Wireless Sensor Networks and IoT (4353201) - Winter 2024 Solution

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Question 1(a) [3 marks]

Compare Single hop and Multihop Network.

Solution

Parameter	Single Hop Network	Multihop Network
Communication	Direct to base station	Via intermediate nodes
Energy consumption	High for distant nodes	Distributed among nodes
Network coverage	Limited by transmission range	Extended coverage area
Complexity	Simple routing	Complex routing protocols

- **Single hop**: All nodes communicate directly with base station
- **Multihop**: Data passes through multiple intermediate nodes to reach destination

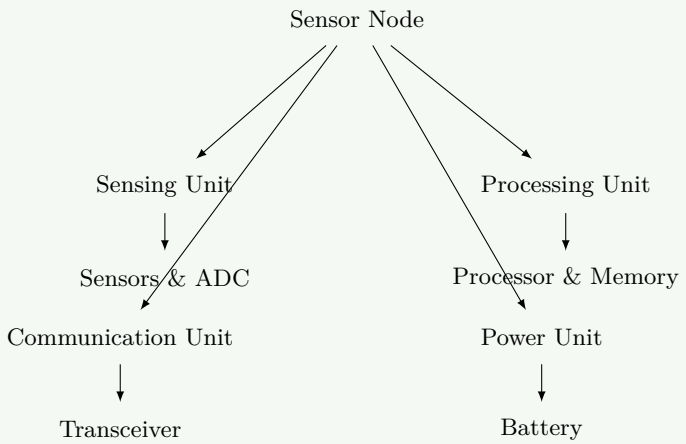
Mnemonic

Single Direct, Multi Relay

Question 1(b) [4 marks]

Explain the Basic Components of Sensor Node.

Solution



Basic Components:

- **Sensing subsystem**: Collects data from environment using sensors and ADC
- **Processing subsystem**: Microcontroller/processor with memory for data processing

- **Communication subsystem**: Radio transceiver for wireless data transmission
- **Power subsystem**: Battery or energy harvesting unit for power supply

Mnemonic

Sense Process Communicate Power

Question 1(c) [7 marks]

List out any four technologies to reduce power consumption in WSN and explain any two technologies in detail.

Solution

Table 1. Four Power Reduction Technologies:

Technology	Description
Sleep scheduling	Nodes alternate between active and sleep modes
Data aggregation	Combines multiple data packets into single transmission
Topology control	Optimizes network structure to reduce energy
Energy harvesting	Uses renewable sources like solar, vibration

Detailed Explanation:

1. Sleep Scheduling:

- **Active mode**: Node performs sensing, processing, communication
- **Sleep mode**: Node powers down non-essential components
- **Benefits**: Reduces idle listening energy consumption by 90%

2. Data Aggregation:

- **Process**: Multiple sensor readings combined at intermediate nodes
- **Techniques**: Average, maximum, minimum functions applied
- **Advantage**: Reduces total number of transmissions significantly

Mnemonic

Sleep Aggregate Topology Harvest

OR

Question 1(c) [7 marks]

List out any four challenges of wireless sensor network and explain any two in detail.

Solution

Table 2. Four WSN Challenges:

Challenge	Impact
Limited energy	Affects network lifetime
Limited bandwidth	Constrains data transmission
Security vulnerabilities	Threatens data integrity
Scalability issues	Affects large network performance

Detailed Explanation:

1. **Limited Energy:**
   - **Battery constraint**: Nodes operate on small batteries with limited capacity
   - **Energy depletion**: High energy consumption during transmission and reception
   - **Solution approaches**: Power management protocols, energy-efficient routing
2. **Security Vulnerabilities:**
   - **Physical attacks**: Nodes can be physically captured or damaged
   - **Network attacks**: Eavesdropping, jamming, denial of service attacks
   - **Countermeasures**: Encryption, authentication, secure routing protocols

Mnemonic

Energy Bandwidth Security Scale

Question 2(a) [3 marks]

"IEEE 802.15.4 standard and the Zigbee specifications are popular protocol choices for Wireless Sensor Network" - Justify

Solution

Table 3. Justification Table:

Feature	Benefit for WSN
Low power consumption	Extends battery life
Low data rate	Suitable for sensor data
Short range	Perfect for clustered sensors
Low cost	Economical for large deployments

- **IEEE 802.15.4**: Provides PHY and MAC layer specifications
- **ZigBee**: Adds network and application layers on top
- **Perfect match**: WSN requirements align with protocol capabilities

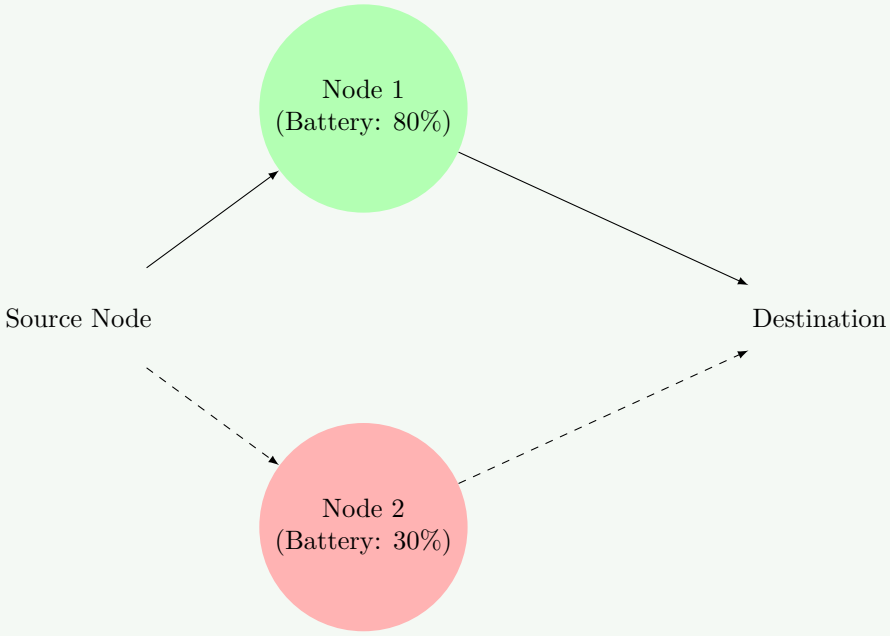
Mnemonic

Low Power, Low Data, Low Cost, Low Range

Question 2(b) [4 marks]

Explain Energy Efficient routing with the help of suitable example

Solution



Energy Efficient Routing:

- **Objective**: Select paths that maximize network lifetime
- **Approach**: Consider remaining battery levels of nodes
- **Example**: Route through Node 1 (80% battery) instead of Node 2 (30% battery)

Key Techniques:

- **Battery awareness**: Monitor remaining energy levels
- **Load balancing**: Distribute traffic among multiple paths
- **Clustering**: Group nearby nodes to reduce long-distance transmissions

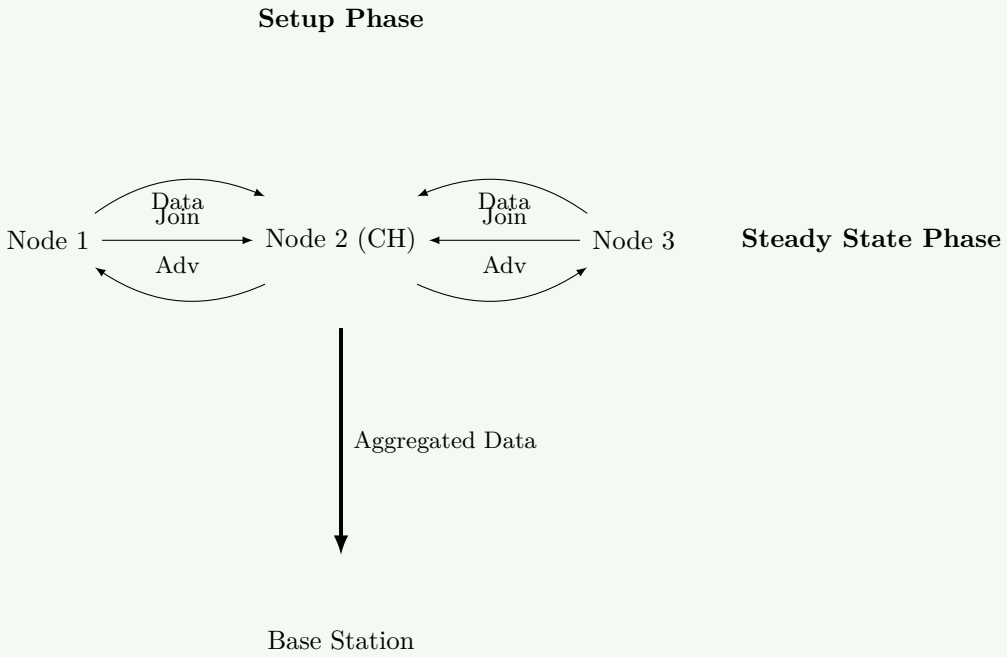
Mnemonic

Battery Balance Cluster

Question 2(c) [7 marks]

Explain setup and steady state phase of LEACH protocol with the help of suitable sketch.

Solution



LEACH Protocol Phases:
Setup Phase:
- **Cluster head selection**: Random selection based on probability threshold
- **Advertisement**: Selected CHs broadcast announcement messages
- **Cluster formation**: Non-CH nodes join nearest cluster head
- **Schedule creation**: CH creates TDMA schedule for cluster members

Steady State Phase:
- **Data transmission**: Nodes send data to CH according to TDMA schedule
- **Data aggregation**: CH combines received data from cluster members
- **Data forwarding**: CH transmits aggregated data to base station

Advantages:
- **Energy distribution**: Rotates CH role among nodes
- **Collision avoidance**: TDMA scheduling prevents interference

Mnemonic

Select Advertise Join Schedule, Send Aggregate Forward

OR

Question 2(a) [3 marks]

Give Classification of routing protocols in Wireless Sensor Network.

Solution

Table 4. WSN Routing Protocol Classification:

Classification Basis	Types
Network Structure	Flat, Hierarchical, Location-based
Protocol Operation	Multipath, Query-based, Negotiation-based
Path Establishment	Proactive, Reactive, Hybrid

Main Categories:
- **Flat routing**: All nodes have equal roles (e.g., Flooding, SPIN)
- **Hierarchical routing**: Cluster-based approach (e.g., LEACH, TEEN)
- **Location-based routing**: Uses geographic information (e.g., GEAR)

Mnemonic

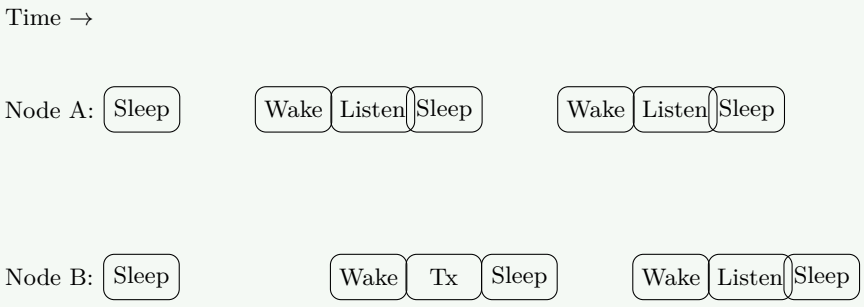
Flat Hierarchical Location

OR

Question 2(b) [4 marks]

Explain the wakeup concept of low duty cycle protocol with the help of sketch.

Solution



Low Duty Cycle Wakeup Concept:
- **Sleep period**: Nodes turn off radio to save energy
- **Wake period**: Nodes periodically wake up to check for communication
- **Synchronization**: Sender must know receiver's wakeup schedule

Key Benefits:
- **Energy savings**: Reduces idle listening by up to 99%
- **Coordinated access**: Prevents collisions during wakeup periods

Mnemonic

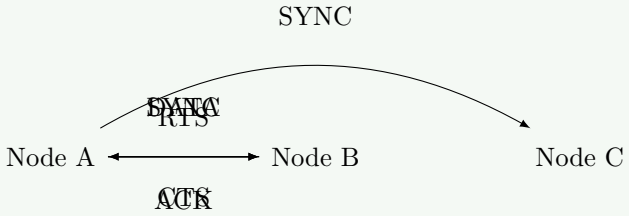
Sleep Wake Listen Repeat

OR

Question 2(c) [7 marks]

Explain Synch, RTS & CTS Phases of S-MAC Protocol and message passing approach of it.

Solution



1. SYNC Phase

2. RTS/CTS Phase

Node C overhears CTS and sleeps

3. Data Phase

S-MAC Protocol Phases:

1. Synchronization Phase:

- **Purpose**: Establish common sleep/wake schedule
- **Process**: Nodes exchange SYNC packets containing schedule information
- **Benefit**: Ensures coordinated sleep patterns across network

2. RTS Phase (Request to Send):

- **Initiation**: Sender transmits RTS packet to intended receiver
- **Content**: Source address, destination address, transmission duration

3. CTS Phase (Clear to Send):

- **Response**: Receiver sends CTS packet confirming availability
- **Virtual sensing**: Neighboring nodes overhear CTS and defer transmission

Message Passing Approach:

- **Collision avoidance**: RTS/CTS handshake prevents hidden terminal problem

- **Energy conservation**: Overhearing nodes enter sleep mode during data exchange
- **Periodic synchronization**: Maintains network-wide schedule coordination

Mnemonic

Sync Request Clear Transmit

Question 3(a) [3 marks]

Explain Super Frame structure of IEEE 802.15.4 standard.

Solution

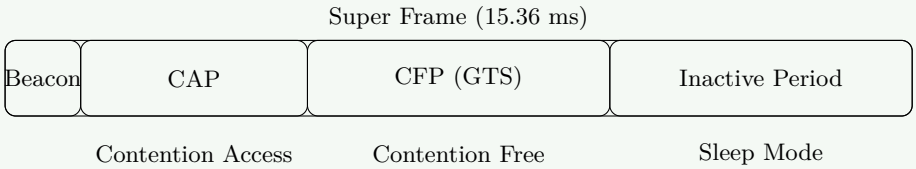


Table 5. Super Frame Components:

Component	Description	Duration
Beacon	Network synchronization	Fixed
CAP	Contention Access Period	Variable
CFP	Contention Free Period	Variable
Inactive	Sleep period	Variable

- **CAP**: Uses CSMA/CA for channel access
- **CFP**: Uses GTS (Guaranteed Time Slots) for real-time data
- **Inactive period**: Devices can enter low-power mode

Mnemonic

Beacon Contend Guarantee Sleep

Question 3(b) [4 marks]

Compare M2M and IoT Technology.

Solution

Parameter	M2M	IoT
Communication	Point-to-point	Internet-based
Data processing	Local	Cloud-based
Connectivity	Cellular/Wired	Multiple protocols
Applications	Specific industries	Consumer & industrial

Key Differences:

- **M2M**: Machine-to-Machine direct communication
- **IoT**: Internet of Things with cloud integration
- **Scope**: M2M is subset of broader IoT ecosystem
- **Intelligence**: IoT provides more advanced analytics and AI

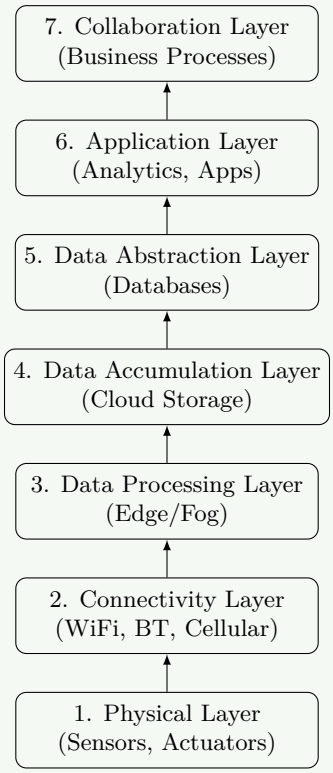
Mnemonic

M2M Direct, IoT Internet

Question 3(c) [7 marks]

Draw Block Diagram of IoT Architecture and explain it

Solution



IoT Architecture Layers:

1. **Physical Layer:**
   - **Components**: Sensors (temperature, humidity), actuators (motors, valves)
   - **Function**: Data collection from physical environment
2. **Connectivity Layer:**
   - **Protocols**: WiFi, Bluetooth, Zigbee, LoRaWAN, cellular
   - **Function**: Transmit data from devices to processing centers
3. **Data Processing Layer:**
   - **Technologies**: Edge computing, fog computing
   - **Function**: Real-time processing and filtering of sensor data
4. **Data Accumulation Layer:**
   - **Infrastructure**: Cloud storage, data warehouses
   - **Function**: Store massive amounts of IoT data
5. **Data Abstraction Layer:**
   - **Components**: Databases, data analytics engines
   - **Function**: Organize and prepare data for applications
6. **Application Layer:**
   - **Services**: Web applications, mobile apps, dashboards
   - **Function**: Provide user interfaces and business logic
7. **Collaboration Layer:**

- **Integration**: ERP systems, business processes
- **Function**: Enable collaboration between different stakeholders

Mnemonic

Physical Connect Process Accumulate Abstract Apply Collaborate

OR

Question 3(a) [3 marks]

Explain Energy problems of MAC Protocol

Solution

Table 6. Energy Problems in MAC Protocols:

Problem	Description	Impact
Idle listening	Radio stays on without communication	50-60% energy waste
Collision	Multiple transmissions interfere	Retransmission overhead
Overhearing	Receiving irrelevant packets	Unnecessary energy consumption

Main Issues:
- **Idle listening**: Most energy-consuming activity in WSN
- **Protocol overhead**: Control packets consume additional energy
- **Poor scheduling**: Inefficient channel access increases energy usage

Mnemonic

Idle Collide Overhear

OR

Question 3(b) [4 marks]

Explain modified OSI model for IoT system

Solution

Table 7. Modified OSI Model for IoT:

Layer	Traditional OSI	IoT Modification
Application	User applications	IoT applications, cloud services
Presentation	Data formatting	JSON, XML, CoAP
Session	Session management	MQTT, HTTP sessions
Transport	TCP, UDP	UDP, CoAP, MQTT
Network	IP routing	6LoWPAN, IPv6
Data Link	Ethernet, WiFi	IEEE 802.15.4, LoRa
Physical	Physical medium	Sensors, actuators, radio

Key Modifications:
- **Lightweight protocols**: Optimized for resource-constrained devices
- **Energy efficiency**: Protocols designed for low power consumption

- **Interoperability**: Support for diverse IoT devices and platforms

Mnemonic

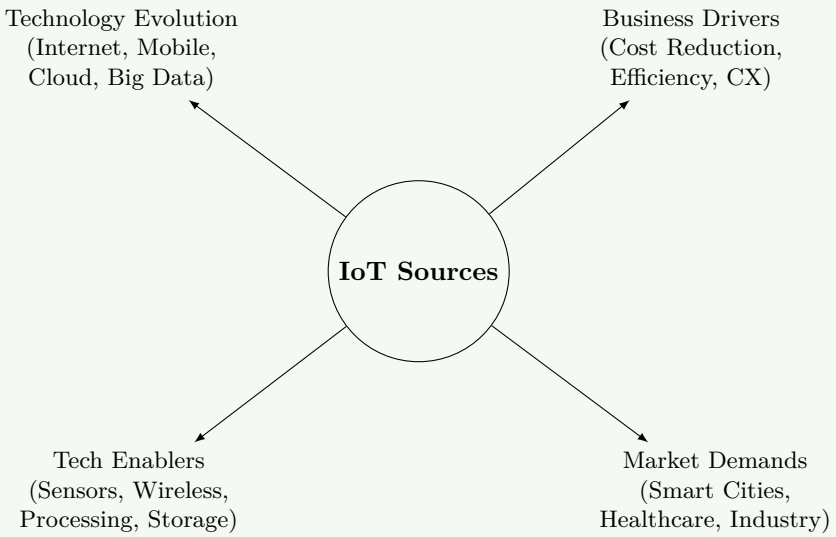
Apps Present Session Transport Network Link Physical

OR

Question 3(c) [7 marks]

Explain Sources of IoT in detail

Solution



1. **Technology Evolution Sources:**
   - **Internet expansion**: Global connectivity infrastructure development
   - **Mobile revolution**: Smartphones and tablets creating connected ecosystem
   - **Cloud computing**: Scalable computing and storage resources
   - **Big data analytics**: Ability to process massive data volumes
2. **Business Drivers:**
   - **Operational efficiency**: Automation and optimization of business processes
   - **Cost reduction**: Lower operational and maintenance costs
   - **New business models**: Data-driven services and products
   - **Customer satisfaction**: Enhanced user experience through smart services
3. **Technological Enablers:**
   - **Sensor advancement**: Smaller, cheaper, more accurate sensors
   - **Communication progress**: Improved wireless protocols and standards
   - **Processing evolution**: More powerful yet energy-efficient processors
   - **Storage revolution**: Cheaper and more reliable data storage solutions
4. **Market Demands:**
   - **Smart cities**: Urban planning and infrastructure management
   - **Healthcare**: Remote monitoring and telemedicine
   - **Industrial automation**: Industry 4.0 and smart manufacturing
   - **Environmental monitoring**: Climate change and sustainability concerns

Key Convergence Factors:

- **IPv6 adoption**: Unlimited addressing for billions of devices
- **5G networks**: High-speed, low-latency communication
- **AI integration**: Machine learning for intelligent decision making

Mnemonic

Technology Business Enable Market

Question 4(a) [3 marks]

Explain basic Components of IoT in brief.

Solution

Table 8. Basic IoT Components:

Component	Function	Examples
Sensors	Data collection	Temperature, pressure, motion
Connectivity	Data transmission	WiFi, Bluetooth, cellular
Data processing	Information analysis	Edge/cloud computing
User interface	Human interaction	Mobile apps, dashboards

Core Functions:

- **Sensing**: Collect environmental data
- **Connecting**: Transmit data to processing centers
- **Processing**: Analyze and extract insights
- **Acting**: Control actuators based on analysis

Mnemonic

Sense Connect Process Interface

Question 4(b) [4 marks]

Discuss Constrained Application Protocol (CoAP) in brief.

Solution

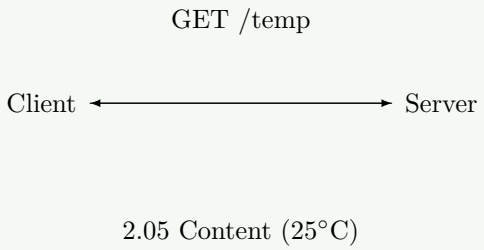


Table 9. CoAP Features:

Feature	Description	Benefit
Lightweight	Simple protocol design	Low resource usage
UDP-based	Uses UDP transport	Reduced overhead
RESTful	REST architecture	Easy integration
Reliable	Built-in retransmission	Ensures delivery

Key Characteristics:

- **Request/Response**: Similar to HTTP but optimized for IoT
- **Confirmable messages**: Reliability through acknowledgments
- **Resource discovery**: Built-in service discovery mechanism
- **Block transfer**: Support for large data transfers

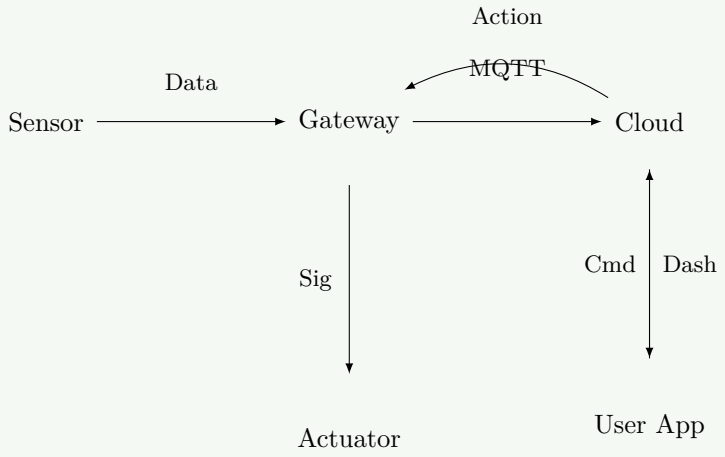
Mnemonic

Light UDP REST Reliable

Question 4(c) [7 marks]

Explain Process of Sensor and controlling device (actuator) management through cloud.

Solution



Cloud-based IoT Management Process:

1. **Data Collection Phase:**
   - **Sensors**: Collect environmental data (temperature, humidity, motion)
   - **Local processing**: Basic filtering and formatting at edge devices
   - **Data transmission**: Send data to cloud via WiFi/cellular connection
2. **Cloud Processing Phase:**
   - **Data ingestion**: Receive and store sensor data in cloud databases
   - **Real-time analytics**: Process data streams for immediate insights
   - **Machine learning**: Apply AI algorithms for pattern recognition and prediction
3. **Decision Making Phase:**
   - **Rule engine**: Apply business rules to determine required actions
   - **Threshold monitoring**: Trigger alerts when values exceed limits
   - **Automated responses**: Generate control commands for actuators
4. **Control Execution Phase:**
   - **Command dispatch**: Send control signals to appropriate actuators

- **Device management**: Monitor actuator status and performance
- **Feedback loop**: Collect confirmation of successful command execution

5. User Interaction:

- **Dashboard**: Real-time visualization of sensor data and system status
- **Mobile apps**: Remote monitoring and manual control capabilities
- **Notifications**: Alerts and warnings sent to users

Benefits:

- **Scalability**: Handle thousands of devices simultaneously
- **Remote access**: Control devices from anywhere with internet
- **Data analytics**: Historical analysis and predictive maintenance
- **Integration**: Connect with other business systems and services

Mnemonic

Collect Process Decide Control Interact

OR

Question 4(a) [3 marks]

Define Internet of Things and state its Vision.

Solution

Definition: Internet of Things (IoT) is a network of interconnected physical devices embedded with sensors, software, and connectivity to collect and exchange data over the internet.

Table 10. IoT Vision:

Aspect	Vision
Connectivity	Everything connected everywhere
Intelligence	Smart decision making
Automation	Minimal human intervention
Integration	Seamless system interaction

Core Vision Elements:

- **Ubiquitous computing**: Technology embedded in everyday objects
- **Seamless interaction**: Natural human-device communication
- **Intelligent environment**: Context-aware responsive systems

Mnemonic

Connect Intelligence Automate Integrate

OR

Question 4(b) [4 marks]

Discuss (Message Queue Telemetry Transport) MQTT protocol in brief.

Solution

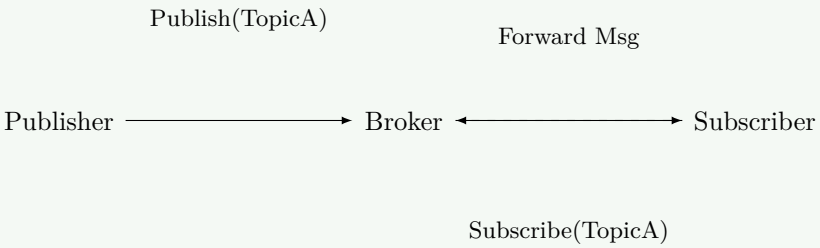


Table 11. MQTT Characteristics:

Feature	Description	Advantage
Lightweight	Minimal protocol overhead	Suitable for IoT devices
Publish/Subscribe	Decoupled communication	Scalable architecture
QoS levels	Quality of service options	Reliable delivery
Persistent sessions	Session state maintained	Connection resilience

MQTT Components:

- **Publisher**: Sends messages to broker
- **Subscriber**: Receives messages from broker
- **Broker**: Central message router
- **Topics**: Message categorization system

Quality of Service Levels:

- **QoS 0**: At most once delivery
- **QoS 1**: At least once delivery
- **QoS 2**: Exactly once delivery

Mnemonic

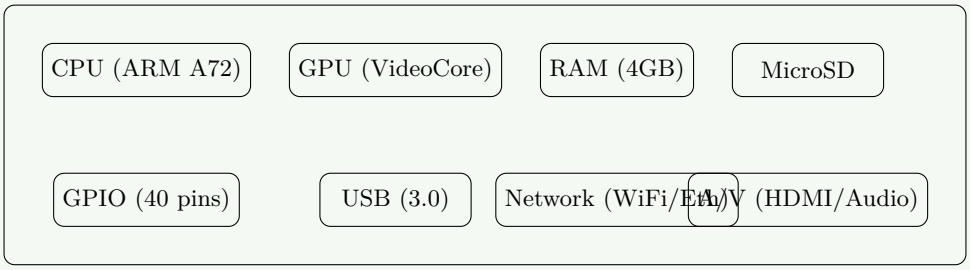
Publish Subscribe Broker Topic

OR

Question 4(c) [7 marks]

Draw Architecture block diagram of Raspberry Pi and explain it.

Solution



Raspberry Pi Architecture Components:

1. Processing Unit:
- **CPU**: Quad-core ARM Cortex-A72 processor running at 1.5GHz
- **GPU**: VideoCore VI for graphics processing and video acceleration
- **Performance**: Capable of running full operating systems like Linux

2. Memory System:
- **RAM**: 4GB LPDDR4 system memory for program execution
- **Storage**: MicroSD card slot for operating system and data storage
- **Cache**: On-chip cache memory for improved performance

3. Input/Output Interfaces:
- **GPIO**: 40-pin general purpose input/output for sensor connectivity
- **USB ports**: 4x USB 3.0 ports for peripherals and storage devices
- **Display**: 2x micro-HDMI ports supporting 4K video output

4. Connectivity Options:
- **Ethernet**: Gigabit Ethernet port for wired network connection
- **Wireless**: Dual-band WiFi 802.11ac and Bluetooth 5.0
- **Camera**: Dedicated camera serial interface (CSI) port

5. Power and Audio:
- **Power**: USB-C power input with efficient power management
- **Audio**: 3.5mm audio jack and HDMI audio output
- **Power consumption**: Optimized for continuous operation

IoT Applications:
- **Home automation**: Control lights, fans, security systems
- **Industrial monitoring**: Temperature, pressure, vibration sensing
- **Robotics**: Motor control, sensor integration, computer vision
- **Data logging**: Environmental monitoring and data collection

Advantages for IoT:
- **Cost-effective**: Low-cost computing platform
- **Versatile**: Supports multiple programming languages
- **Community support**: Large ecosystem of tutorials and projects
- **Expandability**: Compatible with numerous sensors and modules

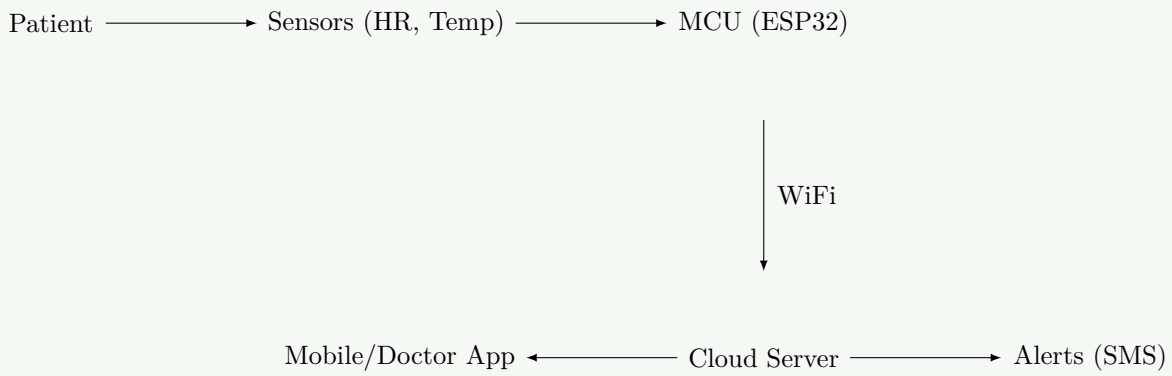
Mnemonic

Process Memory Interface Connect Power

Question 5(a) [3 marks]

Draw Block Diagram of Smart Health Monitoring System with IoT.

Solution



System Components:

- **Sensors**: Collect vital signs (heart rate, blood pressure, temperature)
- **Microcontroller**: Process sensor data and manage communication
- **Connectivity**: Transmit data to cloud via WiFi/cellular networks
- **Cloud platform**: Store data and provide analytics services
- **User interfaces**: Mobile apps and web dashboards for monitoring

Mnemonic

Sense Process Connect Store Monitor

Question 5(b) [4 marks]

List out different types of sensors in IoT and briefly explain working of any two.

Solution

Table 12. IoT Sensor Types:

Sensor Type	Measurement	Applications
Temperature	Heat/cold levels	HVAC, weather monitoring
Humidity	Moisture content	Agriculture, storage
Pressure	Force per unit area	Weather, industrial
Motion/PIR	Movement detection	Security, automation
Gas	Chemical composition	Air quality, safety
Light	Illumination levels	Smart lighting

Detailed Working:

1. Temperature Sensor (DHT22):

- **Principle**: Thermistor resistance changes with temperature
- **Process**: Microcontroller reads resistance value and converts to temperature
- **Output**: Digital signal with temperature and humidity data
- **Applications**: Smart thermostat, environmental monitoring

2. PIR Motion Sensor:

- **Principle**: Detects infrared radiation emitted by moving objects
- **Components**: Pyroelectric sensor with fresnel lens
- **Working**: Changes in infrared levels trigger digital output signal
- **Applications**: Security systems, automatic lighting, occupancy detection

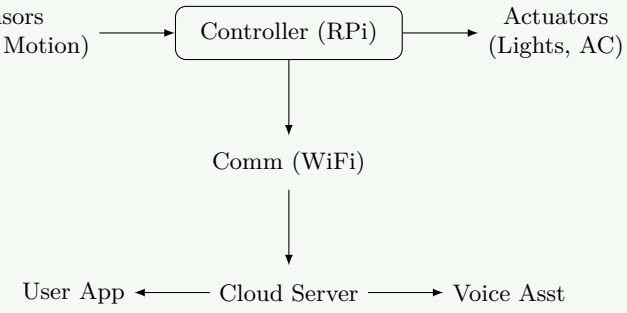
Mnemonic

Temperature Humidity Pressure Motion Gas Light

Question 5(c) [7 marks]

Draw Block diagram of smart home automation with IoT and Explain its working.

Solution



Smart Home Automation Working:

- **Data Collection**: Sensors (environment, security, presence) monitor home status.
- **Data Processing**: Local (critical) and cloud (analytics) processing of sensor data.
- **Decision Making**: Rules (if temp > 25 then AC on) and AI (learning habits) control actions.
- **Control Execution**: Controller sends signals to actuators (lights dimmed, doors locked).
- **User Interaction**: Apps and voice assistants allow remote monitoring and control.

Key Features:

- **Energy efficiency**: Optimized usage saves 30-40% power.
- **Security**: Real-time alerts and monitoring.
- **Convenience**: Automated routines and voice control.

Mnemonic

Collect Process Decide Control Interact Secure

OR

Question 5(a) [3 marks]

List out any three Industrial and Military IoT applications.

Solution

Table 13. Industrial IoT Applications:

Application	Description	Benefits
Predictive maintenance	Monitor equipment health	Reduce downtime
Supply chain tracking	Track goods movement	Improve efficiency
Energy management	Optimize power consumption	Reduce costs

Table 14. Military IoT Applications:

Application	Description	Benefits
Battlefield surveillance	Real-time combat zone monitoring	Situational awareness
Asset tracking	Monitor equipment/vehicles	Logistics optimization
Soldier health	Track personnel vital signs	Safety and response

Mnemonic

Predict Track Energy, Survey Track Monitor

OR

Question 5(b) [4 marks]

List out different types of actuators in IoT and briefly explain working of any two.

Solution

Table 15. IoT Actuator Types:

Actuator Type	Function	Applications
Servo motor	Angular positioning	Robotics
Relay	Electrical switching	Lights, appliances
Solenoid valve	Fluid control	Irrigation
LED	Light emission	Indicators
Buzzer	Sound generation	Alarms
Stepper motor	Rotational control	3D printers

Detailed Working:

1. Servo Motor:

- **Control signal**: PWM signal determines position
- **Feedback**: Internal potentiometer ensures accuracy
- **Working**: Circuit compares desired vs actual position
- **Applications**: Robotic arms, automatic doors

2. Relay Module:

- **Principle**: Electromagnet moves mechanical switch
- **Switching**: Connects/disconnects high voltage circuit
- **Isolation**: Safely controls high loads from low voltage MCU
- **Applications**: Home automation switching

Mnemonic

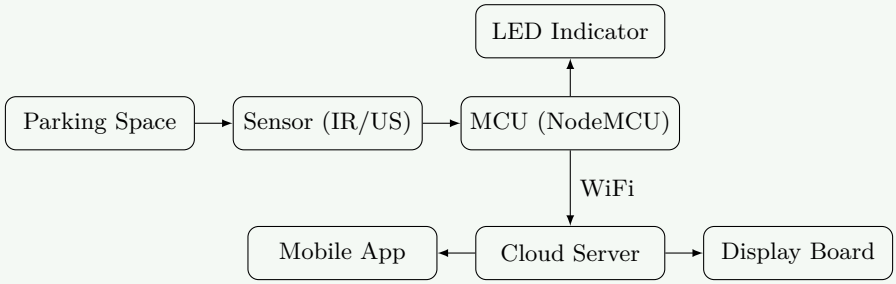
Servo Relay Solenoid LED Buzzer Stepper

OR

Question 5(c) [7 marks]

Draw Block diagram of smart parking system with IoT and Explain its working.

Solution



Smart Parking System Working:

1. **Vehicle Detection:**
   - IR/Ultrasonic sensors at each space detect vehicle presence.
   - Continuous monitoring ensures accurate occupancy status.
2. **Data Collection & Processing:**
   - Microcontroller processes sensor data (Occupied/Free).
   - Validates data to avoid false positives from debris.
3. **Communication:**
   - WiFi transmits real-time status to cloud server.
   - Cloud database stores records and performs analytics.
4. **User Services:**
   - Mobile app allows finding and reserving spaces.
   - Real-time navigation to available spots.
   - Online payment integration.
5. **Indicators:**
   - On-site LED indicators (Red/Green) and display boards.
   - Admin dashboard for management.

Benefits:

- **Time saving**: Quick parking spot location.
- **Traffic reduction**: Less circling.
- **Revenue**: Optimized space utilization.

Mnemonic

Detect Process Communicate Interface Indicate Serve