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

**WORK-INTEGRATED LEARNING PROGRAMMES DIVISION**

**M Tech Computing Systems and Infrastructure in collaboration with WIPRO**

**Second Semester 2024 - 2025**

**COURSE HANDOUT**

**Part A: Content Design**

|  |  |
| --- | --- |
| **Course Title** | **Network Embedded Applications** |
| **Course No(s)** | CSIW ZG656 |
| **Credit Units** |  |

**Course Objectives**

|  |  |
| --- | --- |
| **No** | **Objectives** |
| **CO1** | To get an overview of various network embedded applications, architectures, available protocols |
| **CO2** | Understand the application of Wireless Sensor Networks in depth |
| **CO3** | Understand the application of Industrial Networks in depth |
| **CO4** | Understand the application of Automotive Networks in depth |
| **CO5** | Develop Deeply Embedded Systems and IoT Applications |

**Text Book(s)**

|  |  |
| --- | --- |
| No | Author(s), Title, Edition, Publishing House |
| T1 | **R.Zurawski, Network Embedded Systems, CRC press, 2009.** |

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

|  |  |
| --- | --- |
| No | Author(s), Title, Edition, Publishing House |
| R1 | G.Pottie, W.Kaiser, Principles of Embedded Networked System Design |
| R2 | IEEE Journals and Transactions.  IETF Drafts and RFCs  ACM Transactions  Elsiever Journals |

**Modular Content Structure**

**M1. INTRODUCTION TO NETWORKED EMBEDDED SYSTEMS**

* Introduction to the course
* Introduction to various classes of Networked Embedded Applications
* Multi-processing, Distributed and Networked Systems - Differences

**M2. APPLICATION CLASS -1 WIRELESS SENSOR NETWORKS**

* Introduction
  + What is WSN?
  + Monitoring Space
  + Monitoring Objects
  + Monitoring the Interactions between Space and Objects
  + Basic Building Blocks of WSN
  + Design Challenges of WSN
* Deployment of WSN
  + Deployment Issues
  + Deployment Patterns
* WSN Protocol Stack Introduction
  + Role of each layer
  + Cross Layer Architecture
* WSN Time Synchronization
  + Time Synchronization Requirements and Issues
  + Sender- Receiver Synchronization
  + Receiver- Receiver Synchronization
* WSN Localization
  + Need for Localization and Issues
  + Distance Estimation - ToA
  + Distance Estimation - TDoA
  + Distance Estimation - RSSI
  + Classical Localization Techniques
  + WCL
  + APIT
* WSN Routing
  + Introduction
  + Optimization-based
  + Data-centric
  + Cluster-based
  + Location-based
  + QoS Enabled
* WSN Topology Control
  + Introduction
  + GAF,SPAN
* WSN MAC
  + Introduction
  + SMAC
  + TMAC
  + DMAC
  + LMAC
  + EMAC
* WSN – Other Issues
* WSN Example – Red Pine Monitoring

**M3. INDUSTRIAL CONTROL NETWORKS**

* Introduction
  + Industrial Networks -Levels of Hierarchy
  + History of Industrial Networks
  + Industrial Networks - Issues
  + Characteristics of Industrial Networks
* Field Buses
  + Characteristics of Field Buses
  + Field Buses – MAC
  + Field Buses – TDMA
  + Field Buses – CSMA
  + Field Buses - ModBus
* Industrial Ethernet
  + Field Bus Vs Industrial Ethernet
  + Modified Ethernet
  + SERCOS
  + Ethercat
  + Top of Ethernet
  + EPL
  + TCNet
  + EPA
  + Top of TCP/IP
  + ModBus over TCP/IP
* Wireless Industrial Networks
  + Wireless Ethernet
  + 802.11
  + Bluetooth
  + ZigBee
  + Hybrid Wired/Wireless Networks

**M4. VEHICULAR NETWORKS**

* Intra-vehicular Networks
  + Domains
  + Vehicular Buses
  + TTBuses – TTP/C
  + TTBuses – Flexray
  + TTBuses – TT Ethernet
  + TTBuses – TTCAN
  + Event Triggered Buses - LIN
* Inter-Vehicular Networks
  + V2I and V2V Communication and ITS
  + Types of Traffic
  + VANETS- MAC
  + VANETS – Routing
  + VANETS – PBR
  + VANETS – Routing Classification
  + VANETS – Flooding based Routing - UMB
  + SB and IB
  + Geographic Routing - Gytar

**Learning Outcomes:**

|  |  |
| --- | --- |
| **No** | **Learning Outcomes** |
| **LO1** | Design and Implementation of Wireless Sensor Networks |
| **LO2** | Design and Implementation of Industrial Networks |
| **LO3** | Design and Implementation of Automotive Networks |
| **LO4** | Design and Implementation of end-to-end IoT Networks |

**Part B: Contact Session Plan**

|  |  |
| --- | --- |
| **Academic Term** | II Semester 2022 - 2023 |
| **Course Title** | Networked Embedded Applications |
| **Course No** | CSIW ZG656 |
| **Lead Instructor** |  |

## Glossary of Terms

1. Contact Hour (CH) stands for a hour long live session with students conducted either in a physical classroom or enabled through technology. In this model of instruction, instructor led sessions 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 a physical classroom or enabled through technology. In this model of instruction, instructor led sessions 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 an online 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 reference books. 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) or Lecture Segment (LS).
* Contact Sessions **(1.5 hrs 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.

## 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 = 90 minutes contact >

|  |  |  |  |
| --- | --- | --- | --- |
| **Time** | **Type** | **Description** | **References** |
| **M1. INTRODUCTION TO NETWORKED EMBEDDED SYSTEMS** | | | |
| Pre-CH/CS | RL1.1.1, RL 1.1.2,RL2.1 | * Introduction to various classes of Networked Embedded Applications * Multi-processing, Distributed and Networked Systems – Differences * Introduction to WSN | Notes |
| During CS | CS 1 | * Introduction to the course – evaluation components * IoT Vs NEA * Buses Vs Networks * WSN-based systems | Notes |
|  |  |  |  |
| **M2. Wireless Sensor Networks** | | | |
| Pre-CH/CS | RL 2.2, RL 2.3,RL2.4.1 | * WSN Deployment * Network Protocol Stack * WSN Time Synchronization   + Time Synchronization Requirements and Issues | T1 – Part II Ch 3,4 |
| During CS | CS 2 | * Application Examples – Long Term & Short Term Monitoring * Importance of Cross Layer Protocol Stack * WSN Application Examples |  |
| Post-CH/CS |  |  | Papers |
|  | | | |
| Pre-CH/CS | RL 2.4,RL 2.5.1 | * WSN Time Synchronization   + Sender- Receiver Synchronization   + Receiver- Receiver Synchronization * WSN Localization   + Need for Localization and Issues | T1 – Part II Ch 5 |
| During CS | CS 3 | * NTP, HBS, TDP, RBD |  |
| Post-CH/CS |  | * More Time Synchronization Protocols - THSL | Papers |
|  | | | |
| Pre-CH/CS | RL 2.5,RL2.6.1 | * WSN Localization   + Distance Estimation - ToA   + Distance Estimation - TDoA   + Distance Estimation - RSSI   + Classical Localization Techniques   + WCL   + APIT * WSN Routing   + Introduction | T1 – Part II Ch 6 |
| During CS | CS 4 | * Bounding Box Algorithm, Distributed Least Squares, Sweeps * WSN routing examples |  |
| Post-CH/CS |  | * FGL, Assumption-Based Coordinates | Papers |
|  | | | |
| Pre-CH/CS | RL 2.6, RL 2.7 | * WSN Routing   + Optimization-based   + Data-centric   + Cluster-based   + Location-based   + QoS Enabled | T1 – Part II Ch 7 |
| During CS | CS 5 | * Sensor Protocols for Information via Negotiation, Sequential Assigned Routing Protocol, Energy-Aware Routing Protocol in Cluster-Based Sensor Networks * MECN, STEM |  |
| Post-CH/CS |  | * Pegasis, Maximum Lifetime Routing Protocol, TTDD, RPAR, Constrained Anisotropic Diffusion Routing Protocol | Papers |
|  | | | |
| Pre-CH/CS | RL 2.8 | * WSN MAC   + Introduction   + SMAC   + TMAC   + DMAC   + LMAC   + EMAC | T1 – Part II Ch 8 |
| During CS | CS 6 | * BMAC,TRAMA * Mobility and Multi-Channel MAC |  |
| Post-CH/CS |  | * Wise MAC, ZMAC, Crankshaft and other MAC Protocols | Papers |
|  | | | |
| Pre-CH/CS | RL 2.9, RL 2.10 | * WSN – Other Issues * WSN Example – Red Pine Monitoring |  |
| During CS | CS 7 | * WSN Examples |  |
| Post-CH/CS |  | * WSN Examples | Papers |
|  |  |  |  |
| Pre-CH/CS |  |  |  |
| During CS | CS8 | * Review session |  |
| Post-CH/CS |  |  |  |
| **M3. INDUSTRIAL CONTROL NETWORKS** | | | |
| Pre-CH/CS | RL 3.1, RL 3.2 | * Introduction   + Industrial Networks -Levels of Hierarchy   + History of Industrial Networks   + Industrial Networks - Issues   + Characteristics of Industrial Networks * Field Buses   + Characteristics of Field Buses   + Field Buses – MAC   + Field Buses – TDMA   + Field Buses – CSMA   + Field Buses - ModBus |  |
| During CS | CS 9 | * Summary, OSI Model and Industrial Networks, NOAH Approach, Protocol Tunneling, LonWorks |  |
| Post-CH/CS | HW/Lab | * Building Automation |  |
|  | | | |
| Pre-CH/CS | RL 3.3 | * Industrial Ethernet   + Field Bus Vs Industrial Ethernet   + Modified Ethernet   + SERCOS   + Ethercat   + Top of Ethernet   + EPL   + TCNet   + EPA   + Top of TCP/IP   + ModBus over TCP/IP |  |
| During CS | CS 10, CS 11 | * Summary & Comparison * Ethernet IP and other Protocol |  |
| Post-CH/CS | HW/Lab | * Hierarchical Industrial Control |  |
|  | | | |
| Pre-CH/CS | RL 3.4 | * Wireless Network for Industrial Networks |  |
| During CS | CS 12 | * 802.11 * Bluetooth * 802.15.4 |  |
| Post-CH/CS | HW/Lab | * Hybrid Wired/Wireless Industrial Networks |  |
| **M4. Automotive Electronics** | | | |
| Pre-CH/CS | RL 4.1 | * Intra-vehicular Networks * Domains * Vehicular Buses * TTBuses – TTP/C * TTBuses – Flexray * TTBuses – TT Ethernet * TTBuses – TTCAN * Event Triggered Buses - LIN |  |
| During CS | CS 13,CS14 | * Fault Tolerance, Fault & Error Confinement * Fault Tolerant Buses * AutoSAR * Middleware and Automotive OS |  |
| Post-CH/CS | HW/Lab | * Volcano |  |
|  | | | |
| Pre-CH/CS | RL 4.2 | * V2I and V2V Communication and ITS * Types of Traffic * VANETS- MAC * VANETS – Routing * VANETS – PBR * VANETS – Routing Classification * VANETS – Flooding based Routing - UMB * SB and IB * Geographic Routing - Gytar |  |
| During CS | CS 15 | * Geographic Broadcast Routing * Non Safety-Critical Applications – Network Protocol Stack * System Design Example – Mining System * Summary of Course |  |
| Post-CH/CS | HW/Lab | * System Design Examples |  |
|  |  |  |  |
| Pre-CH/CS |  |  |  |
| During CS | CS16 | * Review session |  |
| Post-CH/CS |  |  |  |