**Internet of Things (IoT)**

**Duration:** 40 Hours [20 Days × 2 Hours/Day]  
**Tools:** ESP32 (MicroPython), Raspberry Pi (Python + Frameworks)

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| **Day** | **Theory Topics** | **Hands-on Experiments** | **Assignments** |
| **1** | IoT architecture;  ESP32 vs Raspberry Pi; MicroPython & Python setup | 1. Install MicroPython on ESP32  2️. Setup Python on Raspberry Pi  3. Run “Hello World” on both | 1. ESP32 prints device info (chip, memory)  2️. Pi script prints system uptime |
| **2** | MicroPython syntax, REPL, modules, file system | 1️. Write MicroPython script with loops/functions  2️. Save & auto-run from flash memory  3️. Use os & time modules | 1️. Implement countdown timer  2️. Write factorial function |
| **3** | Networking basics: Wi-Fi, IP, sockets | 1. Connect ESP32 to Wi-Fi  2️. Socket server on Pi  3. ESP32 sends message to Pi | 1️. ESP32 sends timestamp every 5s  2️. Pi logs message with IP |
| **4** | MQTT fundamentals: Publish/Subscribe, brokers | 1️. Install Mosquitto on Pi  2. ESP32 publishes MQTT data  3️. Pi subscribes and displays | 1️. ESP32 publishes random numbers  2️. Pi computes running average |
| **5** | Data formats: JSON, CSV, serialization | 1️. ESP32 sends JSON payload  2️. Pi parses JSON  3️. Pi logs data to CSV | 1️. ESP32 sends nested JSON  2️. Pi extracts selected fields |
| **6** | REST APIs with Flask; HTTP methods | 1. Build REST API on Pi  2️. ESP32 sends POST request  3️. Store in SQLite | 1️. ESP32 retries on failure  2️. Pi returns JSON response |
| **7** | Edge vs Cloud; local filtering | 1️. Pi filters data  2️. Aggregate average  3️. Detect & remove outliers | 1️. Moving average filter  2️. Anomaly detection |
| **8** | Cloud IoT platforms: Adafruit IO, ThingsBoard | 1️. Setup cloud account  2️. Pi publishes to cloud  3️. Create dashboard | 1️. ESP32 → Pi gateway uplink  2️. Cloud alert on threshold |
| **9** | IoT security: TLS, certificates, authentication | 1️. Enable TLS in MQTT  2️. ESP32 verifies cert  3️. Password-protect broker | 1️. ESP32 rejects invalid cert  2️. Pi logs failed auth |
| **10** | SQL vs NoSQL for IoT data | 1️. Store data in SQLite  2️. Store in MongoDB  3. Query stored data | 1️. Retrieve last 10 entries  2️. Find max/min values |
| **11** | Data analytics with Pandas | 1️. Load CSV into DataFrame  2. Compute mean, median, std  3️. Plot line graph | 1️. Handle missing values  2. Compute rolling average |
| **12** | MQTT QoS & retained messages | 1️. Test QoS 0 vs 1  2️. Publish retained message  3️. Compare delivery reliability | 1️. Simulate packet loss  2️. Verify retained delivery |
| **13** | Device management & OTA updates | 1️. Host firmware on Pi  2️. ESP32 downloads update  3️. Auto-run updated code | 1️. ESP32 verifies checksum  2️. Pi logs update status |
| **14** | Docker & containerization for IoT edge | 1️. Install Docker on Pi  2️. Run MQTT broker in container  3️. Deploy Flask API container | 1️. Auto-restart on failure  2️. Scale with Docker Compose |
| **15** | Node-RED for IoT orchestration | 1️. Install Node-RED  2️. Create MQTT flow  3️. Build REST flow | 1️. Dashboard with charts  2️. Trigger alert flow |
| **16** | Time-series databases: InfluxDB, Grafana | 1️. Install InfluxDB  2️. Store ESP32 data  3️. Visualize in Grafana | 1️. Query last 1 hour  2️. Build Grafana alert |
| **17** | Event-driven IoT: asyncio & uasyncio | 1️. ESP32 async tasks  2️. Async TCP server on Pi  3️. Handle multiple clients | 1️. ESP32 dual async loops  2️. Pi handles 5 clients |
| **18** | Edge AI & anomaly detection | 1️. Train logistic regression on Pi  2️. Predict anomalies  3. Integrate with ESP32 data | 1️. Classify 100 samples  2️. Trigger alert on anomaly |
| **19** | Advanced security: JWT, API keys | 1️. Pi issues JWT token  2️. ESP32 authenticates via token  3️. Pi validates token | 1️. Reject expired token  2️. Log unauthorized access |
| **20** | Capstone: End-to-end IoT pipeline | 1️. ESP32 → MQTT → Pi → DB  2️. Pi analytics & visualization  3️. Cloud integration | 1️. Add TLS + JWT security  2️. Anomaly alert & report |

**Program Outcomes**

By the end of this STTP, participants will:

* Understand IoT architectures, protocols, and frameworks
* Develop and deploy IoT applications using ESP32 + Raspberry Pi
* Implement secure communication (MQTT, REST, TLS, JWT)
* Manage data storage, visualization, and analytics
* Integrate with cloud dashboards and perform Edge AI inference