory
- Security

Old but Important (Re-emerging)

What This Course is About

(First lecture slide)

- Politics
- Movies
- Travel to Saturn
- Interviews
- Company Acquisitions
- (Not Kidding)

What This Course is About

(First lecture slide)

- Politics: HW1
- Movies: HW2
- Travel to Saturn: HW3
- Interviews: HW4
- Company Acquisitions: MP1-4
- (Not Kidding)

What This Course is About (2)

- Midterm
- HW's and MP's

How to get good grades (and regrades, and jobs in some cases)
(& that standard devs are important!)

MPs: Amazing work, everyone!

- You've built a new distributed system from scratch!
- And used some open-source distributed systems!

How far is your design from a full-fledged system?
What else do you need to do to make it competitive with open-source?

Rejoinder: Typical Distributed Systems Design Goals

- Common Goals:
  - Heterogeneity
  - Robustness
  - Availability
  - Transparency
  - Concurrency
  - Efficiency
  - Scalability
  - Security
  - Openness

(First lecture slide)

Do they make sense now?

Rejoinder: Typical Distributed Systems Design Goals

(First lecture slide)

- Common Goals:
  - Heterogeneity – can the system handle a large variety of types of PCs and devices?
  - Robustness – is the system resilient to host crashes and failures, and to the network dropping messages?
  - Availability – are data+services always there for clients?
  - Transparency – can the system hide its internal workings from the users?
  - Concurrency – can the server handle multiple clients simultaneously?
  - Efficiency – is the service fast enough? Does it utilize 100% of all resources?
  - Scalability – can it handle 100 million nodes without degrading service? (nodes=clients and/or servers) How about 6 B? More?
  - Security – can the system withstand hacker attacks?
  - Openness – is the system extensible?
  - (Also: consistency, CAP, partition-tolerance, ACID, BASE, and others …)

Problems we have seen in Class

(and their relation to other courses)

- Time and Synchronization
- Global States and Snapshots
- Failure Detectors
- Multicast Communications
- Mutual Exclusion
- Leader Election
- Consensus and Paxos
- Gossiping
- Peer to peer systems – Napster, Gnutella Chord
- Cloud Computing
- Sensor Networks
- Structure of Networks
- Datacenter Disaster Case Studies

Core Material of this course

Related to other graduate classes in department (e.g., CS523, CS525)

Problems we have seen in Class

(and their relation to other courses)

- RPCs & Distributed Objects
- Concurrency Control
- 2PC and Paxos

Core Material of this course

- Replication Control

Related to CS 411/CS 511

- Key-value and NoSQL stores
- Stream Processing
- Graph processing
- Spark
- ML
- Scheduling
- Distributed File Systems

Related to CS 525, CS598FTS, CS598RAP, CS598MS

- Distributed Shared Memory

Related to CS 421/CS 433

- Security

Related to CS 523/561

CS525: Advanced Distributed Systems (taught by Indy)

CS 525, next offered Spring 2024

- Looks at hot topics of research in distributed systems: clouds, p2p, distributed algorithms, ML, sensor networks, and other distributed systems
- We will read many papers and webpages for classical and cutting-edge systems (research and production)
- If you liked CS425's material, it's likely you'll enjoy CS525
- Project: Choose between Research project or Entrepreneurial project
  - Your project will build a cutting edge research distributed system, and write and publish a paper on it
  - Your project will build a distributed system for a new startup company idea (your own!) and perform associated research with it
- Both graduates and undergraduates welcome! (let me know if you need my consent).
- Class size is around 50-80
- Previous research projects published in journals and conferences, some great startup ideas too!

CS598 FTS (taught by Aishwarya)
CS598 RAP (taught by Ram)

CS598 FTS - Fault-tolerant and consistent data center systems, next Spring 2025

- Deep dive deep into replication and consensus protocols, geo-replication, distributed transactions, and various consistency models and how to implement them.
- Designing distributed systems for emerging hardware (e.g., persistent memory, programmable network) and emerging trends in data center (e.g., rack-scale, RDMA)

CS 598 RAP - Storage systems, next Spring 2025

- Covers a set of topics in storage systems both local (e.g., local key-value stores, file systems) and distributed (e.g., disaggregation, control-plane storage).
- Some topics covered in recent offerings: write-optimized storage systems, reliability and performance in local storage systems, crash consistency techniques, shared-log systems, and storage and memory disaggregation.

- Read, review, and discuss research papers; case studies from production systems.
- Semester-long research project

Other Related Grad Courses

- CS525 – Indy
- CS598FTS – (Aishwarya Ganesan) ML+Systems, Distributed computing
- CS598RAP – (Ram Alagappan) Storage systems
- CS598LR – (Ling Ren) Consensus, Blockchain
- CS598MS – (Daniel Kang) Machine Learning and Data Systems
- CS523 – Tianyin Xu

- See also courses by Radhika Mittal (ECE, distributed storage), Andrew Miller (ECE, blockchain), Mingjia Zhang (new in SP24)

Questions?

A working definition for us

(First lecture slide)

A distributed system is a collection of entities, each of which is autonomous, programmable, asynchronous and failure-prone, and which communicate through an unreliable communication medium.

[Is this definition still ok, or would you want to change it?]

Think about it!

Final Exam

- Office Hours: Regular [All TAs] until Dec 11th (usual schedule).
  - Exceptions posted on Piazza (check before heading out to an OH)
- **Final Exam: In person. Dec 12th Tue at 7 pm to 10 pm**
  - There will be a Piazza blackout Dec 8 (Fri) afternoon to Dec 11 (Mon) morning, as Coursera students will be taking the final exam (their final exam is different than yours)
  - Syllabus: Includes all material since the start of the course. There may be more emphasis on material since midterm.

Course Evaluations (“ICES”)

- Please complete them online! (Search for mail from “ICES”)
- Main purpose: to give us feedback on how useful this course was to you (and to improve future versions of the course)
- I won’t see these evaluations until after you see your grades
- Answer all questions
- Please write your detailed feedback – this is valuable for future versions of the course!