Algorithms and Distributed Systems 2023/2024 (Lecture Zero)

MIEI - Integrated Master in Computer Science and Informatics
MEI – Master in Computer Science and Informatics
Specialization block

Nuno Preguiça (nmp@fct.unl.pt)
Alex Davidson (a.davidson@fct.unl.pt)

NOVA SCHOOL OF SCIENCE & TECHNOLOGY

Based on slides from João Leitão

Lecture Zero

- Introduction
- Context of the Course
- Course Structure
- Project
- Evaluation Rules

Introduction

The two Professors for this course will be:

- Nuno Preguiça (avg. 1h of theory's per week)
- Alex Davidson (avg 1 theory's + practical labs)

My (Alex's) background is in:

- Cryptography
- Security / Privacy

Context of the Course

Modern-day systems look very different to the past

Context of the Course

Context of the Course

Context of the Course

Context of the Course

amazon

Google Cloud Platform

Context of the Course

Context of the Course

Context of the Course

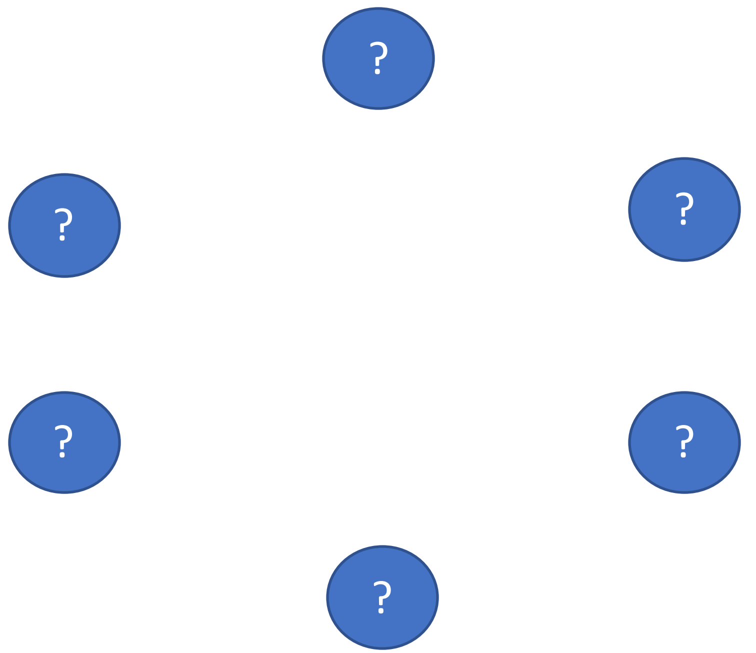
reddit

Google Cloud

Context of the Course

Context of the Course

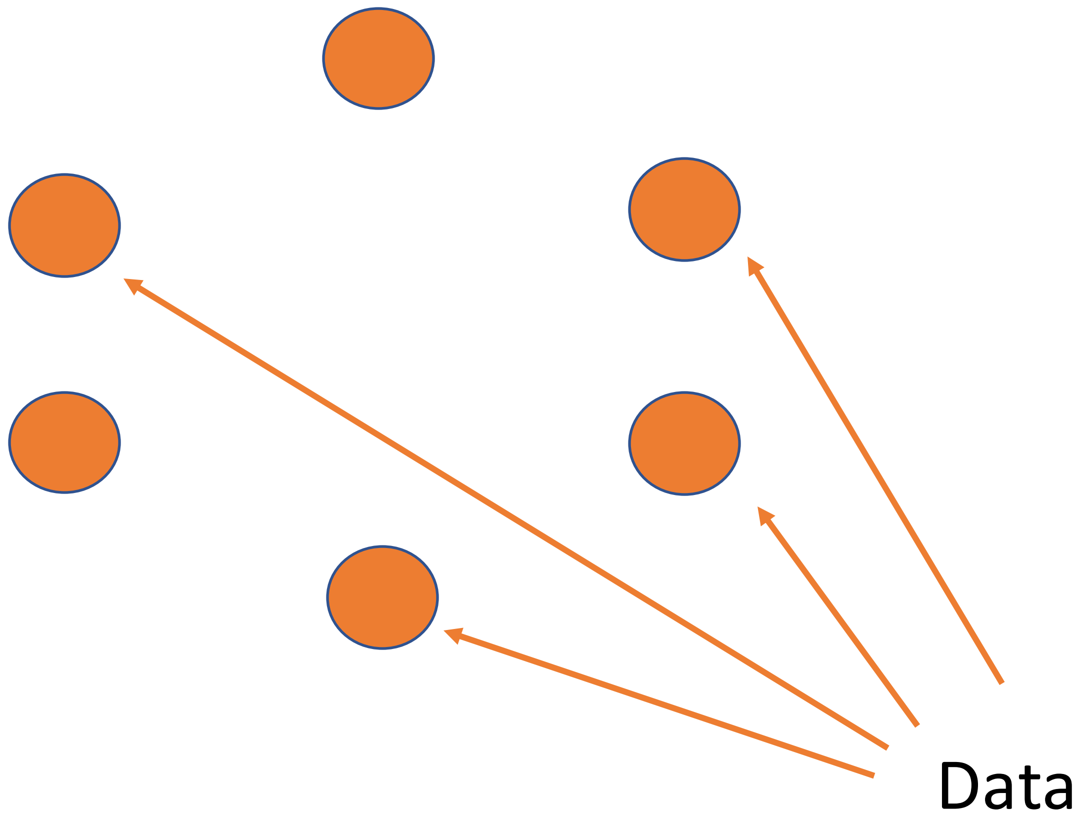
Context of the Course



What application components are part of the system?

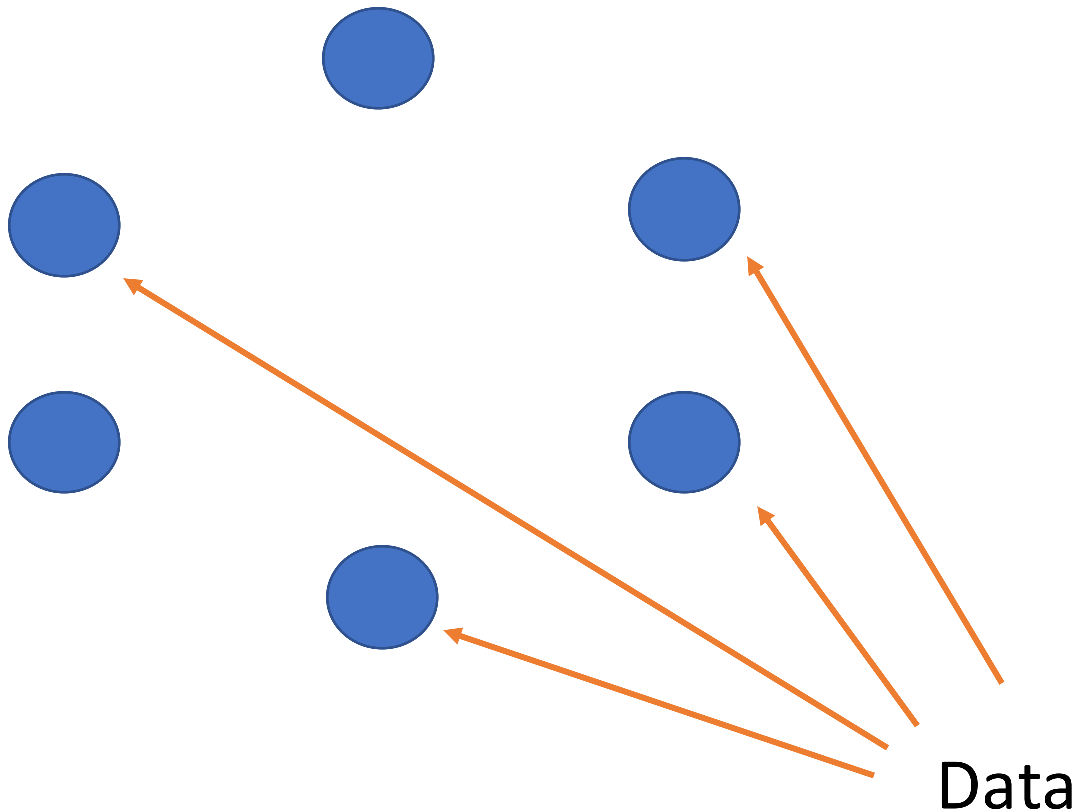
- At a given moment in time

Context of the Course



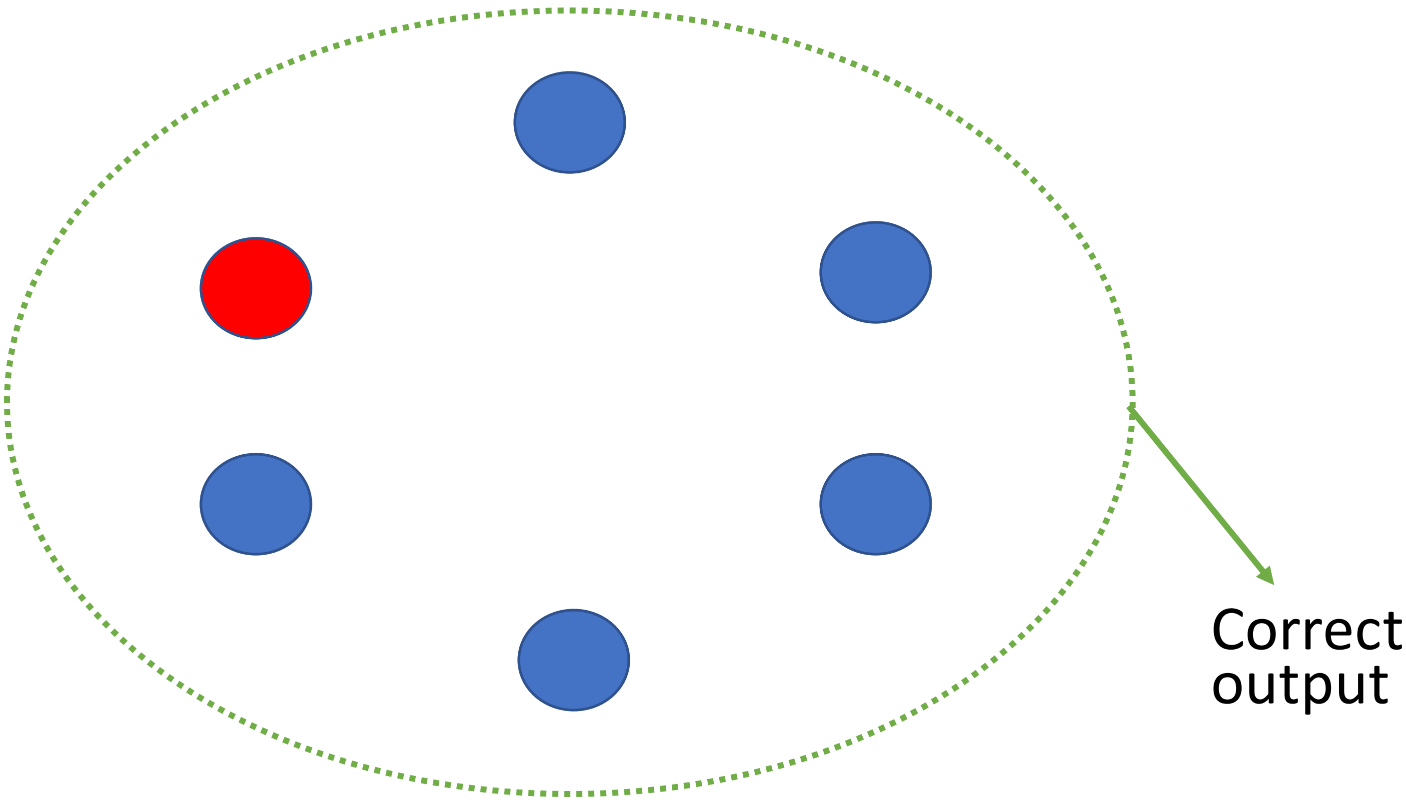
How do you ensure data is not lost?

Context of the Course



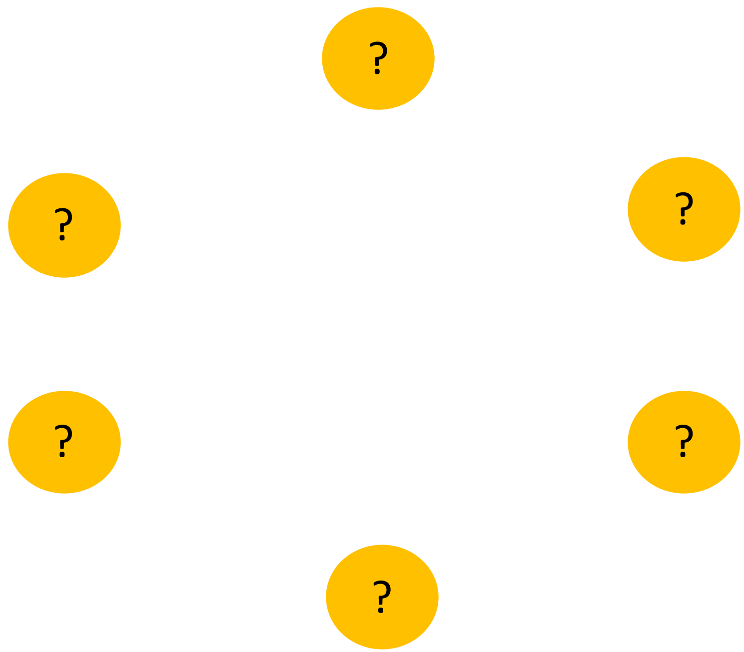
How do you propagate information efficiently?

Context of the Course



How do you propagate information efficiently?

Context of the Course



How do you know if a component (e.g., server) is still active?

Context of the Course

- It might seem like there are two options:

  - Option 1: Writing robust software applications that can operate under large loads and in conjunction with many other applications

  - Option 2: Understanding these problems, understanding under which conditions they can be solved, employing verified and correct (modular) solutions.

Context of the Course

- Dealing with these problems can be achieved by :
  - ~~Option 1: Writing robust software applications that can operate under large loads and in conjunction with many other applications~~
  - <u>Option 2: Understanding these problems, understanding under which conditions they can be solved, employing verified and correct (modular) solutions.</u>

You may ask…

What does are we interested in this?

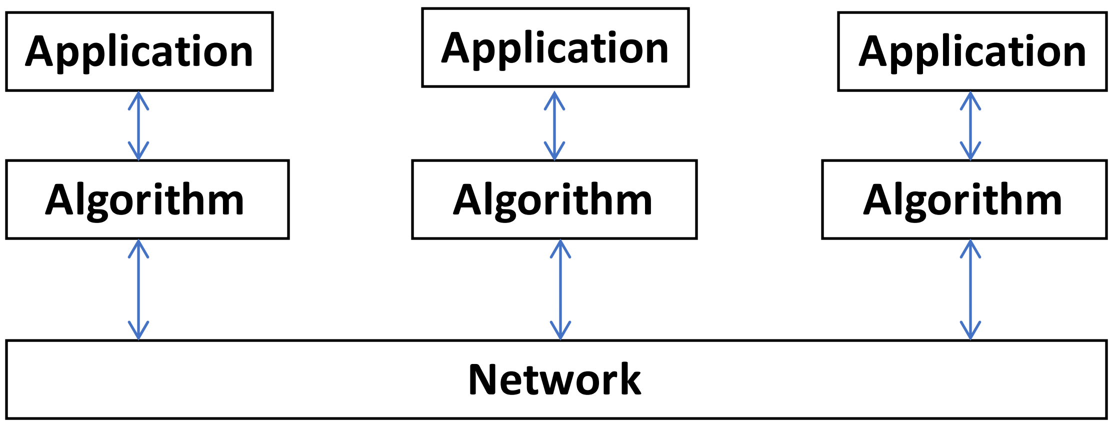
Distributed systems provide a model for running generic computations, with certain guarantees of availability and consistency.

They are crucial for *all* types of systems

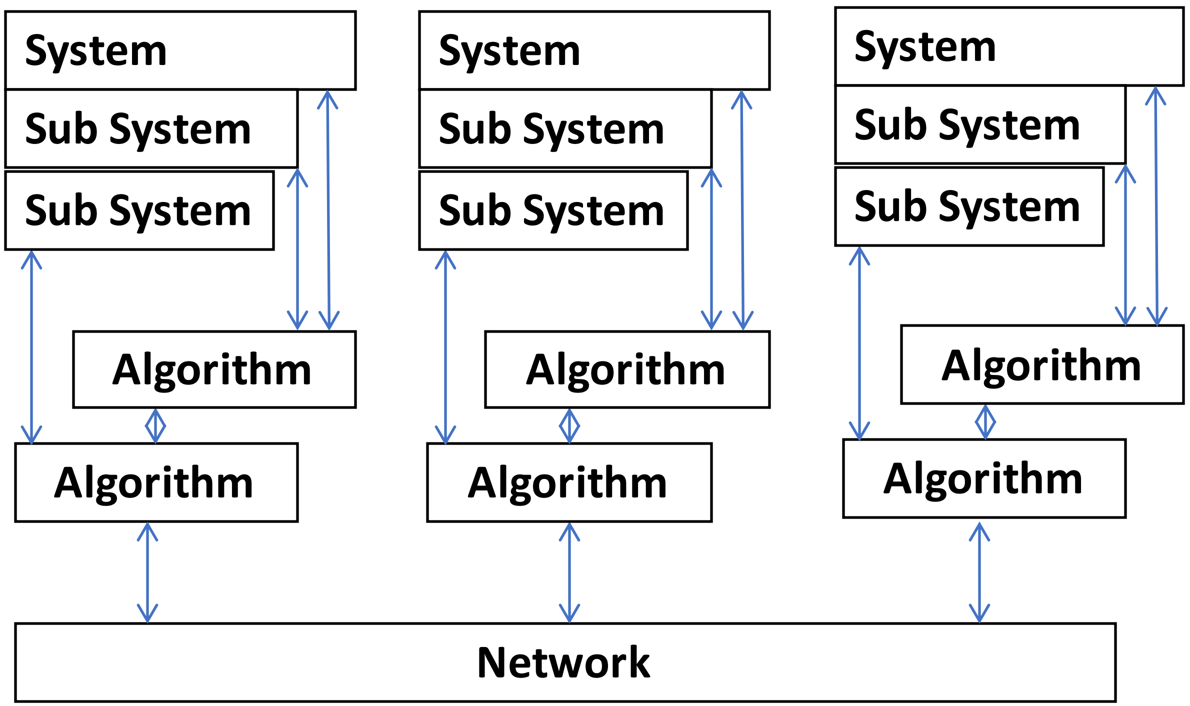
Example: Cloudflare

Example question: how do you replicate data quickly?

Distributed Algorithms (and Protocols)



Distributed Algorithms (and Protocols) – More realistically…



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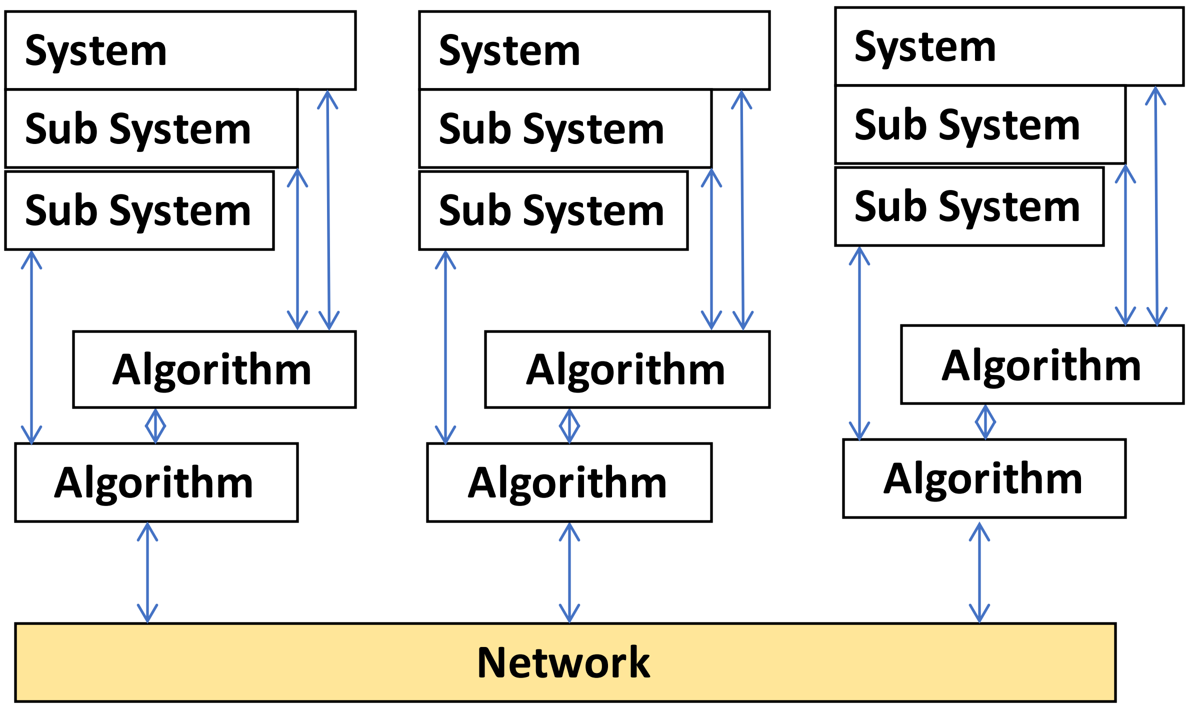

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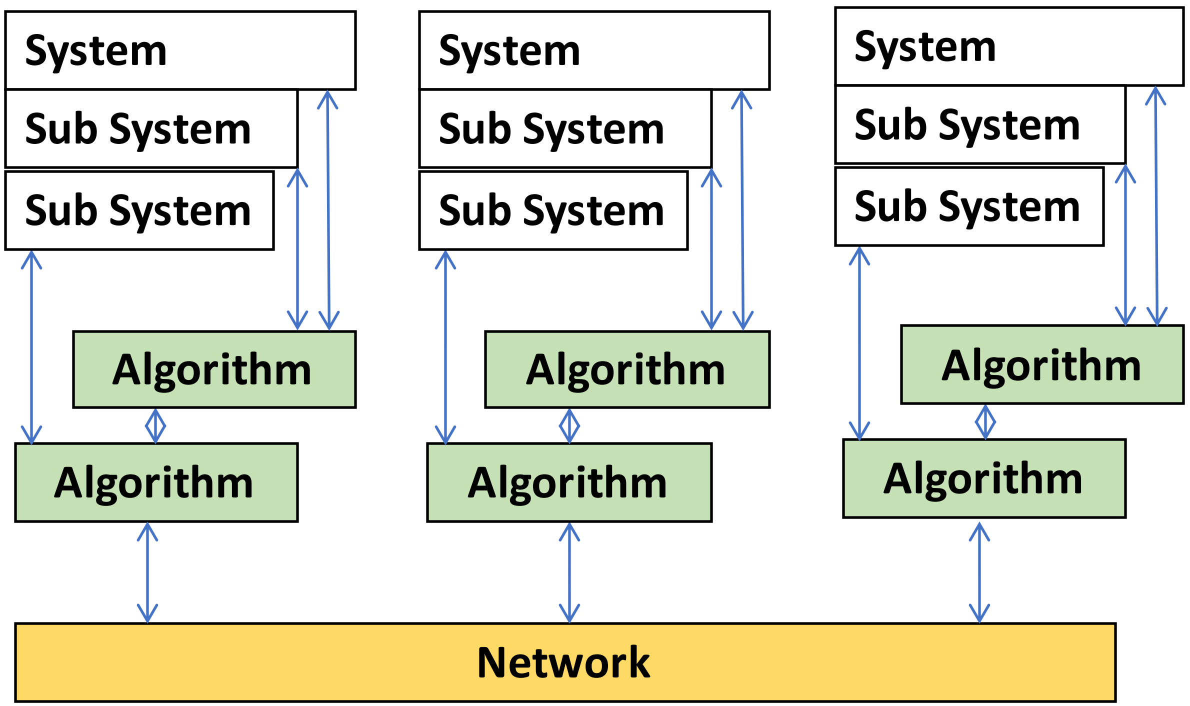

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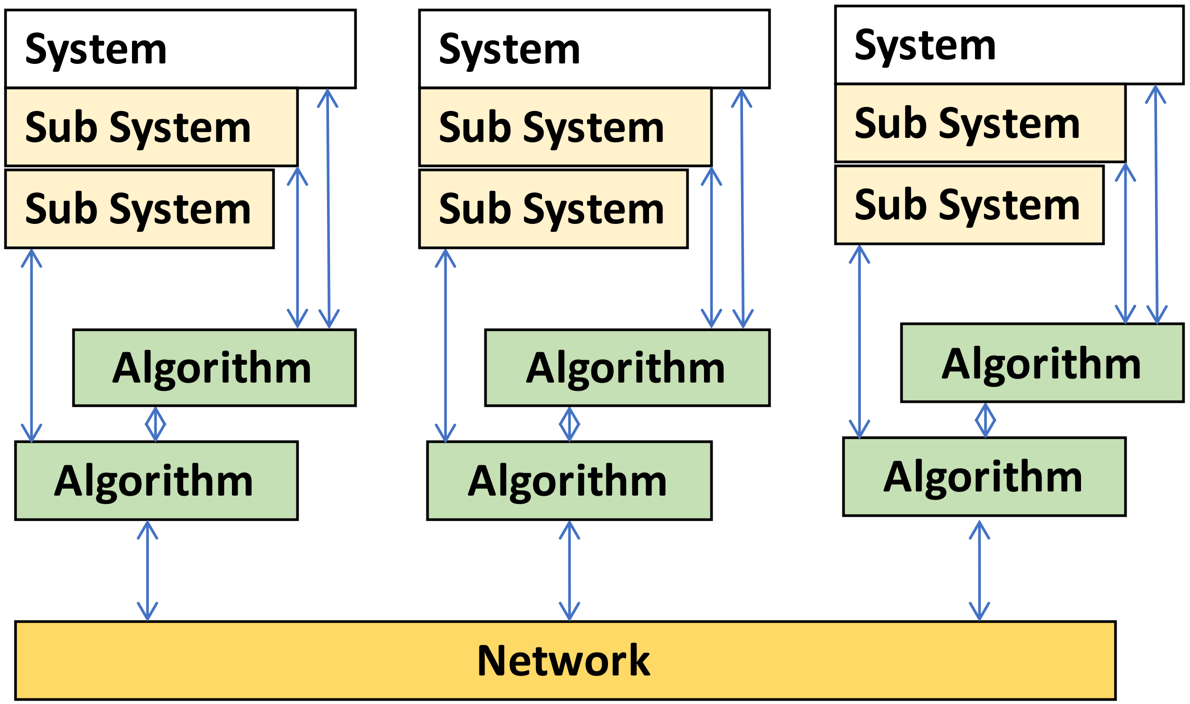

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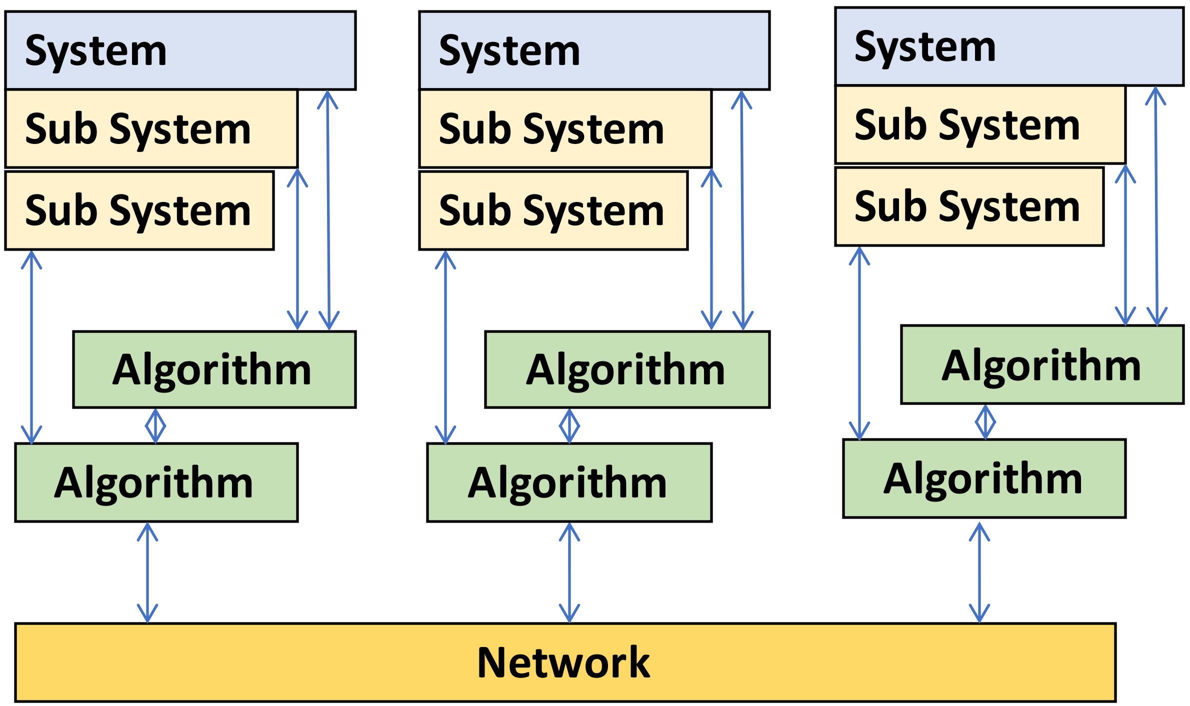

Course Bibliography:

- *Main course reading:*
  - C. Cachin, R. Guerraoui, L. Rodrigues "Introduction to Reliable and Secure Distributed Programming", 2nd ed, Springer, 2011.
  - N. Lynch. Distributed Algorithms Morgan Kauffman, 1996.

  - Selected research papers (TBD).

Course Structure

- Lectures
    - 2 hours / week
        - Wednesday, 11h-13h
    - Hopefully interactive
- Labs
    - 2 hours / week
        - P1: Monday, 16h-18h
        - P2: Thursday, 09h-11h
    - Focused on:
        - Analysis of use cases.
        - Implementation and support for the course project.
        - Project feedback & evaluation.

Course Bibliography:

- *Additional course reading:*
  - H. Attiya and J. Welch. Distributed Computing: Fundamentals, Simulations, and Advanced Topics (2nd Ed.), Wiley 2004.
  - S. Mullender (editor) Distributed Systems, Second Edition, ACM Press, Addison–Wesley, MA, 1994.
  - A.S. Tanenbaum and M. van Steen. Distributed Systems. Principles and Paradigms. (2nd Ed.) Prentice Hall, 2007.
  - Rodrigo Rodrigues, Peter Druschel. Peer–to–Peer Systems. Communications of the ACM. Vol. 53 N10, pp 72 – 82.

Course Bibliography:

- ***Some of the selected research papers:***

  - Ion Stoica, Robert Morris, David Karger, M. Frans Kaashoek, and Hari Balakrishnan. 2001. Chord: A scalable peer-to-peer lookup service for internet applications. In Proceedings of the 2001 conference on Applications, technologies, architectures, and protocols for computer communications (SIGCOMM ’01). ACM, New York, NY, USA, 2001.
  - Leslie Lamport. Paxos Made Simple. ACM SIGACT News (Distributed Computing Column) 32, 4 (Whole Number 121, December 2001).
  - Spyros Voulgaris, Daniela Gavidiam and Maarten van Steen. CYCLON: Inexpensive Membership Management for Unstructured P2P Overlays. Journal of Network and Systems Management June 2005, Volume 13, Issue 2, pp 197–217.
  - Giuseppe DeCandia, Deniz Hastorun, Madan Jampani, Gunavardhan Kakulapati, Avinash Lakshman, Alex Pilchin, Swaminathan Sivasubramanian, Peter Vosshall, and Werner Vogels. 2007. Dynamo: amazon’s highly available key-value store. SIGOPS Oper. Syst. Rev. 41, 6 (October 2007), 205–220.
  - J. Leitão, J. Pereira and L. Rodrigues. HyParView: a membership protocol for reliable gossip-based broadcast. Proceedings of the 37th Annual IEEE/IFIP International Conference on Dependable Systems and Networks, Ed- inburgh, UK, June, 2007.
  - B. Maniymaran, M. Bertier and A. M. Kermarrec, Build One, Get One Free: Leveraging the Coexistence of Multiple P2P Overlay Networks. 27th International Conference on Distributed Computing Systems (ICDCS ’07), Toronto, ON, 2007, pp. 33– 33.
  - J. Leitão, J. Pereira and L. Rodrigues. Epidemic Broadcast Trees. Proceedings of the 26th IEEE International Symposium on Reliable Distributed Systems, Beijing, China, October, 2007.
  - Robbert Van Renesse and Deniz Altinbuken. 2015. Paxos Made Moderately Complex. ACM Computer Surveys 47, 3, Article 42 (February 2015), 36 pages.

Course Project

- 1 Project (2 independent phases)

- Each phase is evaluated with a grade from 0 to 20.
- Project Grade =

  40% Phase 1 + 60% Phase 2

Course Project

- Group composition: 3 students
- Project Topic: Research-Oriented Project
- Experimental evaluation of solutions involving distributed protocols

1st Phase: Communication algorithms

2nd Phase: Consensus & State Machine solutions

Course Project

- Project Topic: Research Oriented Project

Experimental evaluation of solutions involving distributed protocols

Both phases will involve the following tasks:

1. Implementation
2. Review and analysis (performance, other factors)
3. A (short) technical report about your work (in the form of a paper).

Course Project

- Phase 1 (due on 18 October – to be confirmed)
  - Problem Statement: 25 Sep 2023.
  - Topic: Communication Systems
- Phase 2 (due on 29 November – to be confirmed)
  - Problem Statement: 30 Oct 2023.
  - Topic: State Machine Replication & Consensus

You will have access to a computational cluster to run experiments.

Evaluation Rules

- "Attendance" evaluation with a weight of 50% in the final grade.
- Two theoretical tests (or one repeat exam) with a total weight of 50% in the final grade (both tests have the same weight for this component).
- Final grades are rounded to the nearest integer. Intermediate grades are rounded to the decimal point.

Attendance Evaluation

- Course Project (groups of three students).
- **Optional:** In-person discussion in the end of the semester, with a final score between zero and one (Discussion grades are individual).
- The attendance final grade is computed through the following equation:

$$\text{Attendance grade} = \text{Project grade} \times \text{Discussion score. *}$$

* do not forget that zero is an absorbing element on the multiplication operation.

Mid-term tests

- Tests will follow a structure similar to the ones in the previous editions of the course (previous tests will be made available in clip at least two weeks before the test)
- Expect tests to:
  - Ask you about fundamental knowledge covered in the lectures;
  - Ask you to analyse algorithms;
  - Ask you to write pseudo-code or manipulate pseudo-code;
  - Ask you to explain how would you design a protocol/sub-system/system.
- You will be allowed to use 2 pages of notes during each test:
  - Must be handwritten (no prints, no photocopies, no exceptions)
  - Must be identified with name and number and delivered at the end of the test.

Course Planning

ASD WEEK	Date	Lecturer	Lecture Contents	Labs Contents	Meanwhile...
0	11/set	Alex	Course Overview & Introduction	No Labs on this week	
1	18/set	Alex	Distributed Computing Models. Communication Primitives and Broadcast.	Algorithms and specification of an algorithm using pseudo-code (exactly once delivery).	
2	25/set	Nuno	Peer-to-Peer introduction: Membership, Overlays, and Gossip Protocols	Project 1st phase Presentation.	**Phase 1 Project Definition is released**
4	02/out	Nuno	Resource Location Problem, Structured and Partially Structured Overlays	Support for project development	
5	09/out	Alex	Replication: Active Replication, Passive Replication. Register Replication, Quorums.	How to Write a technical Report. Support for project development	
6	16/out	Alex	State Machine Replication. Consensus in Synchronous Systems.	Support for project development	**Phase 1 Project Delivery, First Midterm**
7	23/out	Nuno	Revisions for the first Test (TBC)	Revisions for first test. Feedback on First Project	
8	30/out	**Férias**	**Férias**	Project 2nd phase Presentation.	**Phase 2 Project Definition is released**
9	06/nov	Nuno	Consensus in Asynchronous Systems. FLP. Paxos.	Support for project development	
10	13/nov	Nuno	Paxos, State-machine replication, Multi-Paxos	Support for project development. Also: Operationalizing multi-paxos and SMR.	
11	20/nov	Alex	Strong and Eventual Consistency. Dynamo	Suport for project development	
12	27/nov	Alex	CAP theorem and causal consistency. Multiple Solutions	Support to project Development	**Phase 2 Project delivery, Second Midterm**
13	04/dez	Nuno	Distributed Transactions, 2 Phace Commit/3 Phase Commit	Project Discussions. Revisions for second test.	

Requirements for Approval in ASD

- Attendance grade greater or equal to 8.5;
- Either the average of the two theoretical tests, or the repeat exam greater or equal to 8.5; and
- Final course grade greater or equal to 9.5 (including all components).

Evaluation Dates (TBC)

- *Project Phase 1 available: week of 25th September*
- Project Phase 1: 18th October , 23:59:59
- *Project Phase 2 available: week of 30th October*
- First Mid-Term: 27th October
- Project Phase 2: 29th November, 23:59:59
- Second Mid-Term: 13th December
- Project Discussion: *week of 4th December*
- Exam: To be defined.

Office hours

- Prof. Nuno Preguiça
  - Office hours: TBC, Tuesday afternoons

- Prof. Alex Davidson
  - Office hours: 14-16h, Mondays

- For office hours, remember that it is important to **make an appointment via email**, otherwise we may be away

Next Lecture Preview

- Fundamental concepts and definitions.
- How to model a distributed system.
- Timing assumptions.
- Fault models.