Dependable Distributed Systems – 9 CFU
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Instructors: Silvia Bonomi, Giovanni Farina

Syllabus

Topic	References
Introduction to Distributed Systems	[T1] - Chapter 1 [T2] – Chapter 1 and Chapter 2 [S]
Basic Abstractions • Distributed Computations • Abstracting Processes • Abstracting Communications • Timing Assumptions • Abstracting Time ○ Failure Detector abstractions ○ Leader Election abstractions	[T1] - Chapter 2 (except Section 2.3, Sections 2.4.5-2.4.7, Sections 2.6.6, Section 2.7) [S] *[R11]* ***(*)***
Clock Synchronization • Internal and External synchronization • Christian's algorithm • Berkley's algorithm • NTP • Happened-before relation • Application of scalar logical clocks to the mutual exclusion ○ Lamport's algorithm ○ Ricarta-Agrawala's algorithm	[T2] – Chapter 14 (until Section 14.4 included) [S] [R1]
Distributed Mutual Exclusion ***(*)*** • *Coordinator-based strategy* • *Token-based strategy* • *Quorum-based strategy*	*[T2] - Chapter 11 – section 11.2* *[S]*
Broadcast • Best Effort Broadcast • Reliable Broadcast • Uniform Reliable Broadcast • Probabilistic Broadcast	[T1] - Chapter 3 - from Section 3.1 to Section 3.4 (included) [T1] - Chapter 3 – Section 3.8 except Section 3.8.5 [S]

Consensus • Regular Consensus • FLP Impossibility Result • Uniform Consensus • Paxos Algorithm	[T1] - Chapter 5, Sections 5.1.1, 5.1.2, 5.2.1, 5.2.2 [R2] [S]
Ordered Communication Primitives • FIFO Broadcast • Causal Order Broadcast • Total Order Broadcast ○ TO Hierarchy	[T1] - Chapter 3 - from Section 3.9 (except 3.9.6) [T1] - Chapter 6 – Section 6.1 [R3] [S]
Registers • Regular Register • Atomic Register • Message Passing Implementations • Transformation from (1, N) Regular to (1, N) Atomic	[T1] - Chapter 4 - until Section 4.3 [S]
Software Replication and Consistency Criteria • Linearizability • Primary-backup • Active Replication • *Sequential Consistency* ***(*)*** • *Causal Consistency* ***(*)***	[R4] *[R12]* ***(*)*** [S]
CAP Theorem	[R5] - [R6], [S]
Byzantine Fault Tolerance • Authenticated point-to-point links • Byzantine Broadcast • Reliable Communication ***(*)*** ○ Authenticated Messages ○ Authenticated Links ○ Globally Bounded Failure Model ○ Locally Bounded Failure Model • Byzantine Tolerant Registers • The Byzantine General Problem • State Machine Replication - PBFT	[T1] - Chapter 2 – Section 2.4.6 [T1] - Chapter 3 – Section 3.10 (except 3.10.4), Section 3.11 [T1] - Chapter 4 – Sections 4.6 and 4.7 [R10] [S] [R15] (*), [R16] (*), [R17] (*), [R18] (*)
Information Dissemination in large scale Networks ***(*)*** • *Publish and Subscribe Paradigm* ○ *Topic vs content-based dissemination* ○ *Distributed ENS strategies* • *Overlay Networks* ○ *Basic Graph Metrics* ○ *Structured Overlay Networks* ○ *Unstructured Overlay Networks*	[S] and references listed at the end of the slides *[R13]*

Blockchain and Distributed Ledgers	[S]
*Dependability Evaluation in Distributed Systems' **(*)*** • *Overview on Capacity Planning* • *Workload Characterization* • *Performance Evaluation* ○ *Operational Laws* ○ *Basics of Queueing Theory* ○ *Jackson Networks* ○ *Simulation Model – Discrete Event Simulation* • *Dependability Evaluation* ○ *Availability* ○ *Reliability* ○ *Interconnections* ○ *Introduction to Chaos Engineering*	*[S] + [T3] + [T4] + [T5] + [T6] + [T7] + [T8] + [R13] + [R14] + detailed references provided in the slides*

IMPORTANT NOTE: Items marked with **(*)** are part of the 9 CFU course but can be skipped by whoever needs to take the Distributed Systems 6 CFU module

Main Text Book

[T1] - C. Cachin, R. Guerraoui and L. Rodrigues. Introduction to Reliable and Secure Distributed Programming, Springer, 2011

[S] – Slides from Lectures

Suggested Readings

[T2] - George Coulouris, Jean Dollimore and Tim Kindberg, Gordon Blair "Distributed Systems: Concepts and Design (5th Edition)". Addison - Wesley, 2012.

[T3] - D. A. Menascé, V. A. F. Almeida: Capacity Planning for Web Services: metrics, models and methods. Prentice Hall, PTR

[T4] - M. Law - Simulation modeling and analysis

[T5] - R. Jain, "The Art of Computer Systems Performance Analysis: Techniques for Experimental Design, Measurement, Simulation, and Modeling"

[T6] - Quantitative System Performance, Computer System Analysis Using Queueing Network Models. Edward D. Lazowska, John Zahorjan, G. Scott Graham, Kenneth C. Sevcik

[T7] - L. Kleinrock: Queueing Systems, Vol. 1:Theory, John Wiley & Sons

[T8] - Ken Chen. Performance Evaluation by Simulation and Analysis with

Applications to Computer Networks

[R1] - Roberto Baldoni, Michel Raynal, "*Fundamentals of Distributed Computing: A Practical Tour of Vector Clock Systems*", IEEE Distributed Systems Online 3(2) (2002) https://www.computer.org/csdl/mags/ds/2002/02/o2001.pdf

[R2] - L. Lamport "Paxos Made Simple", https://www.microsoft.com/en-us/research/wp-content/uploads/2016/12/paxos-simple-Copy.pdf

[R3] - Stefano Cimmino, Carlo Marchetti, Roberto Baldoni "A Guided Tour on Total Order Specifications" WORDS Fall 2003: 187-194

[R4] - Rachid Guerraoui and André Schiper: "Fault-Tolerance by Replication in Distributed Systems". In Proceedings of the 1996 Ada-Europe International Conference on Reliable Software Technologies (Ada-Europe '96).

[R5] - Brewer "CAP twelve years later: How the "rules" have changed" http://ieeexplore.ieee.org/document/6133253/

[R6] - Abadi "Consistency Tradeoffs in Modern Distributed Database System Design: CAP is Only Part of the Story" http://ieeexplore.ieee.org/document/6127847/ (see NOTE above)

[R10] - Leslie Lamport, Robert Shostak, and Marshall Pease "The Byzantine Generals Problem " in ACM TOPLAS 1982 Available at https://www.microsoft.com/en-us/research/wp-content/uploads/2016/12/The-Byzantine-Generals-Problem.pdf

[R11] - T. Chandra, S. Toueg Unreliable Failure Detectors for Reliable Distributed Systems https://dl.acm.org/doi/pdf/10.1145/226643.226647

[R12] - Michel Raynal and André Schiper: "A suite of formal definitions for consistency criteria in distributed shared memories" available at: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.52.6880&rep=rep1 & type=pdf

[R13] - Calzarossa, Massari, Tessera. "Workload characterization: A survey revisited." ACM Computing Surveys (CSUR) 48.3 (2016): 1-43 https://doi.org/10.1145/2856127

[R14] - A. Avizienis, J.-C. Laprie, B. Randell, C. E. Landwehr: Basic Concepts and Taxonomy of Dependable and Secure Computing. https://ieeexplore.ieee.org/document/1335465/

[R15] - Danny Dolev. Unanimity in an unknown and unreliable environment https://doi.org/10.1109/SFCS.1981.53

[R16] - Andrzej Pelc and David Peleg. Broadcasting with locally bounded byzantine faults https://doi.org/10.1016/j.ipl.2004.10.007

[R17] - Chris Litsas, Aris Pagourtzis, and Dimitris Sakavalas. A graph parameter that matches the resilience of the certified propagation algorithm https://doi.org/10.1007/978-3-642-39247-4_23.

[R18] - Giovanni Farina. Tractable Reliable Communication in Compromised Networks https://tel.archives-ouvertes.fr/tel-03118108