

1. Water Level Monitoring Sensor Selection

Consider the following conditions:

- (a) Reservoir located at very high altitudes (e.g., Himalayan mountains) with strong winds.
- (b) Lakes that freeze during winter.
- (c) Rivers like the Yamuna, which can have a lot of pollutants, debris, and chemicals.
- (d) Lakes in urban areas like Hyderabad or Bengaluru, where very high levels of pollutants (including chemical foams) are present.

[6 pts]

For each condition:

- (a) Identify which type or technology of water level monitoring sensor you would consider most suitable.
- (b) Justify your choice by mentioning at least one advantage and one disadvantage of the selected sensor technology.

2. Polling vs. Interrupts in IoT Systems

Efficient power management is critical for battery-operated IoT devices. Two common mechanisms for handling external events are polling and interrupts.

Answer the following:

- (a) Define polling and explain how it works in an embedded system. [1½ pts]
- (b) Define interrupts and explain how they differ from polling. [1½ pts]
- (c) List the advantages and disadvantages of using polling versus interrupts in the context of IoT systems, especially considering energy efficiency. [2 pts]
- (d) Consider an IoT sensor node that needs to detect a temperature threshold crossing. [3 pts]
 - In a polling-based design, the ESP32 uses a `delay(100)` function inside a loop to periodically read the sensor every 100 ms. During the delay and the sensor reading, the ESP32 remains in active mode, consuming 80 mW continuously.
 - In an interrupt-based design, the ESP32 remains in deep sleep mode, consuming 5 mW, and wakes up only when the sensor triggers an interrupt, consuming 80 mW during the brief active interrupt handling (5 ms).
 - Assume that temperature threshold crossings (events) happen once every 10 seconds on average.

Estimate the energy consumption over a 10-second window in each case. Which design would result in better battery life? Provide your calculations and reasoning.

3. Over-The-Air Updates

The ESP32 microcontroller allows Over-The-Air (OTA) firmware updates to enable remote firmware upgrades.

Suppose an ESP32 device is performing an OTA update and loses its Wi-Fi connection midway through the firmware download.

[4 pts]

- Final Exam 29/30/2025

(a) Describe what happens to the ESP32's firmware and flash memory when the network connection is lost during an OTA update.

(b) Explain how the ESP32 ensures that the device remains bootable and operational even if the OTA update is interrupted. [4 pts]

4. IoT-Based Occupancy Detection for Energy-Efficient Building

In the context of developing a smart energy-efficient building, your team is tasked with designing an IoT-based occupancy detection system for a circular-architecture (see floor-plan in Figure 1) to control lighting and HVAC (Heating, Ventilation, and Air Conditioning) operations. The house can be individually controlled by each room.

The house is equipped with a central AC system, but the ducts/vents can be individually controlled in each closed room.

The system will rely on pyroelectric sensors (PIR sensors) to detect human presence by sensing infrared radiation emitted by body heat.

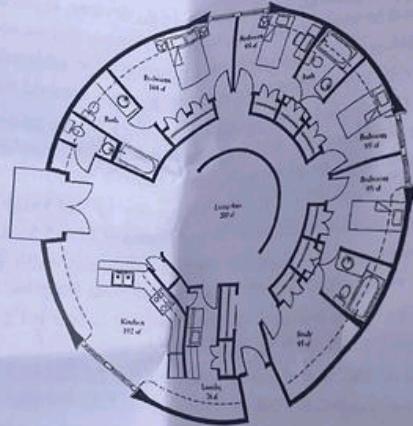


Figure 1: Floorplan of the circular-architecture building

Answer the following:

- (a) Discuss key considerations for the design, including:

 - Sensor sensitivity and its tuning.
 - Optimal placement strategy to ensure full coverage.
 - Techniques to reduce false positives.
 - Approaches to minimize the number of sensors while maintaining reliability.

- (b) Evaluate the benefits and limitations of using pyroelectric (PIR) sensors compared to other motion or occupancy detection technologies, such as ultrasonic sensors. [5 pts]
5. Multiple Choice Questions
- When using MQTT with ThingSpeak to publish sensor data, which of the following is typically required for a successful connection? [5 pts]
 - A unique Device ID and a pre-shared security key.
 - An API Key and a correct channel ID associated with the ThingSpeak account.
 - A REST API token and a webhook setup on the cloud server.
 - Only the device's IP address and the gateway's MAC address.
 - In a resource-oriented design approach used by OM2M, which of the following best represents the structure of a resource tree for managing IoT devices?
 - A flat list of all devices with no hierarchy.
 - A tree structure where each resource (e.g., devices, applications, data) is uniquely addressable and organized hierarchically.
 - A centralized database with no resource-specific addressing.
 - A peer-to-peer network where resources are organized with no hierarchy.
 - In an ESP32-based IoT system controlling home appliances through a 4-channel relay module, which of the following design choices would MOST correctly ensure reliable, safe, and scalable operation?
 - Connect the VCC of the ESP32 directly to the relay VCC to simplify the wiring, relying on software delays to prevent brownouts.
 - Use a separate 5V regulated supply for the relay coils, keep ESP32 on its own 3.3V supply, and connect the grounds of both supplies together.
 - Add external pull-up resistors to the ESP32 control pins to ensure the relay inputs remain LOW when ESP32 boots up.
 - Rely on the internal pull-up resistors of the ESP32 and assume no relay switching will happen unintentionally during ESP32 bootup.
 - For a smart access control system where users unlock doors by tapping their smartphones or cards against a reader at very close range (few centimeters), which communication technology would be the most appropriate?
 - Near Field Communication (NFC)
 - Bluetooth Low Energy (BLE)
 - Wi-Fi 6
 - LoRaWAN
 - Which of the following statements correctly describes the relationship between LoRa and LoRaWAN?

IoT Final Exam

29/30/2025

- A) LoRa is the MAC (Medium Access Control) protocol layer, and LoRaWAN is the physical (radio) layer technology.
B) LoRa is the physical (radio) layer technology, and LoRaWAN is the network protocol built on top of it.
C) LoRa and LoRaWAN are identical terms used interchangeably for the same technology.
D) LoRaWAN is a short-range protocol like Wi-Fi, while LoRa is a cellular technology.

[3 pts]

6. Comparative Analysis of IoT Communication Technologies

Consider the following communication technologies:

1. NFC 3. Bluetooth 5. Wi-Fi
2. ZigBee 4. LoRa 6. 4G/5G

Answer the following:

- (a) Plot the above technologies on a 2D graph where:
– X-axis represents typical communication distance (range).
– Y-axis represents typical bandwidth (data rate).
(b) Arrange the above technologies in increasing order of typical power consumption (from lowest power to highest power).

7. Communication Strategy for Wildlife Monitoring You are designing an IoT-based system to monitor the movement and behavior of wild animals in a large natural reserve. The system must meet the following operational goals: - Devices are attached to animals and powered by batteries expected to last several months without recharging. - Location data and basic activity data (e.g., resting, walking) must be periodically transmitted to a central station. - The reserve has very limited cellular coverage, and accessibility for frequent device maintenance is challenging. Tasks: [5 pts]

- (a) Identify a suitable wireless communication technology (you may propose more than one if needed) and justify your choice based on factors such as range, power consumption, data rate requirements, and reliability.
(b) Discuss one major technical challenge you anticipate in deploying this communication system in such an environment, and propose a possible mitigation.
(c) Would you recommend using direct communication to a central base station or a multi-hop (relay) network among the animal devices? Briefly justify your choice.
(d) Suggest one additional feature or technology that could improve the battery life of the attached devices.