Course Code	Course Title	ECTS Credits
COMP-532	Distributed Systems	10
Prerequisites	**Department**	**Semester**
DFIN-511	Computer Science	Fall/Spring/Summer
Type of Course	**Field**	**Language of Instruction**
Elective	Computer Science	English
Level of Course	**Lecturer(s)**	**Year of Study**
2nd Cycle	Dr Harald Gjermundrød	2nd
Mode of Delivery	**Work Placement**	**Co-requisites**
Distance Learning	N/A	N/A

Objectives of the Course:

The main objectives of the course are to:

1. Introduce the principles of design, construction and development of distributed systems along with distributed algorithms, which are necessary to build decentralized digital currency systems.
2. Cover in detail the different interaction paradigms for distributed systems like interprocess communication, remote invocation, and indirect communication and discuss them in the context of digital currency systems.
3. Cover in detail distributed algorithms for time, state consistency, coordination, agreement, transaction, and replication
4. Provide deep knowledge and contrast different middleware paradigms like distributed objects, components based, and peer-to-peer systems
5. Provide deep knowledge of how digital currencies are using the peer-to-peer architecture to achieve their design goal
6. Explain in detail naming structure and organization in distributed systems
7. Expose the students to development tools/environments/frameworks to develop distributed frameworks for digital currencies.
8. Cover in detail how topics of distributed systems are applied for devising a digital currency framework.

Learning Outcomes:

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

1. Describe the principles, design, architecture, organization, algorithms and development of distributed systems, with special attention on systems for decentralized digital currencies
2. Compare and contrast the various interaction methods (interprocess communication, remote invocation, and indirect communication) that are used in distributed systems
3. Critically assess time, state consistency, coordination, agreement, transaction, and replication algorithms used in distributed systems, such as the distributed ledger in digital currencies
4. Critically assess different middleware paradigms like distributed objects, components based, and

peer-to-peer systems
5. Critically assess how the decentralized peer-to-peer architecture is applied in the various digital currencies systems
6. Summarize the naming structure and organization in distributed systems
7. Demonstrate the ability to select an appropriate distributed algorithm and middleware paradigm that fulfills the design requirements for a general distributed system, with emphasis on a distributed digital currency system
8. Design and develop a distributed digital currency system based on a description of its required functionality and purpose.

Course Contents:

1. Characterization of Distributed Systems
    1. Examples of distributed systems.
    2. Trends in distributed systems.
    3. Focus on resource sharing.
    4. Challenges like heterogeneity, scalability, failure handling, and security.
    5. Characterization of distributed frameworks for digital currencies.
2. System models
    1. Physical models.
    2. Architectural models.
    3. Fundamental models.
    4. Applicability of models in digital currencies frameworks.
3. Interprocess Communication
    1. The API for the Internet protocols.
    2. External data representation and marshaling.
    3. Multicast communication.
    4. Request-reply protocols.
    5. Network virtualization: Overlay networks.
4. Indirect communication
    1. Group communication
    2. Publish-subscribe systems
    3. Message queues
    4. Case study of comparing the various communication patterns used for digital currencies frameworks.
5. Distributed objects and components
    1. Distributed objects
    2. Case study of a distributed object middleware
    3. From objects to components
    4. Case study of a component based middleware
6. Peer-to-peer Systems
    1. Napster and its legacy
    2. BitCoin compared with Napster as a disruptive technology
    3. Peer-to-peer middleware
    4. Routing overlays
    5. Case study of an overlay network and application using digital currency frameworks as example application.
7. 7. Name Services

   1. Name services and the Domain Name System
   2. Directory services
   3. X.500 Directory Service.
8. Time and Global States
   1. Clocks, events and process states
   2. Synchronizing physical clocks
   3. Logical time and logical clocks
   4. Global states
   5. Case study of maintaining a global state using distributed ledgers for digital currencies as example application.
9. Coordination and Agreement
   1. Distributed mutual exclusion
   2. Elections
   3. Coordination and agreement in group communication
   4. Case study of agreement for distributed ledgers for digital currencies.
10. Distributed Transactions
    1. Flat and nested distributed transactions
    2. Atomic commit protocols
    3. Distributed deadlocks
    4. Transaction recovery
    5. Checkpoints of distributed ledgers
11. Replication
    1. System model and the role of group communication
    2. Fault-tolerant services
    3. Gossip based architectures
    4. Transaction with replicated data
    5. Case study of resilience of decentralized systems for managing digital currencies.
12. Designing Distributed systems
13. Case study of all the aspects of a large distributed system using a digital currency as the application domain.

Learning Activities and Teaching Methods:

Lectures, Practical Exercises, and Assignments.

Assessment Methods:

Assignments, Mid-term Exam, Final Exam.

Recomended Textbooks / Reading:

Title	Author(s)	Publisher	Year	ISBN
Distributed Systems: Concepts and Design, 5th Edition	G. Coulouris, J. Dollimore, T. Kindberg, G. Blair	Addison Wesley	2011	978-0132143011

Distributed Systems: Principles and Paradigms, 2nd Edition	Andrew S. Tanenbaum and Maarten Van Steen	Prentice Hall	2006	978-0132392273
Programming Distributed Computing Systems: A Foundational Approach	Carlos A. Varela	The MIT Press	2013	978-0262018982

Recommended Articles / Reading List:

- Decker, C. and Wattenhofer, R. (2013) ―Information Propagation in the Bitcoin Network‖ in 13-th IEEE International Conference on Peer-to-Peer Computing (P2P), pp. 1 – 10, 9 – 13 September.
- Szefer, J. and Lee, R.B. (2013) ―BitDeposit: Deterring Attacks and Abuses of Cloud Computing Services through Economic Measures‖ in 13th IEEE/ACM International Symposium on Cluster, Cloud and Grid Computing (CCGrid), pp. 630 – 635, 13 – 16 May.
- Ian M., Garman C., Green M., and Rubin A.D. (2013) ―Zerocoin: Anonymous Distributed E-Cash from Bitcoin‖ in Proceedings of the IEEE Symposium on Security and Privacy (SP), pp. 397 – 411, 19 – 22 February.
- Barber S., Boyen X., Shi E., and Uzun E. (2012) ―Bitter to Better — How to Make Bitcoin a Better Currency‖ in Financial Cryptography and Data Security, Lecture Notes in Computer Science, Volume 7397, pp. 399 – 414.
- Plohmann D. and Gerhards-Padilla E. (2012) ―Case Study of the Miner Botnet‖ in 4th International Conference on Cyber Conflict (CYCon), pp. 345 – 360, 5 – 8 June.
- Laurie B. (2011) ―Decentralised Currencies Are Probably Impossible But Let‗s At Least Make Them Efficient‖ [Online]. Available: www.links.org/files/decentralised-currencies.pdf, [Mar. 3, 2014].
- Nakamoto S. (2009) ―Bitcoin: A Peer-to-Peer Electronic Cash System‖