 **BIRLA INSTITUTE OF TECHNOLOGY & SCIENCE, PILANI**

**WORK INTEGRATED LEARNING PROGRAMMES**

**COURSE HANDOUT**

**Part A: Content Design**

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| --- | --- |
| **Course Title** | DISTRIBUTED COMPUTING |
| **Course No(s)** | SS ZG526 |
| **Credit Units** |  |
| **Course Author** |  |
| **Version No** | V1 |
| **Date** | 08/02/2018 |

**Course Description**

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**Course Objectives**

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| **No** | Objective |
| **CO1** | This course will cover various hardware architectures for building distributed systems, and their communication models. |
| **CO2** | This will help students understand the design aspects of various software applications that can be deployed on various distributed systems. |
| **CO3** | This will provide an understanding of the complexities and resource management issues that are critical in a large distributed system. |
| **CO4** | This course will cover algorithmic aspects of building/designing distributed systems in domains like IoT, P2P, Cluster, Grid computing etc. |

**Text Book(s)**

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| --- | --- |
| No | Author(s), Title, Edition, Publishing House |
| T1 | Ajay D. Kshemkalyani, and Mukesh Singhal “Distributed Computing: Principles, Algorithms, and Systems”, Cambridge University Press, 2008 (Reprint 2013). |

**Reference Book(s) & other resources**

|  |  |
| --- | --- |
| No | Author(s), Title, Edition, Publishing House |
| R1 | John F. Buford, Heather Yu, and Eng K. Lua, “P2P Networking and Applications”, Morgan Kaufmann, 2009 Elsevier Inc. |
| R2 | Kai Hwang, Geoffrey C. Fox, and Jack J. Dongarra, “Distributed and Cloud Computing: From Parallel processing to the Internet of Things”, Morgan Kaufmann, 2012 Elsevier Inc. |

**Content Structure**

|  |  |  |
| --- | --- | --- |
| **No** | **Title of the Module** | **References** |
| M1 | **Introduction to Distributed Computing**   * Introduction to Distributed computing * Motivation, Multiprocessor Vs Multicomputer Systems * Distributed Communication Model; RPC * Design issues and challenge | T1 (Chap.1) |
| M2 | **Logical Clocks & Vector clocks**   * A framework for a system of logical clock * Scalar time, Vector time. * Implementation of Logical and Vector clocks, Efficient implementation of Vector clocks. * Physical Clock synchronization: NTP | T1 (Chap.3) |
| M3 | **Global state and snapshot recording algorithms**   * System model and definitions * Snapshot recording algorithms for FIFO channels * Snapshot recording algorithms for non-FIFO channels * Necessary and sufficient conditions for consistent global snapshots * Classifications and basic concepts * Elementary graph algorithms, Synchronizers * Maximal Independent set, and Connected dominating set | T1 (Chap.4 & 5) |
| M4 | **Message ordering and Termination detection**   * Message ordering paradigms * Group Communication * Protocols for ensuring Causal order of messages * Total order * Application level multicast * Termination detection using distributed snapshots * Termination detection using weight throwing * A spanning-tree based termination detection algorithm | T1 (Chap.6) |
| M5 | **Distributed Mutual Exclusion**   * Introduction and Preliminaries * Assertion based: Lamport’s algorithm, and Ricart-Agrawala’s algorithm * Assertion based: Maekawa’s algorithm * Token based: Suzuki-Kasami’s broadcast based algorithm * Token based: Raymond’s tree based algorithm | T1 (Chap.9, 10) |
| M6 | **Deadlock detection**   * Models of distributed deadlock * Chandy-Misra-Haas deadlock detection for AND model * Chandy-Misra-Haas deadlock detection for OR model * Deadlock resolution |  |
| M7 | **Consensus and Agreement Algorithms**   * Problem definition * The Byzantine agreement and other consensus problems * Overview of Results * Agreement in failure-free system (synchronous or asynchronous) * Agreement in (message-passing) synchronous systems with failures | T1 (Chap.14) |
| M8 | **Peer-to-Peer computing and Overlay graphs**   * Introduction * Data indexing and Overlays * Unstructured Overlays * Structured Overlays: CHORD DHT * Design issues of P2P overlays * Security concerns from P2P networks * Mitigating security risks in P2P networks | T1 (Chap.18) |
| M9 | **Cluster Computing & Grid Computing**   * Cluster development trends * Design objectives of Computer clusters * Cluster organization and resource sharing * Node architecture and MPP packaging * Cluster system interconnects * Hardware, software and Middle ware support * GPU Clusters for massive parallelism * Cluster job and resource management * Grid architecture and service modeling * Grid resource management and brokering | R2 (Chap.2, 7) |
| M10 | **Internet of Things**   * IoT for Ubiquitous computing, RFID, Sensors and ZigBee technologies, * Applications of IoT (smart buildings, cyber-physical systems) * Graph theoretic analysis of social networks; Facebook, and Twitter case studies | R2 (Chap.9) |

**Learning Outcomes:**

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| --- | --- |
| **No** | **Learning Outcomes** |
| LO1 | Understanding of middleware platforms like RPC(Sun RPC, Java RMI, etc) for implementing communication models over distributed systems. |
| L02 | Understanding the need of Logical clocks and their usages in building distributed systems and its’ components. |
| LO3 | Understanding of Mutual exclusion primitives, Agreement protocols, and deadlock handling scenarios in distributed systems. |
| LO4 | Understanding of search, storage, communication, efficiency and other related issues in paradigms like P2P, Cluster, Grid, and IoT. |

**Part B: Contact Session Plan**

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| --- | --- |
| **Academic Term** | Second Semester 2023-2024 |
| **Course Title** | DISTRIBUTED COMPUTING |
| **Course No** | SS ZG526 |
| **Lead Instructor** | K.Srinivas |

## Glossary of Terms

1. Contact Hour (CH) stands for a hour long live session with students conducted either in aphysical classroom or enabled through technology. In this model of instruction, instructor ledsessions will be for 22 CH.
   1. Pre CH = Self Learning done prior to a given contact hour
   2. During CH = Content to be discussed during the contact hour by the course instructor
   3. Post CH = Self Learning done post the contact hour
2. Contact Hour (CS) stands for a two-hour long live session with students conducted either in aphysical classroom or enabled through technology. In this model of instruction, instructor ledsessions will be for 11 CS.
   1. Pre CS = Self Learning done prior to a given contact session
   2. During CS = Content to be discussed during the contact session by the course instructor
   3. Post CS = Self Learning done post the contact session
3. RL stands for Recorded Lecture or Recorded Lesson. It is presented to the student through anonline portal. A given RL unfolds as a sequences of video segments interleaved with exercises
4. SS stands for Self-Study to be done as a study of relevant sections from textbooks and referencebooks. It could also include study of external resources.
5. LE stands for Lab Exercises
6. HW stands for Home Work.
7. M stands for module. Module is a standalone quantum of designed content. A typical course is delivered using a string of modules. M2 means module 2.

## Teaching Methodology (Flipped Learning Model)

The pedagogy for this course is centered around flipped learning model in which the traditional class-room instruction is replaced with recorded lectures to be watched at home as per the student’s convenience and the erstwhile home-working or tutorials become the focus of classroom contact sessions. Students are expected to finish the home works on time.

## Contact Session Plan

* Each Module (M#) covers an independent topic and module may encompass more than one Recorded Lecture (RL).
* Contact Sessions **(2hrs each week)** are scheduled alternate weeks after the student watches all Recorded Lectures (RLs) of the specified Modules (listed below) during the previous week
* In the flipped learning model, Contact Sessions are meant for in-classroom discussions on cases, tutorials/exercises or responding to student’s questions/clarification--- may encompass more than one Module/RLs/CS topic.
* Contact Session topics listed in course structure (numbered CSx.y) may cover several RLs; and as per the pace of instructor/students’ learning, the instructor may take up more than one CS topic during each of the below sessions.

## Detailed Structure

**Introductory Video/Document:** *<< Introducing the faculty, overview of the course, structure and organization of topics, guidance for navigating the content, and expectations from students>>*

* Each of the sub-modules of **Recorded Lectures** (RLx.y ) shall delivered via **30 – 60mins videos** followed by:
* **Contact session** (CSx.y) of 2Hr each for illustrating the concepts discussed in the videos with exercises, tutorials and discussion on case-problems (wherever appropriate); contact sessions (CS) may cover more than one recorded-lecture (RL) videos.

## Course Contents

<From content structure in Part A of this document. Detail the plan of delivery across each contact hour or each contact session. 1 contact session = 2 contact hours>

|  |  |  |  |
| --- | --- | --- | --- |
| Time | Type | Description | References |
| **M1: Introduction to Distributed Computing** | | | |
| Pre-CH/CS | RL1.1 | Introduction - introduction to Distributed computing in terms of various hardware and software models |  |
|  | RL1.2 | Multiprocessing and Multi computing System, Distributed System Design Issues |  |
|  | RL1.3 | Distributed Communication Model (RPC) |  |
| During CH/CS | CH/CS 1 | Review of different communication models  Review of Design issues and Challenges for building distributed systems |  |
| Post-CH/CS | HW/Lab |  |  |
| Lab Reference | Module 1 Lab Capsule |  |  |
| **M2: Logical Clocks & Vector Clocks** | | | |
| Pre-CH/CS | RL2.1 | Distributed Computational Model and Logical Clocks. |  |
|  | RL2.2 | Lamport Logical Clocks |  |
|  | RL2.3 | Vector Clocks |  |
| During CH/CS | CH/CS 2 | Review of logical clocks.  Review Lamport logical and vector clocks examples |  |
| Post-CH/CS | HW/Lab |  |  |
| Lab Reference | Module 2 Lab Capsule |  |  |
| **M3: Global state and snapshot recording algorithms** | | | |
| Pre-CH/CS | RL3.1 | Global States, Principles to use to record the global states |  |
|  | RL3.2 | Chandy Lamport global state recording Algorithm for FIFO channels and Lai yang Algorithm for non-FIFO channels |  |
| During CH/CS | CH/CS 3 | Review of recording global state  Review of algorithms Chandy Lamport global state recording Algorithm and Lai yang Algorithm for FIFO and non-FIFO channels |  |
| Post-CH/CS | HW/Lab |  |  |
| Lab Reference | Module 3 Lab Capsule |  |  |
| **M4: Message ordering and Termination detection** | | | |
| Pre-CH/CS | RL4.1 | Casual Ordering of messages; Birman Schipher Stephenson (BSS) Algorithm with Example |  |
|  | RL4.2 | Schipher Eggli Sandoz (SES) Protocol for casual ordering with example |  |
| During CH/CS | CH/CS 4 | Review of Birman Schipher Stephenson (BSS) Algorithm  Review of Schipher Eggli Sandoz (SES) Algorithm with examples |  |
| Post-CH/CS | HW/Lab |  |  |
| Lab Reference | No Lab |  |  |
| **M5: Distributed Mutual Exclusion** | | | |
| Pre-CH/CS | RL5.1 | Distributed Mutual Exclusion; Centralized Algorithm |  |
|  | RL5.2 | Lamport DME Algorithm with Examples |  |
|  | RL5.3 | Ricart Agrawala DME Algorithm with Example |  |
|  | RL5.4 | Maekawa’s DME Algorithm with Example |  |
|  | RL5.5 | Token Based DME, Broadcast Based Algorithm; Suzuki Kasami Algorithm |  |
|  | RL5.6 | Raymond’s Tree Based Algorithm |  |
| During CH/CS | CH/CS 5 | Review of DME algorithms like, Lamport. Ricart Agrawala, Maekawa’s and Raymond Tree based algorithms with example  Review of previous Modules  Quiz-1 |  |
| Post-CH/CS | HW/Lab |  |  |
| Lab Reference | Module 5 Lab Capsule |  |  |
| **M6: Deadlock Detection** | | | |
|  | RL6.1 | Deadlocks in distribution system |  |
|  | RL6.2 | Chandy Misra Haas(CMH) Algorithm for AND Model (Edge Chasing) |  |
|  | RL6.3 | Chandy Misra Haas(CMH) Algorithm for OR Model (Diffusion Computation) |  |
| During CH/CS | CH/CS 6 | Review of Chandy Misra Haas algorithms for deadlock.  Assignment Announcement |  |
| Post-CH/CS | HW/Lab |  |  |
| Lab Reference | Module 6 Lab Capsule |  |  |
| **M7: Consensus and Agreement Algorithm** | | | |
| Pre-CH/CS | RL7.1 | Agreement Algorithm |  |
|  | RL7.2 | Oral Message Algorithm |  |
|  | RL7.3 | Applications of Byzantine Algorithm |  |
| During CH/CS | CH/CS 7 | Review of Agreement and OM algorithms |  |
| Post-CH/CS | HW/Lab |  |  |
| Lab Reference | Module 7 Lab Capsule |  |  |
| **M8: Peer to Peer Computing and Overlay graphs** | | | |
| Pre-CH/CS | RL8.1 | Introduction , P2P Architecture |  |
|  | RL8.2 | Design of Unstructured peer to peer networks |  |
|  | RL8.3 | Design of structured peer too peer networks |  |
|  | RL8.4 | Security Solutions for threats in P2P networks |  |
| During CH/CS | CH/CS 8 | Review of deign of structured and unstructured P2P network |  |
| Post-CH/CS | HW/Lab |  |  |
| Lab Reference | Module 8 Lab Capsule |  |  |
| **M9: Cluster computing, Grid Computing** | | | |
| Pre-CH/CS | RL9.1 | Cluster computing Introduction |  |
|  | RL9,2 | Design Components of cluster computers |  |
|  | RL9.3 | Grid Computing Introduction |  |
| During CH/CS | CH/CS 9 | Review of Cluster computing, grid computing |  |
| Post-CH/CS | HW/Lab |  |  |
| Lab Reference | Module 9 Lab Capsule | Provide the lab capsule name or number |  |
| **M10: Internet of Things** | | | |
| Pre-CH/CS | RL number | RL description |  |
|  | RL9.4 | IoT ; IoT Architecture |  |
| During CH/CS | CH/CS 10 | Review of IoT Architecture and Technologies  Review of Previous Modules  Assignment Evaluation  Quiz-2 |  |
| Post-CH/CS | HW/Lab |  |  |
| Lab Reference | Module 10 Lab Capsule |  |  |

## Lab Details

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| --- | --- | --- | --- |
| Lab No | Lab Objective | Lab Sheet/Capsule Access URL | Content Reference |
| 1 | To understand Remote procedure call in client server environment. | Module 1 Labcapsule |  |
| 2 | To understand Lamport clock to determine order of events in distributed system | Module 2 Labcapsule |  |
| 3 |  | Module 3 Labcapsule |  |
| 4 |  | Module 5 Labcapsule |  |
| 5 | To understand Lamport’s distributed mutual exclusion algorithm | Module 6 Labcapsule |  |
| 6 | To understand Byzantine agreement algorithm to determine tolerance of systems to faulty nodes | Module 7 Labcapsule |  |
| 7 | To understand Peer2Peer distributed applications | Module 8 Labcapsule |  |
| 8 | To understand the concept of clustered network can be implemented over HTTP/HTTPS protocol | Module 9 Labcapsule |  |
| 9 | A security system that sends an email once an intrusion is detected | Module 10 Labcapsule |  |

## Select Topics and Case Studies from business for experiential learning

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| --- | --- | --- |
| Topics No. | Select Topics/Case Studies in Syllabus for experiential learning | Access URL |
|  |  |  |

## Evaluation Scheme

Legend: EC = Evaluation Component

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| --- | --- | --- | --- | --- | --- |
| **No** | **Name** | **Type** | **Duration** | **Weight** | **Day, Date, Session, Time** |
| EC-1 | Quiz-1 | | \* | 5% | February 19-28, 2024 |
| Quiz-2 | | \* | 5% | March 19-28, 2024 |
| Assignment | | \* | 10% | April 19-28, 2024 |
| EC-2 | Mid-Semester Test | Closed Book | 2 hours | 30% | Saturday, 16/03/2024 (AN) |
| EC-3 | Comprehensive Exam | Open Book | 2 ½ hours | 50% | Saturday, 18/05/2024 (AN) |

***Note*** *- Evaluation components can be tailored depending on the proposed model.*

## Important Information:

Syllabus for Mid-Semester Test (Closed Book): Topics in CS 1-5.

Syllabus for Comprehensive Exam (Open Book): All topics given in plan of study

Evaluation Guidelines:

1. For Closed Book tests: No books or reference material of any kind will be permitted. Laptops/Mobiles of any kind are not allowed. Exchange of any material is not allowed.
2. For Open Book exams: Use of prescribed and reference text books, in original (not photocopies) is permitted. Class notes/slides as reference material in filed or bound form is permitted. However, loose sheets of paper will not be allowed. Use of calculators is permitted in all exams. Laptops/Mobiles of any kind are not allowed. Exchange of any material is not allowed.
3. If a student is unable to appear for the Regular Test/Exam due to genuine exigencies, the student should follow the procedure to apply for the Make-Up Test/Exam. The genuineness of the reason for absence in the Regular Exam shall be assessed prior to giving permission to appear for the Make-up Exam. Make-Up Test/Exam will be conducted only at selected exam centres on the dates to be announced later.

It shall be the responsibility of the individual student to be regular in maintaining the self-study schedule as given in the course handout, attend the lectures, and take all the prescribed evaluation components such as Assignment/Quiz, Mid-Semester Test and Comprehensive Exam according to the evaluation scheme provided in the handout.