1 UNIT

Internet of Things (IoT) and Design Principle for Connected Devices

CONTENTS

PART-1

Internet of Things (IoT) : Vision, Definition.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.1. Write short note on Internet of Things (IoTs).

Answer

1. The Internet of Things (IoTs) is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with Unique Identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.
2. The Internet of Things (IoTs) is the network of devices such as vehicles, and home appliances that contain electronics, software, sensors, actuators, and connectivity which allows these things to connect, interact and exchange data.
3. The Internet of Things (IoTs) is also a natural extension of SCADA (Supervisory Control and Data Acquisition), a category of software application program for process control, the gathering of data in real time from remote locations to control equipment and conditions.
4. SCADA systems include hardware and software components.
5. The hardware gathers and feeds data into a computer that has SCADA software installed, where it is then processed and presented it in a timely manner.

Que 1.2. Explain the vision of Internet of Things.

Answer

1. The vision of the Internet of Things (IoT) can be seen from two perspectives "internet centric" and "thing centric".
2. The internet centric architecture involves internet services as the main focus, as data is being generated by the "things".
3. In the thing centric architecture, smart devices take the center stage.
4. There are a number of factors powering the progression of the IoT within the digital economy, including :

a. Powerful new mobile, wearable or connected devices.

b. Application (apps) that fuel demand for mobile data and test the limits of the network within most industry sector.

c. Cloud-based apps and those that rely on content stored in the cloud, which will increase as development accelerates on new platform as a service, mobile point of sale and independent software vendor platforms.

d. New use cases, such as mobile video, which will be significant factors in driving expensive capacity upgrades in networks.

5. Device evolution, cloud-based application innovation and the proliferation of communication technologies within all industries will ensure the exponential growth in the demand for mobile-connected devices.

6. As a result, the expected throughput and performance of each device will continue to increase in the next decade.

PART-2

Conceptual Framework, Architectural View, Technology behind IoT.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.3. **Write short notes on conceptual framework of IoT.**

Answer

IoT conceptual framework can be given in terms of three equations :

1. **Physical Object + Controller, Sensor and Actuators + Internet = Internet of Things :**
   a. It describes the internet of single object (umbrella) which consists of a controller, sensor and actuators, and the internet for connectivity to a web service and a mobile service provider.
   b. IoT consists of an internetwork of devices and physical objects wherein a number of objects can gather the data at remote locations and communicate to units managing, acquiring, organising and analysing the data in the processes and services.
2. **Gather + Enrich + Stream + Manage + Acquire + Organise and Analyse = Internet of Things with connectivity to Data Centre and Enterprise Server (Oracle IoT Architecture) :**
   a. It represents the actions and communications of data at successive levels in IoT consisting of internetworked devices and objects.

b. It is an IoT conceptual framework for the enterprise processes and services, based on a suggested IoT architecture given by Oracle.

c. The steps are as follows :

i. At level 1 data of the devices (things) using sensors or the things gather the pre data from the internet.

ii. A sensor connected to a gateway, functions as a smart sensor (smart sensor refers to a sensor with computing and communication capacity). The data then enriches at level 2.

iii. A communication management subsystem sends or receives data streams at level 3.

iv. Device management, identity management and access management subsystems receive the device's data at level 4.

v. A data store or database acquires the data at level 5.

vi. Data routed from the devices and things organises and analyses at level 6.

3. Physical Objects + Gather and Consolidate + Connect + Collect + Assemble + Manage = Internet of Things (IBM IoT Foundation) :

a. It represents complex conceptual framework for IoT using cloud-platform based processes and services.

b. The steps are as follows :

i. Levels 1 and 2 consist of a sensor network to gather and consolidate the data. First level gathers the data of the things (devices) using sensors circuits. The sensor connects to a gateway. Data then consolidates at the second level.

ii. The gateway at level 2 communicates the data streams between levels 2 and 3. The system uses a communication-management subsystem at level 3.

iii. An information service consists of connect, collect, assemble and manage subsystems at levels 3 and 4. The services render from level 4.

iv. Real time series analysis, data analytics and intelligence subsystems are also at levels 4 and 5. A cloud infrastructure, a data store or database acquires the data at level 5.

Que 1.4. Explain the architectural view of IoT.

Answer

Architectural view of IoT consists of three layers. The functionalities of the layers are specified as :

1. **Perception layer :**
   a. Object identification and information collection is the main function of this layer.
   b. It comprises of sensors, actuators, RFID tags, RFID readers/ writers and information display units (like PDA, Tablet PC, cell phone etc.)

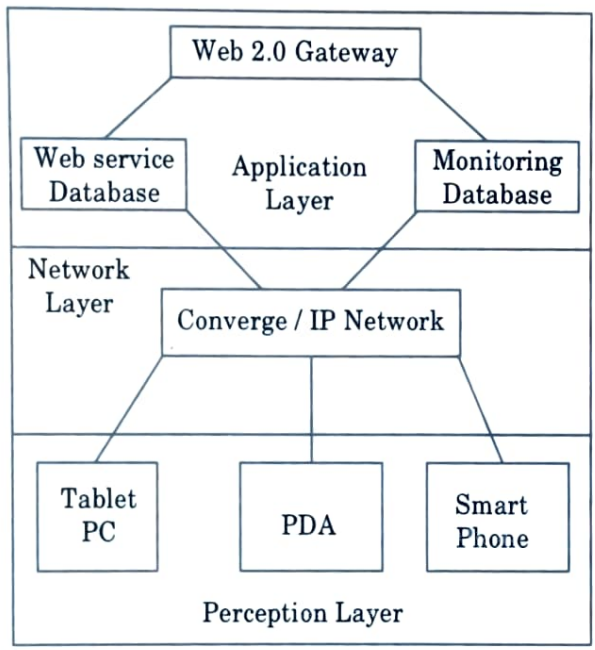

Fig. 1.4.1.

2. **Network layer :**
   a. Information transfer that is collected via perception layer is the main objective of this layer.
   b. Wireless networks, wired networks, internet, network management systems are the major components of the network layer.
3. **Application layer :** Event detection, intelligent solutions and to perform user required functions is the responsibility of this layer.

Que 1.5. Give the example of technologies which are involved in IoT.

Answer

The following entities provide a diverse technology environment and are examples of technologies, which are involved in IoT :

1. Hardware (Arduino Raspberry Pi, Intel Galileo, Intel Edison, ARM mBed, Bosch XDK110, BeagleBone Black and Wireless SoC).
2. Integrated Development Environment (IDE) for developing device software, firmware and APIs.

3. Protocols [RPL, CoAP, RESTful HTTP, MQTT, XMPP (Extensible Messaging and Presence Protocol)].
4. Communication (Powerline Ethernet, RFID, NFC, 6LowPAN, UWB, ZigBee, Bluetooth, WiFi, WiMax, 2G/3G/4G).
5. Network backbone (IPv4, IPv6, UDP and 6LowPAN).
6. Software (RIOT OS, Contiki OS, Thingsquare Mist firmware, Eclipse IoT).
7. Internetwork Cloud Platforms/Data Centre (Sense, ThingWorx, Nimbits, Xively, openHAB, AWS IoT, IBM BlueMix, CISCO IoT, IOx and Fog, EvryThng, Azure, TCS CUP).
8. Machine learning algorithms and software. An example of machine learning software is GROK.

Que 1.6. What are the challenges that are linked with IoT ?

Answer

Challenges that are linked with the IoT are :

1. **Standards :** There is no standard available for the deployment of IoT globally that may make it conventional for the people.
2. **Network foundation :** Limitations imposed due to the current internet architecture for mobility, scalability, manageability and availability, IoT network establishment is facing difficulties.
3. **Security, privacy and trust :** The crucial areas in IoT are security, privacy and trust.
   a. In security area, IoT domain is facing the following challenges :
      i. Security to be ensured at design time and execution time for the architecture of IoT.
      ii. Proactive identification and protection of IoT from arbitrary attacks (For example, DoS and DDoS attacks) and malicious software.
   b. Privacy is the second major concern. The term of privacy in IoT means user/object privacy that is facing the following challenges :
      i. There is no privacy control over personal information and location privacy of individual's physical location and movement.
      ii. Unavailability of Standard Operation Procedures (SOP)/ methodologies and tools, privacy enhancement technologies and relevant protection laws.
   c. Trust is having the specific following challenges :
      i. The system must provide the environment for easy and natural exchange of critical protected and sensitive data. For example, smart objects may communicate with the available trusted services on behalf of users / organizations.

ii. The IoT system design must provide built-in trust facility for each available service.

4. **Identification and authentication :**
   a. In IoT, purpose of identification and tracking entities is to protect identification from tracking by unauthorized attacks in the network.
   b. It must be provided to users with right control over the privacy of their personal information.

5. **Integration and coordination :**
   a. The challenge in IoT is how to collaborate with two different type of network, one of them is internet and other is the physical world and they work as a joint venture for meaningful results.
   b. In the integration, the major issues are cost, stability, communication speed, bandwidth, trust and security of the physical world and the internet.
   c. IoT requires collaboration and teamwork among people, programs, process and services to globally share the data.

Que 1.7. What are the five entities considered behind an IoT system ?

Answer

Five entities that can be considered behind an IoT system are :

1. Device platform consisting of device hardware and software using a microcontroller and software for the device APIs and web application.
2. Connecting and networking (connectivity protocols, and circuits) enabling internetworking of devices and physical object called things and enabling the internet connectivity to remote servers.
3. Server and web programming enables web applications and web services.
4. Cloud platform enables storage, computing prototype and product development platforms.
5. Online transactions processing, online analytics processing, data analytics, predictive analytics, and knowledge discovery enables wider applications of an IoT system.

PART-3

Source of IoT, M2M Communication, IoT Example.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.8. Give example of hardware sources for IoT prototype development.

Answer

Examples of hardware sources for IoT prototype development are :

1. **Arduino Yún :**
   i. Arduino Yún board uses microcontroller ATmega32u4 that supports Arduino and includes Wi-Fi, Ethernet, USB port, micro-SD card slot and three reset buttons.
   ii. The board also combines with Atheros AR9331 that runs Linux.
2. **Microduino :**
   i. Microduino is a small board compatible with Arduino that can be stacked with the other boards.
   ii. All the hardware designs are open source.
3. **Intel Galileo :**
   i. Intel Galileo is a line of Arduino-certified development boards.
   ii. Galileo is based on Intel ×86 architecture.
   iii. It is open-source hardware that features the Intel SoC X1000 Quark based Soc.
   iv. Galileo is pin-compatible with Arduino. It has 20 digital I/O (12 GPIOs fully native), 12-bit PWM for more precise control, six analog inputs and supports power over Ethernet (PoE).
4. **Intel Edison :**
   i. Intel Edison is a compute module.
   ii. It enables creation of prototypes and fast development of prototyping projects and rapidly produces IoT and wearable computing devices.
   iii. It enables seamless device internetworking and device-to-cloud communication.
   iv. It includes foundational tools which collect, store and process data in the cloud, and process rules on the data stream.
   v. It generates triggers and alerts based on advanced analytics.
5. **BeagleBone Board :**
   i. BeagleBone based board has very low power requirement.
   ii. It is a card-like computer which can run Android and Linux.

ii. Both the hardware designs and the software for the IoT devices are open source.

6. Raspberry Pi Wireless Inventors Kit (RasWIK) :

i. RasWIK enables Raspberry Pi Wi-Fi connected devices.

ii. It includes documentation for 29 different projects.

iii. This devices are not open source but all of the included code is open source, and we can use it to build commercial products as well.

Que 1.9. Explain M2M communication. How it works ? Give the benefit of M2M communication.

Answer

1. Machine-to-Machine Communication (M2M) is two machines communicating, or exchanging data, without human interfacing or interaction.
2. In general, M2M communication, are referred to cellular communication for embedded devices.
3. Switching over to wireless has made M2M communication much easier and enabled more applications to be connected.
4. M2M can refer to any two machines wired or wireless communicating with one another.

Working of M2M :

1. The main purpose of machine-to-machine technology is to tap into sensor data and transmit it to a network.
2. M2M systems often use public networks and access methods for example, cellular or Ethernet, to make it more cost effective.
3. The main components of an M2M system include sensors, RFID, a Wi-Fi or cellular communications link, and autonomic computing software programmed to help a network device to interpret data and make decisions.
4. These M2M applications translate the data, which can trigger pre-programmed, automated actions.
5. M2M is able to remotely monitor equipment and systems.

Benefits of M2M are :

1. Reduced costs by minimizing equipment maintenance and downtime.
2. Boosted revenue by revealing new business opportunities for servicing products in the field.
3. Improve customer service.

Que 1.10. **Differentiate between M2M and IoT.**

Answer

S. No.	M2M	IoT
1.	Point-to-point communication usually embedded within hardware at the customer site.	Device communicates using IP networks, incorporating with varying communication protocols.
2.	Many devices use cellular or wired networks.	Data delivery is relayed through a middle layer hosted in the cloud.
3.	Devices do not necessarily rely on an internet connection.	Devices require an active internet connection.
4.	Limited integration as devices must have corresponding communication standards.	Unlimited integration options, but requires a solution that can manage all of the communications.
5.	Deployed in a closed system.	Connects to a larger network.
6.	Uses non-IP protocol.	Uses IP protocol.
7.	Often one-way communication.	Back and forth communication.
8.	It has structured data.	It has structured and unstructured data.

Que 1.11. **Write some of the application of M2M communication.**

Answer

Applications of M2M communication are :

1. **Security :** Surveillances, alarm systems, access control, car/driver security.
2. **Tracking and tracing :** Fleet management, order management, pay as we drive, asset tracking, navigation, traffic information, road tolling, traffic optimization / steering.
3. **Payment :** Point of sales, vending machines, gaming machines.
4. **Health :** Monitoring vital signs, supporting the aged or handicapped, web access telemedicine points, remote diagnostics.
5. **Remote maintenance / control :** Sensors, lighting, pumps, valves, elevator control, vending machine control, vehicle diagnostics.
6. **Metering :** Power, gas, water, heating, grid control, industrial metering.

7. **Manufacturing :** Production chain monitoring and automation.
8. **Facility management :** Home / building / campus automation.

Que 1.12. What are the key features of M2M communication ?

Answer

Key features of M2M communication are :

1. **Low mobility :** M2M devices do not move, move infrequently, or move only within a certain region.
2. **Time controlled :** Send or receive data only at certain pre-defined periods.
3. **Time tolerant :** Data transfer can be delayed.
4. **Packet switched :** Network operator to provide packet switched service with or without an MSISDN.
5. **Online small data transmissions :** Machine Type Communication (MTC) devices frequently send or receive small amounts of data.
6. **Monitoring :** Provide functionality to detect the events.
7. **Low power consumption :** To improve the ability of the system to efficiently service M2M applications.
8. **Location specific trigger :** Intending to trigger M2M device in a particular area.

Que 1.13. What are the features of hyperconnected wearable smart watches based on IoT concept ?

Answer

Features of hyperconnected wearable smart watches are :

i. **Samsung galaxy gear S smartwatch :**
   1. Two-inch curved display.
   2. Ability to make a phone call or send a text.
   3. Wi-Fi and Bluetooth connectivity options.
   4. GPS enabled.
   5. S Health App measures heart rate and UV monitors and informs the wearer of a good time to eat, when he/she has had enough exercise and a good time to take rest.
   6. Has navigational features to assist walking.

ii. **Microsoft wrist band 2 :**
   1. Fitness tracking.
   2. Can help with productivity by displaying email, calendar and message notifications.

3. Works with Windows phone, iOS devices and Android devices.
4. Sensors : Optical heart rate, 3-axis accelerometer, gyrometer, GPS, ambient light, UV, skin temperature, capacitive sensor, galvanic skin response, barometer.

PART-4

Design Principles for Connected Device : IoT / M2M Systems Layers and Design Standardization.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.14. Explain M2M communication architecture.

Answer

1. **M2M application :**
   a. Wireless M2M applications include connectivity-enabled devices that use a cellular data link to communicate with the computer server.
   b. A database to store collected data and a software application that allows the data to be analyzed, reported, and acted upon are also key components of a successful end-to-end solution.
2. **Service capabilities :**
   a. Service capabilities are the set of functionalities defined in the specification and are used to put in communication applications among them; both network applications, and gateway and device applications.
3. **Capillary network :**
   a. The sensors, communication and processing units act as endpoints of M2M applications and together constitute the capillary network.
   b. The devices will interconnect amongst themselves over various PAN and LAN technologies in both Wireless and Wireline domain.
4. **M2M gateways :**
   a. The gateway module provides control and localization services for data collection.
   b. The gateways also double up in concentrating traffic to the operator's core.
   c. It supports Bluetooth, ZigBee, GPRS capabilities.

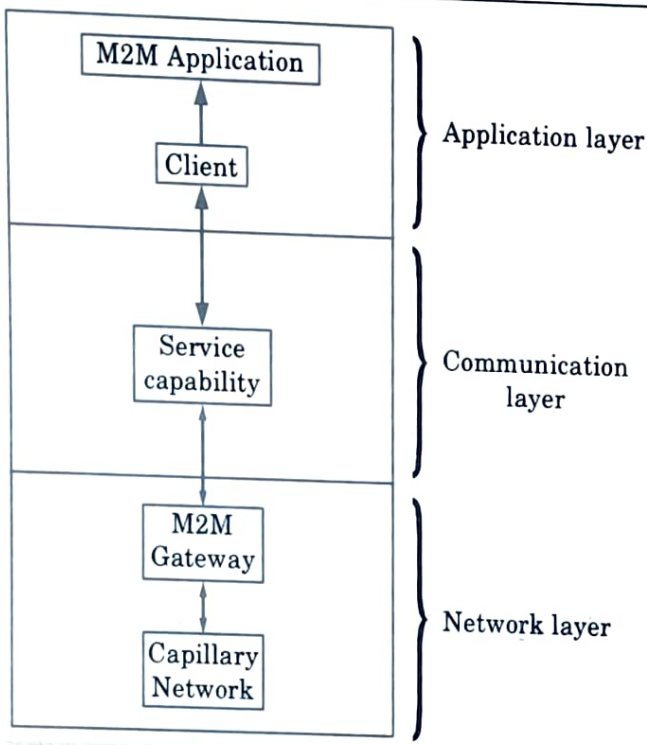

Fig. 1.14.1. M2M communication architecture.

Que 1.15. **Write short note on standardization efforts in M2M.**

Answer

1. Today's telecoms networks are designed mainly for human-to-human communication.
2. At present for human-to-machine and machine-to-machine communication standardization are limited to standalone system not involving the mobile networks and other general transport models.
3. In order to deliver effective M2M solutions and to allow the market to take off, efforts in the direction of standardizations to involve the existing technologies are taken up by various SDOs.
4. European Telecommunication Standards Institute (ETSI) has been established Machine-to-Machine Communications Technical Committee (TC M2M) to develop these necessary standards.
5. TC M2M aims to bring disjointed component-level standards together, and to fill the standardization gaps.
6. It is developing an end-to-end architecture to support multiple machine-to-machine type applications.
7. The main gap currently being addressed is the development of a 'horizontal' platform which is application-agnostic but which is capable of supporting a very wide range of services, including smart metering, city automation, consumer applications and car automation.

8. Significant progress on two technical specifications :
   a. The first includes the detailed specification of M2M functional architecture, covering all the new functionality (service capabilities) required to support M2M services, identification of the new interfaces required and the overall data model. It also includes a security solution appropriate to M2M service needs.
   b. The second technical specification provides the first detailed specification of the necessary interfaces, in the form of a formal definition of the Application Programming Interface (API) and of the required parameters.
9. The standardization efforts in International Telecommunication Union (ITU) are being addressed under various banners like 'Internet of Things (IoT)', 'Machine-to-Machine (M2M) communication', 'Machine Oriented Communication (MOC)', 'Smart Ubiquitous Networks (SUN)', 'Ubiquitous Sensor Networks (USN)', etc.

Que 1.16. Explain the role of standardization activities with proper diagram.

Answer

1. Standards are needed for interoperability both within and between domains.
2. Within a domain, standards can provide cost efficient realizations of solutions and a domain mean a specific organization or enterprise realizing an IoT.
3. Between domains, the interoperability ensures cooperation between the engaged domains, and is more oriented towards Internet of Things applications.
4. There is a need to consider the life cycle process in which standardization is one activity.
5. Significant attention is given to the "pre-selection" of standards through collaborative research, but focus should also be given to regulation, legislation, interoperability and certification as other activities in the same life cycle.
6. A complexity with IoT comes from the fact that IoT intends to support a number of different applications covering a wide array of disciplines that are not part of the ICT domain.
7. Requirements in these different disciplines can often come from legislation or regulatory activities.
8. As a result, such policy making can have a direct requirement for supporting IoT standards to be developed.
9. It would therefore be beneficial to develop a wider approach to standardization and include anticipation of emerging or on-going policy making in target application areas, and thus be prepared for its potential impact on IoT-related standardization.

10. A typical example is the standardization of vehicle emergency call (EC) services called eCall driven from the EC.
11. Based on the objective of increased road safety, directives were established that led to the standardization of solutions for services and communication for example, ETSI, and subsequently 3GPP.
12. Another example is the Smart Grid standardization mandate M/490 from the EC towards the European Standards Organizations (ESOs), and primarily ETSI, CEN and CENELEC.

Standardization process :

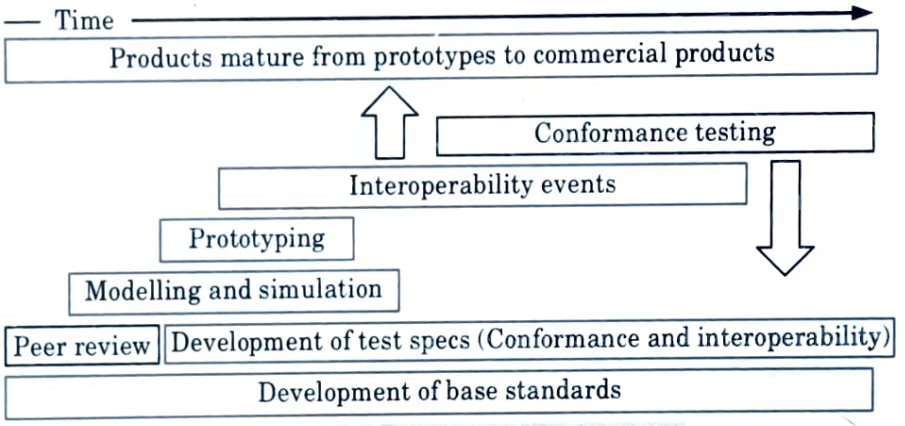

Fig. 1.16.2. Standardization process.

PART-5

Communication Technologies, Data Enrichment and Consolidation, Ease of Designing and Affordability.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.17. Describe communication technology in IoT.

Answer

1. Communication technologies play an important role in any wireless network.
2. The networks comprise on energy constraint devices require low power communication technologies.

3. Internet of Things (IoT) is a new and progressing concept that provides connectivity to the internet via smart sensing devices to attain identification and management in a heterogeneous connectivity environment.
4. Various communication technologies for Wireless Personal Area Networks (WPAN) like IoT are available presenting several properties.
5. IoT concept involves all heterogeneous objects around us communication with each other locally and via internet globally.
6. Such kind of network poses several challenges and requirements for choosing the best amongst the available communication technologies.

Que 1.18. Explain communication technologies that are utilized by IoT devices.

Answer

The major communication technologies that can be utilized by IoT devices are :

1. **ZigBee :**
   a. ZigBee is IEEE 802.15.4 standard.
   b. It is reliable wireless networking technology.
   c. It is designed for limited range network monitoring and controlling due to its low data rate and short range.
   d. The main area of utilization of this technology is in home automation, smart energy devices, lighting, HVAC and security etc.
   e. Due to its low-power, high level communication protocol using small digital radios, it comes under Wireless Personal Area Network (WPAN).
2. **RFID :**
   a. RFID has been categorized as the enabling communication power for the Internet of Things, due to its low cost, high mobility and efficiency in identifying devices and objects.
   b. The Radio Frequency Identification (RFID) technology has been initially introduced for identifying and tracking objects with the help of small electronic chips, called tags.
   c. It can provide communication range between 100m and 1km (depending on the transmission power and the antenna used).
   d. Data rates are quite low (up to 1 Mbps) and also need an Internet-enabled gateway that will provide access to the devices for making a complete IoT network.
3. **Bluetooth :**
   a. Bluetooth is an IEEE 802.15.1 standard for low cost, short range and cheap devices of wireless radio technology.

b. Bluetooth has been one of the first wireless communication protocols designed with low power consumption for replacing short-range wired communications, short distance data sharing and devices mobility support.

c. It has a property of creating personal area network during communication and discovers and communicates to its neighbour without need to be in visual line of sight.

4. **6LoWPAN :**

a. The 6LoWPAN is Wireless PAN with low power and supports IPv6 network.

b. It is a connection oriented technology in which router forward the data to its next hop to 6LoWPAN gateway which is connected to 6LoWPAN with the IPv6 domain and then forward the data to its respected device correctly.

c. In IP based network standard protocols (HTTP, TCP/IP) are directly applied on sensor nodes just as they do with traditional web servers out there in the Internet.

5. **6Z-Wave :**

a. It is low power consuming which mostly used in automation and light commercial environment.

b. It has an open communication protocol.

c. The main purpose of 6Z-wave is for a reliable message passing from a control unit to one or more nodes in the network.

6. **Wi-Fi :**

a. Wireless fidelity is known as Wi-Fi, the IEEE 802.11x standards, is the most common way to connect devices wirelessly to the internet.

b. Laptop, Smartphone and tablet PC are equipped with Wi-Fi interfaces and talk to wireless router and provide two way accesses to the internet.

c. The Wi-Fi standard family allows establishing wireless network on short distances.

d. The Wi-Fi group is working on unlicensed spectrum of 2.4 GHz (ISM) band.

Que 1.19. Describe data enrichment with its steps.

Answer

1. Data enrichment refers to adding value, security and usability of the data.
2. There are three steps used for data enrichment :

a. **Aggregation :** It refers to the process of joining together present and previously received data frames after removing redundant or duplicate data.

b. **Compaction :** It means making information short without changing the meaning or context; for example, transmitting only the incremental data so that the information sent is short.

c. **Fusion :** It means formatting the information received in parts through various data frames and several types of data (or data from several sources), removing redundancy in the received data and presenting the formatted information created from the information parts. Data fusion is used in cases when the individual records are not required and/or are not retrievable later.

Que 1.20. What are the functions of data consolidation ?

Answer

Functions of data consolidation are :

1. **Transcoding :**
   a. Transcoding means data adaptation, conversion and change of protocol, format or code using software.
   b. Similarly, the IoT device requests are adapted, converted and changed into required formats acceptable at the server by the transcoding software.
   c. Transcoding involves formats, data and code conversion from one end to another when the multimedia data is transferred from a server to the mobile TV, internet TV, VoIP phone or Smartphone as the client devices.
   d. Transcoding applications also involve filtering, compression or decompression.
2. **Privacy :**
   a. Privacy is an aspect of data management and must be remembered while designing an application.
   b. Data such as patient medical data, data for supplying goods in a company from and to different locations, and changes in inventories, may need privacy and protection from conscious or unconscious transfer to untrustworthy destinations using die internet.
   c. The design should ensure privacy by ensuring that the data at the receiving end is considered anonymous from an individual or company.
3. **Secure data access :**
   a. Access to data needs to be secure.

b. The design ensures the authentication of a request for data and authorization for accessing a response or service.

c. It may also include auditing of requests and accesses of the responses for accountability in future.

Que 1.21. Describe ease of designing and affordability of IoT devices.

Answer

1. Design for connected devices for IoT applications, services and business processes considers the ease in designing the devices physical, data-link, adaption and gateway layer.
2. It means availability of SDKs (Software Development Kits), prototype development boards with smart sensors, actuators, controllers and IoT devices, which are low in cost and hardware which embeds and are preferably open source software components and protocols.
3. Hardware which includes the device should embed minimum number of components and use ready solutions for ease in designing local devices personal area network and secure connectivity with the internet.
4. Designing also considers ease as well as affordances for example, RFID or card. The card has an embedded microcontroller, memory, OS, NFC peripheral interfaces, access point-based device activation, RF module and transceiver at low cost.
5. A wireless sensor uses, for example, a mobile terminal (Mote) which is a low cost device with an open-source OS (tiny OS) and software components. Usages of Motes provide ease and affordance in a WSN network.
6. Devices of smart homes and cities use ZigBee IP or BT LE 4.2 (dual mode or single mode) due to their affordability, ease of designing, usage and low cost.
7. Connected devices may add complexity in the form ensuring data transfer to trusted destinations using encryption tools.

2 UNIT

Hardware of IoT and Embedded Platforms for IoT

CONTENTS

PART-1

Hardware of IoT : Sensors, Digital Sensors, Actuators.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.1. What is sensor ? What are the features of sensors ?

Answer

1. A sensor is a device that is able to detect and responds to some type of input from physical environment.
2. A sensor is able to measure a physical phenomenon and transform it into an electric signal.
3. Example of sensors include infrared sensor, ultrasonic sensor, camera sensor, temperature sensor, etc

Features of sensors are :

1. It should be sensitive to the phenomenon that it measures.
2. It should not be sensitive to other physical phenomenon.
3. It should not modify the measured phenomenon during the measurement process.

Que 2.2. What are the characteristics of sensor ?

Answer

Characteristics of sensors are :

1. **Range :** The maximum and minimum values of the phenomenon that the sensor can measure.
2. **Sensitivity :** The minimum change of the measured parameter that causes a detectable change in output signal.
3. **Resolution :** The minimum change in the phenomenon that the sensor can detect.
4. **Selectivity :** Selectivity is the ability of the sensor to measure a target property in the presence of other properties. The sensor should only be sensitive to the measured property and should be insensitive to any other property likely to be encountered in its application.
5. **Response time :** The response time is the time taken by the sensor for its output to reach 95% of its final value when it is exposed to a target material.

6. **Hysteresis :** The hysteresis is the characteristic of a sensor by which the sensor produces a different set of outputs if the data is recorded in different directions (increasing input or decreasing input).
7. **Calibration :** If meaningful measurement is to be made, it is necessary to tune the output of the sensor with accurately known input.
8. **Precision :** The precision of a sensor is its ability to produce same output when repeatedly measured for the same input. The precision is determined using statistical analysis like standard deviation.
9. **Accuracy :** The accuracy of a sensor defines how close the output is to the real value. The accuracy defines the maximum error the sensor may produce.

Que 2.3. Explain classification of sensors.

Answer

Classification of sensors :

1. **Active sensor :**
   a. A sensor that requires external power to operate, for example carbon microphone, thermistor, strain gauges, capacitive and inductive sensors, etc.
   b. The active sensor is also called as parametric sensor (output is a function of a parameter-like resistance).
2. **Passive sensor :**
   a. It generates its own electric signal and does not require a power source, for example thermo couples, magnetic microphones, piezoelectric sensors, photodiode.
   b. The passive sensor is also called as self-generating sensors.
3. **Contact sensor :** A sensor that requires physical contact with the stimulus, for example strain gauges, temperature sensors.
4. **Non-contact sensor :** It requires no physical contact, for example most optical and magnetic sensors, infrared thermometers, etc.
5. **Absolute sensor :** A sensor that reacts to a stimulus on an absolute scale, such as thermistor, strain gauges, etc., (thermistor always reads the absolute temperature).
6. **Relative sensor :** The stimulus is sensed relative to a fixed or variable reference, for example thermocouple measures the temperature difference; pressure is often measured relative to atmospheric pressure.
7. **Analog sensors :**
   a. They produce a continuous output signal or voltage which is generally proportional to the quantity being measured.
   b. Physical quantities such as temperature, speed, pressure, displacement, strain etc. are all analog quantities as they tend to be continuous in nature.

8. **Scalar sensors :**
   a. These are the sensors that produce output signal or voltage which is generally proportional to the magnitude of the quantity being measured.
   b. Physical quantities such as temperature, colour, pressure, strain etc. are all scalar quantities as only their magnitude is sufficient to convey the information.
9. **Vector sensors :**
   a. Vector sensors produce output signal or voltage which is generally proportional to the magnitude, direction as well as the orientation of the quantity being measured.
   b. Physical quantities such as, sound, image velocity, acceleration, orientation etc. are all vector quantities as only their magnitude is not sufficient to convey the complete information.

Que 2.4. **Write short note on digital sensors.**

Answer

1. A digital sensor is an electronic or electrochemical sensor, where data is digitally converted and transmitted.
2. Digital sensors are the modern successors of analog sensors.
3. Digital sensors replace analog sensors because they overcome the traditional drawbacks of analog sensor systems.
4. In digital sensors, the signal measured is directly converted into digital signal as output inside the digital sensor itself.
5. Digital sensors are mainly used in water and industrial processes.
6. A digital sensor system also consists of the sensor itself, a cable, and a transmitter.

Que 2.5. **Write short note on actuators.**

Answer

1. An actuator is a device that converts an electrical signal to a physical output.
2. An actuator is a component of a machine or system that moves or controls the mechanism or the system.
3. In Internet of Things (IoT), actuators are used whenever there is a need to switch on/off another device or equipment by applying a force.
4. Actuators may be based on hydraulic, electric, thermal or mechanical means, but are increasingly being driven by software.

5. An actuator turns a control signal into mechanical action such as an electric motor.
6. It can be categorized by the energy source they require to generate motion.
7. The control system can be simple, software-based, a human or any other input.

Que 2.6. Explain different type of actuators.

Answer

Different types of actuators are :

1. **Hydraulic actuators :**
   a. A hydraulic actuator consists of a cylinder or fluid motor that uses hydraulic power to facilitate mechanical operation.
   b. The mechanical motion is converted to linear, rotary or oscillatory motion.
   c. Since liquids are nearly impossible to compress, a hydraulic actuator exerts considerable force.
   d. The actuator's limited acceleration restricts its usage.
   e. Examples for hydraulic actuator is the hydraulic brake in a vehicle.
2. **Pneumatic actuators :**
   a. A pneumatic actuator converts energy formed by vacuum or compressed air at high pressure into either linear or rotary motion.
   b. They are responsible for converting pressure into force.
   c. Example for pneumatic actuators are rack and pinion actuators which are used for valve controls of pipes.
3. **Electric actuators :**
   a. An electric actuator is generally powered by a motor that converts electrical energy into mechanical torque.
   b. The electrical energy is used to actuate equipment such as solenoid valves which control the flow of water in pipes in response to electrical signals.
   c. This is considered as one of the cheapest, cleanest and speedy actuators types available.
   d. Example of electric actuator is a solenoid based electric bell ringing mechanism.
4. **Thermal or magnetic actuators :**
   a. Thermal (magnetic) actuators are the types of actuators that can be actuated by applying thermal or magnetic energy.

b. These actuators to be compact, lightweight, economical and with high power density.

c. These actuators use shape memory materials such as shape memory alloys.

d. Example of thermal actuators is a thermostat and that of a magnetic actuator is an electro magnet.

5. **Mechanical actuators :**

a. A mechanical actuator converts rotary motion into linear motion to execute some movement.

b. It involves gear, rails, pulleys, chains and other devices to operate.

c. Examples of mechanical actuators are the rack and pinion mechanism and crank shaft acting as mechanical actuator.

PART-2

Radio Frequency Identification (RFID) Technology, Wireless Sensor Networks, Participatory Sensing Technology.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.7. Write short notes on RFID technology.

Answer

1. RFID stands for Radio Frequency Identification.
2. RFID refers to small electronic devices that consist of a small chip and an antenna.
3. The chip typically is capable of carrying 2,000 bytes of data or less.
4. The RFID device serves the same purpose as a bar code or a magnetic strip on the back of a credit card or ATM card.
5. It provides a unique identifier for that object.
6. RFID device must be scanned to retrieve the identifying information.
7. Data read from RFID tags are stored in a database by the reader.
8. The tag is covered by a protective material which also acts as a shield against various environmental effects.
9. Tags may be passive or active. Passive tags have to be powered by a reader inductively before they can transmit information, whereas active tags have their own power supply.

Que 2.8. **Explain the working of RFID.**

Answer

1. RFID technology is derived from Automatic Identification and Data Capture (AIDC) technology.
2. AIDC performs object identification, object data collection and mapping of the collected data to computer system with little or no human intervention.
3. AIDC uses wired communication.
4. RFID uses radio waves to perform AIDC functions.
5. RFID systems consist of three components :
   a. **RFID tags :** RFID tags contain an integrated circuit and an antenna, which is used to transmit data to the RFID reader (also called an interrogator).
   b. **RFID reader :** The reader converts the radio waves to a more usable form of data.
   c. **Antenna :** Information collected from the tags is then transferred through a communications interface *i.e.*, antenna to a host computer system, where the data can be stored in a database and analyzed at a later time.

Que 2.9. **Write short note on WSN.**

Answer

1. Wireless Sensor Network (WSN) refers to a group of spatially dispersed and dedicated sensors for monitoring and recording the physical conditions of the environment and organizing the collected data at a central location.
2. A WSN acquires data from multiple and remote locations.
3. WSN is defined as a network in which each sensor node connects wirelessly and has the capability of computation, for data compaction, aggregation and analysis.
4. Sensor nodes are capable of collaborating with one another and measuring the condition of their surrounding environments.
5. The sensed measurements are then transformed into digital signals and processed to reveal some properties of the phenomena around sensors.

Que 2.10. **What are the characteristics of WSN ?**

Answer

The main characteristics of WSN are :

1. Power consumption constraints for nodes using batteries or energy harvesting
2. Ability to cope with node failures
3. Mobility of nodes
4. Heterogeneity of nodes
5. Homogeneity of nodes
6. Scalability to large scale node deployment
7. Ability to withstand harsh environmental conditions
8. Ease of use
9. Cross-layer design

Que 2.11. Explain the architecture of WSN node.

Answer

1. The application layer software components are sensor management, sensor query and data dissemination, task assignment, data advertisement and application-specific protocols.
2. Network layer links serially to the data link layer, and may include the coordination or routing software. A serial link interconnects the layers to a wireless radio circuit and antenna.
3. Sensor, CPU and program sensor node constitute the application and network layers.

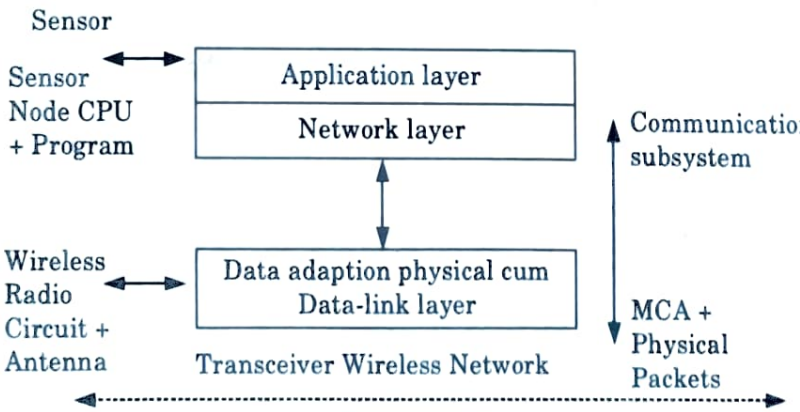

Fig. 2.11.1.

4. The radio circuit is at physical cum data link layer. Communication subsystem uses MAC and physical protocols.

Que 2.12. Explain the components of sensor node.

Answer

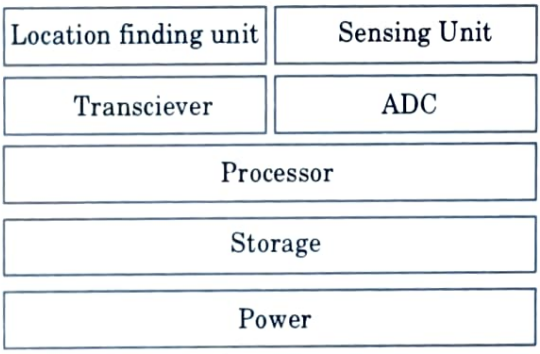

Fig. 2.12.1. Architecture of a sensor node.

Components of sensors node are :

1. **Location finding unit :**
   a. Location finding unit contains a transceiver which transmits or receives data.
   b. Sensor node often makes use of ISM band, which gives free radio, spectrum allocation and global availability. The possible choices of wireless transmission media are Radio Frequency (RF), optical communication (laser) and infrared.
   c. Laser requires less energy, but need line-of-sight for communication and are sensitive to atmospheric conditions.
2. **Sensing unit :**
   a. Sensors are used by wireless sensor nodes to capture data from their environment.
   b. They are hardware devices that produce a measurable response to a change in a physical condition like temperature of pressure.
   c. Sensors measure physical data of the parameter to be monitored and have specific characteristics such as accuracy, sensitivity etc.
3. **Transceiver :**
   a. The functionality of both transmitter and receiver are combined into a single device known as a transceiver.
   b. Transceivers often lack unique identifiers.
   c. The operational states are transmit, receive, idle, and sleep. Current generation transceivers have built-in state machines that perform some operations automatically.
   d. Most transceivers operating in idle mode have a power consumption almost equal to the power consumed in receive mode.

4. **Processor :**
   a. The processor processes data and controls the functionality of other components in the sensor node.
   b. While the most common processor is a microcontroller, other alternatives that can be used as a controller are a general purpose desktop microprocessor, digital signal processors etc.
   c. A microcontroller is often used in many embedded system such as sensor node because of its low cost, flexibility to connect to other devices, ease of programming and low power consumption.
5. **Storage or External memory :**
   a. Flash memories are used due to their cost and storage capacity. Memory requirements are very much application dependent.
   b. Two categories of memory based on the purpose of storage are : user memory and program memory where user memory is used for storing application related or personal data and program memory is used for programming the device.
6. **Power source :**
   a. A wireless sensor node is a popular solution when it is difficult or impossible to run a mains supply to the sensor node.
   b. An important aspect in the development of a wireless sensor node is ensuring that there is always adequate energy available to power the system.
   c. The sensor node consumes power for sensing, communicating and data processing.
   d. Power is stored either in batteries or capacitors.

Que 2.13. What is Participatory Sensing (PS) ? Explain the phases of PS process.

Answer

1. Participatory sensing is the process whereby individuals and communities use mobile phones and cloud services to collect and analyse systematic data for use in discovery.
2. Sensing by the individuals and groups of people contributing sensors information to form a body of knowledge.
3. Applications of PS include retrieving information about weather, environment information, pollution, waste management, road faults, health of individuals and group of people, traffic congestion, urban mobility, etc.
4. Participatory sensing has many challenges such as security, privacy, reputation and ineffective incentives to participating entities.

Phases of a PS process :

1. Phase 1 is coordination phase, in which the participants of PS process organise after identifying the sources.
2. Next two phases, *i.e.*, phases 2 and 3 involve data capture, communication and storage on servers or cloud.
3. Next two phases *i.e.*, phase 4 and 5 involve PS data processing and analytics visualisation and knowledge discovery.
4. Last phase *i.e.*, phase 6 is for initiating appropriate actions.

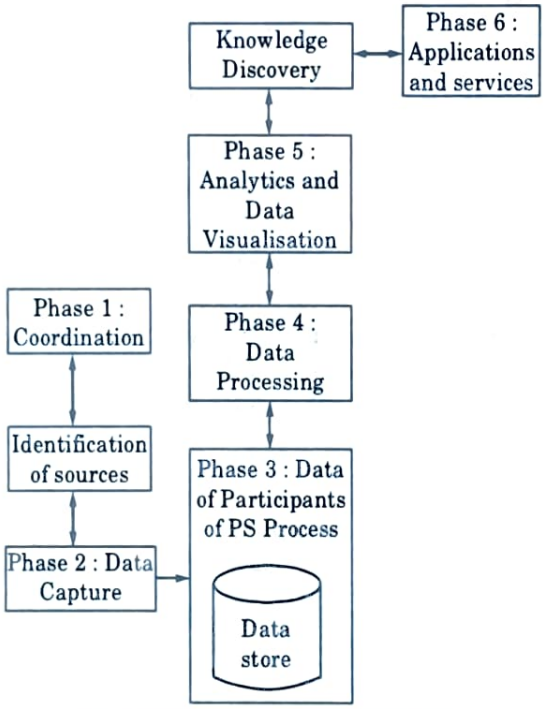

Fig. 2.13.1. Phases of PS process.

PART-3

Embedded Platforms for IoT : Embedded Computing Basics.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.14. Explain key terms used to understand prototype designing for creating IoTs devices.

Answer

1. **Embedded system :** It denotes a system that embeds software into a computing platform. The system is dedicated for either an application, specific part of an application, product or a component of a large system.
2. **Embedded device :** It refers to a device, which embeds software into a computing platform and performs the computations and communication for specific systems.
3. **Microcontroller Unit (MCU) :** It means a single-chip VLSI unit (also called microcomputer), which may be having limited computational capabilities. The MCU possesses memory, flash, enhanced input-output capabilities and a number of on-chip functional units.
4. **Port :** It refers to a device that enables input-output (IO) communication between the MCU and another device such as a sensor or actuator or keypad or with an external computing device.
5. **GPIO pins :** It refers to General Purpose Input-Output pins. A pin that can be used in addition to digital input and output for other purposes, such as R_X and T_X or SDA and SCK. The R_X and T_X pins are used during UART protocol-based reception and transmission, SDA and SCK are used during use of I2C protocol-based serial data and clock communication.
6. **Platform :**
   a. It denotes a set consisting of computing and communication hardware, software and operating system (OS).
   b. A platform enables working with different software, APIs, IDE and middleware.
   c. A platform may enable the development of codes at the development stage. It may also enable prototype development for an application or specific parts of an application.
7. **Module (hardware) :** It is smaller form-factor hardware which can be placed onto a board. The module may embed the software.
8. **Shield :** Shield means a supporting circuit with connection pins, socket and supporting software. The supporting circuit enables the connectivity of a board or computing platform to external circuits.
9. **Interrupt :** It means an action in which a running program interrupts a hardware signal such as timer timeout or on execution of a software instruction for interrupt.
10. **Integrated Development Environment (IDE) :** It means a set of software components and modules which provide the software environment for developing and prototyping.

11. **Operating system (OS) :** It is a system software which facilitates the running of process allocation of memory, system calls to the IOs, facilitates the use of network subsystems, and which does devices management, priority allocations of processes and threads.

Que 2.15. Explain the basic concept of embedded system.

Answer

1. Embedding means embedding function software into a computing hardware to enable a system function for the specific dedicated applications.
2. A device embeds software into the computing and communication hardware, and the device functions for the applications.
3. Embedded system consists of the following components :

a. Embedded software :

i. Software consists of instructions, commands and data.

ii. A computing and communicating device needs software.

b. Bootloader :

i. Bootloader is a program which runs at the start of a computing device, such as microcontroller unit (MCU).

ii. A bootloader initiates loading of system software (OS) when the system power is switched on, and power-on-self test completes.

iii. Bootloader may also facilitate the use of system hardware and networking capabilities.

c. Operating system :

i. An operating system facilitates the use of system hardware and networking, capabilities.

ii. When a load of the OS into RAM completes then the MCU starts the normal operational runtime environment.

iii. The OS enables memory allocation to different processes, and prioritizing of the processes enables the use of network hardware and device hardware functions and execution of software components and processes.

d. Real-time operating system :

i. Real-Time Operating System (RTOS) is an OS that enables real-time execution of processes on computing and communication hardware.

ii. RTOS uses prioritization and priories allocation concept to enable the execution of processes in real-time.

e. **Integrated development environment :**

i. Integrated development environment (IDE) is a set of software components and modules which provide the software and hardware environment for developing and prototyping.

ii. An IDE enables the codes development on a computer, and enables the codes to be executed on the hardware platform.

iii. IDE enables software that communicates with the internet web server or cloud server.

f. **Simulator :** It is software that enables development on the computer without any hardware, and then prototyping hardware can be connected for embedding the software and further tests.

g. **APIs :** Software consists of device Application Programming Interfaces (APIs) and device interface for communication over the network and communication circuit/port(s) which also includes a middleware.

h. **Device interfaces :** A connectivity interface consists of communication APIs, device interfaces and processing units.

Que 2.16. Write short notes on the following :

i. **Microcontroller unit (MCU)**
ii. **System-on-Chip**

Answer

i. **Microcontroller unit (MCU) :**

1. An MCU is a single-chip VLSI unit which has limited computational capabilities but possesses enhanced input-output capability and has a number of on-chip functional units.
2. An MCU is an IC chip, available from a number of sources, such as ATMEL, Nexperia, Microchip, Texas Instruments or Intel.
3. Following are the considerations when using a specific MCU version from a source, family or group of MCUs :
   a. MCU can be of 8-bit, 16-bit or 32-bit family.
   b. MCU clock frequency can be 8 MHz, 16 MHz, 100 MHz, 200 MHz or higher. Performance defines number of instructions executed per sec that primarily depends on the clock frequency also.
   c. MCU includes RAM which can be 4 kB, 16 kB, 32 kB or higher. RAM is used for temporary variables, stack and run-time, need of the memory.
   d. MCU includes timers, I/O ports, GPIO pins, serial synchronous and asynchronous ports and interrupt controllers.

ii. System-on-chip :

1. An SoC is a system on a VLSI chip that has multiple processors, software and all the needed digital as well as analog circuits on chip.
2. An SoC embeds processing circuit with memory and is specific to dedicated applications s and may have the analog circuits.
3. SoC may associate an external SD card in a mobile phone.

PART-4

Overview of IoT supported Hardware Platforms such as Arduino, Netduino, Raspberry Pi, BeagleBone, Intel Galileo Board and ARM Cortex.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.17. Describe Arduino platform for IoT. Also give its architecture.

Answer

1. Arduino boards modules and shields are popular AVR MCU-based products.
2. Each board has clear markings on the connection pins, sockets and in-circuit connections.
3. Arduino boards are easy to program. For example, Arduino Uno board is a robust as well as widely used board to get started with electronics and coding.
4. The analog input pins and PWM pins in the board can connect sensors, actuators and analog circuits.
5. The digital I/O pins can connect On-Off states, set of On-Off states, digital input forms sensors, digital outputs to actuators and other digital circuits.

Architecture of Arduino board :

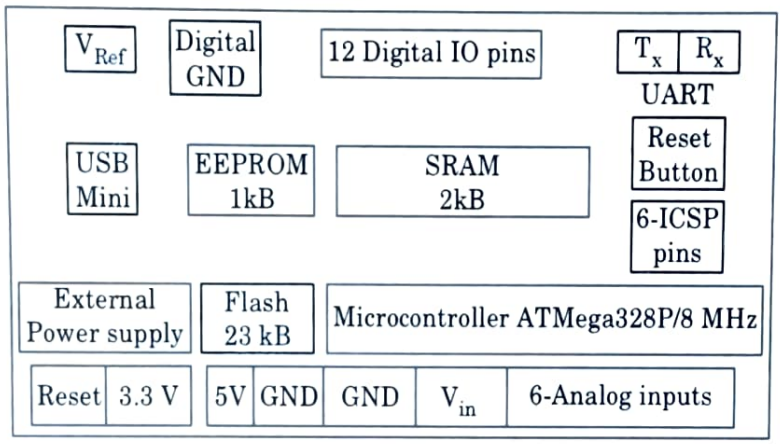

Fig. 2.17.1.

Que 2.18. What are the features that makes Arduino board to be used widely ?

Answer

Features which make Arduino boards widely used are :

1. Ease of prototyping.
2. Flexibility and ease of assembling modules on the board.
3. Arduino IDE uses a simplified version of C++, making it easier to learn a program.
4. Arduino provides a standard from factor that breaks the function of the microcontroller into a more accessible package.
5. Unlike most previous programmable circuit boards, Arduino does not need an extra piece of hardware (called a programmer) in order to load a new code onto the board. We can simply use a USB cable.
6. Arduino boards are able to read analog or digital input signals from different sensors and turn it into an output such as activating a motor, turning LED on/off, connect to the cloud and many other actions.

Que 2.19. Write short note on Netduino.

Answer

1. Netduino is an open-source electronics prototyping platform based on the .NET micro-framework.
2. It uses the ARM Cortex-M 32-bit RISC ARM processor core as a 32-bit ARM-microcontroller.
3. The Netduino boards are designed to be pin-compatible with most Arduino shields.
4. Applications can be built on Windows (with Visual Studio), or on Mac OS (with Xamarin Studio).
5. It is more powerful than Arduino platform.

6. Programming used to embed Netduino are written in C#(C sharp) which make it more powerful and use high-level language constructs.
7. Netduino board consist of 22 General Purpose Input/Output (GPIO) ports with 6 Pulse Width Modulation (PWM) hardware, 4 UARTs (serial communication), I2C, and SPI (Serial Peripheral Interface Bus) and 6 ADC channels.

Que 2.20. Write short note on Raspberry Pi. Also give its architecture.

Answer

1. Raspberry Pi is a low cost, credit-card sized computer that plugs into a computer monitor or TV and uses a standard keyboard and mouse.
2. Its capable of doing everything we except from a desktop computer.
3. Most commonly used programming languages in Raspberry Pi are Python, C, C++, Java, Scratch and Ruby.
4. The Raspberry Pi includes hardware and software which provides high performance computing and graphics.
5. The basic set up for Raspberry Pi includes HDMI cable, monitor, keyboard, mouse, 5 volt power adapter for raspberry Pi, LAN cable, 2 GB micro SD card (minimum).

Architecture of Raspberry Pi board :

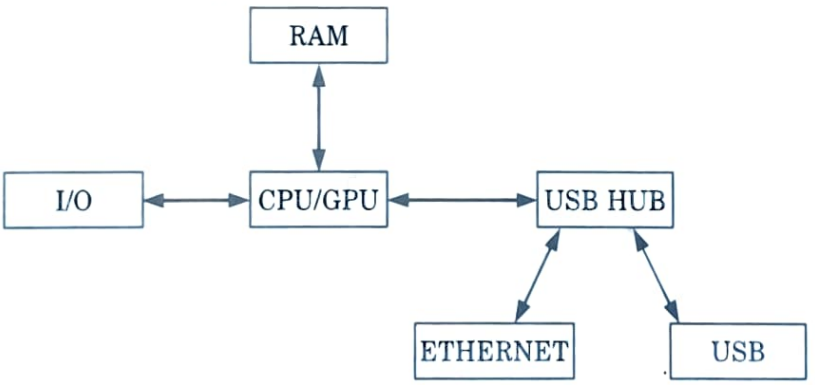

Fig. 2.20.1.

Que 2.21. What are the features that make Raspberry Pi board to be used widely ?

Answer

1. Computer-like prototyping easy for developing media server.
2. Coding in Python, C++ and the libraries.
3. Software runs on multiple environments, python, scratch, squeek, IDLE, C, Linux and BSD OSes, Windows 10 and several OSes with external keyboard and display monitor.

4. Flexibility and ease of connecting the hardware to external systems, connectivity of RPi takes place through two USB hosts hub and ethernet connector.
5. Connectivity to the extended memory through a micro SD slot.

Que 2.22. Briefly describe BeagleBone board.

Answer

1. BeagleBone X15 (BB-X15) is a single-board computer for computing and communication.
2. BB runs on the OS Linux, RSIX OS, FreeBSD, OpenBSD and additional distributions of Linux such as Ubuntu boards.
3. The SoC uses the processor (ARM Cortex A15 Core) and DSP processor (TMS320C64x plus multimedia 4 GB eMMC) for graphic and video.
4. The power required is 2W. Memory on-board is 2GB, plus in the memory support plus and microSD cards.
5. BB applications are for media, 2D and 3D graphics, and video servers.

Que 2.23. Write the features of BeagleBone board.

Answer

Features of BeagleBone board are :

1. Single-board computer and communication board.
2. Prototyping ease for media, graphics and video servers needing IoT applications.
3. IDEs for BB includes environment for code development in Python, Scratch, Squeek, Cloud9/Linux, C, Linux.
4. Programmability for number of times downloading of codes takes place through USB port during edit-test-debug cycles of development.
5. Flexibility and ease of connecting the extended memory and hardware connectivity board to external sockets for the 2-channel PCI peripheral connect interconnect express (PCIe) slot (which also functions and WiFi adapted), stereo audio, Ethernet x2 and micro SD slot.
6. Extended interfacing capabilities using 157 GPIO pins.

Que 2.24. Write short note on Intel Galileo board.

Answer

1. Intel Galileo boards are Arduino certified boards for development and prototyping.
2. A Galileo is based on the Intel Pentium architecture which includes features of single threaded single core and 400 MHz constant speed processor.
3. No separate graphic and video processors support is included in the board.

4. The Galileo is hardware and software pin-to-pin compatible with shields the designed for Arduino Uno R3 and Arduino IDEs.
5. Galileo additionally provides large 8 MB SPI flash to store firmware (Bootloader) and enables the users to incorporate Linux firmware calls in Arduino sketch programming.
6. Galileo supports a set of 30 sensors and accessories for Arduino.

Que 2.25. What are the features that make Intel Galileo boards to be used widely ?

Answer

Features of Galileo boards are :

1. It has single board computations and networking support.
2. IDE latest version and appropriate OS from open source.
3. IDE and software runs on multiple environments, Linux, Windows and Mac OS X.
4. Programmability number of times on downloading of codes through USB port, which enables the number of times download occurs during edit-test and debug cycles.
5. Flexibility and ease of connecting the extended memory and hardware connectivity board to external a full-sized mini-PCI Peripheral Connect Interconnect Express (PCIe) slot, Ethernet port socket, Micro-SD slot.
6. Extended interfacing capabilities using SPI.

Que 2.26. Write short notes on ARM cortex.

Answer

1. The ARM Cortex-M is a group of 32-bit RISC ARM processor cores.
2. They are intended for microcontroller use, and have been shipped in tens of billions of devices.
3. The cores consist of the Cortex-M0, Cortex-M0+, Cortex-M1, Cortex-M3, Cortex-M4, Cortex-M7, Cortex-M23, Cortex-M33, Cortex-M35P.
4. The Cortex-M4 / M7 / M33 / M35P cores have an FPU silicon option, and when included in the silicon these cores are known as "Cortex-Mx with FPU" or "Cortex-MxF", where 'x' is the core number.
5. The ARM Cortex-M family is ARM microprocessor cores which are designed for use in microcontrollers, ASICs, ASSPs, FPGAs, and SoCs.
6. Cortex-M cores are commonly used as dedicated microcontroller chips, but also are "hidden" inside of SoC chips as power management controllers, I/O controllers, system controllers, touch screen controllers, smart battery controllers, and sensors controllers.

3
UNIT

Network and Communication Aspects in IoT

CONTENTS

PART-1

Network and Communication Aspects in IoT : Wireless Medium Access Issues, MAC Protocol Survey.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.1. What are the roles of network for IoT deployment in various devices ?

Answer

Roles of network for IoT deployment in various devices are :

1. **Connectivity :**
   a. The IoT devices need connectivity to the controllers that helps in controlling the devices.
   b. The connectivity to the network can be wired or wireless.
   c. There are several protocol options in this space like ZigBee, Bluetooth, 6LoWPAN, Wi-Fi, Cellular, NFC, Sigfix etc.
2. **Power :**
   a. Power over Ethernet (PoE) is one of the significant innovation that has powered devices like phones and access points, enabling innovations like VoIP.
   b. PoE is being leveraged to power lights in the enterprise.
3. **Security :**
   a. The network is needed to secure devices.
   b. It needs to protect the devices from being infected by malware, but will also need to protect the network and application servers from attacks originating from the infected IoT devices.
   c. The devices connecting to the network would have to be authenticated, which is something that the network would play a major role.
4. **Compute :**
   a. The network has compute that can be leveraged in the IoT deployments to process events that cannot afford latency in processing.

b. The IoT devices themselves are highly cost optimised, which will limit the compute available in those devices.

c. The network, as a result, would have to support an application hosting environment that would allow the IoT vendors to host their software locally.

5. Manageability :

a. Manageability means to manage the IoT devices.

b. The network can helps to manage software stack in the computer that is part of the networking infrastructure.

c. It will help to deliver the critical messages from the controller to the devices with high reliability.

d. It will also help to automate the provisioning of the network for supporting IoT deployments.

Que 3.2. What are the benefits of network in IoT ?

Answer

Benefits of network in IoT are :

1. The ability to connect large numbers of heterogeneous IoT elements.
2. High reliability.
3. Real-time awareness with low latency.
4. The ability to secure all traffic flows.
5. Programmability for application customization.
6. Traffic monitoring and management at the device level.
7. Low cost connectivity for large number of devices/sensors.

Que 3.3. Explain wireless medium access issues.

Answer

Wireless medium access issues are :

1. Half duplex operation :

a. In wireless, it is difficult to receive data when the transmitter is sending the data, because when node is transmitting, a large fraction of the signal energy leaks into the receiver path.

b. The transmitted and received power levels can differ by orders of magnitude.

c. The leakage signal typically has much higher power than the received signal *i.e.*, impossible to detect a received signal, while transmitting data.

2. **Time varying channel :**
   a. The received signal by a node is a superposition of time-shifted and reduced versions of the transmitted signals *i.e.*, received signal varies with time.
   b. The time varying signals (time varying channel) phenomenon also known as multipath propagation.
   c. The rate of variation of channel is determined by the coherence time of the channel.
   d. Coherence time is defined as time within which the received signal strength changes by 3 dB.
3. **Burst channel errors :**
   a. As a consequence of time varying channel and varying signals strengths errors are introduced in the transmission.
   b. In wired networks, the Bit Error Rate (BER) is typically 10^{-6} *i.e.*, the probability of packet error is small.
   c. In wired networks, the errors are due to random noise.
   d. In wireless networks, the BER is as high as 10^{-3}.
   e. In wireless networks, the errors are due to node being in fade as a result errors occur in a long burst.

Que 3.4. Classify MAC protocol used in sensor network.

Answer

1. **Timeout-MAC (T-MAC) :**
   a. In T-MAC, listen period ends when no activation event has occurred for time threshold TA.
   b. The T-MAC protocol attempts to improve upon the performance of the Sensor-MAC (S-MAC) protocol.
   c. It proposes using a dynamic duty cycle as against the fixed one in S-MAC to further reduce the idle listening periods.
2. **Shift protocol :**
   a. The Shift protocol exploits the event driven nature of the sensor networks for MAC protocol design.
   b. This means that at a given time, only a set of adjacent sensors have data to transmit and this is most likely to be after detection of some specific event.
3. **Unified protocol :**
   a. In a Unified Protocol Framework (UNPF), that comprises a network organization protocol, a MAC protocol and a routing protocol, are presented for large-scale wireless sensor network architecture.

b. In this network architecture, the network nodes are organized into layers where the layers are formed based on a node's hop count to the base station.

4. Traffic-Adaptive MAC (TRAMA) protocol :

a. TRAMA protocol is provide a completely collision free medium access and thus achieve significant energy savings.

b. It is primarily a scheduled based MAC protocol with a random access component for establishing the schedules.

c. TRAMA relies on switching the nodes to a low power mode to realize the energy savings.

Que 3.5. Explain schemes of MAC protocol.

Answer

Schemes of MAC protocol are :

1. Frequency Division Multiple Access (FDMA) :

a. FDMA divides the entire channel bandwidth into equal subchannels that are sufficiently separated (via guard bands) to prevent co-channel interference, as shown in Fig.3.5.1.

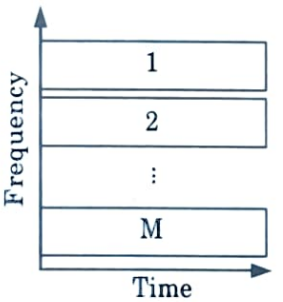

Fig. 3.5.1. Frequency division multiple access.

b. The capacity of each subchannel is the capacity associated with the entire channel bandwidth.

c. Each source node can then be assigned one (or more) of these subchannels for its own exclusive use.

d. To receive packets from a particular source node, a destination node must be listening on the proper subchannel.

2. Time Division Multiple Access (TDMA) :

a. TDMA divides the entire channel bandwidth into equal time slots that are then organized into a synchronous frame, as shown in Fig. 3.5.2.

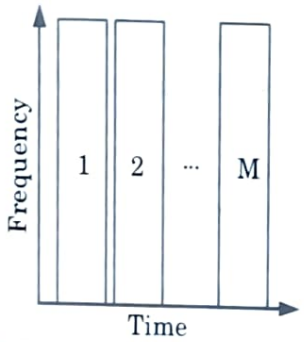

Fig. 3.5.2. Time division multiple access.

b. Each slot represents one channel which has a capacity equal to the capacity of the entire channel bandwidth.

c. Each node can then be assigned one (or more) time slots for its own exclusive use.

d. Consequently, packet transmission in a TDMA system occurs in a serial fashion, with each node taking turns accessing the channel.

3. **Code Division Multiple Access (CDMA) :**

a. CDMA allows transmissions to occupy the channel at the same time without interference.

b. Collisions are avoided through the use of special coding techniques that allow the information to be retrieved from the combined signal.

c. CDMA works by effectively spreading the information bits across an artificially broadened channel.

d. This increases the frequency diversity of each transmission, making it less susceptible to fading and reducing the level of interference that might be caused to other systems operating in the same spectrum.

e. It also simplifies system design and deployment since all nodes share a common frequency band.

Que 3.6. **What are the roles of MAC layer in sensor network ?**

Answer

The roles of MAC layer in sensor network are :

1. It divides the data into "frames".
2. MAC layer inserts address information (unit to send data).
3. MAC layer are used for error detection bits in the frame.
4. It controls incoming packets, address information, and error detection bits.

Que 3.7. **What are the cause of energy consumption in MAC layer ?**

Answer

The causes of energy consumption in MAC layer are :

1. **Collision :**
   a. Packets become unavailable when two packets collide being transmitted in overlapping time interval, thus the packets need to be resent.
   b. Resending means addition energy used.
   c. Collision also increases the delay.
2. **Overhearing :** Overhearing occurs when node unit receives a packet that has not been transmitted to it.
3. **Control packets :**
   a. Power consumption will be adversely affected if there are too many control packets in the design.
   b. The large protocol headings (MAC, Network, etc.) of small data packets will also increase the power consumption.
4. **Idle listening :**
   a. Receiver of radio chips must be always on for a node unit to receive the packets.
   b. This results in considerable power consumption.
5. **Traffic fluctuation :**
   a. The traffic has ups and downs in Transportation Data and Analysis (TDA).
   b. This is a matter of stability, adversely affects the power consumption.

PART-2

Survey Routing Protocol, Sensor Deployment and Node Discovery.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.8. Explain routing protocols with its type.

Answer

The routing protocols mean how nodes will communicate with each other and how the information will be disseminated through the network.

Types of routing protocols are :

1. **Node centric :**
   a. In node centric protocols, the destination node is specified with some numeric identifiers and this is not expected type of communication in Wireless sensor networks.
   b. For example, Low Energy Adaptive Clustering Hierarchy (LEACH), which is a routing protocol that organizes the cluster such that the energy is equally divided in all the sensor nodes in the network.
2. **Data centric :**
   a. In most of the wireless sensor networks, the sensed data or information is far more valuable than the actual node itself.
   b. Data centric routing techniques focus on the transmission of information specified by certain attributes rather than collecting data from certain nodes.
   c. For example, Sensor Protocol for Information via Negotiation (SPIN), which is a protocol use to remove the deficiency like flooding and gossiping that occurs in other protocols.
3. **Source initiated routing protocol :**
   a. The Dynamic Source Routing Protocols (DSR) is reactive routing protocol and efficient routing protocol designed specifically for use in multi-hop wireless ad hoc networks of mobile nodes.
   b. It uses source routing which means that the source must know the complete hope sequence to the destination.
   c. For example, Ad-hoc On-demand Distance Vector (AODV) is reactive on request protocol. AODV is engineered for mobile infrastructure less networks.
4. **Destination initiated routing protocol :**
   a. Protocols are called destination initiated protocols when the path setup generation originates from the destination node.
   b. For examples, Directed Diffusion (DD) and LEACH.

Que 3.9. Write short note on Neighbour Node Discovery (NND) in WSNs. Also give algorithm used in NND.

Answer

1. Neighbour Node Discovery is an indispensable first step in the initialization of a wireless network since knowledge of one-hop neighbours is essential for Medium Access Control (MAC) protocols, routing protocols, and topology control algorithms to work efficiently and correctly.
2. Neighbour Node Discovery (NND) is a family of protocols designed to find nodes.

3. The information acquired through neighbour node discovery protocols is extremely useful for further operations such as media access and routing.

Algorithm used in Neighbour Node Discovery (NND) :

1. **Randomized neighbour discovery algorithm :** In randomized neighbour discovery, each node transmits at randomly chosen times and discovers all its neighbours by a given time with high probability.
2. **Deterministic neighbour discovery algorithm :** In deterministic neighbour discovery, each node transmits according to a predetermined transmission schedule that allows it to discover all its neighbours by a given time with probability one.

Que 3.10. Explain the methods used in node discovery.

Answer

Methods used in node discovery are :

1. **Sensor network with Dynamic Source Routing (DSR) :**
   i. A synchronized sensor network can initiate efficient neighbour node discovery using dynamic source routing protocol.
   ii. In DSR, all the routing information is maintained and updated continually at the dynamic nodes and it is independent of routing tables of intermediate nodes.
   iii. The neighbour discovery in the network is done as follows :
      a. First of all the source node will flood a number of route request packets to all other nodes in the network.
      b. When a node receives it, a route reply packet will be transmitted back to the source.
      c. The sequence number of each packet avoids loop formation and multiple broadcast of same route request.
2. **Energy management using Hybrid MAC (HMAC) protocol :**
   i. In hybrid MAC protocol, the time is divided into two slots namely Wakeup Slot (W-SLOT) and Information Slot (I- SLOT).
   ii. W-SLOT is very shot in time, while I-SLOT is subdivided into a number of slots.
   iii. Every node in the network is assigned a unique W-SLOT so that it can listen to other wakeup messages. Fig. 3.10.1 shows the implementation of HMAC protocol.
   iv. The nodes will be in sleep state during all other wakeup slots. Whenever a node desires to transmit data, it will arbitrarily pick an I-SLOT and indicates the receiver node with corresponding slot number in the receivers W-SLOT through a wakeup message.

v. Thus only that receiver wakes in the corresponding I-SLOT for data reception.

vi. During this time, all the other nodes will be in sleep mode.

vii. Hence the energy utilization by the nodes in the network will reduce drastically.

viii. HMAC protocol supports one-hop broadcasting. Whenever a node desires to broadcast information, it will send a wakeup message including the address of broadcasting and an information slot in each wakeup slot.

ix. Once the wakeup message is received, all the neighbour nodes will wake up in the same I-SLOT and receives the broadcast message.

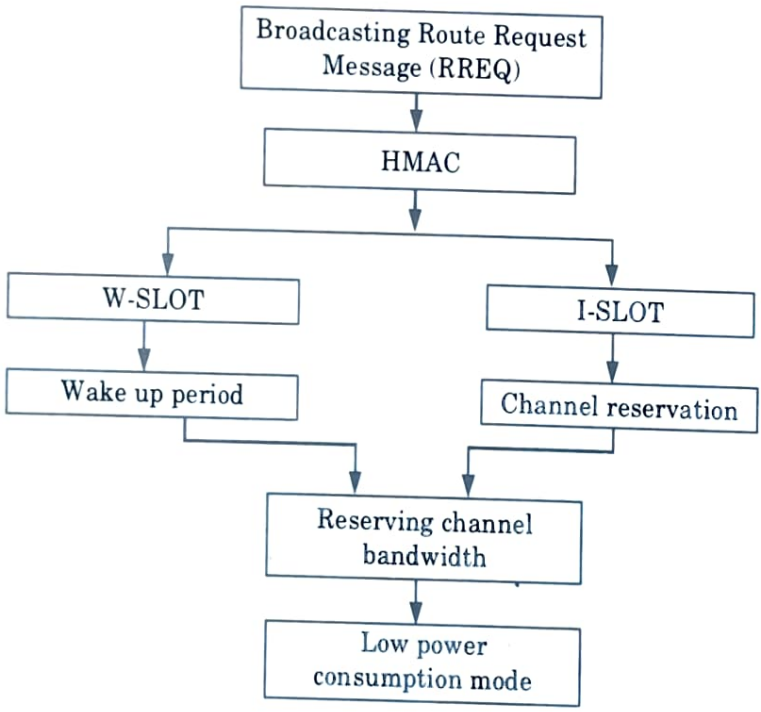

Fig. 3.10.1. Implementation of HMAC protocol.

3. **Sensor network with Adhoc On-demand Multipath Distance Vector (AOMDV) routing :**

i. AOMDV is sound informulating multiple paths which are loop free and disjoint.

ii. The routing entries for each destination are maintained in such a way that it consists of a list of next hops along with corresponding hops. Same sequence number is allotted to next hops.

iii. This is done based on the advertised hop count which is maintained. Advertised hop count is the maximum hop count for all the paths.

iv. During this session, the source node will flood of Route Request (RREQ) messages throughout the network.

v. The node which is intermediate to source node will receive the RREQ and sets up a reverse path. This is done by making the previous hop of the request message as the next hop on the reverse path.

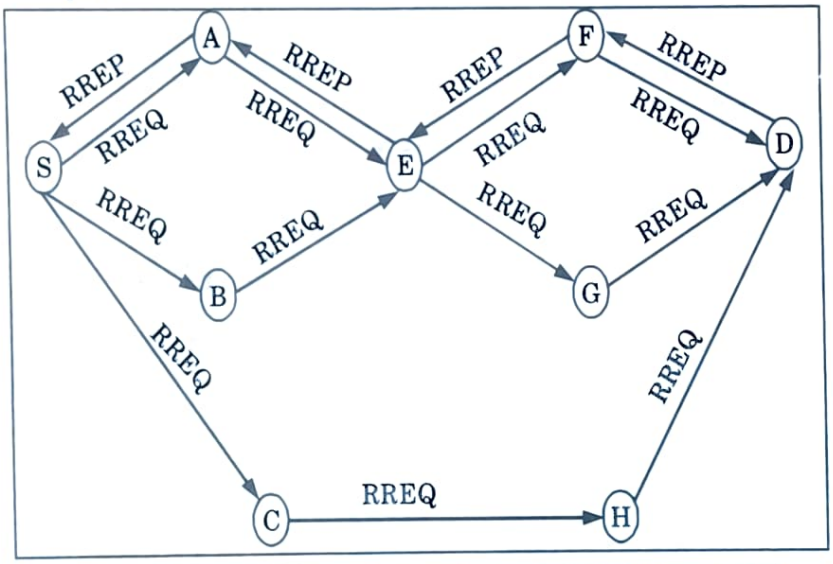

Fig. 3.10.2. Message transmission in AOMDV protocol.

vi. Multiple numbers of RREQ messages reached at the same node will be discarded. This will significantly reduce the network load and delay in the network.

vii. As the RREQ message reaches the destination, a Route Reply (RREP) message is generated and sends back to the source node through the same path followed by the RREQ message.

viii. The next session is the Route Maintenance. Whenever the connection between any two nodes is damaged or lost, a Route Error (RERR) message is generated and sends to all sources through precursor routes which are maintained discretely.

ix. Pre-defined routes are erased by RERR messages accordingly. When a source receives a RERR message, it initiates Route Discovery session again.

PART-3

Data Aggregation and Dissemination.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.11. What is data aggregation ? What are the performance measures of data aggregation ?

Answer

1. Data aggregation is the process in which information is gathered and expressed in a summary form, for purposes such as statistical analysis.
2. It is a process of aggregating the sensor data using aggregation approaches.
3. A common aggregation purpose is to get more information about particular groups based on specific variables.

Performance measures of data aggregation are :

1. **Network lifetime :**
   a. The network lifetime is defining the number of data fusion rounds.
   b. Till the specified percentage of the total nodes dies and the percentage depend on the application.
2. **Latency :**
   a. Latency is defined as the delay involved in data transmission, routing, and data aggregation.
   b. It can be measured as the time delay between the data packet received at the sink and data generated at the source node.
3. **Data accuracy :** Data accuracy is the evaluation of ratio of total number of reading received at the base station (sink) to the total number of readings generated.

Que 3.12. Explain the types of data aggregation approach.

Answer

Following are the types of data aggregation approach :

1. **Centralized approach :**
   a. This is an address centric approach where each node sends data to a central node via the shortest possible route using a multi-hop wireless protocol.
   b. The sensor nodes simply send the data packets to a leader, which is the powerful node.
   c. The leader aggregates the data which can be queried.
2. **In-Network aggregation approach :**
   a. In-network aggregation approach is the global process of gathering and routing information through a multi-hop network, processing data at intermediate nodes with the objective of reducing resource consumption (in particular energy), thereby increasing network lifetime.

3. **Tree-based approach :**
   a. Tree-based approach perform aggregation by constructing an aggregation tree, which could be a minimum spanning tree, rooted at sink and source nodes are considered as leaves.
   b. Each node has a parent node to forward its data.
   c. Flow of data starts from leaves nodes up to the sink and therein the aggregation done by parent nodes.
4. **Cluster-based approach :**
   a. In cluster-based approach, whole network is divided into several clusters.
   b. Each cluster has a cluster head which is selected among cluster members.
   c. Cluster-heads do the role of aggregator which aggregate data received from cluster members locally and then transmit the result to sink.

Que 3.13. Write short note on data dissemination.

Answer

1. Data dissemination and data gathering algorithms must take into account decentralized nature of sensor networks and limited battery power of sensor nodes.
2. A data dissemination is a process by which data and queries for data are routed in the sensor network.
3. In a scope of data dissemination, a source is the node that generates the data and an event is the information to be reported.
4. A node that is interested in data is called sink and the interest is a descriptor for some event that node is interested in.
5. Data dissemination is a two-step process :
   a. In the first step, the node that is interested in some events, like temperature or air humidity, broadcasts its interests to its neighbours periodically. Interests are then propagated through the whole sensor network.
   b. In the second step, nodes that have requested data send back data after receiving the request. Intermediate nodes in the sensor network also keep a cache of received interests and data.

Que 3.14. Explain method of data dissemination.

Answer

Method of data dissemination are :

1. **Flooding :**
   a. In flooding method, each sensor node receives a packet and broadcasts it to its neighbours.
   b. Assuming that node itself is not the destination of the packet and the maximum hop count is not reached.
   c. This ensures that the data and queries for data are sent all over the network.
2. **Gossiping :**
   a. Gossiping method is based on flooding, but node that receives the packet forwards it only to a single randomly selected neighbour instead of sending it to all neighbours.
   b. Gossiping avoids the problem of implosion and it does not waste network resources.
   c. In this method, neighbour is selected randomly, so some nodes in the large network may not receive the message.
3. **SPIN :**
   a. Sensor Protocols for Information via Negotiation (SPIN) use negotiation and resource adaption to address the disadvantages of basic flooding.
   b. SPIN uses data-centric routing, nodes are advertising their data and they will send the data after receiving a reply from interested nodes.
   c. SPIN uses three types of messages : ADV, REQ, and DATA.
4. **Cost-field approach :**
   a. Cost-field approach solves the problem of setting paths to the sink.
   b. The cost-field approach is a two-phase process, in the first phase the cost-field is set up in all sensor nodes, based on some metric.
   c. In the second phase, data is disseminated using the costs.
   d. The cost at each node is the minimum cost from the node to the sink, which occurs on the optimal path. With the cost-field approach explicit path information does not need to be maintained.

4
UNIT

Programming the Arduino

CONTENTS

PART-1

Programming the Arduino, Arduino Platform Boards Anatomy, Arduino IDE.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.1. Explain the anatomy of Arduino platform board.

OR

What are the components of Arduino board ?

Answer

The components of Arduino board are :

1. **Power USB :** Arduino board can be powered by using the USB cable from the computer. For this we need to connect the USB cable to the USB connection.
2. **Power (Barrel Jack) :** Arduino boards can be powered directly from the AC main power supply by connecting it to the Barrel Jack.
3. **Voltage regulator :** The function to the voltage regulator is to control the voltage given to the Arduino board and stabilize the DC voltages used by the processor and other elements.
4. **Crystal oscillator :**
   i. The crystal oscillator helps Arduino in dealing with time issues.
   ii. The number printed on top of the Arduino crystal is 16.000H9H. It tells us that the frequency is 16,000,000 Hertz or 16 MHz.
5. **Arduino reset :**
   i. We can reset the UNO board in two ways.
   ii. First, by using the reset button (17) on the board. Second, we can connect an external reset button to the Arduino pin labelled RESET (5).
6. **Pin (3.3) :** Supply 3.3 output volt.
7. **Pin 5V :** Supply 5 output volt.
8. **GND (Ground) :** There are several GND pins on the Arduino, any of which can be used to ground our circuit.
9. **Vin (9) :** This pin can be used to power the Arduino board from an external power source, like AC main power supply.

10. Analog pins :

i. The Arduino UNO board has five analog input pins A0 through A5.

ii. These pins can read the signal from an analog sensor like the humidity sensor or temperature sensor and convert it into a digital value that can be read by the microprocessor.

11. Main microcontroller :

i. Each Arduino board has its own microcontroller. It is the brain of our board.

ii. We must know what IC our board has before loading up a new program from the Arduino IDE.

iii. This information is available on the top of the IC.

12. ICSP pin :

i. ICSP is an AVR, a tiny programming header for the Arduino consisting of MOSI, MISO, SCK, RESET, VCC, and GND.

ii. It is often referred to as an SPI (Serial Peripheral Interface), which could be considered as an "expansion" of the output.

13. Power LED indicator :

i. This LED should light up when we plug our Arduino into a power source to indicate that our board is powered up correctly.

ii. If this light does not turn on, then there is something wrong with the connection.

14. TX and RX LEDs :

i. On the board, there will be two labels : TX (transmit) and RX (receive).

ii. They appear in two places on the Arduino UNO board :

a. First at the digital pins 0 and 1. This indicates that the pins are responsible for serial communication.

b. Second, the TX and RX led, the TX led flashes with different speed while sending the serial data. RX flashes during the receiving process.

15. Digital I/O :

i. The Arduino UNO board has 14 digital I/O pins (15) of which 6 provide PWM (Pulse Width Modulation) output.

ii. These pins can be configured to work as input digital pins to read logic values (0 or 1) or as digital output pins to drive different modules like LEDs, relays, etc.

iii. The pins labeled "~" can be used to generate PWM.

16. AREF :

i. AREF stands for Analog Reference.

ii. It is used to set an external reference voltage (between 0 and 5 Volts) as the upper limit for the analog input pins.

Que 4.2. What is Arduino IDE ? What are the steps required to set up an Arduino boards ?

Answer

Arduino IDE : Arduino IDE is open source software that is used to program the Arduino controller board. It is based on variations of C and C++ programming language.

Following steps are required to set up an Arduino board :

1. **Power the board by connecting it to a PC via USB cable:**
   a. The power source is selected with a jumper, a small piece of plastic that fits onto two of the three pins between the USB and power jacks.
   b. Check that it is on the two pins closest to the USB port.
   c. The green power LED (labelled PWR) should glow.
2. **Launch the Arduino IDE :**
   a. After the Arduino IDE software is downloaded, we need to unzip the folder.
   b. Inside the folder, we can find the application icon with an infinity label (application.exe).
   c. Double-click the icon to start the IDE.
3. **Open the first project :**
   a. Once the software starts, we have two options - Create a new project or open an existing project example.
   b. To create a new project, select File and click on New.
   c. To open an existing project example, select File and click on Example.
4. **Select the Arduino board :**
   a. To avoid any error while uploading our program to the board, we must select the correct Arduino board name, which matches with the board connected to our computer.
   b. Go to Tools and click on Board and select our board.
5. **Select the serial port :**
   a. Select the serial device of the Arduino board.
   b. Go to Tools and click on Serial port menu.
   c. This is likely to be COM3 or higher (COM 1 and COM2 are usually reserved for hardware serial ports).
   d. To find out, we can disconnect our Arduino board and re-open the menu, the entry that disappears should be of the Arduino board.

e. Reconnect the board and select that serial port.

6. **Upload the program to our board :** We can upload our program to the board using Arduino IDE toolbar.

PART-2

Coding, Using Emulator, Using Libraries.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.3. Explain the basic syntax of Arduino programming code.

Answer

1. Program coded in Arduino IDE is called a sketch.
2. The basic syntax of the sketch language is simple and runs in at least two parts *i.e.*, setup() and loop()

Syntax :

```
void setup( ) {
pinMode(pin, OUTPUT);          // sets the 'pin' as output
}
void loop() {
digitalWrite(pin, HIGH);       // turns 'pin' on
 delay(1000);                  // pauses for one second
digitalWrite(pin, LOW);        // turns 'pin' off
delay(1000);                   // pauses for one second
}
```

a. setup() :

i. The setup() function is called once when our program starts.

ii. We use it to initialize pin modes, or begin serial. It must be included in a program even if there are no statements to run.

iii. The setup function follows the declaration of any variables at the beginning of the program.

iv. It is the first function to run in the program which runs only once, and is used to set pinMode or initialize serial communication.

b. loop() :

i. After calling the setup() function, the loop() function allows the program to change, respond, and control the Arduino board.

ii. The loop function follows next and includes the code to be executed continuously *i.e.*, reading inputs, triggering outputs, etc.

iii. This function is the core of all Arduino programs.

Que 4.4. Write short note on variable in Arduino programming.

Answer

1. A variable is a way of naming and storing a numerical value for later use by the program.
2. They can be continually changed as opposed to constants whose value never changes.
3. A variable needs to be declared and optionally assigned to the value needing to be stored.
4. The following code declares a variable called inputVariable and then assigns it the value obtained on analog input pin 2 :

```
int inputVariable = 0; // declares a variable and assigns value of 0
inputVariable = analogRead(2); // set variable to value of analog pin 2
```

   a. 'inputVariable' is the variable itself.
   b. The first line declares that it will contain an int, short for integer.
   c. The second line sets the variable to the value at analog pin 2.
   d. This makes the value of pin 2 accessible elsewhere in the code.
   e. Once a variable has been assigned, or re-assigned, we can test its value to see if it meets certain conditions, or we can use its value directly.

Que 4.5. Write short note on scope of variables.

Answer

1. Variables use a property called scope.
2. A scope is a region of the program and there are two places where variables can be declared.
   a. Local variables :
      i. Variables that are declared inside a function or block are local variables.
      ii. They can be used only by the statements that are inside that function or block of code.
      iii. Local variables are not known to function outside.
   b. Global variables :
      i. Global variables are defined outside of all the functions, usually at the top of the program.

ii. The global variables will hold their value throughout the life time of the program.

iii. A global variable can be accessed by a function.

iv. A global variable is available for use throughout the entire program after its declaration.

Que 4.6. Explain different data types supported by Arduino programming.

Answer

The following data types are supported by Arduino programming :

1. **Void :**
   a. The void keyword is used only in function declarations.
   b. It indicates that the function is expected to return no information to the function from which it was called.
2. **Boolean :**
   a. Boolean holds one of two values, true or false.
   b. Each Boolean variable occupies one byte of memory.
3. **Char :**
   a. A data type that takes up one byte of memory stores a character value.
   b. Character literals are written in single quotes like 'c'.
   c. For multiple characters called strings we use double quotes : "ABC".
4. **Byte :** A byte stores an 8-bit unsigned number from 0 to 255.
5. **Int :**
   a. Integers are the primary data type for number storage.
   b. Int stores a 16-bit (2-byte) value.
   c. This yields a range of – 32,768(-2^{15}) to 32,767($2^{15}-1$).
   d. The int size varies from board to board.
6. **Word :** On the Uno and other ATMEGA based boards, a word stores a 16-bit unsigned number.
7. **Long :** Long variables are extended size variables for number storage and store 32-bits (4 bytes) from –2,147,483,648 to 2,147,483,647.
8. **Short :**
   a. A short is a 16-bit data type.
   b. On all Arduinos a short stores a 16-bit (2-bytes) value.
9. **Float :**
   a. Data type for floating point number is a number that has a decimal point.

b. Floating point number can be as large as 3.4028235E + 38 and as low as –3.4028235E + 38.

c. They can store 32-bits (4 bytes) of information.

Que 4.7. Explain function libraries in Arduino programming.

Answer

Following are several function libraries in Arduino programming :

1. **Input-output functions :**
   a. The pins on the Arduino board can be configured as either inputs or outputs using the pinMode() function.
   b. Pins configured as INPUT are said to be in a high impedance state.
   c. Pins configured as OUTPUT with pinMode() are said to be in a low impedance state.
   d. The syntax of pinMode() function is as follows :

```
Void setup () {
pinMode (pin, mode) ;
}
```

   Where pin is the pin number on the Arduino board that we wish to set to a mode and mode can be either INPUT or OUTPUT.

2. **Character functions :**
   a. All data is entered into computers as characters, which includes letters, digital and various special symbols.
   b. The character handling library includes several functions that perform useful tests and manipulations of character data.
   c. The following are the functions of the character handling library :
      i. **int isdigit(int c) :** Returns 1 if c is a digit and 0 otherwise.
      ii. **int isalpha(int c) :** Returns 1 if c is a letter and 0 otherwise.
      iii. **int isxdigit(int c) :** Returns 1 if c is a hexadecimal digit character and 0 otherwise.
      iv. **int isupper(int c) :** Returns 1 if c is an uppercase letter, 0 otherwise.

3. **Math library :**
   a. For using mathematical functions we need to include math.h header file.
   b. Following are the mathematical functions included in math library :
      i. sin(double radian)
      ii. exp(double val)
      iii. log(double val)

iv. square(double val)

Que 4.8. Write short note on Arduino emulator.

Answer

1. Emulation means to do the actions similar to a real entity.
2. Emulator software emulates the running of an embedded device platform, known as target board.
3. Software emulates the embedded device platform onto the computer.
4. The developer observes the actions on the computer.
5. In-circuit Emulation (ICE) means hardware debugging by emulation after connecting the target board to the computer.
6. The computer sets the break points in the embedded software.
7. The results at the end of each break point enable a programmer to find the bug (erroneous code or code-section).
8. Computer can initiate single stepping through the codes.
9. The screen displays the registers in the microprocessor or microcontroller, the variables values at the end of each step or at the end of a specified section of codes.
10. Computer display also displays the contents of memory addresses at each break point.
11. JTAG (Joint Test Action Group) standard enables testing of the target board onto the computer when JTAG software embeds into hardware, and JTAG connecter connects the hardware to computer.

Que 4.9. Explain decision making statement supported by Arduino with example.

Answer

Following are the decision making statements supported by Arduino :

1. **If statement :**
   a. It takes an expression in parenthesis and a statement or block of statement, if the expression is true then the statement or block of statements gets executed otherwise these statements are skipped.
   b. **Syntax :**

```
if (expression) {
block of statements;
}
```

   c. Example of if statement :

```
int a = 5;
```

```
void setup () {
}
void loop () {
/* check the Boolean condition */
if (a>0) /* if condition is true then execute the following statement*/
a++;
}
```

2. If ..else statement :

a. An if statement can be followed by an optional else statement, which executes when the expression is false.

b. Syntax :

```
if (expression) {
block of statements;
}
else {
block of statements; }
```

c. Example of if..else statement :

```
int a = 5;
void setup () { }
void loop () {
/* check the Boolean condition */
if (a>0) /* if condition is true then execute the following statement*/
else /* else condition is true then execute the following statement*/
statement;
}
```

3. If..else..if..else statement :

a. The if statement can be followed by an optional else if...else statement, which is very useful to test various conditions using single if...else if statement.

b. Syntax :

```
if (expression 1) {
block of statements;
}
else if (expression 2) {
block of statements; }
else if (expression n) {
block of statements; } else {
```

```
block of statements; }
```

c. Example of if..else..if..else statement :

```
int a = 5;
void setup () {
}
vaid loop () {
/* check the Boolean condition */
if (a>0) /* if condition is true then execute the following statement*/
a++;
else if(a<0)/* else if condition is true then execute the following
statement*/
a--;
else /* else condition is true then execute the following statement*/
a = 0;
}
```

Que 4.10. Explain different types of time manipulation function provided by Arduino.

Answer

Following are the four different time manipulation function provided by Arduino :

1. **delay() function :** It accepts a single integer (or number) argument. This number represents the time (measured in millisecond).
2. **delaymicroseconds() function :** The delaymicroseconds() function accepts a single integer (or number) argument. There are a thousand microseconds in a millisecond, and a million microseconds in a second.
3. **millis() function :** This function is used to return the number of millisecond at the time Arduino board begins running the current program.
4. **micros() function :** The micros() function returns the number of microseconds from the time Arduino board begins running the current program. This number overflows *i.e.*, goes back to zero after approximately 70 minutes.

Que 4.11. What is an operator ? Explain the operator supported by Arduino.

Answer

1. An operator is a symbol that tells the compiler to perform specific mathematical or logical functions.
2. Arduino supports following types of operators :

a. **Arithmetic operators :** Addition (+), subtraction (–), multiplication (×), division (/), modulus (%) and assignment (=).

b. **Comparison operators :** Logical equal to (==), not equal to (!=), less than (<), less than or equal to (<=), greater than (>) and greater than or equal to (>=).

c. **Boolean operators :** Logical AND (&&), Logical OR (||) and Logical NOT (!)

d. **Bitwise operators :** Bitwise AND (&), Bitwise OR (|), Bitwise Exclusive OR (^), Bitwise NOT (~), Bitwise Left Shift (<<) and Bitwise Right Shift (>>).

e. **Compound operators :** Increment (++), Decrement (– –) and shorthand (+=, –=, *=, /=, %=, |=, &=).

PART-3

Addition in Arduino, Programming the Arduino for IoT.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.12. **Write a program to add two numbers in Arduino.**

Answer

```
void setup() {
int a = 2;
int b = 7;
int result;
float result_fl;
Serial.begin(9600);
Serial.print("Addition (a + b): ");
result = a + b;
Serial.println(result);
}
void loop() {
}
```

Que 4.13. **Write a program in Arduino for uses of timer library functions.**

Answer

Step 1: Statements for preprocessor commands, declarations of data types and functions and inclusion of required library files.

```
#include <MsTimer2.h>
void action ( ) {
/* Write statements for actions on preset time over, for example change of
output at an IO pin*/
}
```

Step 2 : Statements are for pin configuring and initial set up statements. A statement specifies a preset value for the interval after which timer MsTimer2 will interrupt and call interrupt handing function. Let function be specified and named action ().

```
void setup ( ) {
/* Write pins and initial setup statements. */
/* Set the millisecond timer to execute the function action ( ) after 3000
ms*/
MsTimer2:set (3000, action);
/* Start the millisecond timer*/
MsTimer2:          start ();}
```

Step 3 : Statements are for codes for actions during 3s and which are repeatedly done, if stop condition not defined inside the loop.

```
loop ( ) { }
```

Que 4.14. **Write a program to blink LED in Arduino.**

Answer

```
void setup ( )
{
pinMode (LED, OUTPUT);        //Declaring pin 13 as output pin
}
void loop( )                  // The loop function runs again and again
{
digitalWrite (LED, HIGH);     //Turn ON the LED
delay(1000);                  //Wait for 1sec
digitalRead (LED, LOW);       // Turn off the LED
delay(1000);                  // Wait for 1sec
}
```

Que 4.15. **Write a program to demonstrate the use of increment operator.**

Answer

```
void setup() {
int count = 0;
Serial.begin(9600);
Serial.println(count++);
```

```
Serial.println(count++);
Serial.println(count++);
Serial.println(count);
}
void loop() {
}
```

Que 4.16. **Write a program to check the lowercase and uppercase version of alphabet character using logical operator.**

Answer

```
void setup() {
Serial.begin(9600);
pinMode(13, OUTPUT);                    // LED on pin 13 of UNO
}
void loop() {
char rx_byte;

if (Serial.available() > 0) {           // is a character available?
rx_byte = Serial.read();
if (rx_byte == 'a' || rx_byte == 'A') {
digitalWrite(13, HIGH);
}
else {
digitalWrite(13, LOW);
}
}
}
```

UNIT 5

Challenges in IoT Design and IoT Applications

CONTENTS

PART-1

Challenges in IoT Design : Development Challenges, Security Challenges, Other Challenges.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.1. What are the challenges in IoT ?

Answer

Challenges in IoT are :

1. **Security :**
   a. Data encryption is one method of providing data security in IoT.
   b. Internet of Things collects tons of data.
   c. Data retrieval and processing is integral part of the whole IoT environment.
   d. To address IoT security issue we can use Secure Socket Layer (SSL) protocol wherever our data is present online.
2. **Scalability :**
   a. If the system is not scalable, then it will not be able to accommodate future expansion when shift in technology occur.
   b. This leaves business with unusable systems and devices that must either be replaced or augmented, but both are expensive prospects.
   c. The network can adapt when failures occur and remain mostly operational until the issue is repaired.
3. **Interoperability :**
   a. At the most basic level, the Internet of Things (IoT) is connectivity among people, processes and things.
   b. The challenge in IoT is the enablement of seamless interoperability between each connection.
   c. These issues include the following :
      i. Different devices or equipments that are not made by the same manufacturer cannot be integrated.
      ii. Different/inconsistent communication protocol standards (*i.e.*, rules)
      iii. Lack of programs needed to connect the devices.

4. **Data storage :**
   a. The Internet of Things will have a huge impact on storage, the sheer volume of data, the radically different types of data created and the storage needed.
   b. Machine generated data comes in two distinct types, creating two entirely different challenges.
   c. First, there is large-file data, such as images and videos captured from smart phones and other devices. This data is typically accessed sequentially.
   d. The second data type is very small, for example, log-file data captured from sensors.
5. **Data analytics :**
   a. The analysis of Internet of Things (IoT) data is quickly becoming a mainstream activity.
   b. With many data sources, it is often quite an effort to gather the source data required for analysis.
   c. It is necessary to identify what information is available, how it is formatted, and also to reconcile data from different sources that often contained similar information, but have inconsistencies in how it is provided.
6. **Standards :**
   a. A lack of documented or standard had a larger impact on Internet of Things devices that goes well beyond simply limiting their development and potential.
   b. An absence of standards may enable inappropriate behaviour by IoT devices.
   c. Without the right standards to guide and regulate manufactures, developers may design products that operate in any number of disruptive ways online without regard for their impact.

Que 5.2. **Explain development challenges in IoT.**

Answer

Development challenges in IoT are :

1. **Connectivity :** Connectivity means how to connect devices to the internet and the cloud computing platform. Connectivity and transmission of data in real-time is the essence of IoT.
2. **Security and privacy :** The following are some key points for security design :
   a. **Physical security :** IoT devices are often located in open and are unattended and not physically protected. One must ensure that they are not tampered by anyone.

b. **Security of data exchange :** Data protection is important because data must get transmitted from the IoT sensors and devices to the gateway, and then to the cloud. Therefore, use of encrypted transfer protocols is necessary. In addition to encryption, one must also consider the authentication and authorization to ensure IoT security.

c. **Security of cloud storage :** Data stored in the cloud is equally fragile as other parts of the IoT ecosystem. Our platform should be able to protect data stored in the cloud. Protection measures include appropriate encryption, access control.

3. **Hardware and device compatibility :**
   a. In order to set up a full-fledged IoT network, there are various hardware elements to be made use of; such as sensors, development boards, gateways, and more.
   b. Hence, enterprises need to make sure that they source their hardware from the same manufacturer to avoid compatibility issues.
4. **Data collection and processing :**
   a. In addition to security and privacy, we must also properly plan how to process all collected data.
   b. We must first evaluate the amount of processed and collected data to control the size of cloud storage.

Que 5.3. **What are the security challenges in IoT ?**

Answer

The main security challenges in IoT are :

1. **Data confidentiality :**
   a. Insufficient authentication
   b. Insecure interfaces (web, mobile, cloud, etc.)
   c. Lack of transport encryption
   d. Confidentiality preserving
   e. Access control
2. **Privacy :**
   a. Privacy, data protection, and information security, risk management
   b. Privacy by design and default
   c. Data protection legislation
   d. Traceability/profiling/unlawful processing
3. **Trust :**
   a. Identity management system
   b. Insecure software/firmware
   c. Ensuring continuity and availability of services
   d. Realization of malicious attacks against IoT devices and system
   e. Loss of user control/difficult in making decision

PART-2

IoT Application, Smart Metering, E-health, City Automation.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.4. Write short note on smart metering.

Answer

1. A smart meter is an electronic device that records consumption of electric energy and communicates the information to the electricity supplier for monitoring and billing.
2. Smart meters record energy hourly or more frequently, and report at least daily.
3. Smart meters enable two-way communication between the meter and the central system.
4. Smart metering consist of several different technical components which may vary according to the specific market conditions in different member states, but the majority include the following features :
   a. Accurate measurement and transmission of electricity, gas, water or heat consumption data.
   b. Provision of a two-way information gateway and communication infrastructure between the meters and relevant parties and their systems, for :
      i. Raising awareness and empowering the consumer through delivery of actual consumption data.
      ii. Improving Customer Relationship Management (CRM) and services, including automated billing/invoicing based on detailed metering data.
      iii. Managing energy networks/grids better by shifting or reducing energy consumption.
      iv. Enabling new energy services for improving energy efficiency.
      v. Encouraging decentralized, micro-generation of energy, thus transforming the consumer into an energy producer ("Prosumer").

Que 5.5. What are the benefits of using smart meter ?

Answer

Benefits to consumers using smart meter are :

1. Consumers can be informed remotely (historical data) or locally (real-time data) on energy costs and carbon emissions.
2. Energy consumption of household gas, electrical and water equipment can be displayed on the appliance or on displays.
3. Multi-tariff functions can be added to allow demand response techniques.
4. It allows electrical appliances to be automatically controlled.
5. It allows the consumer to reduce costs by increasing energy consumption during off-peak cheaper tariff periods.

Benefits to utilities using smart meter are :

1. Allows to gain first-class data.
2. Influence the energy consumption of their users.
3. Improve profitability of the technology once smart metering is also used for gas, water and heat readings.
4. A reduction in 'costs to serve'.
5. Open gateways for the delivery of energy services.
6. Assistance in the development of liberalised energy market.
7. Help for revenue protection.
8. Monitoring of the generation from building renewables.
9. Support in demand response techniques.
10. More effective grid management.

Que 5.6. Write short note on e-health.

Answer

1. The Internet of Things (IoT), has an extensive applicability in numerous areas, including healthcare.
2. IoT in e-health allows medical centers to function more competently and patients to obtain better treatment.
3. With the use of this technology based healthcare method, there are unparalleled benefits which could improve the quality and efficiency of treatments and accordingly improve the health of the patients.
4. In the context of e-health, Internet of Things is of immense importance since connected data about patient would facilitate treatment with more efficiency and comprehensive knowledge.
5. Virtually storing the patient data and making it accessible to concerned healthcare personnel would be the first step towards mutual knowledge sharing.

6. Another important aspect of using this connected data is the design of an intelligent clinical decision support system which would assist the doctors in every possible way during the treatment phase.

Que 5.7. **What are the benefits of IoT in e-health ?**

Answer

Benefits of IoT in e-health :

1. **Simultaneous reporting and monitoring :**
   a. Real-time monitoring via connected devices can save lives in event of a medical emergency like heart failure, diabetes, asthma attacks, etc.
   b. With real-time monitoring of the condition in place by means of a smart medical device connected to a smart phone app, connected devices can collect medical and other required health data.
2. **End-to-end connectivity and affordability :**
   a. IoT enables interoperability, machine-to-machine communication, information exchange, and data movement that make healthcare service delivery effective.
   b. Technology-driven setup brings down the cost, by cutting down unnecessary visits, utilizing better quality resources, and improving the allocation and planning.
3. **Data assortment and analysis :**
   a. Vast amount of data that a healthcare device sends in a very short time owing to their real-time application is hard to store and manage if the access to cloud is unavailable.
   b. IoT devices can collect, report and analyse the data in real-time and cut the need to store the raw data.
4. **Tracking and alerts :**
   a. On-time alert is critical in event of life-threatening circumstances.
   b. IoT allows devices to gather vital data and transfer that data to doctors for real-time tracking, while dropping notifications to people about critical parts via mobile apps and other linked devices.
5. **Remote medical assistance :**
   a. In event of an emergency, patients can contact a doctor who is many kilometers away with a smart mobile apps.
   b. IoT will improve the patient's care in hospital. This reduces the cost of healthcare services.

Que 5.8. **Write a short note on city automation.**

Answer

1. A smart city is a city where information technology and the Internet of Things are used to manage and control the city.
2. This includes both their administration and the management of facilities such as libraries, hospitals and utilities and, the public transportation system.
3. The main aim of smart cities is to use technology, information and data to improve infrastructure and services.
4. This includes access to water, electricity, affordable homes, education, health services and IT connectivity.
5. Smart cities can improve the efficiency of city services by eliminating redundancies in finding way to save money and streamlining worker's responsibilities.

Que 5.9. Explain some IoT applications.

Answer

Following are the IoT applications :

1. **Smart metering :** Refer Q. 5.4, Page 5-5E, Unit-5.
2. **E-health :** Refer Q. 5.6, Page 5-6E, Unit-5.
3. **Smart city :** Refer Q. 5.8, Page 5-7E, Unit-5.

PART-3

Automotive Applications, Home Automation, Smart Cards, Communicating Data with H/W units, Mobiles, Tablets.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.10. What are the applications of IoT in automotive industry ?

Answer

Applications of IoT in the automotive industry are :

1. **In-vehicle infotainment :** Smart apps are being installed for vehicle infotainment systems to provide in-car navigation such as Google maps, play store and Google assistant.

2. **Predictive maintenance :**
   a. Sensors in the operational components of vehicles monitor functional metrics such as temperature, engine status, speed, electrical systems and navigation, which measure performance variables and forecast performance benchmarks.
   b. The information gathered is used to update owners with preventative and predictive maintenance alerts helping them to address issues before they arise.
3. **Security, surveillance, and safety :**
   a. External sensors are used in the form of rear-view cameras and proximity sensors that aid in blind spot detection and assist in easier parking, and safer driving.
   b. Drivers are protected because of advanced sensors that can monitor surrounding traffic patterns and the environment to ensure safe driving.
4. **Data analytics and dashboard reporting :**
   a. Connected cars offer a rich source of driver data essential to the development, testing, and prototyping of better self-driving vehicles.
   b. As more vehicles with IoT enabled systems engage with the real world, the wealth and quality of data will inevitably improve.
5. **Real-time monitoring :**
   a. IoT also allows for real-time data sharing from vehicles to manufacturers that helps in the improvement of maintenance and manufacturing processes throughout the vehicle's lifecycle.
   b. This sharing of data also helps to enhance predictive insights to allow faster response times, in case of any serious problematic issues, and make it easier for manufacturers to be accountable and proactive in case of crisis scenarios.
6. **Cognitive insights for management :**
   a. Connected cars allow manufacturers to directly and efficiently inform drivers about any problems and automate tedious tasks such as scheduling a car servicing appointment with the nearest car dealer or service center.
   b. This two-way exchange ensures that cars are regularly serviced in an autonomous fashion with little inconvenience to the user.

Que 5.11. Explain home automation with its benefits.

Answer

1. Home automation means to control item around the house with the help of IoT.
2. Home automation (domotics) is building automation for home called smart home.

Benefits of IoT in home automation :

1. **Savings :**
   a. Smart thermostats and smart light bulbs save energy, cutting utility costs over time.
   b. Some home automation technologies monitor water usage, helping to prevent excessive water bills.
2. **Safety :**
   a. Many home automation technologies fall under the umbrella of home security.
   b. Consumers purchase these devices because they want to make their homes safer and more secure.
   c. Motion sensors help people enter doors and walk hallways late at night.
3. **Convenience :**
   a. Home automation technology performs rote (repetitive) tasks automatically, end users experience great convenience.
   b. Lots of smart gadgets are compatible with one another, and we can set different triggers between devices to automate regular home processes.
   c. For instance, we could set our smart locks to turn on our smart lighting when we unlock the front door.
4. **Control :**
   a. Consumers also choose smart home devices to better control functions within the home.
   b. With home automation technology, we can know what is happening inside our home at all times.
5. **Comfort :**
   a. Some people use smart technology to record shows or to play music throughout the home.
   b. Connected devices can also help to create a comfortable atmosphere, they provide intelligent and adaptive lighting, sound, and temperature, which can help to create an inviting environment.

Que 5.12. Explain smart card with its working.

Answer

1. A smart card is a physical card that has an embedded integrated chip that acts as a security token.
2. Smart cards are typically the same size as a driver's license or credit card and can be made out of metal or plastic.

3. They connect to a reader either by direct physical contact (also known as chip or through a short-range wireless connectivity standard such as Radio Frequency Identification (RFID) or Near-Field Communication (NFC).
4. The chip on a smart card can be either a microcontroller or an embedded memory chip.
5. Smart cards are designed to be tamper-resistant and use encryption to provide protection for in-memory information.
6. Smart cards are used for a variety of applications, and commonly used for credit cards and other payment cards.

Working of smart card :

1. Smart card microprocessors or memory chips exchange data with card readers and other systems over a serial interface.
2. The smart card itself is powered by an external source, usually the smart card reader.
3. A smart card communicates with readers either via direct physical contact or using a short-range wireless connectivity standard such as RFID or NFC.
4. The card reader then passes data from the smart card to its intended destination, usually a payment or authentication system connected to the smart card reader over a network connection.

Que 5.13. Discuss briefly different types of smart cards.

Answer

Different types of smart cards :

1. **Contact smart cards :**
   a. Contact smart cards are inserted into a smart card reader that has a direct connection to a conductive contact plate on the surface of the card.
   b. Commands, data and card status are transmitted over these physical contact points.
2. **Contactless smart cards :**
   a. Contactless smart cards require only close proximity to a card reader to be read; no direct contact is necessary for the card to function.
   b. The card and the reader are both equipped with antenna and communicate using radio frequencies over the contactless link.
3. **Dual-interface cards :**
   a. Dual-interface cards are equipped with both contactless and contact interfaces.
   b. This type of card enables secure access to the smart cards chip.

4. **Memory smart cards :**
   a. Memory smart card contains memory chips only and can only store, read and write data to the chip.
   b. The data on memory smart cards can be over-written or modified.
   c. Memory smart cards can be read-only and used to store data such as a PIN, password or public key; they can also be read-write and used to write or update user data.
5. **Microprocessor smart cards :**
   a. Microprocessor smart cards have a microprocessor embedded onto the chip in addition to memory blocks.
   b. A microprocessor card may also incorporate specific sections of files where each file is associated with a specific function.
   c. The data in the files and the memory allocation are managed with a smart card operating system.

Que 5.14. Explain the block diagram of IoT device hardware.

Answer

Block diagram of IoT device hardware :

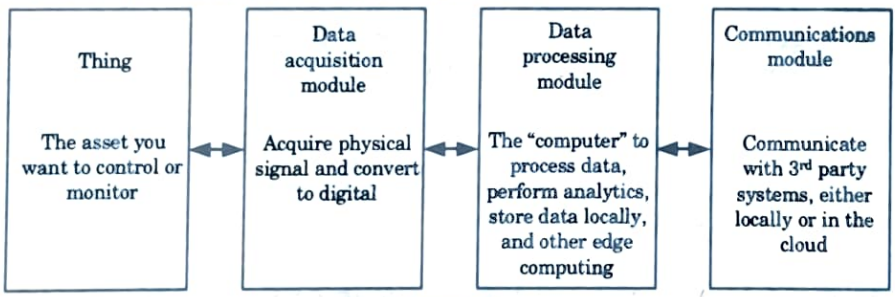

Fig. 5.14.1.

1. **Thing :**
   a. Thing is defined as the asset that we want to control or monitor.
   b. In many IoT products, the "thing" is fully integrated into the smart device.
   c. For example, think of products like a smart water pump or an autonomous vehicle. These products control and monitor themselves.
2. **Data acquisition module :**
   a. The data acquisition module focuses on acquiring physical signals from the "thing" and converting them into digital signals that can be manipulated by a computer.
   b. This is the hardware component that includes all the sensors acquiring real-world signals such as temperature, motion, light, vibration, etc. The type and number of sensors we need depend on our application.

c. The data acquisition module also includes the necessary hardware to convert the sensor signal into digital information for the computer to use. This includes signal conditioning, analog-to-digital conversion, scaling, and interpretation.

3. **Data processing module :**
   a. The third building block of the device is the data processing module.
   b. This is the "computer" that processes the data, performs local analytics, stores data locally, and performs any other computing operations at the edge.
   c. The two most important considerations to focus on are :
      i. Processing power (*i.e.*, how much processing will we do at the edge?)
      ii. Amount of local data storage (*i.e.*, hard drive size - how much data will we need to store at the edge?)

4. **Communications module :**
   a. This is the circuitry that enables communications with our cloud platform and with third party systems either locally or in the cloud.
   b. This module may include communication ports such as USB, serial (232/485), CAN, or Modbus, to name a few.
   c. The communications module can be included in the same device as our other modules, or it could be a separate device that is specifically for communications. This approach is often referred to as "gateway architecture".
   d. It may also include the radio technology for wireless communications such as Wi-Fi, LoRA, ZigBee, etc.

Que 5.15. How connectivity or communication between various hardware unit is achieved in IoT ?

Answer

Connectivity or communication between various hardware unit in IoT is achieved by using following wireless communication protocols :

1. **Satellite :**
   a. Satellite communications enable cell phone communication from a phone to the next antenna of about 10 to 15 miles.
   b. They are called GSM, GPRS, CDMA, GPRS, 2G / GSM, 3G, 4G / LTE, EDGE and others based on connectivity speed.
   c. In Internet of Things language, this form of communication is mostly referred to as "M2M" (Machine-to-Machine) because it allows devices such as a phone to send and receive data through the cell network.

2. **Wi-Fi :**
   a. Wi-Fi is a Wireless Local Area Network (WLAN) that utilizes the IEEE 802.11 standard through 2.4 GHz UHF and 5 GHz ISM frequencies.
   b. Wi-Fi provides Internet access to devices that are within the range (about 66 feet from access point).
3. **Radio Frequency (RF) :**
   a. Radio frequency communications are probably the easiest form of communications between devices.
   b. Protocols like ZigBee or ZWave use a low-power RF radio embedded into electronic devices and systems.
4. **RFID :** Refer Q.2.7, Page 2-6E, Unit-2.
5. **Bluetooth :**
   a. Bluetooth is a wireless technology standard for exchanging data over short distances.
   b. Bluetooth exists in many products, such as telephones, tablets, media players, robotics systems.
   c. The technology is extremely useful when transferring information between two or more devices that are near each other in low-bandwidth situations.

PART-4

Designing of Smart Street Lights in Smart Cities.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.16. Write short note on smart street lighting.

Answer

1. A smart street lighting system is a system that adjusts light output based on usage and occupancy.
2. A smart street light management proposes the installation of the wireless based system to remotely track and control the actual energy consumption of the street lights and take appropriate energy consumption reduction measures through power conditioning and control.
3. A smart street lighting system can cut municipal street lighting costs by as much as 50 % to 70 %.

4. The street light controller installed on the street light pole will control LED Street lighting depending on traffic flow, communicate data between each street light.
5. The data from the street light controller can be transferred to base station using wireless technology to monitor the system.
6. The mode of operation of the system can be conducted using auto mode and manual mode.
7. The control system will switch on-off the lights at required timings and can also vary the intensity of the street light according to requirement.

Que 5.17. Explain the block diagram of design of smart street light system in smart city.

Answer

Block diagram of street light system :

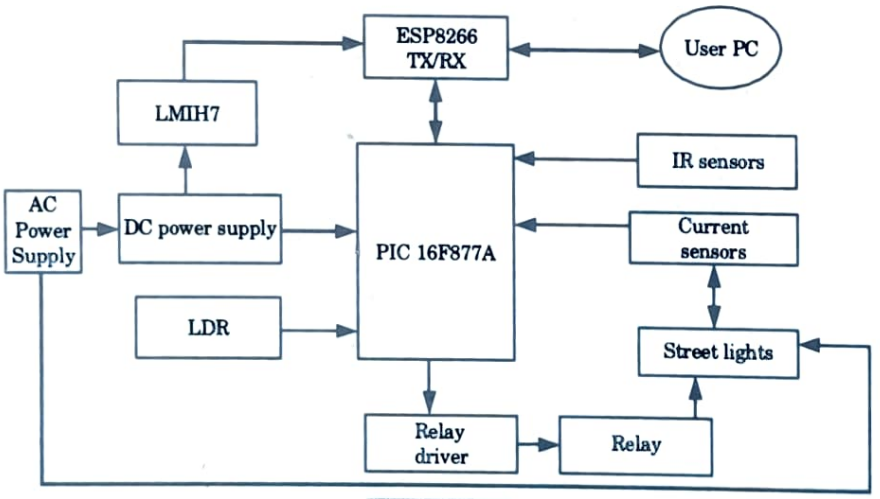

Fig. 5.17.1.

The working principle of "Design of a street light system in a smart city" is divided into six units :

1. **Sensor circuit :**
   a. It detects the environmental light to assume whether it is day or night (or evening).
   b. This unit is having two sensors. The 1st sensor to detect sunlight and the 2nd sensor to identify the LED panel is working or not.
2. **8-bit microcontroller :**
   a. It is responsible for monitoring the status of the 1st Light Dependent Resistors (LDR) *i.e.*, whether the environment is having enough sunlight or not.
   b. If it has enough sunlight it will do nothing but if the sunlight is low the microcontroller triggers the next unit.

3. **Relay driver :**
   a. The relay which is controlled by designated I/O pin of the microcontroller.
   b. If there is no sunlight, it activates the relay driver circuit designed with NPN transistor 2N2222. This transistor collector is connected to 1st terminal of relay and the other terminal of the relay is connected to +12V.
   c. When the relay is energized, the mechanical switch in the relay allows to pass current to the LED unit.
4. **LED panel mode :**
   a. It is of 6×8 matrix. The size of the panel can be increased by adding more LEDs.
   b. The panel can be controlled by solid state relay.
   c. When the microcontroller activates the LED panel, the second LDR detect the light from the panel if the second LDR is getting enough panel if the second LDR is getting enough light the system assumes that panel is working properly but if the panel is not working (2nd LDR is not getting enough light).
   d. The microcontroller transmits information to the web server through the ESP8266 unit.
5. **ESP8266 :** This is a Wi-Fi modem based on ESP8266, microcontroller is communicating ESP8266 through the serial communication.
6. **Web server :**
   a. The transmitted data is handled by web server.
   b. ESP8266 itself is using web server, ESP8266 is used here as client, so that it can transmitted the data to web server and we do not have to number any IP address of the ESP8266.
   c. All devices will communicate with a single web server.
   d. In the web server unit it has a set of web pages through which we can monitor and configure the street light.

Que 5.18. Explain the task done by control and monitoring services for city street light ?

Answer

A control and monitoring service for city street lights does the following tasks :

1. Measures and monitors the street lights and measures traffic parameters in real-time at present intervals.
2. Each WSN is uploaded by the program for configuring and communication within the WSN network.

3. The network connects a coordinator which deploys the data adaption, store, time, locations, IDs stamping and gateway interfaces.
4. Communicates the WSN network messages.
5. Messages transmit at the preset intervals to the access point, which connects a coordinator.
6. Coordinator generates and communicates alerts, triggers, messages and data after aggregating, compacting and processing at data adaptation layer.
7. Coordinator creates and updates a database in real-time which transfers to the cloud for processing and for cloud data store.
8. Uses the OTP features and uploads the programs at the WSNs and gateways. An OTP module at the cloud node provides OTP management and uploads connectivity programs for gateways.
9. Integrates data, and activates the alerts and triggers.
10. Cloud node provides platform for processes, analyses and visualisation of the data and database information. The node provides analytics and AI for optimising monitoring and control functions.