Decentralized Systems Engineering

CS-438 – Fall 2024

DEDIS

Bryan Ford, Pierluca Borsò-Tan

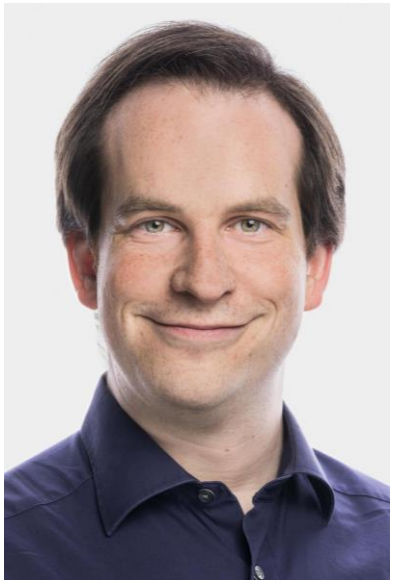
EPFL

Credits: P. Tennage, C. Basescu, et al.

Your Lecturers

Prof. Bryan Ford

Pierluca Borsò-Tan



What are Distributed and Decentralized Systems?

- *Distributed system*:

  a system of multiple computers (nodes) communicating
  over a network to achieve a common goal.

- *Decentralized system*:

  a distributed system without a single point of control or authority.

  different nodes or subsets of the network may be owned
  or controlled by different people, organizations or interests.

Some examples

- Centralized distributed systems
  - Google
  - Netflix
  - Facebook
  - WeChat
- Decentralized distributed systems
  - “The Internet”
  - E-mail
  - Usenet
  - BitTorrent
  - Bitcoin, Ethereum
  - Avionics, control systems
  - E-Voting
  - Tor, I2P

Course Goals

- Understand the fundamental and practical challenges inherent in designing and building decentralized systems.
- Get a feel for the (limited) body of techniques and solutions
- Examine a number of real systems, past and present: how they work, and why they succeeded …or failed
- Become better engineers: solidify this knowledge by applying it !
  → Build a small, but working, usable and robust, decentralized system

Why Study Decentralized Systems?

- Devise solutions when there is no common authority everyone trusts
- Add new tools to your engineering toolbox
- Learn to think and question your assumptions
- The world is full of decentralized systems

Course Organization

Course Organization

Lecturers:	Prof. Bryan Ford, Pierluca Borsò-Tan
TAs:	Pasindu Tennage, Charly Castes, Tao Lyu
AEs:	Derya Cogendez, Kilian Lauener, Mariem Baccari
E-mail:	cs438@groupes.epfl.ch
Material:	Moodle (lectures, readings, announcements, Q&A, etc.) https://go.epfl.ch/CS-438
Assessment:	40% homework 30% project 30% written exam (MCQ)

Class participation is not graded, but fundamental to success !

Weekly workload

Lectures: Monday 10:15-12:00 (INF1)

+ Sep. 13, this Friday !
15:15-17:00 (CM1 3)

Q&A w/ TAs: Friday 15:15-17:00 (INJ218)

- Help understanding concepts, homework requirements & architecting
- *The TAs will not debug your code for you !*

Self-guided: Monday 13:15-15:00 (INM200)

- Room open to hack, discuss design/problems, and test with classmates !

Homework: 8-12h depending on your understanding & development skills

No sharing or copying code; everyone implements their own Peerster!

Course Syllabus

Week	Content	
1	Course intro | UseNet and gossip	Foundations for Decentralization
2	Jeûne fédéral | exercise session only	
3	Flooding search and routing	
4	Structured search and compact routing	
5	Distributed storage	
6	Replication and consensus	
7	Threat modeling and threshold crypto	Attacks & Defenses
8	Anonymous communication	
9	Sybil attacks and defenses	
10	Blockchains and cryptocurrencies	Blockchains
11	Smart contracts	
12	Advanced blockchain architectures	
13	Testing & chaos engineering	Engineering
14	Decentralized democracy	E-Voting

Homework & Project

Build a decentralized system

Individually:

- Network layer (introduction to Go)
- Gossiping
- File sharing
- Consensus & blockchain

In groups of ~3 students:

- One of many predefined projects,
- … or your own !

Course Syllabus

Homework & Project Schedule

Week	Content	HW0	HW1	HW2	HW3	Project
1	Course intro | UseNet and gossip	Sep 9>				
2	Jeûne fédéral | exercise session only	*Network*				
3	Flooding search and routing		Sep 27 >			
4	Structured search and compact routing	> Oct 1	*Gossiping*			
5	Distributed storage			Oct 11 >		
6	Replication and consensus		> Oct 15	*File*		
7	Threat modeling and threshold crypto			*Sharing*	Nov 1 >	
8	Anonymous communication			> Nov 5	*Consensus & Blockchain*	
9	Sybil attacks and defenses					
10	Blockchains and cryptocurrencies				> Nov 24	
11	Smart contracts					Nov 25 >
12	Advanced blockchain architectures					*Your Project*
13	Testing & chaos engineering					
14	Decentralized democracy					> Dec 20

Homework : Your Path to Success !

- They build on top of each other
  - Don’t skip !
  - Improving previous HW is rewarded
- Defensive programming
- Manage your time
  - Don’t wait for the last minute – you will fail !
  - How much is that perfect score worth to you ?

Homework Assessment (40%)

	Code Quality	HW0	HW1	HW2	HW3	Total grade
HW0 due	1%	3%				4%
HW1 due	1%	1%	9%			11%
HW2 due	1%	1%	9%	14%		25%
HW3 due	4%	1%	11%	15%	29%	60%
Total	7%	6%	29%	29%	29%	100%

- You can talk with each other and exchange ideas, ***not*** share code
  Plagiarism will be checked for and dealt with severely

Homework Assessment (40%)

Public tests (90%):

- Unit tests 55%
- Integration tests 30%
- Performance (benchmarks) 5%

Hidden tests (10%):

- Verify robustness / defensive programming

Project: Organization

- Group Project (~3 members)
  - Build on top of (some part of) Peerster

- Guided topic selection, with clear goals
  … or you can be creative !

- Example project topics
  - Secure routing
  - Anonymous reputation
  - E-Voting
  - CRDTs

Project: Organization (cont’d)

- Regular meetings with TAs (week 11+)
- Final project report (December 20)

(More detailed information will follow later in the semester)

Project Assessment (30%)

- Group grade (50%)
  - Report
  - Project quality
  - Goals achieved

- Individual grade (50%)
  - Contribution to the project
  - (1 page) individual report

- **No winners in a losing team !**

Final Exam (30%)

- Format: multiple-choice questions

- Assessment of:
  - your understanding of fundamental concepts
  - your ability to reason about decentralized systems
  - your ability to engineer such systems
    (design, evaluate, test, make trade-offs)

- Non-goal:
  - You learning the slides by heart – it won’t help.

Support structure

Questions ?

Lecturer:	Bryan Ford, Pierluca Borsò-Tan
TAs:	Pasindu Tennage, Charly Castes, Tao Lyu
AEs:	Derya Cogendez, Kilian Lauener, Mariem Baccari
E-mail:	cs438@groupes.epfl.ch
Questions:	Exercise sessions (Fridays)
	Moodle forums & FAQs
Engineering	Week 3: Go thinking & best practices
Classes:	Week 13: testing & chaos engineering

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Why Build a Decentralized System?

- Sometimes a basic requirement
- Availability, reliability and safety
- Lower resource usage (in specific scenarios)
- Enabler for resilient ecosystems
- Nature has shown they can work incredibly well !

Major Topics & Applications

- Communication: messaging, chat, voice/video
- Data: storing, sharing, searching and mining
- Collaboration mechanisms
- Social networking
- Deliberation, e-voting, reputation
- Blockchains, cryptocurrencies, and smart contract systems

Related, but (mostly) out of scope in this class:

- Decentralized control systems, industrial automation
- Intelligent agents, self-organizing robotics
- Military & civilian ad-hoc networks (MANET, VANET, FANET, etc.)

Recurrent Issues and Themes

- Identity (real, sybil) versus location
- Information integrity and privacy
- Behavior accountability
- Denial-of-service
- Protocol efficiency, in the normal case and under load or attack

Why might we prefer centralized systems?

Let's think !

~ 2 min, write down your ideas
~ 1 min, discuss with your neighbor

Then share with the class !

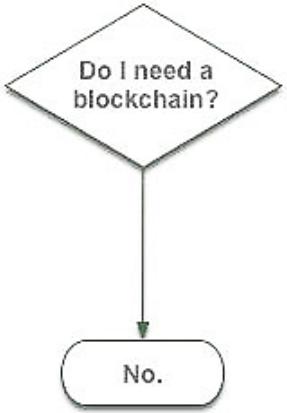
Why might we prefer centralized systems?

Simplicity:

- Engineering
- Management
- Security model
- Version management

Thereof:

- Performance / Efficiency
- Cost



Decentralized Communication

An introduction

Communicating with a (known) peer

- Same machine
  a file in a shared directory
- Local networking
  shared drive, file transfer
- Global networking, centralized trust
  a file on a shared server (FTP? Dropbox?)
- Decentralized
  e-mail (signed, encrypted)

or `write` command on UNIX/Linux

Communicating with (many, unknown) peers

- Same machine
  - a file in a shared directory, or Linux `wall` command
- Local networking
  - shared drive, intranet website
- Global networking, centralized trust
  - mailing lists, forums, Reddit, …
- Decentralized
  - ??? → next week's lecture

Communicating with (many, unknown) peers

- Decentralized

  ??? → this Friday's lecture

Many open questions:

- How do we reach unknown peers ?
- How do they find out about us / our node ?
- How do we eventually reach *every* peer ?
- How can we communicate reliably ?
  - Are they online ?
  - Is the network « stable » ?