COURSE TITLE: IoT Architectures and Protocols

COURSE CODE: BCSE310L

Module 1: IoT Fundamentals (5 hours)

1. **Definition and Characteristics of the Internet of Things (IoT)**
   IoT refers to a **network of physical objects** embedded with sensors, software, and other technologies that connect and exchange data with other systems over the internet.
   - **Ubiquitous Connectivity** – Seamless device communication through WiFi, Bluetooth, and cellular networks.
   - **Scalability** – Ability to add or remove devices without compromising system performance.
   - **Intelligence and Automation** – AI-based decision-making that processes collected data to perform automated actions.
2. **Challenges and Issues in IoT**
   - **Security and Privacy** – Vulnerability to cyberattacks, including denial-of-service (DoS), man-in-the-middle (MITM), and data breaches.
   - **Interoperability** – Integration of devices from different manufacturers with varied communication protocols.
   - **Data Management** – Storing, processing, and analyzing vast amounts of data generated by IoT devices.
   - **Energy Efficiency** – Prolonging device lifespan while managing power consumption effectively.
3. **Physical Design of IoT**
   Physical IoT architecture consists of:
   - **Sensors and Actuators** – Collect environmental data and execute control actions.
   - **Microcontrollers and Gateways** – Process and transmit data between devices and the cloud.
   - **Communication Interfaces** – Enable data exchange through WiFi, Zigbee, LoRa, or cellular networks.
4. **Logical Design of IoT**
   Logical IoT design focuses on:

- **Application Layer** – Interfaces with end-users via mobile apps and web platforms.
- **Data Management Layer** – Stores and processes collected data securely.
- **Communication Layer** – Manages data transmission between devices.

5. **IoT Functional Blocks**
   Core functional blocks include:
   - **Sensing Layer** – Captures and transmits physical data.
   - **Processing Layer** – Transforms raw data into actionable insights.
   - **Application Layer** – Presents data to users for decision-making.
   - **Security Layer** – Protects the system from unauthorized access.

Module 2: IoT Communication Architectures and Protocols (7 hours)

1. **Control Units & Communication Modules**
   - **Microcontrollers** – Process IoT data and control device operations (e.g., Arduino, ESP8266).
   - **Gateways and Edge Devices** – Bridge communication between IoT devices and cloud services.
2. **Wireless Communication Technologies:**
   - **Bluetooth** – Short-range, low-power communication ideal for wearable and home automation devices.
   - **Zigbee** – Low-power, low-data rate wireless standard for smart home and industrial applications.
   - **WiFi** – High-speed wireless communication for data-intensive IoT applications.
   - **GPS (Global Positioning System)** – Enables geolocation and tracking services in IoT systems.
3. **IoT Protocols:**
   - **IPv6** – Extends the address space required to connect billions of IoT devices.
   - **6LoWPAN (IPv6 over Low-Power Wireless Personal Area Networks)** – Optimizes IPv6 for low-power, constrained devices.

- **RPL (Routing Protocol for Low-Power and Lossy Networks)** – Efficient routing protocol for IoT networks.
- **CoAP (Constrained Application Protocol)** – Lightweight protocol enabling IoT devices to interact over HTTP.
- **MQTT (Message Queuing Telemetry Transport)** – Publish-subscribe protocol ideal for real-time data transfer.

4. **Wired Communication & Power Sources**
    - **Ethernet and PoE (Power over Ethernet)** – Reliable data transmission and power supply to IoT devices.
    - **Serial Communication (RS-232/RS-485)** – Facilitates wired data transfer in industrial environments.

Module 3: Technologies Behind IoT (5 hours)

1. **Four Pillars of IoT Paradigm:**
    - **RFID (Radio Frequency Identification)** – Automates object identification and tracking using electromagnetic fields.
    - **Wireless Sensor Networks (WSN)** – Networks of sensor nodes that gather and transmit environmental data.
    - **Supervisory Control and Data Acquisition (SCADA)** – Industrial control systems used in critical infrastructure to monitor processes.
    - **Machine-to-Machine (M2M) Communication** – Autonomous data exchange between devices without human intervention.
2. **IoT Enabling Technologies:**
    - **Big Data Analytics** – Extracts insights from massive IoT datasets using AI/ML algorithms.
    - **Cloud Computing** – Provides scalable storage and processing power for IoT-generated data.
    - **Embedded Systems** – Real-time computing systems that control IoT devices.

Module 4: Programming the Microcontroller for IoT (5 hours)

1. **Working Principles of Sensors**
    - Sensors convert physical phenomena into electrical signals for data collection.
    - Types: Temperature, humidity, motion, proximity, and pressure sensors.
2. **IoT Deployment on:**
    - **Raspberry Pi** – A versatile, low-cost computing platform for prototyping IoT applications.
    - **Arduino** – Microcontroller-based development board for simple IoT solutions.
    - **Equivalent Platforms** – ESP8266 and ESP32 for IoT connectivity and low-power operations.
3. **Sensor Data Processing and Communication:**
    - **Reading from Sensors** – Analog and digital data acquisition from IoT devices.
    - **Connecting Microcontroller with Mobile Devices** – Bluetooth, WiFi, or USB interfaces to relay data.
    - **Communication through Bluetooth, WiFi, and USB** – Enables data exchange between microcontrollers and end-user interfaces.
4. **Operating Systems & Simulation:**
    - **Contiki OS** – Open-source operating system designed for IoT applications.
    - **Cooja Simulator** – Simulates IoT networks to evaluate system performance.

Module 5: Resource Management in IoT (5 hours)

1. **Scalability in IoT:**
    - **Network Configuration Protocol** – Dynamically configures network parameters in growing IoT ecosystems.
    - **OpenvSwitch Database Management Protocol (OVSDB)** – Manages configurations of virtual switches in SDN-enabled IoT networks.
2. **Routing and Protocols:**
    - **Collection Tree Protocol (CTP)** – Efficient protocol that organizes IoT networks into tree structures for data collection.

- **LOADng (Lightweight On-Demand Ad hoc Distance-vector Routing Protocol – Next Generation)** – Ad-hoc routing for low-power, constrained networks.

Module 6: IoT to Web of Things (WoT) (9 hours)

1. **Scope of Web of Things (WoT)**
    - WoT bridges IoT and web technologies to improve device interoperability.
    - Standard protocols (HTTP, REST APIs) ensure seamless device-to-device communication.
2. **IoT Data Management:**
    - **Setting up Cloud Environment** – AWS, Azure, and Google Cloud offer scalable storage and computing for IoT data.
    - **Cloud Access from Sensors** – Sensors transmit data securely to cloud platforms for real-time analytics.
    - **Data Analytics Platforms for IoT** – Apache Kafka and AWS IoT Analytics process IoT data for decision-making.
3. **Resource Identification:**
    - **Richardson Maturity Model** – Classifies RESTful APIs to ensure compatibility in WoT ecosystems.
    - **REST API** – Standardized API architecture that enables seamless interaction between IoT devices and web services.

Module 7: Applications of IoT (7 hours)

1. **Business Models for IoT**
    - **Subscription Models** – Revenue from recurring payments for IoT-based services.
    - **Data Monetization** – Selling insights generated from IoT data to third parties.
    - **Platform-as-a-Service (PaaS)** – Offering IoT platforms that allow other developers to build and manage applications.
2. **Smart Technologies & Use Cases:**
    - **Green Energy Buildings & Infrastructure** – IoT-based energy management systems optimize power consumption and reduce costs.

- **Smart Farming** – IoT solutions for precision agriculture, automated irrigation, and pest control.
- **Smart Retailing** – Enhances customer experience with smart shelves, inventory tracking, and personalized recommendations.
- **Smart Fleet Management** – Real-time fleet tracking, predictive maintenance, and route optimization using IoT.
