BLOC 512 – Course Outline

Institution	**University of Nicosia**		
Program of Study	**MSc in Blockchain and Digital Currency**		
Course	**BLOC 512 – Blockchain Systems and Architectures**		
Level	Undergraduate ☐	Postgraduate (Master) ☒	
Language of Instruction	English		
Mode of Delivery?	Distance Learning ☒	Conventional ☐	
Type of Course	Required ☒	Elective ☐	
Number of Group Advising Meetings/Teleconferences/Lectures	Total: 6	With Physical Presence 0	On-line: 6
Number of assignments	6 Assignments & Interactive Activities		
Assessment	• Assignments & Interactive Activities (40%) • Final Exam (60%)		
Number of ECTS credits	**10**		

Preparation of Study Guide by:	Dr. Klitos Christodoulou
Review and approval of study Guide by:	School of Business

i. Teaching Faculty

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ii. Course

Brief Description of the Course and Objectives

This course is designed to provide an understanding to the building blocks and components that fuel modern Blockchain-based systems or Distributed Ledgers in general. Thus, the aim of the course is to position Distributed Ledger Systems (DLTs) in the ecosystem and investigate the roots of the architecture that goes back to distributed systems, cryptography, peer-to-peer networks, data integrity, incentivization mechanisms etc.

The main pillars on which this course is structured are the following:

1. The architecture of distributed ledger systems (including Blockchains) by discussing the fundamental building blocks of the technology.
2. The perspective of using a blockchain-based systems as a building block for a software architecture (e.g., as a storage element)
3. The problem of synchronization and the relationship with Distributed Systems and Consensus algorithms.
4. The hidden dimensions of the architecture, such as, game theoretical aspects, incentivization, and governance models (including algorithmic governance).

Main Topics/Thematic Areas

1. Describe the Blockchain Architecture
2. Blockchains and the Architecture of Trust
3. Databases 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)
    - Blockchains-as-a-Service
    - Enterprise Developments and Architectures
10. Securing and Interconnecting DLTs
11. Oracles & On-Chain/ Off- Chain Governance

12. Development and Adoption of DLTs in the Future: Use cases, expansion, potential risks and challenges

Expected Learning Outcomes

Upon completion of this course students are expected to be able to:

1. define the key characteristics of Blockchains (i.e., decentralization, persistency, anonymity, auditability etc.);
2. explain the different layers of components that compose the architecture of a blockchain-based system;
3. relate a blockchain-based system with concepts from state-machines;
4. understand the challenges of consensus algorithms at the high-level;
5. understand and evaluate the components of blockchain-based technologies which support Turing-complete languages;
6. 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;
7. understand the inner workings of smart contracts as means for developing decentralized applications;
8. understand the interaction between the enclosed smart contract network and the external world, be aware of further implications these interactions;
9. understand a set of technologies that support the backbone of a decentralized storage network (e.g., IPFS, Swarm);
10. describe the various categories of DLTs;
11. understand the underlying incentivization and governance models;
12. anticipate the development and adoption of DLTs in the future through various use-cases;
13. understand how other emerging technologies (e.g., IoT and AI) can be exploited and combined with blockchains.

Teaching Material

Weekly PowerPoint presentations with extended descriptions and explanations

Note: Due to the theoretical nature of this course and the diversity of the material. The **slide decks** are considered the main reading material for this course. Pointers to other, external resources are optional.

Indicative Textbooks (Optional for further reading):

- [Xu et al., 2019] Xu, X., Weber, I., & Staples, M. (2019). Architecture for blockchain applications. Springer.

- [Attaran, 2019] Attaran M., Gunasekaran A. (2019) The Evolution of Blockchain. In: Applications of Blockchain Technology in Business. SpringerBriefs in Operations Management. Springer, Cham

- [Xu et al., 2016] Xu, X., Pautasso, C., Zhu, L., Gramoli, V., Ponomarev, A., Tran, A. B., and Chen, S. (2016). The blockchain as a software connector. In 2016 13th Working IEEE/IFIP Conference on Software Architecture (WICSA).

- [Zheng et al., 2017] Zheng, Zibin, Shaoan Xie, Hongning Dai, Xiangping Chen, and Huaimin Wang. "An overview of blockchain technology: Architecture, consensus, and future trends." In *2017 IEEE International Congress on Big Data (BigData Congress)*, pp. 557-564. IEEE, 2017.

- [Maiyya et al., 2019] Maiyya, Sujaya, Victor Zakhary, Mohammad Javad Amiri, Divyakant Agrawal, and Amr El Abbadi. "Database and Distributed Computing Foundations of Blockchains." In Proceedings of the 2019 International Conference on Management of Data, pp. 2036-2041. ACM, 2019.

- [Xu et al., 2017] Xu, Xiwei, Ingo Weber, Mark Staples, Liming Zhu, Jan Bosch, Len Bass, Cesare Pautasso, and Paul Rimba. "A taxonomy of blockchain-based systems for architecture design." In 2017 IEEE International Conference on Software Architecture (ICSA), pp. 243-252. IEEE, 2017.

Recommended eBooks / Further Readings:

- [Zharg, 2018] Zharg, Derek, “Trustless Trust with Verifiable Computation” (2018) https://medium.com/@lei_zhang/trustless-trust-with-verifiable-computation-302110d80d6a

- [Luu, 2015] Luu, Loi, Jason Teutsch, Raghav Kulkarni, and Prateek Saxena. "Demystifying incentives in the consensus computer." In Proceedings of the 22nd ACM SIGSAC Conference on Computer and Communications Security, pp. 706-719. ACM, 2015.

- [Ioini, 2018] El Ioini, Nabil, and Claus Pahl. "A review of distributed ledger technologies." In OTM Confederated International Conferences" On the Move to Meaningful Internet Systems", pp. 277-288. Springer, Cham, 2018.

- [Mohan, 2018] 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 in provided at the end of each lecture given the fact that Digital Currencies and Blockchain Technologies constitute recent and rapidly evolving disciplines.

ECTS

10 ECTS

iii. Main Topics/Thematic Areas

The details for each topic are provided in the respective week that follows in the given study guide.

Note: Due to the theoretical nature of this course and the diversity of the material. The **slide decks** are considered the main reading/revision material for this course.

iv. Teaching Timetable

Week	Session	Topic & Objectives	Readings	Assessed work and WebEx meetings
#1	#1	**Describe the Blockchain Architecture** Objectives: • to understand the architectural components of a Blockchain protocol • to define the key characteristics of Blockchains (i.e., decentralization, persistency, anonymity, auditability etc.) • to explain the different layers of components that compose the architecture of a blockchain-based system	Slide deck (Presentation) Optional reading: [Xu et al., 2019]:Part I Blockchain in Software Architecture; Chapter 1.1 & 1.5	Live Session #1 Summative interactive activity #1 (2%) Formative self-assessment questions
	#2	**Blockchains and the Architecture of Trust** Objectives: • to investigate the architecture of trust that builds on verifiable computation • to define the challenges from the Byzantine Generals Problem	Slide deck (Presentation) Optional reading: [Zharg, 2018]; [Xu et al., 2019]:Part I	Live Session #2 Summative interactive activity #1 (2%)

		• to discuss variations of BFTs adapted to Blockchain protocols • to understand the challenges of consensus algorithms at the high-level • to define the categories of DLTs	Blockchain in Software Architecture; [Zheng, 2017]	Formative self-assessment questions
#2	#3	**Databases vs. Blockchain Architectures** Objectives: • to understand the purpose of a Blockchain as a storage medium • to understand the different data structure underlying different implementations of distributed ledgers • to briefly introduce the Database architecture and compare it with a Blockchain-based system • to discuss the fusion of Blockchains and Databases	Slide deck (Presentation) Optional reading: [Mohan, 2018]; [Xu et al., 2019]:Part I Blockchain in Software Architecture; [Maiyya, 2019]	Live Session #3 Interactive activity #2 (5%) Formative self-assessment questions
	#4	**Hidden Incentivized Models and Game Theoretical Aspects** Objectives: • to introduce the reward schemes and incentivization structures • to introduce the game theoretical aspects of blockchains	Slide deck (Presentation) Optional reading: [Luu, 2015]; [Zheng, 2017];[Xu et al., 2019]:Part I Blockchain in Software Architecture; Chapter 3	Live Session #4 Formative self-assessment questions

#3	#5	**Algorithmic Governance with Smart Contracts** Objectives: • to understand the various aspects of algorithmic governance • to understand any potential flaws from algorithms governance • to explain the capabilities offered by smart contracts • to define distributed autonomous organizations.	Slide deck (Presentation) Optional reading: [Hazard, 2017]; [Gillespie, 2014]; [Filippi, 2016]	Live Session #5 Formative self-assessment questions
	#6	**Hierarchical and Alternative Blockchain Structures** Objectives: • to explore the various alternative blockchain structures • to provide an overview of the alternative ledger data structures proposed (e.g., DAGs) • to experiment with DAG architectures (e.g., IOTA)	Slide deck (Presentation) Optional reading: [Xu et al., 2019]:Part I Blockchain in Software Architecture; Chapter 3	Live Session #6 Interactive activity #3 (5%) Formative self-assessment questions

#4	#7	**From Blockchains to Distributed Ledger Technologies (DLTs)** Objectives: • to provide an overview of the evolution of blockchain-based systems to distributed ledger systems • to familiarize students with notable examples and use-cases of such systems • to examine notable use-case projects (e.g., Bitcoin, Ethereum, Hyperledger Fabric, Corda, Ripple etc.)	Slide deck (Presentation) Optional reading: [Xu et al., 2019]:Part I Blockchain in Software Architecture; Chapter 3; [Ioini, 2018]; [Attaran, 2019]	Live Session #7 Formative self-assessment questions
	#8	**Permission-less vs. Permissioned Architectures** Objectives: • to explain the different types distributed ledger architectures in terms of access control • to explain the democratic or close-end aspects of blockchain systems • to expose the features that distinguish distributed ledgers as permissioned or permissionless • to expose the capabilities of the technology as a new layer that sits on top of the Internet	Slide deck (Presentation) Optional reading: [Xu et al., 2019]:Part I Blockchain in Software Architecture; Chapter 3 & 4; [Xu et al., 2019]; [Zheng, 2017]; [Xu et al., 2017]; [Ioini, 2018]	Live Session #8 Summative interactive activity - Wiki #4 (8%) Formative self-assessment questions

#5	#9	**Programmable Chains vs. Enterprise Architectures (towards inter-chains, interoperable chains)** Objectives: • to examine the expressivity of smart contracts that are interpreted by various chains • to discuss various deployment options (Blockchains-as-a-Service)	Slide deck (Presentation) Optional reading: [Xu et al., 2019]:Part I Blockchain in Software Architecture; Chapter 6	Live Session #9 Formative self-assessment questions
	#10	**Securing and Interconnecting DLTs** Objectives: • to understand the impact of security and scalability • to discuss various security concerns with regards to interoperability of blockchains • to understand the tradeoffs between security, privacy, efficiency, flexibility, platform complexity	Slide deck (Presentation) Optional reading: [Buterin, 2016]; Part I Blockchain in Software Architecture; Chapter 4	Live Session #10 Summative interactive activity #5 – Wiki (8%) Formative self-assessment questions

#6	#11	**Oracles & On-Chain/ Off- Chain Governance** Objectives: • To explain the main functional characteristics of oracles (on-chain & off-chain communication) • To explain the main functional characteristics of IPFS/DHT in comparison to centralized data structures • To explain the complementarities between DLTs and IPFS/DHT • To present use cases demonstrating the synergy of on-blockchain and off-blockchain data management	Slide deck (Presentation) Optional reading: [Xu et al., 2019]:Part I Blockchain in Software Architecture;	Live Session #11 Summative interactive activity #6 – Wiki (5%) Formative self-assessment questions
	#12	**Development and Adoption of DLTs in the Future: Use cases, expansion, potential risks and challenges** Objectives: • to explore the prospective contribution of blockchains to challenges that exhibit strong societal dimensions (exploration based on use cases, including the support of unbanked people, digital identities for refugees) • to explain how the integration of blockchain and AI can combat the illegal utilization of crypto-currencies	Slide deck (Presentation) Optional reading: [Xu et al., 2019]:Part I Blockchain in Software Architecture;	Live Session #12 Summative interactive activity #7 – Quiz (5%) Formative self-assessment questions

	End of Week #7	**Final Exam**		

v. Teaching methods

Teaching material including slide decks with extended descriptions and explanations, additional readings (journal articles and/or e-books), access to additional videos related to the course, synchronous meetings, forums, case studies and other formative and summative assessments.

vi. Written work – Exams – Assessment

Formative Self-Assessment (not graded)

Several formative self-assessment questions (not graded) will be provided during each lecture.

Summative Assessments

Weekly Interactive Summative Activities: On-going until Week 6 (end of week), assessed out of 100. Overall, the total grade from all summative interactive activities corresponds to 40% of the total course mark.

Purpose of weekly interactive summative activities:

Overall, these activities are designed to engage students with the learning outcomes leveraging on an interactive character. Different interactive approaches are utilized as follows:

1. Interactive discussions during the class
2. Interactive use of Web simulators
3. Interactive quizzes
4. Interactive use of a Wiki for sharing content generated by the students

- **Final exam:** assessed out of 100, contributes 60% of the total course mark.

vii. Communication

The following opportunities for communication are provided to students in an attempt to enhance interaction between a) student and faculty, b) student and student and c) student and content.

- Weekly Q&A and discussion forums.
- Weekly live sessions

Duration of each live meeting: approx. 2 hours

- **Moodle (Official Communication Channel)**
- Email
- Office hours (online remote meetings – upon student request)