



Course Syllabus

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| Course Code | Course Title | ECTS Credits |
| BLOCK-512 | Blockchain Systems and Architectures | 10 |
| Prerequisites | Department | Semester |
| N/A | Digital Innovation | Fall/Spring |
| Type of Course | Field | Language of Instruction |
| Elective | Blockchain, Distributed Systems, Architectures | English |
| Level of Course | Lecturer(s) | Year of Study |
| 2 nd Cycle | Dr. Klitos Christodoulou | 1 st |
| Mode of Delivery | Work Placement | Corequisites |
| Face to Face | N/A | N/A |

Course Objectives:

The main objectives of the course are to:

- Describe the idea behind trustless-trust that emerges from verifiable computation
- Define the key characteristics of Blockchains (i.e., decentralization, persistency, anonymity, auditability etc.)
- Expose students to the main components of a Blockchain data structure
- Define the idea behind smart contracts and algorithmic governance
- Understand and evaluate the components of blockchain-based technologies which support Turing-complete languages
- Define the challenges from solving the Byzantine Generals problem
- Define the verifier's dilemma and discuss the proof-of-work (Nakamoto consensus)
- Discuss common solutions and algorithms for solving the Byzantine Generals problem among untrusted/ malicious nodes over a peer-to-peer environment
- Define the notion of *consensus* in distributed systems and provide a taxonomy of the main approaches to consensus (aka consensus algorithms)
- Discuss recent advancement in consensus algorithms and position them into the categories of private and public blockchains
- Understand the parameters for incentivization and how untrusted parties are incentivised enough to reach agreement in such a distributed system
- Discuss the various security considerations that pertain such systems (e.g., privacy leakage, selfish mining, smart contracts vulnerabilities)
- Define and discuss most prominent challenges (e.g., scalability, interoperability) and recent advancements of distributed ledgers (including Blockchains)

- Define the differences between open/public and permissionless architecture vs. close/private permissioned architectures
- Explain the ideas behind on-chain vs. off-chain transactions, governance and ways for interoperability between different architectures
- Discuss the various governance models for both permissioned and permissionless systems
- Anticipate future challenge and developments

Learning Outcomes:

After completion of the course students are expected to be able to:

- Define the key characteristics of Blockchains (i.e., decentralization, persistency, anonymity, auditability etc.)
- Explain the different layers of components that compose the architecture of a blockchain-based system
- Compare a blockchain-based system with a replicated state-machine
- Understand the challenges of consensus algorithms at the high-level
- Understand and evaluate the components of blockchain-based technologies which support Turing-complete languages
- Establish a deep understanding of algorithmic execution in DLTs, their consensus model, code execution, operation of its network, storage options and main actors that participate on each protocol
- Understand the inner workings of smart contracts as means for developing decentralized applications
- Understand the interaction between the enclosed smart contract network and the external world, be aware of further implications these interactions
- Understand a set of technologies that support the backbone decentralized storage network (e.g., IPFS, Swarm, Filecoin)
- Describe the various categories of DLTs
- Understand the underlying incentivization and governance models
- Anticipate the development and adoption of DLTs in the future through various use-cases
- Understand how other emerging technologies (e.g., IoT and AI) can be exploited and combined with blockchains.

Course Content:

1. Describe the Blockchain Architecture?
2. Blockchains and the Architecture of Trust
3. Database vs. Blockchain Architectures (Types of Blockchain Architectures Explained)
4. Hidden Incentivized Model and Game Theoretical Aspects

5. Algorithmic Governance with Smart Contracts
6. Hierarchical and Alternative Blockchain Structures
7. From Blockchains to Distributed Ledger Technologies (DLTs)
8. Permission-less vs. Permissioned Architectures
9. Programmable Chains vs. Enterprise Architectures (towards inter-chains, interoperable chains)
10. Blockchains-as-a-Service
11. Enterprise Developments and Architectures
12. Securing and Interconnecting DLTs
13. Oracles & On-Chain/ Off- Chain Governance
14. Development and Adoption of DLTs in the Future: Use cases, expansion, potential risks and challenges

Learning Activities and Teaching Methods:

Lectures, Seminars, Assignments, Live Discussions, Forum Discussions, Practical Projects

Assessment Methods:

Assignments, Final Exam

Required Textbooks / Readings:

| Title | Author(s) | Publisher | Year | ISBN |
|--|--|---|------|------|
| Architecture for blockchain applications | [Xu et al., 2019] Xu, X., Weber, I., & Staples, M. (2019) | Springer | 2019 | |
| The blockchain as a software connector | [Xu et al., 2016] Xu, X., Pautasso, C., Zhu, L., Gramoli, V., Ponomarev, A., Tran, A. B., and Chen, S. (2016). | In 2016 13th Working IEEE/IFIP Conference on Software Architecture (WICSA). | 2016 | |
| "An overview of blockchain technology: Architecture, | Zheng, Zibin, Shaoan Xie, Hongning Dai, Xiangping Chen, | In 2017 IEEE International Congress on Big Data | 2017 | |

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| consensus, and future trends." | and Huaimin Wang | (BigData Congress), pp. 557-564. IEEE | | |
| "Database and Distributed Computing Foundations of Blockchains." | Maiyya, Sujaya, Victor Zakhary, Mohammad Javad Amiri, Divyakant Agrawal, and Amr El Abbadi. | In Proceedings of the 2019 International Conference on Management of Data, pp. 2036-2041. ACM, 2019. | 2019 | |
| "A taxonomy of blockchain-based systems for architecture design." | Xu, Xiwei, Ingo Weber, Mark Staples, Liming Zhu, Jan Bosch, Len Bass, Cesare Pautasso, and Paul Rimba. | In 2017 IEEE International Conference on Software Architecture (ICSA), pp. 243-252 | 2017 | |

Selected Online Readings

- Zharg, Derek, "Trustless Trust with Verifiable Computation" (2018) https://medium.com/@lei_zhang/trustless-trust-with-verifiable-computation-302110d80d6a
- Mohan, C. "Blockchains and databases: A new era in distributed computing." In 2018 IEEE 34th International Conference on Data Engineering (ICDE), pp. 1739-1740. IEEE, 2018.
- **ConsenSys, Decentralized Storage: The Backbone of the Third Web.** <https://media.consensys.net/decentralized-storage-the-backbone-of-the-third-web-d4bc54e79700>

Note: an updated list of readings is provided at the end of each lecture given the fact that Digital Currency and Blockchain Technologies constitute recent and rapidly evolving disciplines.