Lahore University of Management Sciences

CS 382/EE 475 – Network-Centric Computing
Spring 2024
Subject to Change

COURSE DESCRIPTION
The main goal of this course is to introduce students to fundamental principles and concepts in designing large networked systems. The first half of the course covers networking fundamentals, with the Internet as the case study; in this part, we cover the design of different layers in the network stack. In the second half of the course, we cover fundamental concepts in designing scalable and fault tolerant distributed applications. In the course, students will also study the applications of these concepts and principles in real distributed systems. The course will provide students with hands-on experience to apply learnt concepts through multiple programming assignments.

Course Distribution	
Core	
Elective	Yes
Open for Student Category	All
Close for Student Category	None

COURSE PREREQUISITE(S)	
	• CS 200 (Introduction to Programming)

COURSE OFFERING DETAILS				
Credit Hours	3			
Lecture(s)	Nbr of Lec(s) Per Week	2	Duration	75 minutes
Recitation/Lab (per week)	Nbr of Lec(s) Per Week		Duration	
Tutorial (per week)	Nbr of Lec(s) Per Week		Duration	

Instructor	Zafar Ayyub Qazi
Room No.	SBASSE 9-G24A
Class timings	12:30pm-1:45pm Mondays and Wednesdays
Zoom meeting link for class lectures	TBA
Email	zafar.qazi@lums.edu.pk
Office hours	Online via Zoom
TA	TBA
TA Office Hours	TBD
Course URL (if any)	http://lms.lums.edu.pk

COURSE TEACHING METHODOLOGY
• Live lectures twice a week during class timings on Zoom • Lectures will be recorded, and recordings shared with students after each class • We will use piazza for course-related discussions; you can post questions related to lectures on piazza. Live questions will be taken over Zoom during the lectures • The instructor and the TA will be holding online office hours per week via zoom

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PROGRAM EDUCATIONAL OBJECTIVES (PEOs)	
PEO-01	Demonstrate excellence in profession through in-depth knowledge and skills in the field of Computing.
PEO-02	Engage in continuous professional development and exhibit quest for learning.
PEO-03	Show professional integrity and commitment to societal responsibilities.

COURSE OBJECTIVES	
CO1 CO2 CO3	• To teach students fundamental networking principles, concepts and protocols. • Study the principles and techniques behind the design of distributed systems. • Study the application of these principles and concepts in various real large scale distributed systems

COURSE LEARNING OUTCOMES (CLOs)	
	At completion of the course students should be able to:
CLO1 CLO2 CLO3	• Appreciate the key principles behind the design of the Internet • Articulate the organization of the Internet (Internet) • List and define appropriate network terminology
CLO4 CLO5 CLO6	• List the differences and the relation between names and addresses in a network • List the factors that affect the performance of reliable delivery protocols (Netwok characteristicss) • Implement a simple client-server socket-based application.
CLO7 CLO8 CLO9	• Design and implement a simple reliable protocol • Describe the organization of the network layer -- (Network Layer model) • Describe how packets are forwarded in an IP network
CLO10 CLO11 CLO12	• Describe the different approaches for intra-domain routing and inter-domain routing • List the scalability benefits of hierarchical addressing - (Network protocol – TCP/IP) • Describe the congestion problem in a large network
CLO13 CLO14	• Distinguish network faults from the other types of faults • Write a program that perform any required marshaling and conversion into message units, such as packets, to communicate interesting data between two hosts
CLO15 CLO16 CLO17 CLO18 CLO19 CLO20	• Explain why perfect time synchronization is impossible over real networks (Time synchronization) • Explain how and when logical clocks can be used to solve coordination in distributed applications (Time synchronization) • Describe how consistent hashing works and what properties it provides. • Explain why no distributed system can be simultaneously consistent, available, and partition tolerant • Write a distributed program, to handle load distribution, coordination, replication, and failures • Describe how the MapReduce framework works, and decompose a problem (e.g., counting the number of occurrences of someword in a document) via map and reduce operations.

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CLO	CLO Statement	Bloom's Cognitive Level	PLOs/Graduate Attributes (Seoul Accord)
CLO1	Appreciate the key principles behind the design of the Internet	C2	PLO2
CLO2	Articulate the organization of the Internet	C2	PLO3
CLO3	List and define appropriate network terminology	C2	PLO2
CLO4	List the differences and the relation between names and addresses in a network	C1, C2	PLO2
CLO5	List the factors that affect the performance of reliable delivery protocols	C1, C2	PLO2
CLO6	Implement a simple client-server socket-based application.	C3	PLO4
CLO7	Design and implement a simple reliable protocol	C3, C4	PLO3, PLO4, PLO5
CLO8	Describe the organization of the network layer	C2	PLO2
CLO9	Describe how packets are forwarded in an IP network	C2	PLO2
CLO10	Describe the different approaches for intra-domain routing and inter-domain routing	C2	PLO4
CLO11	List the scalability benefits of hierarchical addressing	C1, C2	PLO2
CLO12	Describe the congestion problem in a large network	C4	PLO2
CLO13	Distinguish network faults from the other types of faults	C5	PLO3
CLO14	Write a program that perform any required marshaling and conversion into message units, such as packets, to communicate interesting data between two hosts	C3, C5	PLO4, PLO5
CLO15	Explain why perfect time synchronization is impossible over real networks	C4, C5	PLO3, PLO4
CLO16	Explain how and when logical clocks can be used to solve coordination in distributed applications	C4	PLO3, PLO4
CLO17	Describe how consistent hashing works and what properties it provides.	C4	PLO2, PLO3
CLO18	Explain why no distributed system can be simultaneously consistent, available, and partition tolerant	C4	PLO2, PLO3
CLO19	Write a distributed program, to handle load distribution, coordination, replication, and failures	C6	PLO3, PLO4, PLO5
CLO20	Describe how the MapReduce framework works, and decompose a problem (e.g., counting the number of occurrences of someword in a document) via map and reduce operations	C5, C6	PLO3, PLO4, PLO5

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Grading Breakup and Policy

Assessment	Weight (%)	Related CLOs	ACM Recommended Disposition
Programming Assignment(s):	35%	CLO18, CLO19, CLO20	D3, D4, D7, D9
Quizzes	35%	CLO1, CLO2 CLo3, CLO4, CLO5	D4, D7, D9
Final examination (comprehensive)	30%	CLO6, CLO7, CLO8, CLO13, CLO14, CLO15	D4, D7, D9

This Spring, CS 382 will be run entirely online. Below, we describe how each type of assessment will be conducted.

Quizzes

- Quizzes will be announced, in-class, and follow N-3 policy.
- We will have a total of 8 quizzes in the course but only your best 6 quizzes will count towards your grade. An important purpose of having N-2 quizzes is to account for all issues (e.g., Internet connectivity, electricity outage, sickness, etc.) that may prevent you from taking the quiz. No request for a makeup quiz will be entertained if you miss up to 3 quizzes irrespective of the reason. In the exceptional situation in which you end up missing more than 3 quizzes, we will consider a makeup quiz only if there is a valid justification. In that case, we reserve the right to determine the mode of the quiz, which may be oral or textual.
- All quizzes will take place during class timings.
- All quizzes will be announced.
- The syllabus for every quiz will include lecture in which the quiz will be taken.

Exam

- The final exam will take place during the final exam week. It will be a comprehensive final exam, which will be conducted synchronously.

Programming Assignments

- Programming assignments are an integral part of this course and intended to provide students hands-on experience to apply learntconcepts. The assignments will be in Python language. There will be multiple programming assignments spread throughout the semester.
- Please note the following policies regarding the programming assignments. You are responsible adhering to these policies.
    - All deadlines are hard
    - All assigned work must be done individually (unless specified otherwise)
    - Re-grading can be requested within 2 days after grade reporting
    - Students must not share actual program code with other students.
    - Students must be prepared to explain any program code they submit.
    - Students must indicate with their submission any assistance received.
    - All submissions are subject to plagiarism detection.
    - Students cannot copy code from the Internet.

Students are strongly advised that any act of plagiarism will be reported to the Disciplinary Committee

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EXAMINATION DETAIL	
Midterm Exam	Yes/No: No
Final Exam	Yes/No: Yes Combine Separate: Duration: Exam Specifications:

COURSE OVERVIEW

Lecture	Topics	Recommended Reading	Related CLOs	ACM Computing Knowledge Landscape
1	Introduction		CLO1	
2	Overview of the Internet	• Kurose and Ross (K&R) 6th edition: 1.0-1.2 • Review lecture 2 slides	CLO1, CLO2, CLO3	
3	Network Fundamentals	• Kurose and Ross (K&R) 6th edition: 1.3-1.4 • Review lecture 3 slides	CLO4, CLO5, CLO6	
4	Network Design principles	• Kurose and Ross (K&R) 6th edition: 1.5 • Review lecture 4 slides	CLO4, CLO5, CLO6	
5	Application layer, Web and HTTP	• Kurose and Ross (K&R) 6th edition: 2-1-2.2 • Review lecture 5 slides	CLO7, CLO8, CLO9	
6	Application layer, Web and HTTP (cont'd)	• Kurose and Ross (K&R) 6th edition: 2.2 • Review lecture 6 slides	CLO7, CLO8, CLO9	
7	Domain Name Service (DNS)	• Kurose and Ross (K&R) 6th edition: 2.5 • Review lecture 7 slides	CLO7, CLO8, CLO9	
8	Reliable Transport	• Kurose and Ross (K&R) 6th edition: 3.4 • Review lecture 8 slides	CLO7, CLO8, CLO9	
9	Reliable Transport (Cont'd)	• Kurose and Ross (K&R) 6th edition: 3.4 • Review lecture 8 slides	CLO7, CLO8, CLO9	
10	Role of Transport, UDP and TCP	• Kurose and Ross (K&R) 6th edition: 3.3 & 3.5.1,3.5.2 &3.5.4 • Review lecture 9 slides	CLO7, CLO8, CLO9	
11	Congestion Control and TCP	• Kurose and Ross (K&R) 6th edition: 3.6.1,3.6.2 & 3.7 • Review lecture 10 slides	CLO12	
12	Congestion Control (Cont'd)	• Kurose and Ross (K&R) 6th edition: 3.7 • Review lecture 11 slides	CLO12	
13	Fundamentals of Routing	• Kurose and Ross (K&R) 6th edition: 4.1 • Review lecture 12 slides	CLO10, CLO11	
14	Routing Approach: Link State Routing	• Kurose and Ross (K&R) 6th edition: 4.5.1 • Review lecture 13 slides	CLO10, CLO11	
15	Routing Approach: Distance-Vector Routing	• Kurose and Ross (K&R) 6th edition: 4.5.2 • Review lecture 15 slides	CLO10, CLO11	

16	Addressing and Forwarding in the Internet	• Kurose and Ross (K&R) 6th edition: 4.4 • Review lecture 16	CLO10, CLO11	
17	Inter-domain Routing and BGP	• Kurose and Ross (K&R) 6th edition: 4.5.3 & 4.6.3 • Review lecture 17	CLO10, CLO11	
18	Scalable Storage: DHTs and Consistent Hashing	• Review lecture 18	CLO17	
19	Lookup Services	• Review lecture 19	CLO17	
20	Coordination: Time Synchronization & Logical clocks	• Tanenbaum (3rd Edition), Chapter 6.1-6.2 • Review lecture 20	CLO15, CLO16	
21	Coordination: Time Synchronization & Logical clocks (Cont'd)	• Tanenbaum (3rd Edition), Chapter 6.1-6.2 • Review lecture 21	CLO15, CLO16	
22	Coordination: Mutual Exclusion & Election algorithms	• Tanenbaum (3rd Edition), Chapter 6.3-6.4 • Review lecture 22	CLO15, CLO16	
23	Replication and Consistency	• Tanenbaum (3rd Edition), Chapter 7.1 • Review lecture 23	CLO18, CLO19	
24	Consistency Protocols	• Tanenbaum (3rd Edition), Chapter 7.5 • Review lecture 24	CLO18, CLO19	
25	Fault Tolerance	• Tanenbaum (3rd Edition), Chapter 8.1-8.2 • Review lecture 25	CLO13, CLO14	
26	Fault Tolerance (cont'd)	• Tanenbaum (3rd Edition), Chapter 8.1-8.2	CLO13, CLO14	
27	Scalable Big data processing with MapReduce	• Review lecture 27	CLO20	
28	Last Lecture: Lessons			

TEXTBOOK/ SUPPLEMENTARY READINGS

Required Text

- Computer Networking: A Top-Down Approach, 6th Edition, by Jim Kurose and Keith Ross
- Distributed Systems: Principles and Paradigms, 3rd Edition, by Andrew S. Tanenbaum and Maarten Van Steen

Optional Texts

- Computer Networks: A Systems Approach, 5th edition, by Larry Peterson and Bruce Davie
- Distributed Systems: Concepts and Design – 4th Ed., George Colouris, Jean Dollimore, Tim Kindberg. Pearson 2006

Please note the syllabus above is tentative and can be subject to some changes.

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Academic Honesty

The principles of truth and honesty are recognized as fundamental to a community of teachers and students. This means that all academic work will be done by the student to whom it is assigned without unauthorized aid of any kind. Plagiarism, cheating and other forms of academic dishonesty are prohibited. Any instances of academic dishonesty in this course (intentional or unintentional) will be dealt with swiftly and severely. Potential penalties include receiving a failing grade on the assignment in question or in the course overall. For further information, students should make themselves familiar with the relevant section of the LUMS student handbook.

Harassment Policy

SSE, LUMS and particularly this class, is a harassment free zone. There is absolutely zero tolerance for any behaviour that is intended or has the expected result of making anyone uncomfortable and negatively impacts the class environment, or any individual's ability to work to the best of their potential. In case a differently-abled student requires accommodations for fully participating in the course, students are advised to contact the instructor so that they can be facilitated accordingly.

If you think that you may be a victim of harassment, or if you have observed any harassment occurring in the purview of this class, please reach out and speak to me. If you are a victim, I strongly encourage you to reach out to the Office of Accessibility and Inclusion at oai@lums.edu.pk or the sexual harassment inquiry committee at harassment@lums.edu.pk for any queries, clarifications, or advice. You may choose to file an informal or a formal complaint to put an end of offending behavior. You can find more details regarding the LUMS sexual harassment policy here. To file a complaint, please write to harassment@lums.edu.pk

SSE Council on Equity and Belonging

In addition to LUMS resources, SSE's Council on Belonging and Equity is committed to devising ways to provide a safe, inclusive and respectful learning environment for students, faculty and staff. To seek counsel related to any issues, please feel free to approach either a member of the council or email at cbe.sse@lums.edu.pk

Rights and Code of Conduct for Online Teaching

A misuse of online modes of communication is unacceptable. TAs and Faculty will seek consent before the recording of live online lectures or tutorials. Please ensure if you do not wish to be recorded during a session to inform the faculty member. Please also ensure that you prioritize formal means of communication (email, LMS) over informal means to communicate with course staff.

Makeup Policy

- Please refer to Student Handbook 2019-20, page 37, article 25, titled "Makeup Policy for Graded Instruments".
- *"In case N-X policy is implemented for an instrument having multiple sub instruments then petitions will not be accepted for that instrument".*

Code of Conduct

1. When attending classes, please ensure that your video is turned off and your mic is muted unless you are asked to do so.
2. Only authenticated users will be to join class lectures on zoom – please make you join the zoom lectures through an account based on your LUMS email address.
3. All quizzes will be announced, and students must ensure that their devices are charged, and they have a stable internet connection (including smartphones).
4. All assessments including quizzes and the final exam will be timed. Make sure that you are able to start them on time.

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Appendix A
Bloom's Taxonomy

BLOOM's TAXONOMY*	
1 - Remember 2 - Understand 3 - Apply 4 - Analyze 5 - Evaluate 6 - Create	• Recall facts and basic concepts • Explain ideas or concepts • Use information in new situations • Draw connection among ideas • Justify a stand or decision • Produce new or original work

https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/

Appendix B
ACM Dispositions Table - I

ACM Dispositions			
Element	**Elaboration**	**Element**	**Elaboration**
D1 Adaptable:	Flexible; agile, adjust in response to change	D7 Professional:	Professionalism, discretion, ethical, astute
D2 Collaborative:	Team player; willing to work with others	D8 Purpose-driven:	Goal driven, achieve goals, business acumen
D3 Inventive:	Exploratory; Look beyond simple solutions	D9 Responsible:	Use judgment, discretion, act appropriately
D4 Meticulous:	Attentive to detail; thoroughness, accurate	D10 Responsive:	Respectful; react quickly and positively
D5 Passionate:	Conviction, strong commitment, compelling	D11 Self-directed:	Self-motivated, determination, independent
D6 Proactive:	With initiative, self-starter, independent		

ACM Dispositions Table - II

Class Assessments and Proposed Dispositions												
Assessment Type	**D1 Adaptable**	**D2 Collaborative**	**D3 Inventive**	**D4 Meticulous**	**D5 Passionate**	**D6 Proactive**	**D7 Professional**	**D8 Purpose-driven**	**D9 Responsible**	**D10 Responsive**	**D11 Self-directed**	**Included**
Quiz				✓			✓		✓			Yes
Assignment-Individual			✓	✓			✓		✓			Yes
Assignment-Group		✓	✓	✓			✓		✓	✓		Yes
Project-Individual	✓		✓	✓	✓	✓	✓	✓	✓		✓	Yes
Project- Group	✓	✓	✓	✓	✓	✓	✓	✓	✓			Yes
Presentation-Individual				✓			✓		✓	✓	✓	Yes
Presentation-Group		✓		✓			✓		✓	✓		Yes
Labs-Individual			✓	✓			✓		✓			Yes
Labs- Group		✓	✓	✓			✓		✓	✓		Yes
Exams				✓			✓		✓			Yes
Included	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	

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Appendix C
ACM Computing Knowledge Landscape Table

ACM Computing Knowledge Landscape (CK)			
1. Users and Organizations	CK1.1: Social Issues and Professional Practice CK1.2: Security Policy and Management CK1.3: IS Management and Leadership CK1.4: Enterprise Architecture CK1.5: Project Management CK1.6: User Experience Design	**4. Software Development**	CK4.1: Software Quality, Verification and Validation CK4.2: Software Process CK4.3: Software Modeling and Analysis CK4.4: Software Design CK4.5: Platform-Based Development
2. Systems Modeling	CK2.1: Security Issues and Principles CK2.2: Systems Analysis & Design CK2.3: Requirements Analysis and Specification CK2.4: Data and Information Management	**5. Software Fundamentals**	CK5.1: Graphics and Visualization CK5.2: Operating Systems CK5.3: Data Structures, Algorithms and Complexity CK5.4: Programming Languages CK5.5: Programming Fundamentals CK5.6: Computing Systems Fundamentals
3. Systems Architecture and Infrastructure	CK3.1: Virtual Systems and Services CK3.2: Intelligent Systems (AI) CK3.3: Internet of Things CK3.4: Parallel and Distributed Computing CK3.5: Computer Networks	**6. Hardware**	CK6.1: Architecture and Organization CK6.2: Digital Design CK6.3: Circuits and Electronics CK6.4: Signal Processing

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