Subject Name Solutions

4353201 – Winter 2024

Semester 1 Study Material

Detailed Solutions and Explanations

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

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Sensor Node] {-{-}{} B[Sensing Unit]}
    A {-{-}{} C[Processing Unit]}
    A {-{-}{} D[Communication Unit]}
    A {-{-}{} E[Power Unit]}
    B {-{-}{} F[Sensors \& ADC]}
    C {-{-}{} G[Processor \& Memory]}
    D {-{-}{} H[Transceiver]}
    E {-{-}{} I[Battery]}
{Highlighting}
{Shaded}
```

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

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"

Question 1(c) OR [7 marks]

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

Solution

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

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

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Source Node] {-{-}{} B[Node 1{}br/{}Battery: 80\%]}
    A {-{-}{} C[Node 2{}br/{}Battery: 30\%]}
    B {-{-}{} D[Destination]}
    C {-{-}{} D}
    style B fill:\#90EE90
    style C fill:\#FFB6C1
{Highlighting}
{Shaded}
```

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

```
sequenceDiagram
    participant N1 as Node 1
    participant N2 as Node 2 (CH)
    participant N3 as Node 3
    participant BS as Base Station

    Note over N1,BS: Setup Phase
    N2{-N1: Advertisement (CH)}
    N2{-N3: Advertisement (CH)}
    N1{-N2: Join Request}
    N3{-N2: Join Request}
    N2{-N1: TDMA Schedule}
    N2{-N3: TDMA Schedule}

    Note over N1,BS: Steady State Phase
    N1{-N2: Sensor Data (Slot 1)}
    N3{-N2: Sensor Data (Slot 2)}
    N2{-BS: Aggregated Data}
```

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"

Question 2(a) OR [3 marks]

Give Classification of routing protocols in Wireless Sensor Network.

Solution

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"

Question 2(b) OR [4 marks]

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

Solution

```
Time {-{-}}
Node A: [Sleep]{-{-}{-}[Wake]{-}{-}[Listen]{-}{-}[Sleep]{-}{-}{-}[Wake]{-}{-}[Listen]{-}{-}[Sleep]}
Node B: [Sleep]{-{-}{-}{-}{-}[Wake]{-}{-}[Tx]{-}{-}[Sleep]{-}{-}{-}{-}{-}[Wake]{-}{-}[Listen]{-}{-}[Sle
          |     |     |     |   |     |       |     |     |       |
          0    T1    T2    T3  T4    T5      T6    T7    T8      T9
```

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"

Question 2(c) OR [7 marks]

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

Solution

```
sequenceDiagram
    participant A as Node A
    participant B as Node B
    participant C as Node C

    Note over A,C: Synchronization Phase
    A{-B: SYNC (Schedule)}
    A{-C: SYNC (Schedule)}
    B{-A: SYNC (ACK)}
    C{-A: SYNC (ACK)}

    Note over A,C: RTS/CTS Phase
    A{-B: RTS (Request to Send)}
    B{-A: CTS (Clear to Send)}
    Note over C: Overhears CTS, Goes to Sleep

    Note over A,C: Data Transmission
    A{-B: DATA}
    B{-A: ACK}
```

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

```
|{{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-} Super Frame (15.36 ms) {-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-
|{{-}{-}{-}CAP{-}{-}{-}|{-}{-}{-}{-}{-}{-}{-}{-}{-}CFP{-}{-}{-}{-}{-}{-}{-}{-}{-}|{-}{-}Inactive{
| Beacon |Slot|Slot|Slot|GTS|GTS|GTS|    Period    |
|   8    | 0 | 1 | 2 | 1 | 2 | 3 |              |
```

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

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Physical Layer{br/{}Sensors, Actuators] {-}{-}{} B[Connectivity Layer{}br/{}WiFi, Bluetooth, Cell
    B {-{-}{} C[Data Processing Layer{}br/{}Edge/Fog Computing]}
    C {-{-}{} D[Data Accumulation Layer{}br/{}Cloud Storage]}
    D {-{-}{} E[Data Abstraction Layer{}br/{}Databases, Data Lakes]}
    E {-{-}{} F[Application Layer{}br/{}Analytics, Visualization]}
    F {-{-}{} G[Collaboration Layer{}br/{}Business Applications]}
{Highlighting}
{Shaded}
```

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"

Question 3(a) OR [3 marks]

Explain Energy problems of MAC Protocol

Solution

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"

Question 3(b) OR [4 marks]

Explain modified OSI model for IoT system

Solution

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"

Question 3(c) OR [7 marks]

Explain Sources of IoT in detail

Solution

IoT Sources Classification:

```
mindmap
  root((IoT Sources))
    Technology Evolution
      Internet Growth
      Mobile Computing
      Cloud Computing
      Big Data
    Business Drivers
      Cost Reduction
      Efficiency Improvement
      New Revenue Models
      Customer Experience
    Technological Enablers
      Sensor Miniaturization
      Wireless Communication
      Processing Power
      Storage Cost Reduction
```

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

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

CoAP Protocol Overview:

```
Client                    Server
  |                         |
  |{-{-}{-}{-}{-}{-}{-} GET /temp {-}{-}{-}{-}{-}{-}|}
  |                         |
  |{{-}{-}{-}{-}{-} 2.05 Content {-}{-}{-}{-}{-}|}
  |    Payload: 25^        |
  |                         |
```

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

```
sequenceDiagram
    participant S as Sensor
    participant G as Gateway
    participant C as Cloud
    participant A as Actuator
    participant U as User App

    S{-G: Sensor Data}
    G{-C: Upload Data (MQTT/HTTP)}
    C{-C: Data Processing \& Analytics}
    C{-U: Real{-}time Dashboard}
    U{-C: Control Command}
    C{-G: Actuator Command}
    G{-A: Control Signal}
    A{-G: Status Feedback}
    G{-C: Confirmation}
```

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"

Question 4(a) OR [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.

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"

Question 4(b) OR [4 marks]

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

Solution

MQTT Protocol Architecture:

```
Publisher                Broker               Subscriber
    |                       |                       |
    |{-{-} Publish(topic) {-}{-}{-}{-}|                      |}
    |                       |{{-}{-} Subscribe(topic) {-}{-}|}
    |                       |                       |
```

```
    |                        |{-{-} Forward Message  {-}{-}|}
```

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"

Question 4(c) OR [7 marks]

Draw Architecture block diagram of Raspberry Pi and explain it.

Solution

```
+{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}
|                     Raspberry Pi 4                        |
|  +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+  +{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+  +{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+
|  |   CPU     |  |   GPU     |  |  Memory   |  | Storage   | |
|  |Quad{-core |  |VideoCore |  | 4GB RAM   |  |MicroSD    | |}
|  |ARM A72    |  |    VI     |  |  LPDDR4   |  |   Card    | |
|  +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+  +{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+  +{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+
|                                                           |
|  +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+  +{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+  +{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+
|  |   GPIO    |  |   USB     |  | Network   |  |  Audio    | |
|  | 40 pins   |  | 4 ports   |  |Ethernet   |  |3.5mm jack| |
|  |           |  |  USB 3.0  |  |WiFi/BT    |  |   HDMI    | |
|  +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+  +{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+  +{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+
+{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}
```

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

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Patient] {-{-}{} B[Wearable Sensors{}br/{}Heart Rate, SpO2, Temperature]}
    B {-{-}{} C[Microcontroller{}br/{}Arduino/NodeMCU]}
    C {-{-}{} D[WiFi/Bluetooth{}br/{}Communication]}
    D {-{-}{} E[Cloud Server{}br/{}Data Storage \& Processing]}
    E {-{-}{} F[Mobile App{}br/{}Real{-}time Monitoring]}
    E {-{-}{} G[Doctor Dashboard{}br/{}Medical Analysis]}
    E {-{-}{} H[Emergency Alert{}br/{}SMS/Email]}
{Highlighting}
{Shaded}
```

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

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

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Smart Home Controller{br/{}Raspberry Pi/NodeMCU] {-}{-}{} B[Sensors]}
    A {-{-}{} C[Actuators]}
    A {-{-}{} D[Communication Module{}br/{}WiFi/Zigbee]}
    D {-{-}{} E[Cloud Server{}br/{}Data \& Control]}
    E {-{-}{} F[Mobile App{}br/{}User Interface]}
    E {-{-}{} G[Voice Assistant{}br/{}Alexa/Google]}

    B {-{-}{} B1[Temperature{}br/{}Humidity{}br/{}Motion{}br/{}Light{}br/{}Door/Window]}
    C {-{-}{} C1[LED Lights{}br/{}Fan/AC{}br/{}Door Lock{}br/{}Curtains{}br/{}Security Alarm]}
{Highlighting}
{Shaded}
```

Smart Home Automation Working:

1. Data Collection:
- **Environmental sensors**: Monitor temperature, humidity, light levels
- **Security sensors**: Detect motion, door/window status, smoke/gas
- **User presence**: PIR sensors determine occupancy in different rooms

2. Data Processing:
- **Local processing**: Immediate responses for critical situations (fire alarm)
- **Cloud processing**: Complex analytics and pattern recognition
- **Machine learning**: Learn user preferences and habits over time

3. Decision Making:
- **Rule-based control**: If temperature > $25 \cdot turn on AC$
- **Scheduled operations**: Turn on lights at sunset, water plants at 6 AM
- **User preferences**: Adjust lighting and temperature based on learned patterns

4. Control Execution:

- **Lighting control**: Automatic dimming based on ambient light and time
- **Climate control**: Optimize heating/cooling based on occupancy and weather
- **Security management**: Arm/disarm security system, lock/unlock doors

5. **User Interaction:**
   - **Mobile app**: Remote monitoring and control from anywhere
   - **Voice commands**: Integration with Alexa, Google Assistant
   - **Manual override**: Physical switches and controls remain functional
6. **Communication Flow:**
   - **Sensor data**: Collected every few seconds and transmitted to controller
   - **Cloud synchronization**: Data backup and remote access capabilities
   - **Status updates**: Real-time notifications to mobile devices

Key Features:

- **Energy efficiency**: Automatic control reduces power consumption by 30-40%
- **Security enhancement**: Real-time monitoring and alert systems
- **Convenience**: Voice control and smartphone integration
- **Cost savings**: Optimized usage of electricity and water resources

System Benefits:

- **Remote monitoring**: Check home status from office or vacation
- **Automated responses**: Immediate action during emergencies
- **Personalization**: Customized environment based on individual preferences
- **Integration**: Works with existing home appliances and systems

Technical Specifications:

- **Protocols**: WiFi, Zigbee, Z-Wave for device communication
- **Power backup**: Battery backup for critical sensors during power outage
- **Data encryption**: Secure communication between devices and cloud
- **Scalability**: Easy addition of new devices and sensors

Mnemonic

"Collect Process Decide Control Interact Secure"

Question 5(a) OR [3 marks]

List out any three Industrial and Military IoT applications.

Solution

Industrial IoT Applications:

Application	Description	Benefits
Predictive maintenance	Monitor equipment health in real-time	Reduce downtime, lower costs
Supply chain tracking	Track goods from factory to customer	Improve efficiency, reduce losses
Energy management	Monitor and optimize power consumption	Reduce energy costs by 20-30%

Military IoT Applications:

Application	Description	Benefits
Battlefield surveillance	Real-time monitoring of combat zones	Enhanced situational awareness
Asset tracking	Monitor military equipment and vehicles	Prevent theft, optimize logistics
Soldier health monitoring	Track vital signs of personnel	Improve safety, medical response

Mnemonic

"Predict Track Energy, Survey Track Monitor"

Question 5(b) OR [4 marks]

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

Solution

IoT Actuator Types:

Actuator Type	Function	Applications
Servo motor	Precise angular positioning	Robotics, automation
Relay	Electrical switching	Lights, fans, appliances
Solenoid valve	Fluid flow control	Irrigation, HVAC
LED	Light emission	Indicators, displays
Buzzer	Sound generation	Alarms, notifications
Stepper motor	Precise rotational control	3D printers, CNC

Detailed Working:

1. Servo Motor:

- **Control signal**: PWM (Pulse Width Modulation) signal determines position
- **Feedback system**: Internal potentiometer provides position feedback
- **Working**: Control circuit compares desired vs actual position
- **Applications**: Robotic arms, camera pan/tilt, automatic doors

2. Relay Module:

- **Electromagnetic principle**: Coil creates magnetic field when energized
- **Switching action**: Magnetic field moves mechanical contacts
- **Isolation**: Electrical isolation between control and load circuits
- **Applications**: Home automation, industrial control, safety systems

Mnemonic

"Servo Relay Solenoid LED Buzzer Stepper"

Question 5(c) OR [7 marks]

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

Solution

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Parking Space] {-{-}{} B[IR/Ultrasonic Sensors{}br/{}Vehicle Detection]}
    B {-{-}{} C[NodeMCU/Arduino{}br/{}Microcontroller]}
    C {-{-}{} D[WiFi Module{}br/{}Communication]}
    D {-{-}{} E[Cloud Server{}br/{}Data Processing]}
    E {-{-}{} F[Mobile App{}br/{}User Interface]}
    E {-{-}{} G[Display Board{}br/{}Available Spaces]}
    E {-{-}{} H[Payment Gateway{}br/{}Online Payment]}
    C {-{-}{} I[LED Indicators{}br/{}Space Status]}
{Highlighting}
{Shaded}
```

Smart Parking System Working:

1. Vehicle Detection:

- **Sensor placement**: IR or ultrasonic sensors installed at each parking space

- **Detection mechanism**: Sensors detect presence/absence of vehicles
- **Status monitoring**: Continuous monitoring of space occupancy
- **Data accuracy**: Multiple sensors reduce false positive readings

2. **Data Collection and Processing:**
   - **Microcontroller**: NodeMCU/Arduino processes sensor data locally
   - **Status determination**: Occupied (sensor blocked) or Free (sensor clear)
   - **Time stamping**: Record entry and exit times for billing
   - **Data validation**: Filter out temporary obstructions (leaves, debris)
3. **Communication and Cloud Integration:**
   - **WiFi transmission**: Real-time data sent to cloud server
   - **Database storage**: Maintain records of parking space status
   - **Analytics processing**: Generate usage patterns and statistics
   - **API integration**: Connect with mobile apps and display systems
4. **User Interface and Services:**
   - **Mobile application**: Users can find and reserve parking spaces
   - **Real-time updates**: Live status of available parking spaces
   - **Navigation assistance**: GPS guidance to selected parking space
   - **Payment integration**: Online payment for parking fees
5. **Visual Indicators:**
   - **LED indicators**: Green (free), Red (occupied) for each space
   - **Display boards**: Electronic signs showing total available spaces
   - **Mobile notifications**: Alerts when reserved time is expiring
   - **Admin dashboard**: Management interface for monitoring and control
6. **Advanced Features:**
   - **Space reservation**: Book parking space in advance
   - **Automatic billing**: Calculate charges based on parking duration
   - **Violation detection**: Alert for unauthorized parking
   - **Data analytics**: Peak usage hours, revenue analysis

System Benefits:
- **Time saving**: Reduces time spent searching for parking
- **Traffic reduction**: Less circling around looking for spaces
- **Revenue optimization**: Dynamic pricing based on demand
- **Environmental impact**: Reduced fuel consumption and emissions

Technical Components:
- **Sensors**: IR proximity sensors or ultrasonic distance sensors
- **Microcontrollers**: ESP8266/ESP32 based development boards
- **Communication**: WiFi, LoRaWAN, or cellular connectivity
- **Power supply**: Solar panels with battery backup for remote locations

Implementation Challenges:
- **Weather resistance**: Sensors must work in rain, snow, extreme temperatures
- **Power management**: Battery-powered sensors need efficient power usage
- **Network reliability**: Backup communication methods for connectivity issues
- **Maintenance**: Regular cleaning and calibration of sensors

Cost-Benefit Analysis:
- **Initial investment**: Sensor installation and system setup costs
- **Operational savings**: Reduced management overhead
- **Revenue increase**: Improved space utilization and dynamic pricing
- **Payback period**: Typically 12-18 months for commercial installations

Integration Possibilities:
- **Smart city systems**: Connect with traffic management systems
- **Building automation**: Integration with shopping mall or office building systems
- **Public transportation**: Coordinate with bus/metro schedules
- **Emergency services**: Priority access for emergency vehicles

Future Enhancements:
- **AI integration**: Predict parking demand using machine learning
- **Electric vehicle charging**: Integration with EV charging stations
- **Autonomous vehicles**: Support for self-parking cars
- **Mobile payment expansion**: Integration with digital wallets

Mnemonic

"Detect Process Communicate Interface Indicate Serve"