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DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING

SEMESTER-6TH SEM CSE

Lecture Note On

INTERNET OF THINGS

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UNIT-1

IntroductiontoInternetof Things

Internetofthings(IoT)

The Internet of things (IoT) is the inter-networking of physical devices, vehicles (alsoreferredtoas“connecteddevices”and“smartdevices”),buildings,andotheritems embedded with electronics, software, sensors, actuators, and network connectivity which enable these objects to collect and exchange data.

Characteristics:

Things-related services: The IoT is capable of providing thing-related services within the constraintsofthings,suchasprivacyprotectionandsemanticconsistencybetweenphysical things and their associated virtual things

Connectivity: ThingsinI.O.T.shouldbeconnectedtotheinfrastructure,withoutconnection nothing makes sense.

Intelligence:Extractionofknowledgefromthegenerateddataisimportant,sensorgenerate data and this data and this data should be interpreted properly.

Scalability: Theno.ofthingsgettingconnectedtotheI.O.T.infrastructureisincreasedday by day. Hence, an IOT setup shall be able to handle the massive expansion.

UniqueIdentity:EachIOTdevicehasanI.P.address.Thisidentityishelpfulintrackingthe equipment and at times to query its status.

Dynamic and Self-Adapting: The IOT device must dynamically adopt itself to the changingcontext.Assumeacamerameantforsurveillance,itmayhavetoworkindifferent conditions and at different light situations (morning, afternoon, night).

Heterogeneity:ThedevicesintheIoTareheterogeneousasbasedondifferenthardware platforms and networks. They can interact with other devices different networks.

Safety:HavinggotallthethingsconnectedwiththeInternetpossessamajorthreat,asour personal data is also there and it can be tampered with, if proper safety measures are not taken.

Applicationareasof IoT:

Smart Home: The smart home is one of the most popular applications of IoT. The cost of owningahouseisthebiggestexpenseinahomeowner’slife.Smarthomesarepromisedto save the time, money and energy.

Smart cities: The smart city is another powerful application of IoT. It includes smart surveillance,environmentmonitoring,automatedtransformation,urbansecurity,smarttraffic management, water distribution, smart healthcare etc.

Wearables:Wearablesaredevicesthathavesensorsandsoftwareinstalledwhichcancollect data about the user which can be later used to get the insights about the user. They must be energy efficient and small sized.

Connectedcars: Aconnectedcarisabletooptimizeitsownoperation,maintenanceaswell as passenger's comfort using sensors and internet connectivity.

Smartretail: Retailerscanenhancethein-storeexperienceofthecustomersusingIoT.The shopkeeper can also know which items are frequently bought together using IoT devices.

Smarthealthcare: PeoplecanweartheIoTdeviceswhichwillcollectdataaboutuser's health. This will help users to analyze themselves and follow tailor-made techniques to combat illness. The doctor also doesn't have to visit the patients in order to treat them.

IoT Categories

IOTcan beclassifiedinto twocategories:

1. Consumer IoT(CIOT): The Consumer IoT refers to the billions of physical personal devices,suchassmartphones,wearables,fashionitemsandthegrowingnumberofsmart home appliances, that are now connected to the internet, collecting and sharing data.

AConsumerIoTnetworktypicallyentailsfewconsumerdevices,eachofwhichhasa limited lifetime of several years.

The common connectivity used in this kind of solutions are Bluetooth, WiFi, and ZigBee. Thesetechnologiesoffershort-rangecommunication,suitableforapplicationsdeployedin limited spaces such as houses, or small offices.

2. industrialinternetofthings(IIoT):Itreferstointerconnectedsensors,instruments,and other devices networked together with computers' industrial applications, including manufacturing and energy management. This connectivity allows for data collection, exchange,andanalysis,potentiallyfacilitatingimprovementsinproductivityandefficiency as well as another economic ben.

BASELINE TECHNOLOGIES

TherearevariousbaselinetechnologiesthatareverycloselyrelatedtoIOT,Theyinclude: Machine-to-Machine (M2M), Cyber-Physical Systems (CPS), Web Of Things (WOT)

a) Machine-to-Machine(M2M):

- Machine-to-Machine(M2M)referstonetworkingofmachines(ordevices)forthe purpose of remote monitoring and control and data exchange.
- An M2M area network comprises of machines (or M2M nodes) which have embedded network modules for sensing, actuation and communicating various communication protocols can be used forM2M LAN such as ZigBee, Bluetooth, M-bus,WirelessM-Busetc.,Theseprotocolsprovideconnectivitybetween M2Mnodes within an M2M area network.
- ThecommunicationnetworkprovidesconnectivitytoremoteM2Mareanetworks. The communication network provides connectivity to remote M2M area network.
- Thecommunication network can use either wired or wireless network (IP based). WhiletheM2Marenetworksuseeitherproprietaryornon-IPbasedcommunication protocols, the communication network uses IP-based network. Since non-IP based

protocolsareusedwithinM2Mareanetwork,theM2Mnodeswithinonenetwork cannot communicate with nodes in an external network.

- ToenablethecommunicationbetweenremoteM2Marenetwork,M2Mgateways are used

b) Cyber-Physicalsystems:

Cyber-Physical Systems (CPS) are integrations of computation, networking, and physical processes.Embeddedcomputersandnetworksmonitorandcontrolthephysicalprocesses, with feedback loops where physical processes affect computations and vice versa.

Incyber-physicalsystems,physicalandsoftwarecomponentsaredeeplyintertwined,ableto operate on different spatial and temporal scales, exhibit multiple and distinct behavioural modalities, and interact with each other in ways that change with context.

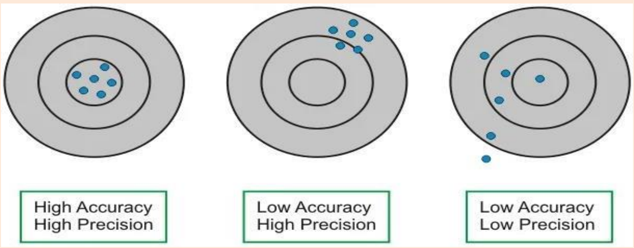
c) **WebofThings**:webofthingsisatermusedtodescribeapproaches,softwarearchitectural style of programming patterns that allow real world objects to be part of WWW.The major portion of the WoT specification is the Thing Description. Thing is an abstract representation of a physical or virtual entity. A Thing Description includes the metadata and interfaces of a Thing in a standardized way, with the aim to make the Thing able to communicate with other Things in a heterogeneous world.

SENSOR

Sensor is a device used for the conversion of physical events or characteristics into the electrical signals. This is a hardware device that takes the input from environment and gives to the system by converting it.
For example, a thermometer takes the temperature as physical characteristic and then converts it into electrical signals for the system.

Characteristicsof Sensors

1. Range: Itistheminimumandmaximumvalueofphysicalvariablethatthesensorcan sense or measure. For example, a Resistance Temperature Detector (RTD) for the measurement of temperature has a range of -200 to 800^{o}C.
2. Span: Itisthedifferencebetweenthemaximumandminimumvaluesofinput.Inabove example, the span of RTD is 800 – (-200) = 1000^{o}C.
3. Accuracy: Theerrorinmeasurementisspecifiedintermsofaccuracy. Itisdefinedasthe differencebetweenmeasuredvalueandtruevalue.Itisdefinedintermsof%offullscaleor %of reading.
4. Precision: Itisdefinedastheclosenessamongasetofvalues.Itisdifferentfrom accuracy.



5. Linearity: Linearityisthemaximumdeviationbetweenthemeasuredvaluesofasensor from ideal curve.

6. Hysteresis: Itisthedifferenceinoutputwheninputisvariedin twoways-increasingand decreasing.

7. Resolution: Itisthe minimumchangein inputthatcanbesensedbythesensor.
8. Reproducibility: Itisdefinedastheabilityofsensortoproducethesameoutputwhen same input is applied.
9. Repeatability: Itisdefinedastheabilityofsensortoproducethesameoutputeverytime when the same input is applied and all the physical and measurement conditions kept the same including the operator, instrument, ambient conditions etc.
10. Response Time: It is generally expressed as the time at which the output reaches a certainpercentage(forinstance,95%)ofitsfinalvalue,inresponsetoastepchangeofthe input.

<u>Classificationofsensors:</u>

Sensorsbasedonthepowerrequirementsensorisclassifiedintotwotypes:ActiveSensors, Passive Sensors.

ActiveSensors: Doesnotneedanyexternalenergysourcebutdirectlygeneratesanelectric signal in response to the external.

Example:Thermocouple,Photodiode,Piezoelectricsensor.

PassiveSensors: Thesensorsrequireexternalpowercalledexcitationsignal.Sensorsmodify the excitation signal to provide output.

Example:Strain gauge.

Sensorsbasedon outputsensoris classifiedinto twotypes:Analog Sensors,Digital Sensors.

Analog Sensors

- AnalogSensorsproducesacontinuousoutputsignalorvoltagewhichisgenerally proportional to the quantity being measured.
- PhysicalquantitiessuchasTemperature,speed,Pressure,Displacement,Strainetc. are all analog quantities as they tend to be continuous in nature.
- For example, the temperature of a liquid can be measured using a thermometer or thermocouple(e.g.ingeysers)whichcontinuouslyrespondstotemperaturechanges as the liquid is heated up or cooled down.

Digital Sensors

- DigitalSensorsproducediscreteoutputvoltagesthatareadigitalrepresentationofthe quantity being measured.
- Digitalsensors produce abinaryoutput signalin theformofalogic"1" or alogic"0" ,("ON"or "OFF").

- Digitalsignalonlyproducesdiscrete(non-continuous)values,whichmaybeoutputas a signal "bit" (serial transmission), or by combing the bits to produce a signal "byte" output (parallel transmission).

Basedontypeofdatameasuredsensorisclassifiedintotwotypes:ScalarSensorsand Vector Sensors.

ScalarSensors

- ScalarSensorsproduceoutputsignalorvoltagewhichgenerallyproportionaltothe magnitude of the quantity being measured.
- Physicalquantitiessuchastemperature,color,pressure,strain,etc.areallscalar quantities as only their magnitude is sufficient to convey an information.
- For example, the temperature of a room can be measured using thermometer or thermocouple,whichrespondstotemperaturechangesirrespectiveoftheorientation of the sensor or its direction.

VectorSensors

- VectorSensorsproduceoutputsignalorvoltagewhichgenerallyproportionaltothe magnitude, direction, as well as the orientation of the quantity being measured.
- Physical quantities such as sound, image, velocity, acceleration, orientation, etc. are allvectorquantities,asonlytheirmagnitudeisnotsufficienttoconveythecomplete information.
- Forexample,theaccelerationofabodycanbemeasuredusinganaccelerometer, which gives the components of acceleration of the body with respect to the x,y,z coordinate axes.

ACTUATOR

Actuator is a device that converts the electrical signals into the physical events or characteristics.Ittakestheinputfromthesystemandgivesoutputtotheenvironment. For example, motors and heaters are some of the commonly used actuators.

Typesof Actuators

1. Hydraulic Actuators: Hydraulic actuators operate by the use of a fluid-filled cylinderwith a piston suspended at the centre. Commonly, hydraulic actuators produce linear movements,andaspringisattachedtooneendasapartofthereturnmotion.Theseactuators are widely seen in exercise equipment such as steppers or car transport carriers.

2. Pneumatic Actuators: Pneumatic actuators are one of the most reliable options for machine motion. They use pressurized gases to create mechanical movement. Many companies prefer pneumatic-powered actuators because they can make very precise motions, especiallywhenstartingandstoppingamachine.Examplesofequipmentthatusespneumatic actuators include: Bus brakes, Exercise machines, Vane motors, Pressure sensors

3. ElectricActuators: Electricalactuators,asyoumayhaveguessed,requireelectricityto work.Well-knownexamplesincludeelectriccars,manufacturingmachinery,androbotics equipment.Similartopneumaticactuators,theyalsocreateprecisemotionastheflowof electrical power is constant.

4. ThermalandMagneticActuators: Thermalandmagneticactuatorsusuallyconsistof shape memory alloys that can be heated to produce movement. The motion of thermal or magneticactuators often comes from the Joule effect, but it can also occur when acoil is placed in a static magnetic field. The magnetic field causes constant motion called the Laplace-Lorentz force. Most thermal and magnetic actuators can produce a wide and powerful range of motion while remaining lightweight.

5. MechanicalActuators: Someactuatorsaremostlymechanical,suchaspulleysorrack and pinion systems. Another mechanical force is applied, such as pulling or pushing, and the actuator will leverage that single movement to produce the desired results. For instance, turningasinglegearonasetofrack andpinionscanmobilizeanobjectfrompointAtopoint B.Thetuggingmovementappliedonthepulleycanbringtheothersideupwardsortowards the desired location.

6. SoftActuators: Softactuators(e.g.,polymerbased)aredesignedtohandlefragileobjects like fruit harvesting in agriculture or manipulating the internal organs in biomedicine.

Theytypicallyaddresschallengingtasksinrobotics.Softactuatorsproduceflexiblemotion due to the integration of microscopic changes at the molecular level into a macroscopic deformation of the actuator materials.

IOTCOMPONENTS

Fourfundamentalcomponentsof IoTsystem, whichtellsushow IoTworks.

i. Sensors/Devices

First, sensors or devices help in collecting very minute data from the surrounding environment.Allofthiscollecteddatacanhavevariousdegreesofcomplexitiesrangingfrom a simple temperature monitoring sensor or a complex full video feed.

Adevicecanhavemultiplesensorsthatcanbundletogethertodomorethanjustsense things. For example, our phone is a device that has multiple sensors such as GPS, accelerometer, camera but our phone does not simply sense things.

ii. Connectivity

Next,thatcollected data is sentto acloudinfrastructurebutit needsamediumfor transport.

The sensors can be connected to the cloud through various mediums of communication and transportssuchascellularnetworks,satellitenetworks,Wi-Fi,Bluetooth,wide-areanetworks (WAN), low power wide area network and many more.

iii. DataProcessing

Oncethedataiscollectedanditgetstothecloud,thesoftwareperformsprocessingonthe acquired data.

Thiscanrangefromsomethingverysimple,suchascheckingthatthetemperaturereadingon devices such as AC or heaters is within an acceptable range. It can sometimes also be very complex, such as identifying objects (such as intruders in your house) using computer vision on video.

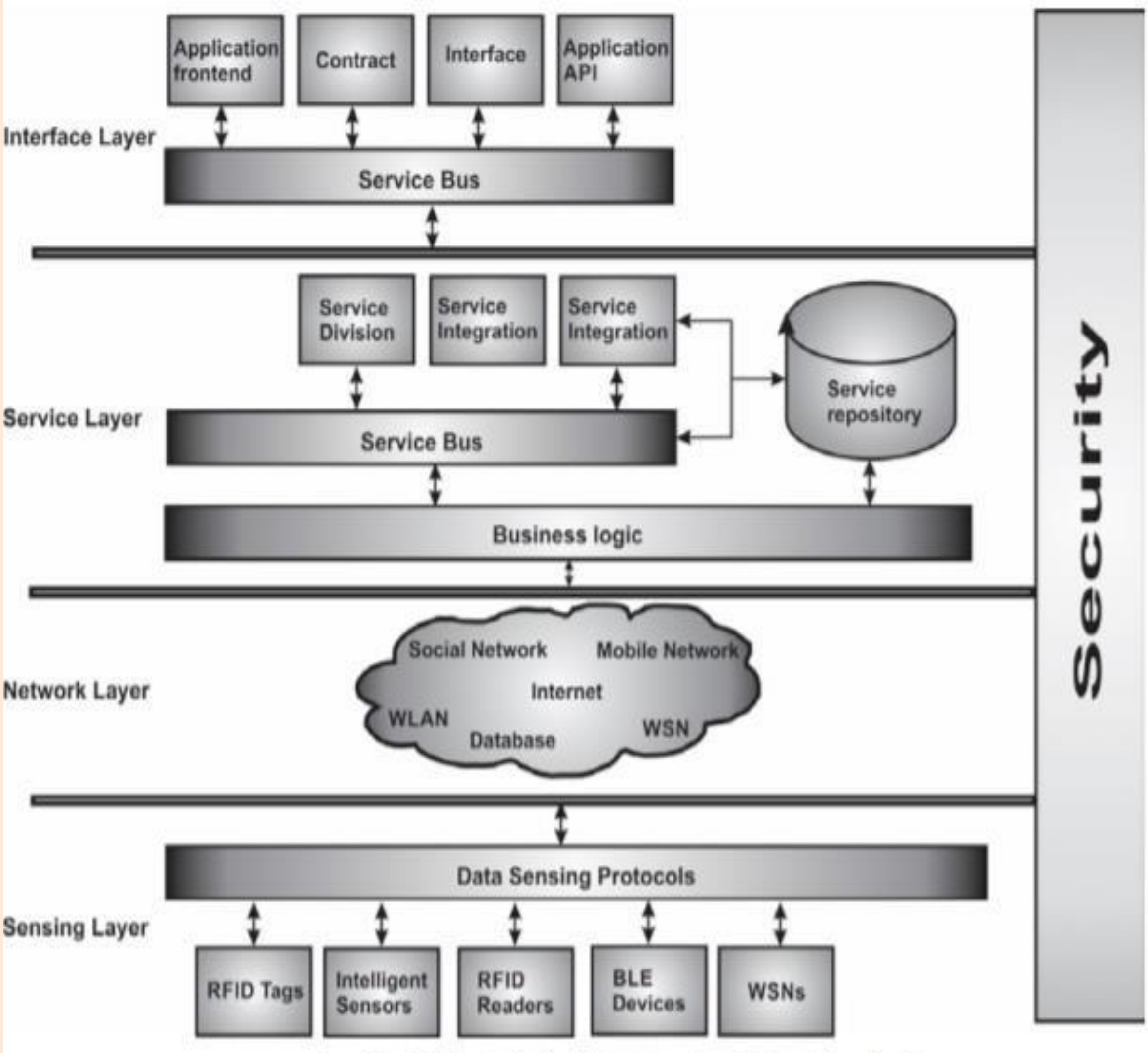
iv. User Interface

Next,theinformationmadeavailabletotheend-userinsomeway.Thiscanachieveby triggering alarms on their phones or notifying through texts or emails.

Also,ausersometimesmightalsohaveaninterfacethroughwhichtheycanactivelycheckin on their IOT system. For example, a user has a camera installed in his house, he might want to check the video recordings and all the feeds through a web server.

ServiceOriented ArchitectureofIoT

SOAcanalsousetosupportIoTasamaincontributingtechnologyindevicesor heterogeneous systems.



Service-Oriented Architecture for IoT technologies.

1. SensingLayer: IoTcanbedefinedasaworldwideinterconnectednetwork,wherethings or devises are controlled remotely. Interconnected things or devices are become easier, as more and more things are furnished with sensors and RFID technologies.

2. Networking Layer: Networking Layer is responsible to connect all device or things together so that they can able to share the information with each other over the Internet. Moreover,networklayeralsocollectsdataandinformationfromthepresentITinfrastructure for example ICT systems, power grids, business systems, healthcare systems, and transportation systems.

3. Service Layer: This layer depends upon the technology used on the middleware layer whichisresponsibleforfunctionalitiesincorporatebetweenapplicationsandservicesinIoT. Thismiddlewaretechnologyalsoprovidesacost-effectiveandefficientplatformforIoTand this platform including software and hardware components which can be reused when needed.

4. Interface Layer: The core responsibility of the interface layer has also simplified the interconnectionandmanagementofthings.Interfacespecificprofilecanbedefinedasthe subset of services that support interaction with the application used in a network

ChallengesforIoT

1. Security: SecurityisthemostsignificantchallengefortheIoT.Increasingthenumberof connected devices increases the opportunity to exploit security vulnerabilities, as do poorly designed devices, which can expose user data to theft by leaving data streams inadequately protected and in some cases people’s health and safetycan be put at risk.

2. Privacy: The IoT creates unique challenges to privacy, many that go beyond the data privacy issues that currently exist. Much of this stems from integrating devices into our environments without us consciously using them. This is becoming more prevalent in consumerdevices,suchastrackingdevicesforphonesandcarsaswellassmarttelevisions.

3. Scalability: Billions of internet-enabled devices get connected in ahuge network, large volumesofdataareneededtobeprocessed.Thesystemthatstores,analysesthedatafrom these IoT devices needs to be scalable.

4. Interoperability: Technological standards in most areas are still fragmented. These technologies need to be converged. Which would help us in establishing a common framework and the standard for the IoT devices. As the standardization process is still lacking,interoperabilityofIoTwithlegacydevicesshouldbeconsideredcritical.Thislackof interoperability is preventing us to move towards the vision of truly connected everyday interoperable smart objects.

5. Bandwidth: Connectivity is a bigger challenge to the IoT than you might expect. As the size of the IoT market grows exponentially, some experts are concerned that bandwidth-intensiveIoTapplicationssuchasvideostreamingwillsoonstruggleforspaceontheIoT’s current server-client model.

6. Standards: Lack of standards and documented best practices have a greater impact than just limiting the potential of IoT devices. Without standards to guide manufacturers, developerssometimesdesignproductsthatoperateindisruptivewaysontheInternetwithout much regard to their impact. If poorly designed and configured, such devices can have negativeconsequencesforthenetworkingresourcestheyconnecttoandthebroaderInternet.

7. Regulation: The lack of strong IoT regulations is a big part of why the IoT remains a severe security risk, and the problem is likely to get worse as the potential attack surface expandstoincludeevermorecrucialdevices.Whenmedicaldevices,carsandchildren’stoys are all connected to the Internet, it’s not hard to imagine many potential disaster scenarios unfolding in the absence of sufficient regulation

UNIT-2

IOTNetworking

ConnectivityTerminologies

IoTNode: ThesearemachinesthingsorcomputersConnectedtoothernodesinsideaLAN via the IoT LAN, May be sometimes connected to the internet through a WAN directly

IoTLAN: ItisLocal,ShortrangeComm,Mayormaynotconnecttolnternet,Buildingor Organization wide

IoTWAN: Connectionofvariousnetworksegments,Organizationallyandgeographically wide, Connects to the internet

IoTGateway: ArouterconnectingtheIoTLANtoaWANtotheInternet,canimplement several LAN and WAN, Forwards packets between LAN and WAN on the IP layer

IoTProxy:PerformsactiveapplicationlayerfunctionsbetweenIoTnodesandotherentities

GatewayPrefixAllotment:

- One of the strategies of address conservation in IoT is to use local addresses which existuniquelywithinthedomainofthegateway.Thesearerepresentedbythecircles in this slide.
- Thenetworkconnectedtotheinternethasrouterswiththeirsetofaddressesand ranges.
- These routers have multiple gateways connected to them which can forward packets fromthenodes,totheInternet,onlyviatheserouters.Theseroutersassignprefixesto gateways under them, so that the gateways can be identified with them.

ImpactofMobility on Addressing

- Thenetworkprefixchangesfrom1to2duetomovement,makingtheIoTLANsafe from changes due to movements.
- IoTgatewayWANaddresschangeswithoutchangeinLANaddress.Thisisachieved using ULA.
- Thegatewaysassignedwithprefixes,whichareattachedtoaremoteanchorpointby using various protocols such as Mobile IPv6, and areimmuneto changes of network prefixes.
- This is achieved using LU. The address of the nodes within the gateways remains unchangedasthegatewaysprovidethemwithlocallyuniqueaddressandthechange in gateway's network prefix doesn't affect them.
- Sometimes,thereisaneedforthenodestocommunicatedirectlytotheinternet.This is achieved by tunnelling, where the nodes communicate to a remote anchor point instead of channelling theirpackets through the router which is achieved by using tunnellingprotocols such as IKEv2:internet key exchange version 2

Multihoming

Multihoming is the practice of connecting a host or a computer network to more than one network.Thiscanbedoneinordertoincreasereliabilityorperformanceortoreducecost. There are several different ways to perform multihoming.

Host multihoming

Asinglehostmaybeconnectedtomultiplenetworks.Forexample,amobilephonemightbe simultaneously connected to a WiFi network and a 3G network, and a desktop computer might be connected to both a home network and a VPN. A multihomed host usually is assigned multiple addresses, one per connected network.

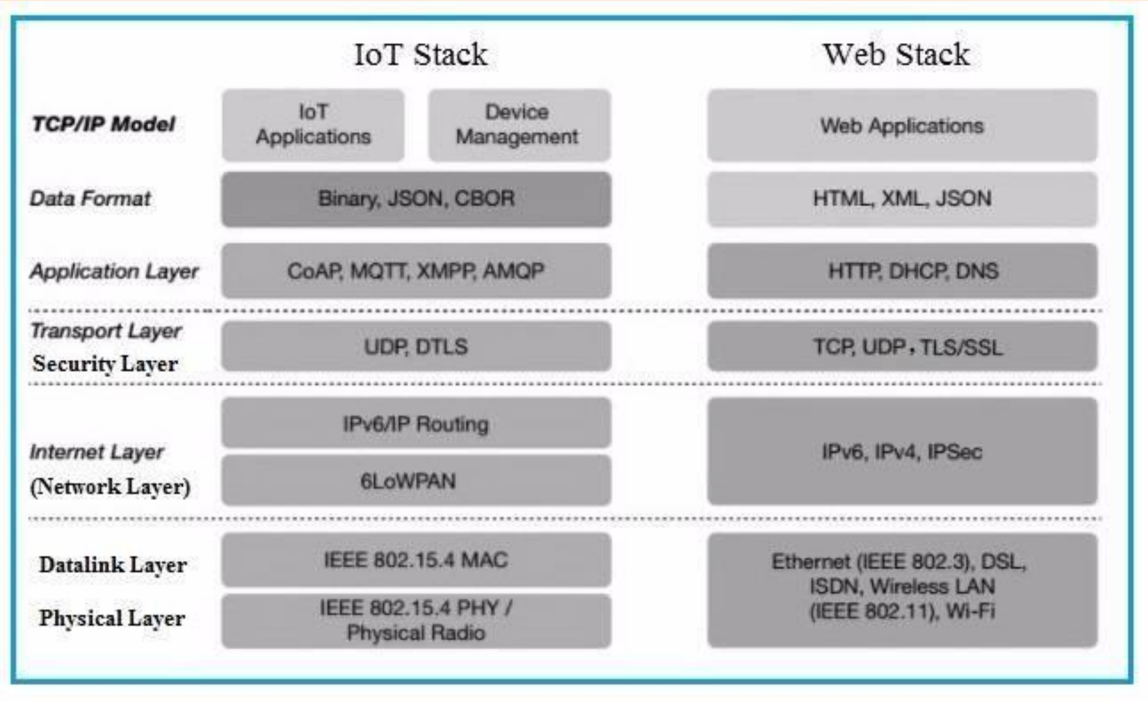
Classicalmultihoming

Inclassicalmultihominganetworkisconnectedtomultipleproviders,andusesitsownrange of addresses (typically from a Provider Independent (PI) range). The network's edge routers communicate with the providers using a dynamic routing protocol, typically BGP, which announces the network's address range to all providers. If one of the links fails, the dynamic routingprotocolrecognizesthefailurewithinsecondsorminutes,andreconfiguresitsrouting tables to use the remaining links, transparently to the hosts.

Multihomingwithmultipleaddresses

In this approach, the network is connected to multiple providers, and assigned multiple addressranges,oneforeachprovider.Hostsareassignedmultipleaddresses,oneforeach provider.

DeviationfromregularWeb



Features	IoTStack	Web Stack
Functionor application	Itisusedinconstrainednetworkhavinglowpower, low bandwidth and low memory requirements.	Itisusedinnon-constrained networkhavingnolimitson power/BW/memory.
Sizeofdatato betransported	tens ofbytes	hundredsorthousandsofbytes
Data format	It uses CBOR (Concise Binary Object Representation) format as IoT is used for tiny messages. CBOR is based on JSON though CBOR usesbinaryencodingwhileJSONusestextencoding.	ItusesHTML,XMLandJSON formats.
Application Layer	ItusesCoAPprotocol atapplicationlayer.	ItusesHTTPprotocolat application layer.
Transport layer	ItusesUDPwhichisfasterduetosmallerheadersize compare to TCP. It is lighter protocol compare to TCP.	ItusesTCPwhichisconnection oriented and slower compare to UDP.
Security layer	ItusesDTLS(DatagramTransportLayerSecurity) protocol for security.	ItusesTLS/SSLprotocolsforthe same.
Internetlayer	Ituses6LoWPANtoconvertlargeIPv6packetsinto small size packets to be carried on wireless medium as per bluetooth, zigbee etc. standards. It does fragmentation and reassembly. It also does header compression to reduce packet size.	Itdoesnotrequireprotocolslike 6LoWPAN. Fragmentation and reassembly is taken care by transport layer (i.e. TCP) itself.
Datalinkor MAC layer	It will have MAC layer as per IoT wireless technologyusedviz.bluetooth,zigbee,zwaveetc.It takes care of medium access control and resource allocation and management.	It will have MAC layer as per LANorWLANorDSLorISDN technologies.
Physical layer and Radio Frequency(RF) layer	It will have physical layer (baseband) as per IoT wirelesstechnologiesviz.bluetooth,zigbee,zwave etc. It uses frequencies as per cellular or indoor wirelesstechnologies andcountrywideallocations for the same.	It will have PHY layer as per LANorWLANorDSLorISDN technologies.

IoTidentificationandDataprotocolsIPv4:

IPversionfouraddressesare32-bitintegerswhichwillbeexpressedindotteddecimal notation. Example-192.0.2.126couldbeanIPv4 address.

CharacteristicsofIPv4

- IPv4couldbea32-BitIPAddress.
- IPv4couldbeanumeric address, andits bitsareseparated byadot.
- Thenumberofheader fieldsis twelveand thelength ofthe headerfield is twenty.
- Ithas Unicast,broadcast,andmulticaststyleofaddresses.
- IPv4supportsVLSM(VirtualLengthSubnet Mask).
- IPv4uses thePost AddressResolutionProtocol tomapto theMAC address.
- RIPmay bearouting protocolsupported bythe routed daemon.
- Networksoughttobedesignedeithermanuallyor with DHCP.
- Packetfragmentationpermitsfromroutersandcausing host.

IPv4Datagram Header

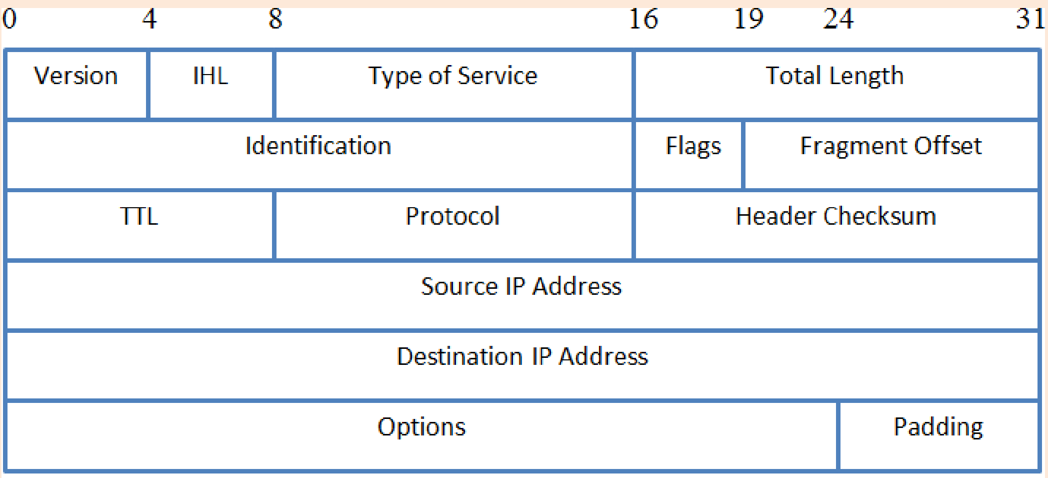


Fig: IPv4 Frame Format

Version:

Thisfieldindicatestheversionnumberofthe IPpacketsothattherevisedversioncanbe distinguished from the previous version. The current IP version is 4.

InternetHeaderLength (IIHL):

It specifies the length of the IP header in unit 32 bits. In case of no option present in the IP header,IHLwillhaveavalueof5.So,ifthevalueofIHLismorethan5thenthelengthof the option field can be easily calculated.

TypeofService: Thisfieldspecifiesthepriorityofthepacketsbasedondelay,throughput, reliability and cost requirements. Three bits are assigned for priority level and four bits for specific requirements (delay, throughput, reliability and cost).

Total Length:

Thisfieldspecifiesthenumberofbytesof theIPpacketincludingheaderanddata.As16bits are assigned to this field, the maximum length of the packet is 65635 bytes.

Identification:

Theidentificationfieldisusedtoidentifywhichpacketaparticularfragmentbelongstoso that fragments for different packets don't get mixed up.

Flags:

Theflagfieldhasthreebits:

1. Unusedbit
2. Don'tfragment(DF)bit
3. Morefragment(MF) bit

Fragment Offset:

The fragment offset field identifies the location of the fragment in a packet. The value measurestheoffsetinaunitof8bytes,betweenthebeginningofthepackettobefragmented and the beginning of the fragment.

Timeto live (TTL):

Thisfieldisusedtoindicatetheamountoftimeinsecondsapacketisallowedtoremainin the network.

Protocol:

Thisfieldspecifiestheprotocol thatistoreceivethe IP dataatthedestination host.

Header Checksum:

Thisfieldverifiestheintegrityoftheheaderof theIPpacket.Theintegrity ofthedatapartis lefttotheupperlayerprotocols.Thechecksumisgeneratedbythesourceanditissentalong with the frame header to the next router.

SourceIPaddress &DestinationIP address:

Thesetwofields containtheIP addressesof thesourceand destinationhosts respectively.

Options:

Optionsfieldsarerarelyusedtoincludespecialfeaturessuchassecuritylevel,theroutetobe taken and time stamp at each router. It is used in RSVP.

Padding:

Thisfield is used to maketheheader amultiple of 32-bit words.

IPv6

InternetProtocolversion 6(IPv6)isalsoknownas **InternetProtocolnext generation**(**IPng**).Italsoaccommodatesmorefeaturetomeettheglobalrequirementof growing Internet.

To allocate a sufficient number of network address, IPv6 allows 128 bits of IP address separatedinto8sectionsof2byteseach.UnlikeIPv4wheretheaddressisrepresentedas dotted-decimal notation, IPv6 uses hexadecimal numbers and colon (**":"**) is used as a delimiter between the sections.

Example:IPv6address maybelikethis:

FA20:B120:6230:0000:0000:CE12:0006: ABDF

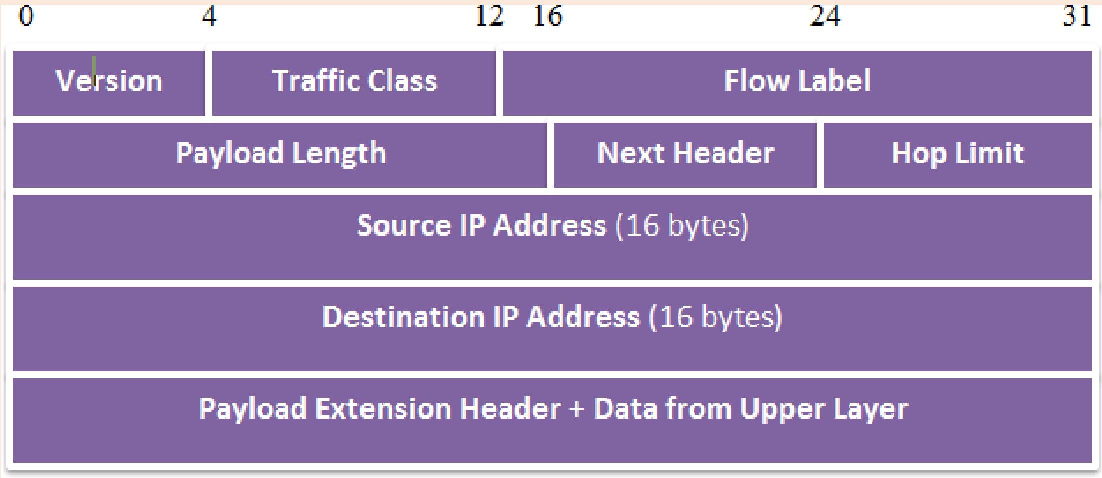


Fig: IPv6 Packet Format

Version: Thisfieldis4bitslonganditdefinestheversionoftheIPpacket.Thevalueofit for IPv6 is 6 and IPv4 its value is 4. During the transition period from IPv4 to IPv6, the routers will be able to distinguish the two versions of the IP packets.

TrafficClass: Thisfieldis20bitslonganditisusedtodistinguishbetweenthedifferent requirements for real-time delivery services.

FlowLabel: Thisfieldis20bitslonganditisusedtoallowthesourceanddestinationnodes to set up a pseudo connection with particular properties and requirements. It is designed to provide special handling of a particular flow of data.

PayloadLength: Itisof2byteslengthandsignifiesthenumberofbytesthatfollowthe40 bytes base header. It is the length of the IP datagram excluding the base header.

NextHeader: Thisfieldisof1byelengthanditdefinesoneoftheextensionheadersthat follow the base header. The extension headers also contain this field to indicate the next header. if this is the last IP header then Next header field tells which of the transport protocols (TCP or UDP) the packet is to be passed.

HopLimit: Thisfieldcontains1byteanditsignifiesthemaximumnumberofhopsapacket can travel. The time to live field in the IPv4 header did the same task, except that in IPv4 it was counted in time and in IPv6 it is counted in terms of the number of routers.

SourceAddress: Itis16byteslongandcontainstheIPaddressofthesourcemachinetothe network interface.

Destination Address: It is 16 bytes long and usually contains the IP address of the ultimate destinationmachinetothenetworkinterface.Incaseofspecificrouting,itmaycontaintheIP address of the next router.
Extension Header: Some of the fields Ipv4 that are missing in IPv6 is necessary in some of the cases. To handle this problem, IPv6 has introduced the concept of the extension header. Therearebeoneormoreofthesixpossibleextensionheaders.Theseheadersappeardirectly after the base header.

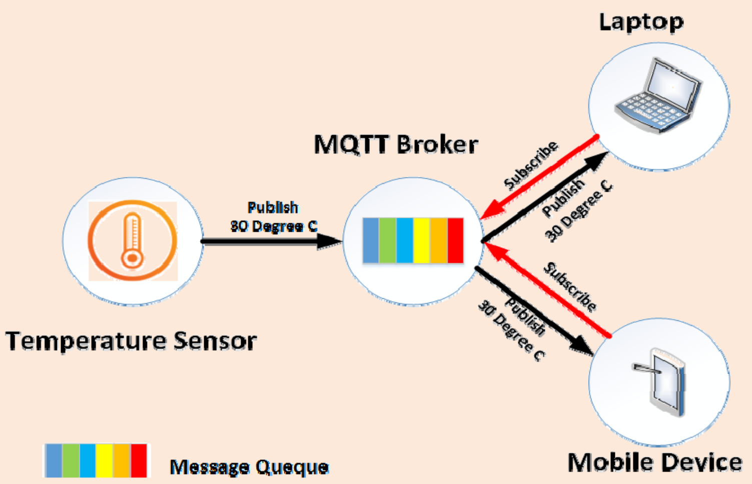
MQTT

- Itisapublish-subscribe-basedlightweightmessagingprotocolforuseinconjunction with the TCP/IP protocol.
- Designedtoprovideconnectivity(mostlyembedded)betweenapplicationsand middle-waresononesideandnetworks andcommunicationsontheotherside.
- Amessagebroker controlsthepublish-subscribemessaging pattern.
- Atopictowhichaclientissubscribedisupdatedintheformofmessagesand distributed by the message broker.
- Designedfor:Remoteconnections,Limitedbandwidth,Small-codefootprint.

MQTTComponents

- **Publishers:**Lightweightsensors
- **Subscribers:**Applicationsinterestedinsensordata
- **Brokers:**ConnectpublishersandsubscribersandClassifysensordataintotopics

Communication:



- Theprotocolusesapublish/subscribearchitecture(HTTPusesarequest/response paradigm).
- Publish/subscribeisevent-drivenandenablesmessagestobepushedtoclients.
- ThecentralcommunicationpointistheMQTTbroker,whichisinchargeof dispatching all messages between the senders and the rightful receivers.

- Eachclientthatpublishesamessagetothebroker,includesatopicintothemessage. The topic is the routing information for the broker.
- Eachclientthatwantstoreceivemessagessubscribesto acertaintopicandthebroker delivers all messages with the matching topic to the client.
- Therefore,theclientsdon'thavetoknoweachother.Theyonlycommunicateover the topic.
- Thisarchitectureenableshighlyscalablesolutionswithoutdependenciesbetweenthe data producers and the data consumers.

Applications

- FacebookMessengerusesMQTTforonlinechat.
- AmazonWebServicesuseAmazonIoTwith MQTT.
- MicrosoftAzure IoT HubusesMQTT asitsmain protocolfortelemetrymessages.
- TheEVRYTHNGIoTplatformusesMQTTasanM2Mprotocolformillionsof connected products.
- AdafruitlaunchedafreeMQTTcloudservicefor IoTexperimenterscalledAdafruit IO.

SMQTT

- SecureMQTTisanextensionofMQTTwhichusesencryptionbasedonlightweight attribute-based encryption.
- The main advantage of using such encryption is the broadcast encryption feature, in whichonemessageisencryptedanddeliveredtomultipleothernodes,whichisquite common in IoT applications.
- Ingeneral,thealgorithmconsistsoffourmainstages: setup,encryption,publishand decryption.

CoAP

- CoAP–ConstrainedApplicationProtocol.
- Webtransferprotocolfor usewithconstrainednodesand networks.
- DesignedforMachinetoMachine(M2M)applicationssuchassmartenergyand buildingautomationandBasedonRequest-Responsemodelbetween end-points
- Client-Serverinteractionisasynchronousoveradatagram-orientedtransportprotocol such as UDP
- TheConstrainedApplicationProtocol(CoAP)isasessionlayerprotocoldesignedby IETF Constrained RESTful Environment (CoRE) working group to provide lightweight RESTful (HTTP) interface.

- RepresentationalStateTransfer(REST)isthestandardinterfacebetweenHTTPclient and servers.

- LightweightapplicationssuchasthoseinloT,couldresult insignificantoverheadand power consumption by REST.

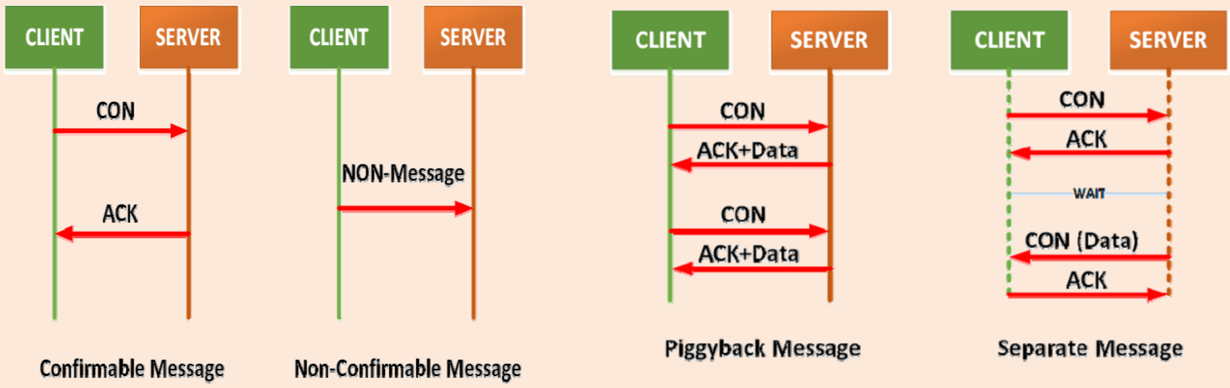
- CoAPisdesignedtoenablelow-powersensorstouseRESTfulserviceswhile meeting their power constraints

- BuiltoverUDP,insteadofTCP(whichiscommonlyusedwithHTTP) andhasalight mechanism to provide reliability.

- CoAParchitectureis dividedinto twomainsub-layers:
    - Messaging
    - Request/response.
- Themessagingsub-layerisresponsibleforreliabilityandduplicationofmessages, while the request/response sub-layer is responsible for communication.

- CoAPhas four messaging modes:
    - Confirmable
    - Non-confirmable
    - Piggyback
    - Separate

CoAPRequest-ResponseModel



- Confirmable and non-confirmable modes represent the reliable and unreliable transmissions,respectively,whiletheothermodesareused forrequest/response.

- Piggybackisusedforclient/serverdirectcommunicationwherethe serversendsits response directly after receiving the message, i.e., within the acknowledgment message.

- On the other hand, the separate mode is used when the server response comes in a messageseparatefromtheacknowledgment,andmaytakesometimetobesentby the server.

- SimilartoHTTP,CoAPutilizesGET,PUT,PUSH,DELETEmessages requeststo retrieve, create, update, and delete, respectively.

XMPP

- XMPP–ExtensibleMessagingandPresenceProtocol.
- Acommunicationprotocolformessage-orientedmiddlewarebasedonXML (Extensible Markup Language).
- Real-timeexchangeofstructureddata.
- Itisanopenstandardprotocol
- XMPPusesaclient-serverarchitecture.
- Asthemodel isdecentralized,no centralserverisrequired.
- XMPPprovidesforthediscoveryofservicesresidinglocally oracrossanetwork, and the availability information of these services.
- Well-suitedforcloudcomputingwherevirtualmachines,networks,andfirewalls would otherwise present obstacles to alternative service discovery and presence-based solutions.
- Openmeanstosupportmachine-to-machineorpeer-to-peercommunications across a diverse set of networks.

Applications:

- Publish-subscribesystems.
- SignalingforVoIP.
- Video.
- Filetransfer.
- Gaming.
- InternetofThingsapplications:SmartgridandSocialnetworkingservices.

AMQP

- AdvancedMessageQueuingProtocol.
- Openstandard forpassingbusinessmessagesbetweenapplicationsororganizations.
- Connectsbetween systemsandbusiness processes.
- Itisabinaryapplication layerprotocol.
- Basicunit ofdata isaframe.

Components

Exchange:

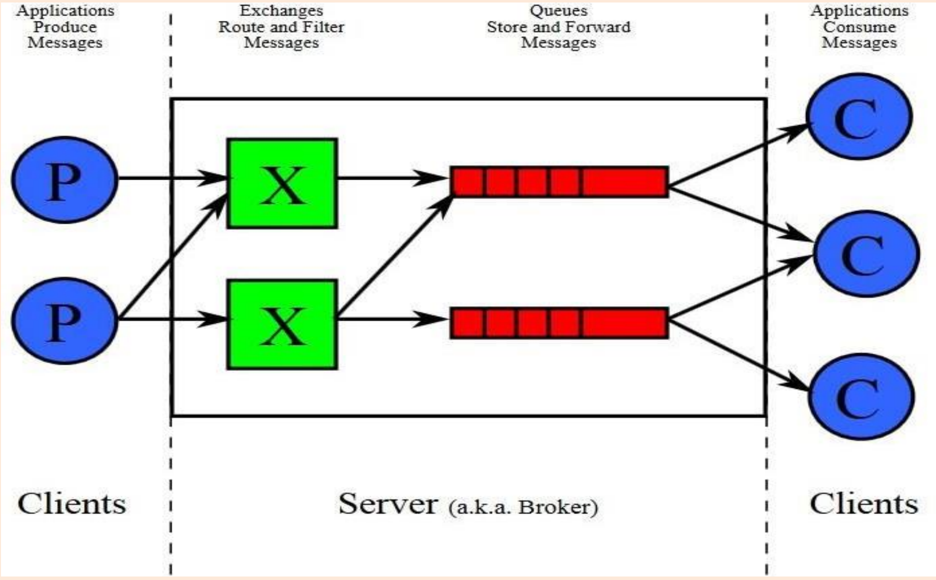
- PartofBroker.
- Receivesmessagesandroutesthemto Queues.

Queue:

- Separatequeuesforseparatebusinessprocesses.
- Consumersreceivemessagesfromqueues.

Bindings:

Rulesfordistributingmessages(whocanaccesswhatmessage,destinationofthe message)



AMQP Features

- TargetedQoS(SelectivelyofferingQoStolinks).
- Persistence(Messagedelivery guarantees).
- Deliveryofmessages tomultiple consumers.
- Possibilityofensuringmultipleconsumption.
- Possibilityofpreventingmultipleconsumption.
- Highspeedprotocol.

Applications

- Monitoringand globalupdate sharing.
- Connectingdifferentsystemsandprocessestotalktoeach other.
- Allowingserverstorespondtoimmediaterequestsquicklyanddelegatetime consuming tasks for later processing.
- Distributingamessageto multiplerecipientsforconsumption.
- Enablingofflineclientstofetchdata atalatertime.
- Introducingfullyasynchronousfunctionalityfor systems.
- Increasingreliabilityand uptimeofapplicationdeployments.

UNIT-3

ConnectivityTechnologies

- CommunicationProtocols:Thefollowingcommunicationprotocolshaveimmediate importance to consumer and industrial IoTs:
  - IEEE802.15.4
  - Zigbee
  - 6LoWPAN
  - WirelessHART
  - Z-Wave
  - ISA100
  - Bluetooth
  - NFC
  - RFID

IEEE 802.15.4

FeaturesofIEEE802.15.4:

- Well-knownstandardforlowdata-rateWPAN.
- Developedforlow-data-ratemonitoringandcontrolapplicationsandextended-life low-power-consumption uses.
- Thisstandardusesonlythefirsttwolayers(PHY,MAC)plusthelogicallinkcontrol (LLC) and service specific convergence sub-layer (SSCS) additions to communicate with all upper layers.
- Usesdirectsequencespreadspectrum(DSSS) modulation.
- Highlytolerantofnoiseandinterferenceandofferslinkreliabilityimprovement mechanisms.
- Low-speedversionsuseBinaryPhaseShiftKeying (BPSK).
- Highdata-rateversionsuseoffset-quadraturephase-shiftkeying(O-QPSK).
- Usescarriersensemultipleaccesswithcollisionavoidance(CSMA-CA)forchannel access.
- Multiplexingallowsmultipleusersornodesinterference-freeaccesstothesame channel at different times.
- Networkingtopologiesdefinedare--Star,andMesh.

IEEE802.15.4supportstwotypesofnetworknode:

1. **FullFunctionDevice(FFD)**
   - Cantalk to alltypes of devices.
   - Supportsfull protocol.
2. **ReducedFunctionDevice (RFD)**
   - Canonlytalk toan FFD.
   - Lowerpowerconsumption.
   - MinimalCPU/RAMrequired.

IEEE 802.15.4 Types:

1. BeaconEnabledNetworks

- Periodictransmissionofbeaconmessages.
- Data-frames sent via Slotted CSMA/CA with a super frame structure managed by PANcoordinator.Beaconsusedforsynchronization&associationofothernodeswith the coordinator.
- Scopeofoperationspansthewhole network.

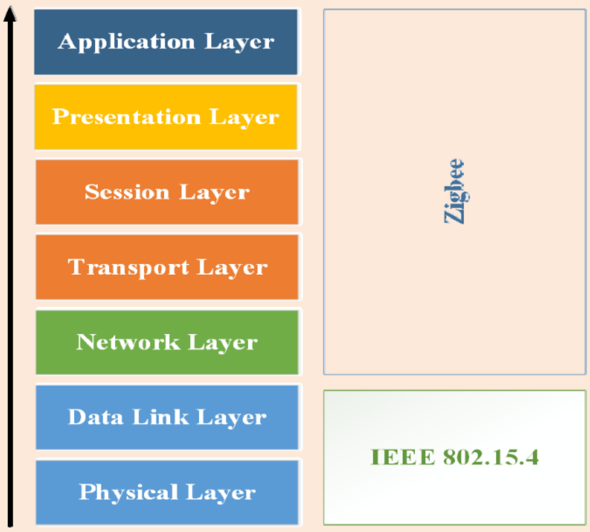
2. Non-BeaconEnabledNetworks

- Data-framessentviaun-slottedCSMA/CA(ContentionBased).
- Beaconsusedonly forlinklayer discovery.
- Requiresbothsource and destinationIDs.
- As802.15.4isprimarily,ameshprotocol,allprotocoladdressingmustadhereto mesh configurations.
- De-centralizedcommunicationamongstnodes.

ZigBee

Featuresof ZigBee

- Mostwidelydeployedenhancementof IEEE 802.15.4.
- TheZigBeeprotocolisdefinedbylayer 3andabove.Itworkswiththe802.15.4 layers 1 and 2.
- Thestandarduseslayers3and4to define additional communication enhancements.
- These enhancements include authenticationwithvalidnodes,



encryptionforsecurity,andadataroutingandforwardingcapabilitythatenables mesh networking.

- ThemostpopularuseofZigBeeiswirelesssensornetworksusingthemeshtopology. ZigBee has two important components:
    - ZigBeeDeviceObject(ZDO):ZDOresponsibleforDevicemanagement, Security, Policies.
    - ApplicationSupportSub-layer(APS):APSresponsibleforInterfacingand control services, bridge between network and other layers

ZigBee Types

1. ***ZigBeeCoordinator (ZC)*:**

    - ThecoordinatorformstherootoftheZigBeenetworktreeandmightactasa bridge between networks.
    - ThereisasingleZigBeeCoordinatorineachnetwork,whichoriginally initiates the network.
    - Itstoresinformation aboutthenetworkunderit andoutside it.
    - ItactsasaTrustCentre& repositoryforsecurity keys**.**

2. ***ZigBeeRouter(ZR)*:**Capableofrunningapplications,aswellasrelaying information between nodes connected to it.

3. ***ZigBeeEndDevice(ZED)*:**

    - Itcontainsjustenoughfunctionalitytotalktotheparentnode,anditcannot relay data from other devices.
    - Thisallowsthenodetobeasleepasignificantamountofthetimethereby enhancing battery life.
    - MemoryrequirementsandcostofZEDsarequitelow,ascomparedtoZRor ZC.

Applications:

- Building automation
- Remotecontrol(RF4CE or RFforconsumer electronics)
- Smartenergyforhomeenergy monitoring
- Healthcareformedicalandfitness monitoring
- Homeautomationfor controlofsmart homes
- LightLink forcontrol ofLEDlighting
- Telecomservices.

6LoWPAN

- Low-powerWirelessPersonalAreaNetworksover IPv6.
- Allowsforthesmallestdeviceswithlimitedprocessingabilitytotransmitinformation wirelessly using an Internet protocol.
- Allowslow-powerdevicestoconnecttothe Internet.
- Createdbythe InternetEngineeringTaskForce(IETF)-RFC5933andRFC4919.

Featuresof 6LoWPANs

- AllowsIEEE802.15.4radiostocarry128-bitaddressesofInternetProtocolversion6 (IPv6).
- Headercompressionandaddresstranslationtechniquesallowthe IEEE802.15.4 radios to access the Internet.
- IPv6packetscompressedandreformattedtofitthe IEEE802.15.4packetformat.
- Usesinclude IoT,Smartgrid,andM2Mapplications.

Addressingin6LoWPAN

- 64-bitaddresses: globally unique.
- 16-bit addresses:PANspecific;assignedbyPANcoordinator

6LoWPANRouting

- Meshrouting within thePANspace.
- Routingbetween IPv6andthe PANdomain
- Routingprotocols in use:
  - LOADng
  - RPL

LOADng Routing

BasicoperationsofLOADnginclude:

- GenerationofRouteRequests(RREQs)byaLOADngRouter(originator)for discovering a route to a destination,
- ForwardingofsuchRREQsuntiltheyreachthedestinationLOADngRouter,
- Generation of Route Replies (RREPs) upon receipt of an RREQ by the indicateddestination,andunicasthop-by-hopforwardingoftheseRREPs towards the originator.
- Ifarouteisdetectedtobebroken,aRouteError(RERR)messageisreturned to the originator of that data packet to inform the originator about the route breakage.

RPLRouting

- DistanceVector IPv6routingprotocolforlossyandlowpowernetworks.
- Maintainsroutingtopologyusinglow-rate beaconing.
- Beaconingrateincreasesondetectinginconsistencies(e.g.node/linkinarouteis down).
- Routinginformationincludedinthedatagramitself.
- **Proactive:**Maintainingroutingtopology.
- **Reactive:**Resolvingroutinginconsistencies**.**

RFID

- RFIDisanacronymfor“radio-frequencyidentification”.
- DatadigitallyencodedinRFIDtags,whichcanbereadbya reader.
- Somewhatsimilarto barcodes.
- Datareadfrom tags arestored inadatabasebythereader.
- AscomparedtotraditionalbarcodesandQRcodes,RFID tagdatacanbereadoutside the line-of-sight.

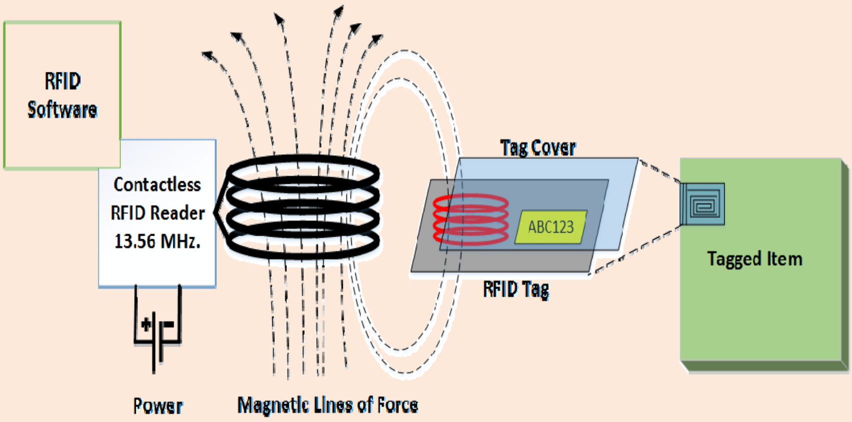
RFIDFeatures

- RFIDtagconsistsofanintegratedcircuitandanantenna.
- Thetagiscoveredbyaprotectivematerialwhichalsoactsasashieldagainstvarious environmental effects.
- Tagsmay bepassiveor active.
- PassiveRFIDtags arethemostwidely used.
- Passivetagshavetobepoweredbyareaderinductivelybeforetheycantransmit information, whereas active tags have their own power supply.

Working Principle

- DerivedfromAutomatic IdentificationandDataCapture(AIDC)technology.
- AIDCperformsobjectidentification,objectdatacollection andmappingofthe collected data to computer systems with little or no human intervention.
- AIDCuseswired communication.
- RFIDusesradiowavestoperformAIDCfunctions.

- ThemaincomponentsofanRFIDsystemincludeanRFIDtag orsmartlabel,an RFID reader, and an antenna.



Applications

1. Inventory management 2. Asset tracking3. Personnel tracking 4. Controlling accesstorestrictedareas5.IDbadging6.Supplychainmanagement7.Counterfeit prevention (e.g. in the pharmaceutical industry)

HART&Wireless HART

- WirelessHARTisthelatestreleaseofHighwayAddressableRemoteTransducer (HART) Protocol.
- HARTstandardwasdevelopedfornetworkedsmartfielddevices.
- Thewirelessprotocolmakes theimplementationof HARTcheaper and easier.
- HARTencompassesthegreatestnumberoffielddevicesincorporatedinanyfield network.
- WirelessHARTenablesdeviceplacementsmoreaccessibleandcheaper–suchas the top of a reaction tank, inside a pipe, or at widely separated warehouses.
- Maindifferencebetweenwiredandunwiredversionsisinthephysical,datalink and network layers. Wired HART lacks a network layer.

HART Physic al Layer

- Derivedfrom IEEE802.15.4protocol.
- Itoperatesonlyinthe2.4 GHz ISMband.
- Employsandexploits15 channelsofthe bandtoincreasereliability.

HART Data Link Layer

- Collisionfreeanddeterministiccommunicationachievedbymeansofsuper-frames and TDMA. Super-frames consist of grouped 10ms wide timeslots.
- Super-framescontrolthetimingoftransmissiontoensurecollisionfreeandreliable communication.

- This layer incorporates channel hopping and channel blacklisting to increase reliabilityandsecurity.Channelblacklistingidentifieschannelsconsistentlyaffected by interference and removes them from use.

HARTNetwork&TransportLayers

- Cooperativelyhandlevarioustypesoftraffic,routing,sessioncreation,andsecurity.
- WirelessHARTreliesonMeshnetworkingforits communication,andeachdeviceis primed to forward packets from every other device. Each device is armed with an updated network graph (i.e., updated topology) to handle routing.
- Networklayer(HART)=Network+Transport+Sessionlayers(OSI).

HARTApplication Layer

- Handlescommunicationbetweengatewaysanddevicesviaaseriesofcommandand response messages.
- Responsibleforextractingcommandsfromamessage,
  - executingitandgenerating responses.
- Thislayerisseamlessanddoesnotdifferentiatebetweenwirelessandwiredversions of HART.

NFC

- Nearfieldcommunication,orNFCforshort,isanoffshootofradio-frequency identification (RFID).
- NFCisdesignedfor use bydeviceswithin closeproximitytoeach other.
- AllNFCtypesaresimilar butcommunicateinslightlydifferentways.

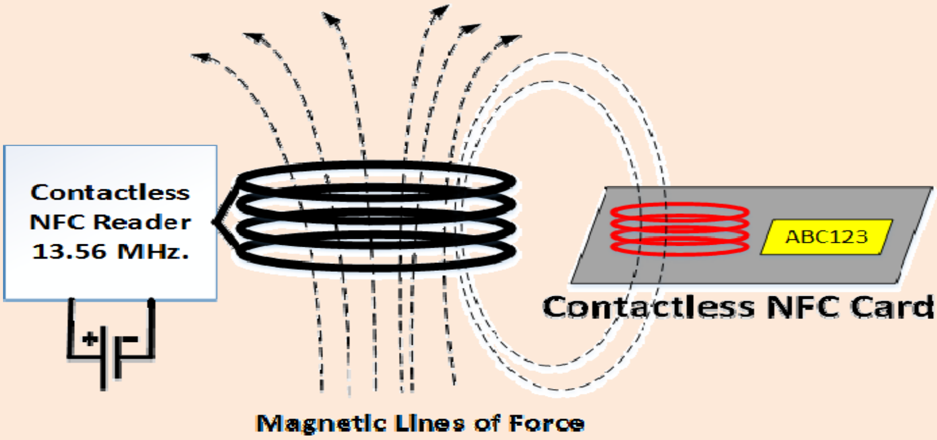
NFCTypes

- **Passivedevices**containinformationwhichisreadablebyotherdevices,howeverit cannot read information itself.
- NFCtagsfoundinsupermarket productsareexamplesofpassiveNFC.
- **Activedevices** areableto collectas wellastransmit information.
- Smartphonesareagoodexampleofactivedevices.

Working Principle

- Worksontheprincipleofmagneticinduction.
- Areaderemitsasmallelectriccurrentwhichcreatesamagneticfieldthatinturn bridges the physical space between the devices.
- The generated field is received by a similar coil in the client device where it is turned backintoelectricalimpulsestocommunicatedatasuchasidentificationnumberstatus information or any other information.

- ‘Passive’NFCtagsusetheenergyfromthereadertoencodetheirresponsewhile ‘active’ or ‘peer-to-peer’ tags have their own power source.



NFCApplications

- Smartphonebased payments.
- Parceltracking.
- Informationtagsinpostersand advertisements.
- Computergamesynchronized toys.
- Low-powerhomeautomation systems.

Bluetooth

- Bluetoothwirelesstechnologyisa short-range communicationstechnology.
- Intendedforreplacingcablesconnectingportable units
- Maintainshigh levelsof security.
- Bluetoothtechnology isbased onAd-hoctechnologyalso knownasAd-hocPiconets

Features

- Bluetoothtechnologyoperatesintheunlicensedindustrial,scientificandmedical (ISM) band at 2.4 to 2.485 GHZ.
- Usesspreadspectrum hopping,full-duplexsignal atanominal rateof1600hops/sec.
- Bluetoothsupports1Mbpsdatarateforversion1.2and 3MbpsdatarateforVersion 2.0combinedwithErrorDataRate.
- Bluetoothoperatingrangedependsonthedevice:
  - Class3 radios havearangeofupto 1meteror 3feet
  - Class2radiosaremostcommonlyfoundinmobiledeviceshavearangeof10 meters or 30 feet
  - Class1radiosareusedprimarilyinindustrialusecaseshavearangeof100meters or 300 feet.

ConnectionEstablishment

- **Inquiry:**InquiryrunbyoneBluetoothdevicetotrytodiscoverotherdevicesnear it.
- **Paging:**Processof formingaconnection betweentwoBluetoothdevices.
- **Connection:**Adeviceeitheractivelyparticipatesinthenetworkorentersalow- power sleep mode

Piconets:

- Bluetoothenabledelectronicdevicesconnectandcommunicatewirelesslythrough short range networks known as Piconets.
- Bluetoothdevicesexistinsmallad-hocconfigurationswiththeabilitytoacteither as master or slave. Provisions are in place, which allow for a **master** and a **slave**to switch their roles.
- Thesimplestconfigurationisapoint-to-pointconfigurationwithonemasterand one slave.
- Devices in adjacent Piconets provide a bridge to support inner-Piconet connections,allowingassembliesoflinkedPiconetstoformaphysically extensible communication infrastructure known as Scatternet.

Applications

- Audio players
- Homeautomation
- Smartphones
- Toys
- Handsfree headphones
- Sensornetworks

Z Wave

- Zwaveis aprotocolforcommunicationamongdevicesused forhome automation.
- Ituses RFforsignallingand control.
- Operatingfrequency is908.42 MHzin theUS& 868.42MHzinEurope.
- Meshnetworktopologyisthemainmodeofoperation,andcansupport232nodesin a network.
- ZwaveutilizesGFSKmodulationandManchesterchannelencoding.
- Acentralnetworkcontrollerdevicesets-upandmanagesa Zwavenetwork.
- EachlogicalZwavenetworkhas1Home(Network)IDandmultiplenodeIDsforthe devices in it.

- NodeswithdifferentHomeIDscannotcommunicate witheachother.
- NetworkIDlength=4Bytes,Node IDlength=1Byte.

ISA 100.11A

- ISAisacronymInternationalSocietyof Automation.
- Designedmainlyforlargescaleindustrialcomplexesand plants.
- Morethan1 billiondevices use ISA 100.11A
- ISA100.11Aisdesignedtosupportnativeandtunnelledapplication layers.
- Varioustransportservices,including‘reliable,’‘besteffort,’‘real-time’are offered.
- Networkandtransportlayers arebasedonTCPorUDP/ IPv6.
- Datalinklayersupports meshroutingandFrequencyhopping.
- PhysicalandMAClayersarebasedonIEEE 802.15.4
- Topologiesallowedare:
    - Star/tree
    - Mesh
- Permittednetworks include:
    - Radiolink
    - ISAover Ethernet
    - Field buses

UNIT-4

WirelessSensorNetworks

WirelessSensorNetworks(WSNs):

- WSNConsistsofalarge numberof sensornodes,densely deployedoveranarea.
- Sensornodesarecapableofcollaboratingwithoneanotherandmeasuringthe condition of their surrounding environments (i.e., Light, temperature, sound, vibration).
- Thesensedmeasurementsarethentransformedintodigitalsignalsandprocessedto reveal some properties of the phenomena around sensors.

ComponentsofaSensor Node:

In any wireless sensor network, sensor node consists of four basic components, a sensing unit,aprocessingunit,atransceiverunit,andapowerunit.Theymayalsohaveadditional applicationdependentcomponentssuchasalocationfindingsystem,powergeneratorand mobilize

Challenges in WSN:

Energy: Power consumption can be allocated to three functional domains: sensing, communication,anddataprocessing,eachofwhichrequiresoptimization.Thesensornode lifetime typically exhibits a strong dependency on battery life. The constraint most often associated with sensor network design is that sensor nodes operate with limited energy budgets.

Limited bandwidth: Bandwidth limitation directly affects message exchanges among sensors, and synchronization is impossible without message exchanges. Sensor networks often operate in a bandwidth and performance constrained multi-hop wireless communicationsmedium.Thesewirelesscommunicationslinksoperateintheradio,infrared, or optical range.

NodeCosts:Asensornetworkconsistsofalargesetofsensornodes.Itfollowsthatthecost ofanindividualnodeiscriticaltotheoverallfinancialmetricofthesensornetwork.Clearly, the cost of each sensor node has to be kept low for the global metrics to be acceptable.

Deployment Node: A proper node deployment scheme can reduce the complexity of problems. Deploying and managing a high number of nodes in a relatively bounded environmentrequiresspecialtechniques.Hundredstothousandsofsensorsmaybedeployed in a sensor region.

Security: One of the challenges in WSNs is to provide high security requirements with constrained resources. Many wireless sensor networks collect sensitive information. The remote and unattended operation of sensor nodes increases their exposure to malicious intrusions and attacks. The security requirements in WSNs are comprised of node authenticationanddataconfidentiality.Toidentifybothtrustworthyandunreliablenodes from a security stand points, the deployment sensors must pass a node authentication examinationbytheircorrespondingmanagernodesorclusterheadsandunauthorizednodes can be isolated from WSNs during the node authentication procedure.

SENSOR WEB

the sensor web is a type of sensor network that is especially well suited for environmental monitoring.Thesensorwebisalsoassociatedwithasensingsystemwhichheavilyutilizes the World Wide Web.

SensorWebEnablement (SWE)

SensorWebEnablement(SWE)isasuiteofstandardsdevelopedandmaintainedbyOpen Geospatial Consortium. SWE standards enable developers to make all types of sensors, transducers and sensor data repositories discoverable, accessible and usable via the Web.

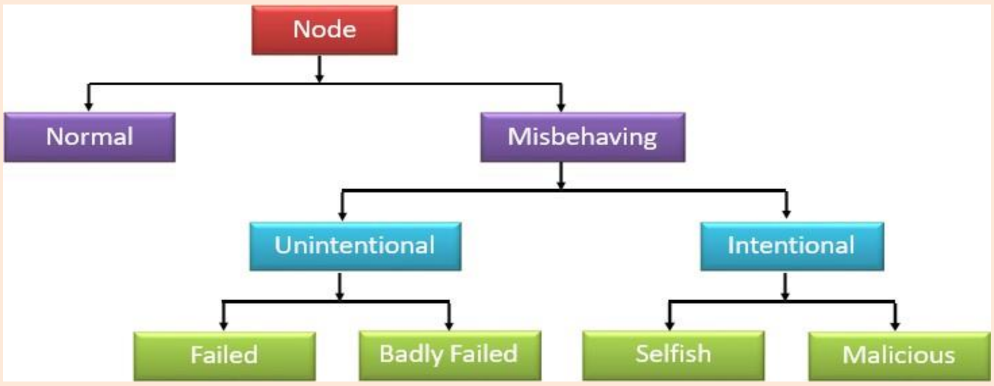
SWEStandardsinclude:

- SensorObservation Service
- SensorPlanningService
- Observationsand Measurements
- SensorModelLanguage
- SensorThingsAPI

Cooperationin WirelessAd HocandSensorNetworks

- Nodescommunicatewithothernodeswiththehelpofintermediatenodes.
- Theintermediatenodesact as relays.
- Wirelessnodesareenergy-constrained.
- Nodesmay ormay not cooperate.
- TwoextremitiesforCooperation:
  - **Totalcooperation:**ifallrelayrequestsareaccepted,nodeswillquickly exhaust limited energy.
  - **Totalnon-cooperation:**ifnorelayrequestsareaccepted,thenetwork throughput will go down rapidly.

NodeBehaviourin WSNs:



- Normalnodesworkperfectlyinidealenvironmentalconditions.
- Failednodesaresimplythosethatareunabletoperformanoperation;thiscouldbe because of power failure and environmental events.
- Badlyfailednodesexhibitfeaturesoffailednodesbuttheycanalsosendfalserouting messages which are a threat to the integrity of the network.
- Selfishnodesaretypifiedbytheirunwillingnesstocooperate,astheprotocolrequires whenever there is a personal cost involved. Packet dropping is the main attack by selfish nodes.
- Maliciousnodesaimtodeliberatelydisruptthecorrectoperationoftherouting protocol, denying network service if possible.

DynamicMisbehaviour(Dumbbehaviour):

- Detectionofsuchtemporarymisbehaviourinordertopreservenormalfunctioningof the network – coinage and discovery of dumb behaviour.
- Inthepresenceofadverseenvironmentalconditions(hightemperature,rainfall,and fog) the communication range shrinks.
- Asensornodecan sense itssurroundingsbut isunableto transmitthesensed data
- Withtheresumptionoffavourableenvironmentalconditions,dumbnodeswork normally.
- Dumbbehaviouristemporalinnature(asitisdependentontheeffectsof environmental conditions).

Self-ManagementofWirelessSensor Networks:

- AWSNis deployedwiththeintention ofacquiring information.
- Thesensedinformationistransmittedintheformofpackets.
- Informationtheoreticself-management(INTSEM)controlsthetransmissionrateofa node by adjusting a node’s sleep time.
- Benefits:
  - Reduceconsumptionoftransmissionenergyoftransmitters.
  - Reduceconsumptionofreceivingenergy ofrelaynodes.

Socialsensing WSN

- SocialSensing-basedDutyCycleManagementforMonitoringRareEventsin Wireless Sensor Networks.

  WSNsareenergy-constrained Scenario:

  - EventmonitoringusingWSNs.
  - WSNssuffer fromineffectivesensingforrareevents.
  - Eventmonitoring orsensing, evenif thereis noevent tomonitor orsense.
  - Example:Submarinemonitoringinunderwatersurveillance.

- Challenges:
    - Distinguishrareeventsandregularevents.
    - Adapttheduty-cyclewiththeeventoccurrence probability.
- Contribution:
    - Probabilisticdutycycle(PDC)in WSNs.
    - Accumulatesinformationfromthesocialmediatoidentifytheoccurrence possibility of rare events.
    - Adjuststhedutycyclesofsensornodesusingweakestimationlearning automata.

Applications of WSNs:

1. Mines

- FireMonitoringandAlarmSystemforUndergroundCoalMinesBord-and-Pillar Panel Using Wireless Sensor Networks.
    - WSN-basedsimulationmodelforbuildingafiremonitoringandalarm(FMA) system for Bord & Pillar coal mine.
    - ThefiremonitoringsystemhasbeendesignedspecificallyforBord&Pillar based mines.
    - Itisnotonlycapableofprovidingreal-timemonitoringandalarmincaseofa fire, but also capable of providing the exact fire location and spreading direction by continuously gathering, analysing, and storing real time information.

2. Healthcare

- WirelessBodyArea Networks
    - Wirelessbodyareanetworks(WBANs)haverecentlygainedpopularitydueto their ability in providing innovative, cost-effective, and user-friendly solution for continuous monitoring of vital physiological parameters of patients.
    - Monitoringchronicandseriousdiseasessuchascardiovasculardiseasesand diabetes.
    - Couldbedeployedin elderlypersonsfor monitoringtheirdaily activities.

3. InternetofThings(IOT)
4. SurveillanceandMonitoringforsecurity,threatdetection
5. Environmentaltemperature,humidity,andairpressure
6. NoiseLevelofthesurrounding
7. Landslide Detection

WirelessMultimediaSensorNetworks (WMSNs)

- Incorporationoflow-cost camera(typicallyCMOS)towirelesssensornodes
- **Camerasensor(CS)nodes:**capturemultimedia(video,audio,andthescalar)data, expensive and resource hungry, directional sensing range
- **Scalarsensor(SS)nodes:**sensescalardata(temperature,light,vibration,andsoon), omni-directional sensing range, and low cost
- WMSNsconsistof asmaller numberofCSnodesand largenumber ofSS nodes

WMSNsApplication

- Insecuritysurveillance,wild-habitatmonitoring,environmentalmonitoring,SSnodes cannot provide precise information
- CSnodesreplaceSSnodestogetpreciseinformation
- DeploymentofbothCSandSSnodescanprovidebettersensingandprolongnetwork lifetime

Nanonetworks:

- Nanodevicehascomponentsof sizesintheordernano-meters.
- Communicationoptionsamong nanodevices
  - Electromagnetic
  - Molecular

MolecularCommunication:

- Moleculeusedasinformation
- Informationpackedintovesicles
- Gapjunctionworks asmediatorbetween cellsandvesicles
- Informationexchangebetweencommunication entitiesusing molecules

Electromagnetic-basedCommunication

- SurfacePlasmonicPolariton(SPP)generateduponelectromagneticbeam
- EMcommunicationforNanonetworks centresaround0.1-10Terahertz channel

UnderwaterAcousticSensorNetworks

- Inalayeredshallowoceanicregion,theinclusionoftheeffectofinternalsolitonson the performance of the network is important.
- Basedonvariousobservations,itisprovedthatnon-linearinternalwaves,i.e., Solitons are one of the major scatters of underwater sound.
- Ifsensornodesaredeployedinsuchtypeofenvironment,inter-nodecommunication is affected due to the interaction of wireless acoustic signal with these solitons, as a result of which network performance is greatly affected.

- TheperformanceanalysisofUWASNsrendersmeaningfulinsightswiththeinclusion of a mobility model which represents realistic oceanic scenarios.
- TheexistingworksonperformanceanalysisofUWASNslacktheconsiderationof major dominating forces, which offer impetus for a node's mobility.

WSN Coverage:

- Coverage–area-of-interestiscoveredsatisfactorily.
- Connectivity–allthenodesareconnectedinthenetwork,sothatsenseddatacan reach to sink node.
- SensorCoveragestudieshowtodeployoractivatesensorstocoverthemonitoring area.
  - Sensorplacement
  - Density control
- Twomodes:
  - Static sensors
  - Mobile sensors
- Determinehow wellthe sensingfieldismonitoredortrackedbysensors.
- Todetermine,withrespecttoapplication-specificperformance criteria,
  - incaseofstaticsensors, whereto deployand/oractivate them
  - incaseof(asubsetof)thesensorsaremobile,howtoplanthetrajectoryofthe mobile sensors.
- Thesetwocasesarecollectivelytermedasthecoverageprobleminwirelesssensor networks.
- ThepurposeofdeployingaWSNistocollectrelevantdataforprocessingor reporting.
- Twotypes ofreporting:
  - eventdriven:e.g., forestfire monitoring
  - ondemand: e.g.,inventory control system
- Objectiveis touseaminimumnumber ofsensorsand maximizethe network lifetime
- Thecoverage algorithmproposedareeither centralizedordistributedandlocalized
- Distributed:Nodescomputetheirpositionbycommunicatingwiththeirneighbours only.
- Centralized:Data collectedatcentralpointandglobalmapcomputed.

- Localized:Localizedalgorithmsareaspecialtypeofdistributedalgorithmswhere only a subset of nodes in the WASN participate in sensing, communication, and computation.

StationaryWirelessSensor Networks

- Sensornodesarestatic.
- Advantages:
  - Easy deployment
  - Nodecanbeplacedinanoptimizeddistance-Reducethetotalnumberof nodes
  - Easytopologymaintenance
- Disadvantages:
  - Nodefailuremayresult inpartition ofnetworks
  - Topologycannot be changeautomatically

<u>MobileWirelessSensor Networks</u>

- MWSNisMobile AdhocNetwork(MANET)
- Letusrememberfrompreviouslectures:-
- MANET-Infrastructurelessnetworkofmobiledevicesconnectedwirelesslywhich follow the self-CHOP properties
  - Self-Configure
  - Self-Heal
  - Self-Optimize
  - Self-Protect
- WirelessSensorNetworks-
  - Consistsof alargenumberof sensornodes, denselydeployed overanarea.
  - Sensornodesarecapableofcollaboratingwithoneanotherandmeasuringthe condition of their surrounding environments (i.e., Light, temperature, sound, vibration).

Componentsof MWSN:

MobileSensorNodes: Sensephysicalparametersfromtheenvironment Whenthesenodes come in close proximity of sink, deliver data.

MobileSink: Movesinordertocollectdatafromsensornodes.Basedonsomealgorithm sink moves to different nodes in the networks.

DataMules: AmobileentityCollectsthedatafromsensornodesandGoestothesinkand delivers the collected data from different sensor nodes.

UNIT-5

MachinetoMachineCommunication

M2MCommunication:M2M,istheCommunicationbetweenmachinesordeviceswith computingand communication facilities, withoutany human intervention.

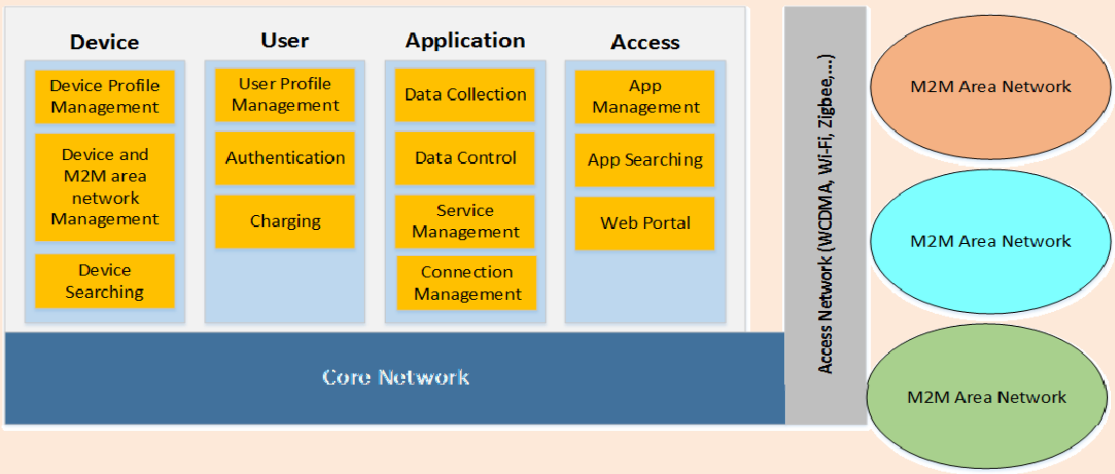
FeaturesofM2M:

- Largenumber ofnodes or devices.
- Lowcost.
- Energy efficient.
- Smalltrafficper machine/device.
- Largequantity ofcollectivedata.
- M2Mcommunicationfreefromhumanintervention.
- Humaninterventionrequiredforoperationalstabilityandsustainability

M2MEcosystem: ItcomprisesofDeviceProviders,InternetServiceProviders(ISPs), Platform Providers, Service Providers and Service Users.

The device provider is basically the owner of these devices. M2M area network sends the data from M2M devices, through gateway to the internet which is handled by the internet serviceprovider.RESTfularchitectureactsasaninterfacebetweenthedeviceproviderand the internet service provider. RESTful architecture is used in low resource environment. Fromthe ISPthereaches theplatformprovider.Theplatformprovidertakescareofdevice management,usermanagement,dataAnalyticsanduseraccessisthedataisthenthrougha RESTful architecture which takes care of the business model to the service providers and users.

M2MServicePlatform (M2SP)



M2MDevice Platform:

- Enablesaccesstoobjectsordevicesconnectedtothe Internetanywhereandatany time.
- Registereddevicescreateadatabaseofobjectsfromwhichmanagers,usersand services can easily access information.
- Managesdeviceprofiles,suchaslocation,device type,address,anddescription.
- Providesauthenticationandauthorizationkeymanagementfunctionalities.
- MonitorsthestatusofdevicesandM2Mareanetworks,andcontrolsthembasedon their status.

M2MUserPlatform

- ManagesM2Mserviceuserprofilesandprovidesfunctionalitiessuchas,
    - Userregistration
    - Modification
    - Charging
    - Inquiry.
- InteroperateswiththeDevice-platform,andmanagesuseraccessrestrictionsto devices, object networks, or services.
- Serviceprovidersanddevicemanagershaveadministrativeprivilegesontheirdevices or networks.
- Administratorscanmanagethedevices throughdevicemonitoringand control.

M2MApplication Platform

- Providesintegratedservicesbasedondevicecollecteddata-sets.
- Heterogeneousdatamergingfromvariousdevicesusedforcreatingnew services.
- Collectscontrolprocessinglogdataforthemanagementofthedevicesbyworking with the Device-platform.
- Connectionmanagementwiththeappropriatenetworkisprovidedforseamless services.

M2MAccessPlatform

- Providesapporwebaccessenvironmentto users.
- Appsandlinksredirecttoservice providers.
- Servicesactuallyprovided throughthisplatform toM2M devices.
- ProvidesAppmanagementforsmartdeviceapps.

- Appmanagementmanagesappregistrationbydevelopersandprovidesamapping relationship between apps and devices.
- Mappingfunctionprovidesanapp listforappropriatedevices.

InteroperabilityinInternetofThings

Interoperabilityisacharacteristicofaproductorsystem,whoseinterfacesarecompletely understood, to work with other products or systems, present or future, in either implementation or access, without any restrictions.

NeedofInteroperability:

- Tofulfilthe IoTobjectives
  - Physicalobjectscaninteractwithanyotherphysicalobjects andcanshare their information
  - Anydevicecancommunicatewithotherdevicesanytimefrom anywhere
  - Machine to Machine communication(M2M), Device to Device Communication(D2D),DevicetoMachineCommunication(D2M)
  - SeamlessdeviceintegrationwithIoTnetwork
- Heterogeneity
  - DifferentwirelesscommunicationprotocolssuchasZigBee(IEEE802.15.4), Bluetooth (IEEE 802.15.1), GPRS, 6LowPAN, and Wi-Fi (IEEE 802.11)
  - DifferentwiredcommunicationprotocolslikeEthernet(IEEE802.3)and Higher Layer LAN Protocols (IEEE 802.1)
  - Differentprogramminglanguagesusedincomputingsystemsandwebsites such as JavaScript, JAVA, C, C++, Visual Basic, PHP, and Python
  - DifferenthardwareplatformssuchasCrossbow,NI,etc.
  - Differentoperating systems
  - Asanexample,forsensornode:TinyOS,SOS,MantisOS,RETOS,and mostly vendor specific OS.
  - Asanexample,forpersonalcomputer:Windows, Mac,Unix,and Ubuntu.
  - Differentdatabases:DB2,MySQL,Oracle,PostgreSQL,SQLite,SQLServer, and Sybase.
  - Differentdatarepresentations.
  - Differentcontrol models.
  - Syntacticorsemanticinterpretations.

Typesof Interoperability

UserInteroperability:Interoperabilityproblembetweenauserandadevice The following problems need to be solved

- Deviceidentificationandcategorizationfordiscovery
- Syntacticinteroperabilityfordevice interaction.
- Semanticinteroperabilityfordevice interaction.

Deviceidentificationandcategorizationfordiscovery: Therearedifferentsolutionsfor generating unique address like Electronic Product Codes (EPC), Universal Product Code (UPC), Uniform Resource Identifier (URI), IP Addresses (IPv6).

SyntacticInteroperabilityforDeviceInteraction:

- Theinteroperability betweendevices anddeviceuserin termofmessageformats
- Themessageformatfromadevicetoauserisunderstandablefortheuser's computer.
- Ontheotherhand,themessageformatfromtheusertothedeviceisexecutableby the device.

SemanticInteroperabilityforDeviceInteraction:

- Theinteroperabilitybetweendevicesanddeviceuserintermofmessage's meaning.
- Thedevicecanunderstandthemeaningofuser'sinstructionthatissentfromthe user to the device.
- Similarly,theusercanunderstandthemeaningofdevice'sresponsesentfromthe device.

DeviceInteroperability:Interoperabilityproblembetweentwodifferentdevices

Solution approach for device interoperability.

- UniversalMiddlewareBridge (UMB)
  - Solvesseamlessinteroperabilityproblemscausedbytheheterogeneityof several kinds of home network middleware.
  - UMBcreatesvirtualmapsamongthephysicaldevicesofallmiddlewarehome networks, such as HAVI, Jini, LonWorks, and UPnP.
  - Createsacompatibility amongthesemiddlewarehome networks.
  - UMBconsistsofUMBCore(UMB-C) andUMBAdaptor (UMB-A).
  - UMB-Aconvertsphysicaldevicesintovirtuallyabstractedone,asdescribed by Universal Device Template (UDT).
  - UDTconsistsofaGlobalDeviceID,GlobalFunctionID, GlobalActionID, Global Event ID, and Global Parameters.

- UMBAdaptorstranslatethelocalmiddleware’smessageintoglobal metadata’s message.
- ThemajorroleoftheUMBCoreisroutingtheuniversalmetadatamessageto thedestinationoranyotherUMBAdaptorsbytheMiddlewareRoutingTable (MRT).

UNIT-6

ProgrammingwithArduino

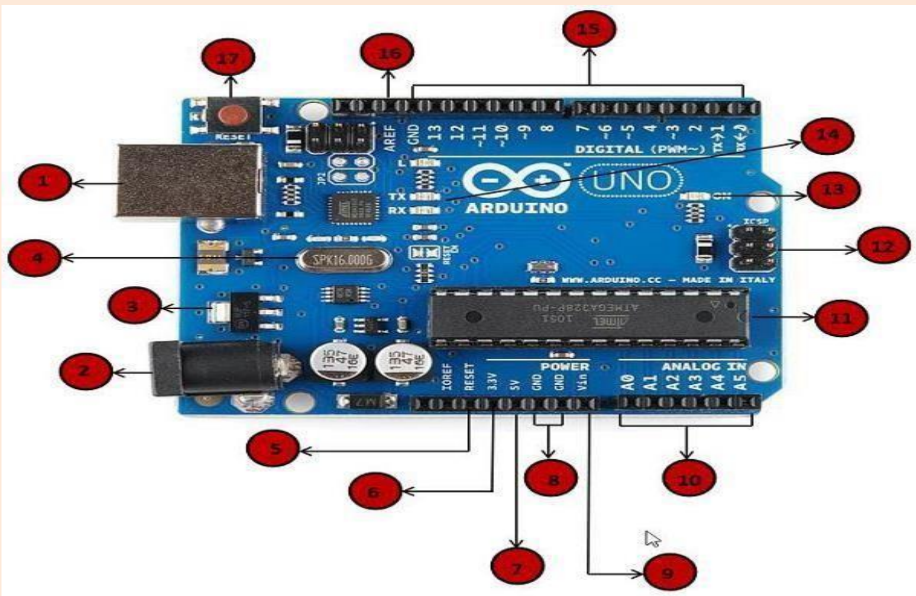
Arduino is a prototype platform (open-source) based on an easy-to-use hardware and software. It consists of a circuit board, which can be programed (referred to as a microcontroller)andaready-madesoftwarecalledArduinoIDE(IntegratedDevelopment Environment), which is used to write and upload the computer code to the physical board.

FeaturesofArduino

- Arduinoboardsareabletoreadanalogordigitalinputsignalsfromdifferentsensors and turn it into an output such as activating a motor, turning LED on/off, connect to the cloud and many other actions.
- You can control your board functions by sending a set of instructions to the microcontrollerontheboardviaArduinoIDE(referredtoasuploadingsoftware).
- Unlike most previous programmable circuit boards, Arduino does not need an extra pieceofhardware(calledaprogrammer)inordertoloadanewcodeontotheboard. You can simply use a USB cable.
- Additionally,theArduinoIDEusesasimplifiedversionofC++,makingiteasierto learn to program.
- Finally,Arduinoprovidesastandardformfactorthatbreaksthefunctionsofthe micro-controller into a more accessible package.

ComponentsofArduinoBoard

We will study the Arduino UNO board because it is the most popular board in the Arduino boardfamily.Inaddition,itisthebestboardtogetstartedwithelectronicsandcoding.Some boards look a bit different from the one given below, but most Arduinos have majority of these components in common.



1	**PowerUSB** Arduino boardcan bepowered by using theUSB cablefromyour computer. All you need to do is connectthe USB cable to the USB connection (1).
2	**Power(BarrelJack)** ArduinoboardscanbepowereddirectlyfromtheACmainspowersupplybyconnecting it to the Barrel Jack(2).
3	**VoltageRegulator** The function of the voltage regulator is to control thevoltage given to the Arduino board and stabilize theDC voltages used by the processor and other elements.
4	**Crystal Oscillator** The crystal oscillator helps Arduino in dealing with time issues. How does Arduino calculatetime?Theansweris,byusingthecrystaloscillator.Thenumberprintedontop oftheArduinocrystalis16.000H9H.Ittellsusthatthefrequencyis16,000,000Hertzor 16 MHz.
5,17	**ArduinoReset** Youcanreset yourArduinoboard,i.e.,startyourprogramfromthebeginning.Youcan reset the UNO boardin two ways. First, by using the reset button (17) on the board. Second,youcanconnectanexternalresetbuttontotheArduinopinlabelledRESET(5).
6,7 8,9	**Pins(3.3,5, GND,Vin)** • 3.3V(6)− Supply3.3 outputvolt • 5V(7)−Supply5 outputvolt • Most of thecomponentsusedwithArduinoboardworksfinewith3.3volt and5 volt. • GND(8)(Ground)−ThereareseveralGNDpinsontheArduino,anyofwhich can be used to groundyour circuit. • Vin(9)−ThispinalsocanbeusedtopowertheArduinoboardfrom an external power source, likeAC mains power supply.
10	**Analogpins** TheArduinoUNOboardhassixanaloginputpinsA0throughA5.Thesepinscanread the signal from an analog sensor like the humidity sensor or temperature sensor and convert it into a digital value that can beread by the microprocessor.

11	**Main microcontroller** EachArduinoboardhasitsownmicrocontroller(11).Youcanassumeitasthebrainof your board. The main IC (integrated circuit) on the Arduino is slightly different from board to board. The microcontrollers areusually of the ATMEL Company. You must know what IC your board has before loading up a new programfrom the Arduino IDE. ThisinformationisavailableonthetopoftheIC.FormoredetailsabouttheIC construction andfunctions,youcanrefertothedatasheet.
12	**ICSPpin** Mostly, ICSP (12)is an AVR, atiny programming header forthe Arduino consisting of MOSI, MISO, SCK,RESET, VCC, and GND. It is often referred to as an SPI (Serial Peripheral Interface), which could be consideredasan"expansion"oftheoutput.Actually,youareslavingtheoutputdeviceto the master of the SPI bus.
13	PowerLED indicator ThisLEDshouldlightupwhenyouplugyourArduinointoapowersourcetoindicate that your board is powered up correctly. If this light does not turn on, then there is something wrong with the connection.
14	TXand RX LEDs Onyourboard,youwillfindtwolabels:TX(transmit)andRX(receive).They appearin two places on the Arduino UNO board. First, at the digital pins 0 and 1, to indicate the pins responsible for serial communication. Second, the TXand RX led (13). TheTXled flashes with different speed while sending theserial data. Thespeed of flashing depends onthebaudrate usedbythe board.RXflashes duringthereceiving process.
15	DigitalI/O The Arduino UNO board has 14 digital I/O pins (15) (of which 6 provide PWM (Pulse WidthModulation)output.Thesepinscanbeconfiguredtoworkasinputdigitalpinsto read logic values (0 or 1) or as digital output pins to drive different modules like LEDs, relays, etc. The pins labeled “~” can be used to generate PWM.
16	AREF AREFstandsforAnalogReference.Itissometimes,usedto setanexternalreference voltage (between 0 and 5 Volts) as the upper limit for the analog input pins.

ArduinoIDE

Afterlearningaboutthemainpartsofthe ArduinoUNOboard,wearereadytolearn howto set up theArduino IDE. Once we learn this, we will be ready to upload our program on the Arduino board.

In this section, we will learn in easy steps, how to set up the Arduino IDE on our computer and preparethe board to receive the program via USB cable.

Step 1 − First you must have your Arduino board (you can choose your favorite board)and aUSB cable.In caseyou useArduino UNO,Arduino Duemilanove, Nano, Arduino Mega 2560, or Diecimila,you will need a standard USB cable (A plug to B plug), the kind you would connect to a USB printeras shown in the following image.

In case you use Arduino Nano, you will need an A to Mini-B cable instead as shown in the following image.

Step2−DownloadArduinoIDESoftware.

You can get different versions of Arduino IDE from the Download pageon the ArduinoOfficialwebsite.You must select your software, which is compatible with your operating system (Windows, IOS, or Linux). After your file download is complete, unzip the file.

Step 3−Powerupyourboard.

The Arduino Uno, Mega, Duemilanove and Arduino Nano automatically draw powerfromeither,theUSBconnectiontothecomputeroranexternalpowersupply. If you are using an Arduino Diecimila, you have to make sure that the board is configured to draw power from the USB connection. 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. Check that itis on the two pins closest to the USB port.

ConnecttheArduinoboardtoyourcomputerusingtheUSBcable.Thegreenpower LED (labeled PWR) should glow.

Step4−LaunchArduinoIDE.

After your Arduino IDE software is downloaded, you need to unzip the folder.Insidethefolder,youcanfindtheapplicationiconwithaninfinity label (application.exe). Double-click the icon to start the IDE.

Step5−Openyourfirstproject.

Oncethesoftwarestarts,you havetwo options−

- Createa newproject.
- Open an

existing project

example.Tocreate

a new project,

selectFile→**New**.

Toopenan existing projectexample,selectFile→Example→Basics→Blink.

Here, we are selecting just one of the examples with the name **Blink**. It turnstheLEDonandoffwithsometimedelay.Youcanselectanyother example from the list.

Step 6−Selectyour Arduinoboard.

Toavoidanyerrorwhileuploadingyourprogramtotheboard,youmust select the correct Arduino board name, which matches with the board connected to your computer.

GotoTools →Board andselectyourboard.

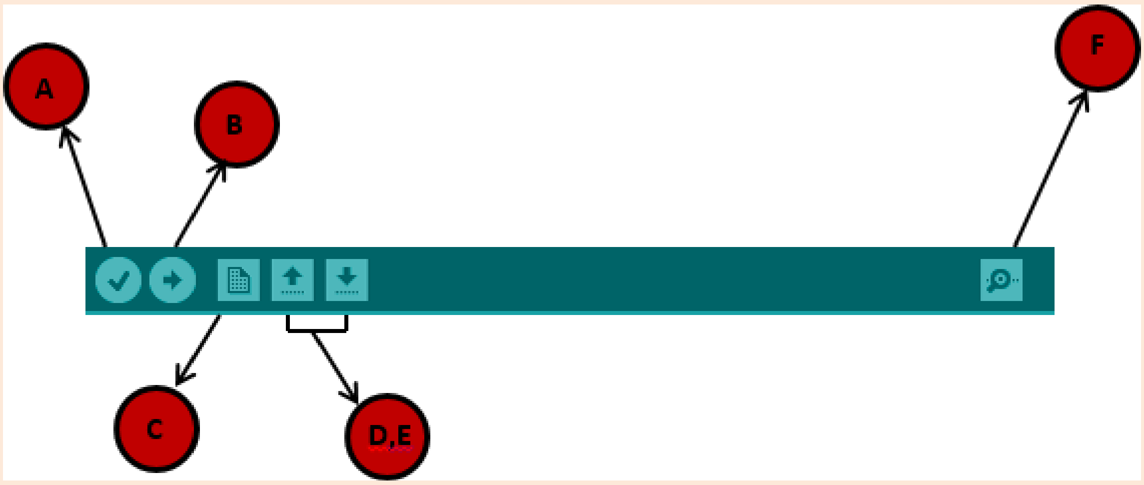
Here,wehaveselectedArduinoUnoboardaccordingtoourtutorial,but you must select the name matching the board that you are using.

Step7−Selectyourserial port.

SelecttheserialdeviceoftheArduinoboard.Goto**Tools→SerialPort** menu.ThisislikelytobeCOM3orhigher(COM1andCOM2areusually reservedforhardwareserialports).Tofindout,youcandisconnectyour Arduinoboardandre-openthemenu,theentrythatdisappearsshouldbe of the Arduino board. Reconnect the board and select that serial port.

Step 8−Uploadtheprogram toyourboard.

Beforeexplaininghowwecanuploadourprogramtotheboard,wemust demonstrate the function ofeach symbol appearing in the Arduino IDE toolbar.



A–Usedtocheckifthereisanycompilationerror.B–Usedtouploadaprogramtothe Arduino board. C – Shortcut used to create a new sketch.

D–Usedto directly openoneoftheexamplesketch.

E– Usedtosaveyoursketch.

F–Serialmonitorusedtoreceiveserialdatafromtheboardandsendtheserialdatatothe board.

Now,simplyclickthe"Upload"buttonintheenvironment.Waitafewseconds;youwillsee the RX and TX LEDs on the board, flashing. If the upload is successful, the message "Done uploading" will appear in the status bar.

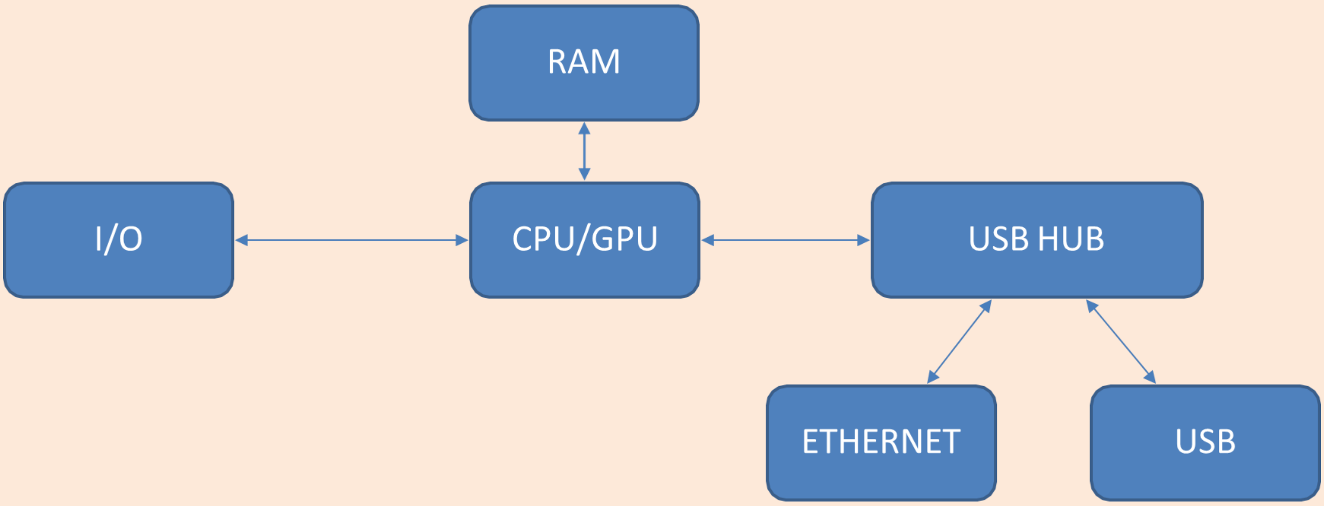
UNIT-7

ProgrammingwithRaspberryPi

Introduction

- RaspberryPiisalowcost,credit-cardsizedcomputerthatplugsintoacomputer monitor TV and uses a standard keyboard and mouse.
- Itisalittle devicethatenables peopleofall agestoexplore computing.
- Programsare writteninlanguageslikeScratchand Python.
- Itiscapableofdoingeverythingweexpectfromadesktopcomputer.Wecanbrowse the Internet, play high-definition video, to make spreadsheets, word-processing and playing games.
- ThereareseveralgenerationsofRaspberryPilikeRaspberryPi3modelB,Raspberry Pi 2 model B, Raspberry Pi zero.

Architecture



(BasicArchitectureofRaspberryPi)

The basic set up for Raspberry Pi includes HDMI cable, monitor, keyboard, mouse, 5volt power adapter for Raspberry Pi, LAN cable, 2 GB micro SD card (minimum). The official operatingsystemssupportedareRaspbianandNOOBS.Otherthird-partyoperatingsystems like Ubuntu mate, Snappy Ubuntu Core, Windows 10 Core, Pinet and Risc OS are also supported by Raspberry Pi.

MostcommonlyPi.usedprogramminglanguagesinRaspberryPiarePython,C,C++,Java, Scratch and Ruby

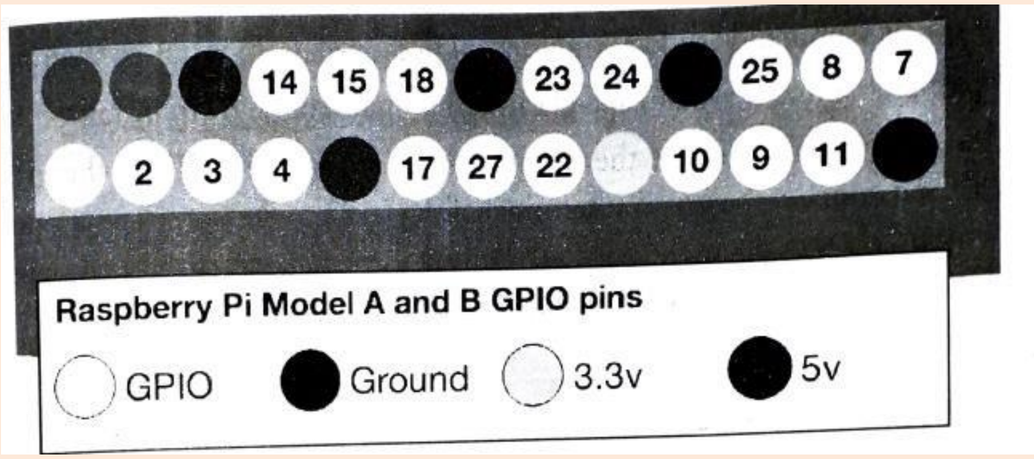
ThepopularapplicationsdevelopedusingRaspberryPiaremediastreamer,home automation,

controllingrobot,VirtualPrivateNetwork (VPN),lightweightWebserverwithIoTetc.

Pin Configuration

GPIO pins in pins in Raspberry Pi are the general-purpose Input-Output pins. These pins are toCommunicateWITHOTHERcircuitsuchassuchasextensionboards,customcircuitsand much more.

Forgetting anoutput, we can turn aGPIO pinHIGH orLOW.



These pins are a physical interface between the Pi and the outside world. At the simplestlevel,wecanthinkofthemasswitchesthatyoucanturnonoroff(input)orthatthe Pi can turn on or off (output). Seventeen of the 26 pins are GPIO pins. Others are power or groundpins.Eachpincanturnonoroff,orgoHIGHorLOWincomputingterms.Whenthe pin is HIGH it outputs 3.3 volts (3v3) and when the pin is LOW, it is off.

Wecanprogramthepinstointeractinamazingwayswiththerealworld.Inputsdon't havetocomefromaphysicalswitch. Itcouldbeinputfromasensororasignalfromanother computer or device. The output can also do anything, from turning on an LED to sending Signal or data to another device. If the Raspberry Pi is on a network, we can control devices that areattached to it from anywhere and thosedevices can send data back. Connectivity and control of physical devices over the Internet is a powerful and exciting thing and the Raspberry Pi is ideal for this.

Case Studies

wewilldiscussabout2exampleprojectsusingRaspberryPi."ThefirstoneisisanLEDand the second one is taking a picture using PiCam. The codes for both the examples are written in Python.

BlinkingLED:

Followingarethe requirements forthis experiment.

- Raspberrypi
- LED
- 100-ohmresistor
- Breadboard
- Jumpercables

WeneedtoinstallGPIO Library

InstallingGPIOlibrary:

- Open terminal
- Enterthecommand"sudo apt-getinstallpython-dev"toinstall python development
- Enterthecommand "sudoapt-getinstallpython-rpi.gpio"toinstallGPIOlibrary.

Connection:

- Connectthenegativeterminalof theLEDto thegroundpin of Pi
- Connectthepositive terminalof theLEDto theoutput pin of Pi

Program

```
import RPi.GPIO as GPIO # GPIO Library
import time
# Set the board for pin numbering
GPIO.setmode(GPIO.BOARD)
# Set GPIO pin as output pin
GPIO.setup(11,GPIO.OUT)
for i in range(0,5):
    GPIO.output(11,True)#Turn on GPIO pin 11
    time.sleep(1)
    GPIO.output(11,False)
    time.sleep(2)
    GPIO.output(11,True)
GPIO.cleanup()
```

The LED blinks in a loop with delay of 1 and 2 seconds for 5 times.

<u>CaptureImageusingRaspberryPi</u>Requirement:

- RaspberryPi
- RaspberryPi Camera

RaspberryPiCamera:

- RaspberryPispecificcamera module
- Dedicated CSIslot in Pifor connection
- ThecableslotisplacedbetweenEthernetportandHDMIport

Connection: Boot the Pi once the camera is connected to Pi

Configuring Pi for Camera

- Intheterminalrunthecommand“sudoraspi-config”andpressenter.
- Navigateto“Interfacing Options”option andpressenter.
- Navigateto“Camera” option.
- Enablethe camera.
- RebootRaspberrypi.

Capture Image

- Openterminalandenterthecommand-

  raspistill -o image.jpg
- Thiswill storethe imageas‘image.jpg’

PiCamcanalsobeprocessedusingPythoncameramodulepython-picamera sudo

apt-get install python-picamera

PythonCode:

Importpicamera

camera=picamera.PiCamera()camera.capture('image.jpg')

<u>ImplementationofloTwithRaspberryPi</u>

For this we need to integrate sensors and actuators interfaced with Raspberry Pi. The data willbereadfromthesensor.Theactuatorwillbecontrolledaccordingtothereadingfrom the sensor. We will see an example of a Temperature Dependent Auto Cooling System.

TemperatureDependentAutoCooling System

InthisexperimentaDHTsensorsensesthetemperatureandwhenthetemperaturegoes above 30° C, a fan needs to be automatically turned on.

Requirements

- DHTSensor
- 4.7Kohm resistor
- Relay
- Jumperwires
- RaspberryPi
- Mini fan

DHT Sensor

InDigitalHumidityandTemperatureSensor(DHT)thereare4pins:PIN1,2,3,4(fromleft to right)

  - PIN1-3.3V-5VPowersupply
  - PIN2-Data
  - PIN3-Null
  - PIN4-Ground

Relay

Thisisamechanicalorelectromechanicalswitch.Thereare3outputterminalsfromleftto right.

- NO(normalopen):
- Common
- NC(normalclose)

Connection

1. SensorinterfacewithRaspberryPi

- Connectpin 1ofDHTsensor to the 3.3Vpin ofRaspberry Pi
- Connectpin2ofDHTsensortoanyinputpinsofRaspberryPi,herewehaveused pin 11
- Connectpin4 ofDHTsensor to the groundpinoftheRaspberry Pi

2. Relayinterfacewith RaspberryPi

- ConnecttheVCCpin of relayto the5V supply pinof Raspberry Pi
- ConnecttheGND(ground) pinofrelayto theground pinof Raspberry Pi

- Connecttheinput/signalpinofRelaytotheassignedoutputpinofRaspberryPi(Here we have used pin 7)

3. FaninterfacewithRaspberryPi

- ConnecttheLi-Pobattery inserieswiththefan.
- NOterminalof therelay is connectedto thepositiveterminal ofthefan.
- Commonterminaloftherelayisconnectedto positiveterminalofthebattery.
- Negativeterminalofthebattery isconnectedtothe negativeterminalofthefan.

Adafruitprovidesalibrarytoworkwiththe DHT22sensor.InstallthelibraryinourPi.Get the clone from GIT

gitclone https://github.com/adafruit/Adafruit_Python_DHT.g...

Goto folder Adafruit_Python_DHT

cdAdafruit_Python_DHT

Installthe library

sudopythonsetup.py install

FollowingisthePythoncodeforinterfacing DHT22,RelayandFanwithRaspberry Pi.

Program

```
import RPi.GPIO as GPIO # GPIO Library
from time import sleep
import Adafruit_DHT # importing the Adafruit Library
# Set the board for pin numbering
GPIO.setmode(GPIO.BOARD)
GPIO.setwarnings(False)
#Create an instance of the sensor type
sensor=Adafruit_DHT.AM2302
print("Getting data from the sensor")
#humidity and temperature are 2 variables that store
#the values received from the sensor
humidity,temperature=Adafruit_DHT.read_retry(sensor,17)
print("Temp={0:0.1f}*c humidity={1:0.1f%".format(temperature,humidity))
# Set GPIO pin as output pin
GPIO.setup(13,GPIO.OUT)
if temperature>30:
    GPIO.output(13,0)#Relay is active low
    print("Relay is on")
    sleep(5)
    GPIO.output(13,1)#Relay is turned off after delay of 5 seconds
```

Result:

Thefan isswitched onwhenever thetemperatureis abovethe thresholdvaluesetin the code.

UINT-8

SOFTWAREDEFINEDNETWORKING

Limitationsin Current Network

- Vendor-specificarchitectureofswitcheslimitsdynamicconfigurationaccordingto application-specific requirements.
- Switchesarerequiredtoconfigureaccordingtotheinstalledoperatingsystem(OS).
- Centralizedcontrolisnot feasibleintraditionalnetwork.
- Theexplodingvolumesofdatatraffic,complexnetworkarchitecture,andgrowing demands to improve network performance obsoletes the traditional approach to network management.

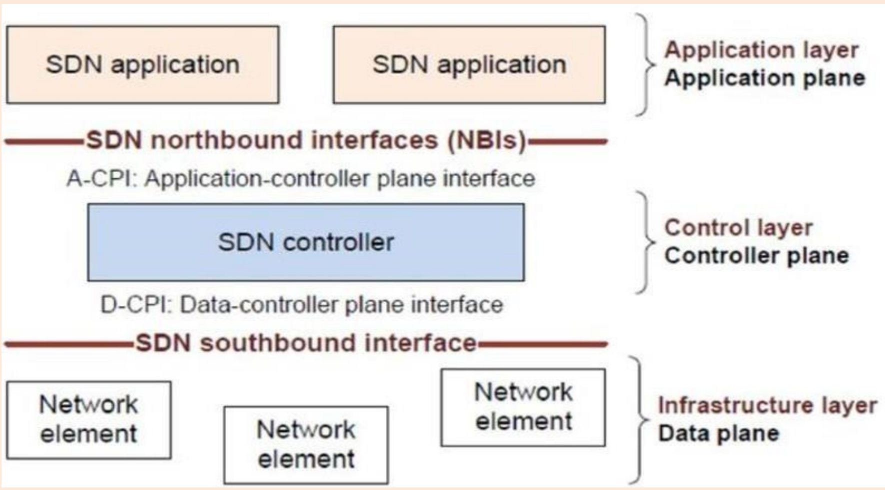
Software-DefinedNetworking(SDN)

Software-DefinedNetworking(SDN)isanapproachtonetworkingthatusessoftware- based controllers or application programming interfaces (APIs) to communicate with underlying hardware infrastructure and direct traffic on a network.

Originof SDN

- 2006: At Stanford university, a team proposes a clean-slate security architecture (SANE)tocontrolsecuritypoliciesinacentralizedmannerinsteadofdoingitat edges.
- 2008:Theideaofsoftware-definednetworkisoriginatedfromOpenFlowproject (ACM SIGCOMM 2008).
- 2009:StanfordpublishesOpenFlowV1.0.0specs.
- June2009: Niciranetwork isfounded.
- March2011:OpenNetworkingFoundationisformed.
- Oct2011:FirstOpenNetworkingSummit.ManyIndustries(Juniper,Ciscoannounced to incorporate.

SDNArchitecture



- Intraditionalnetworks,thecontrolanddataplaneareembeddedtogetherasasingle unit.
- The control plane is responsible for maintaining the routing table of a switch which determinesthebestpathtosendthenetworkpacketsandthedataplaneisresponsible for forwarding the packets based on the instructions given by the control plane.
- WhereasinSDN,thecontrolplaneanddataplaneareseparateentities,wherethe control plane acts as a central controller for many data planes.
- Thedataplaneconsistsofnetworkelements,whichexposetheircapabilitiestothe control plane via southbound interface.
- TheSDNapplicationsareintheapplicationplaneandcommunicatetheirnetwork requirements toward the control plane via northbound interface.
- The control plane sits in the middle to translate the applications' requirements and exertslow-levelcontroloverthenetworkelements,Providenetworkinformationto the applications.

Data-plane

- Datasourcesandsinks
- Trafficforwarding/processingenginewhichMayhavetheabilitytohandlesome types of protocol, e.g., ARP
- ProvideinterfacescommunicatingtothecontrolplaneforProgrammaticcontrolof all functions offered by the network element, Capability advertisement, Event notification.

Control-plane

- ItisplacedatLogicallycentralized.
- Its Core functionalities are Topology and network state information, Device discovery,Pathcomputation,Securitymechanism,Coordinationamongdifferent controllers Interfaces to the application plane.

Application-plane

- Applicationsspecifytheresourcesandbehavioursrequiredfromthenetwork,withthe context of business and policy agreement.
- Itmayneedtoorchestratheobjectives,(Cloudify,Unify)
- Programminglanguages helpdeveloping applications.

RulePlacement

TheSDNcontroller placesrules inthreephases uponreceiving anewflowata switch:

(a) Inthefirstphase,thecontrollerdeterminesoptimalforwardingpathtoroutetheflowfrom source to destination;

(b) Inthesecondphase,thecontrollerselectsoptimalswitchintheselectedpathforexact- match rule placement in order to get per-flow statistics;

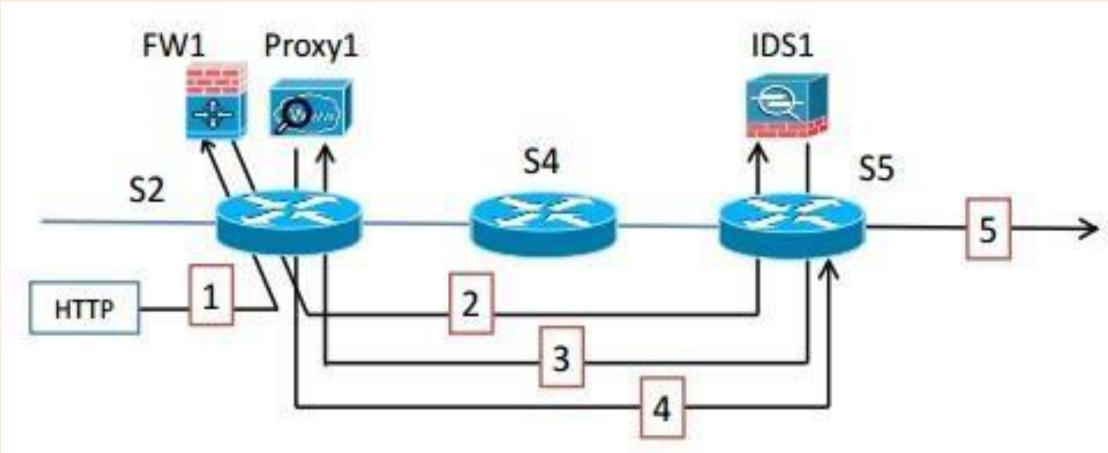
(c) Finally,flow-ruleisredistributedamongtheswitchestoaccommodatenewflowsinthe network upon detecting rule congestion at a switch

ControllerPlacement

- InadistributedSDNcontrollerarchitecture,multiplecontrollersaredeployedto minimize communication latency between the switch and the control plane.
- Thecontrollers arestrategically placedtooptimizenetworkperformance.
- Controllersdefineflow-ruleaccordingtotheapplicationspecific requirements.
- Thecontrollersmustbeableto handleallincomingrequestsfrom switches.
- Ruleshouldbeplacedwithout incurringmuch delay.
- Typically,acontroller canhandle 200requestsina second(throughasinglethread).
- Thecontrollersarelogicallyconnectedtotheswitchesinonehopdistanceand physically, they are connected to the switches in multi-hop distance.
- Ifwehaveaverysmallnumberofcontrollersforalargenetwork,thenetworkmight be congested with control packets (i.e., PACKET-IN messages).

SecurityinSDN

- Software-defined network security involves virtualizing security functions from the traditionalhardwaretheytendtooperateon.Theyenforcevirtualnetworkfunctions, with data and monitoring accessible through one intuitive interface.
- The latest generation of software-defined security applications make use of automationtobetterdetectanomaliesinnetworktrafficandimprovetheenforcement of security policies. This makes it easier to detect suspicious activity more quickly and respond more efficiently to prevent intrusions and minimizedamagein the event of a breach.
- Thereis Enhancedsecurity using SDN.
- TheSecurityisimplementedusingFirewall,Proxy,HTTP,Intrusiondetectionsystem (IDS)



(ExampleofpotentialdataplaneambiguitytoimplementthepolicychainFirewall-IDS- Proxy in the example topology.)

Intheabove example:

1. WhenanHTTPrequestcomes,itisfirstforwardedtoFirewall 1(FW1).
2. Fromthefirewall1,it issenttoInstrusionDetection System1(IDS1)
3. FromIDS1,it issenttoProxy1.
4. Finally,it issent from Proxy1to outside network.

<u>IntegratingSDNin IoT</u>

TheSDN-IoTintegrationbringsseveralsignificantbenefitsforIoTtraffic:

1. Intelligenttrafficroutingandbetternetworkresourcesuse.
2. Simplifiedinformationacquisitionfacilitatinginformationanalysis,decisionmaking and network configuration actions.
3. Virtualization,wheneverrequired,maybeeasilyachievedanddeployedusing common SDN virtualization tools like hypervisors.
4. Visibilityofnetworkresourcesandaccessmanagementbasedonuser,group,device, and application.
5. Intelligentalgorithmstobuildeffectivetrafficpatternanalysers.

ThesebenefitsresultinIoTnetworkswithintegratedSDNcapabilitiesbecomingmoreagile, scalable and based on demand.

DifferencebetweenSDNandTraditionalNetwork:

S.No.	SDN	TRADITIONALNETWORK
01.	SoftwareDefinedNetworkisvirtual networking approach.	Traditionalnetworkistheoldconventional networking approach.
02.	SoftwareDefinedNetworkiscentralized control.	TraditionalNetworkisdistributed control.
03.	Thisnetworkis programmable.	Thisnetwork isnon programmable.
04.	SoftwareDefinedNetwork isopen interface.	Traditionalnetworkisclosed interface.
05.	InSoftwareDefinedNetworkdataplaneand control plane are decoupled by software.	Intraditionalnetworkdataplaneandcontrol plane are mounted on same plane.
06.	Itsupportsautomaticconfigurationsoit takes less time.	Itsupportsstatic/manualconfigurationsoit takes more time.
07.	Itcanprioritizeandblockspecificnetwork packets.	Itleadsallpacketsinthesamewayno prioritization support.

08.	Itiseasytoprogramasperneed.	Itisdifficulttoprogramagainandtoreplace existing program as per use.
09.	CostofSoftwareDefinedNetworkis low.	Costof TraditionalNetwork is high.
10.	StructuralcomplexityislowinSoftware Defined Network.	StructuralcomplexityishighinTraditional Network.
11.	InSDNitiseasytotroubleshootingand reporting as it is centralized controlled.	In Traditional network it is difficult to troubleshootandreportasitisdistributed controlled.
12.	Itsmaintenancecostislowerthantraditional network.	Traditionalnetworkmaintenancecostishigher than SDN.

UINT-

9SMARTHOMES

- Asmarthomereferstoaconvenienthomesetupwhereappliancesanddevicescanbe automaticallycontrolled remotelyfromanywhere withaninternetconnectionusinga mobile or other networked device.
- Devicesinasmarthomeareinterconnectedthroughtheinternet,allowingtheuserto control functions such as security access to the home, temperature, lighting, and a home theater remotely.

Smart Home Implementation:

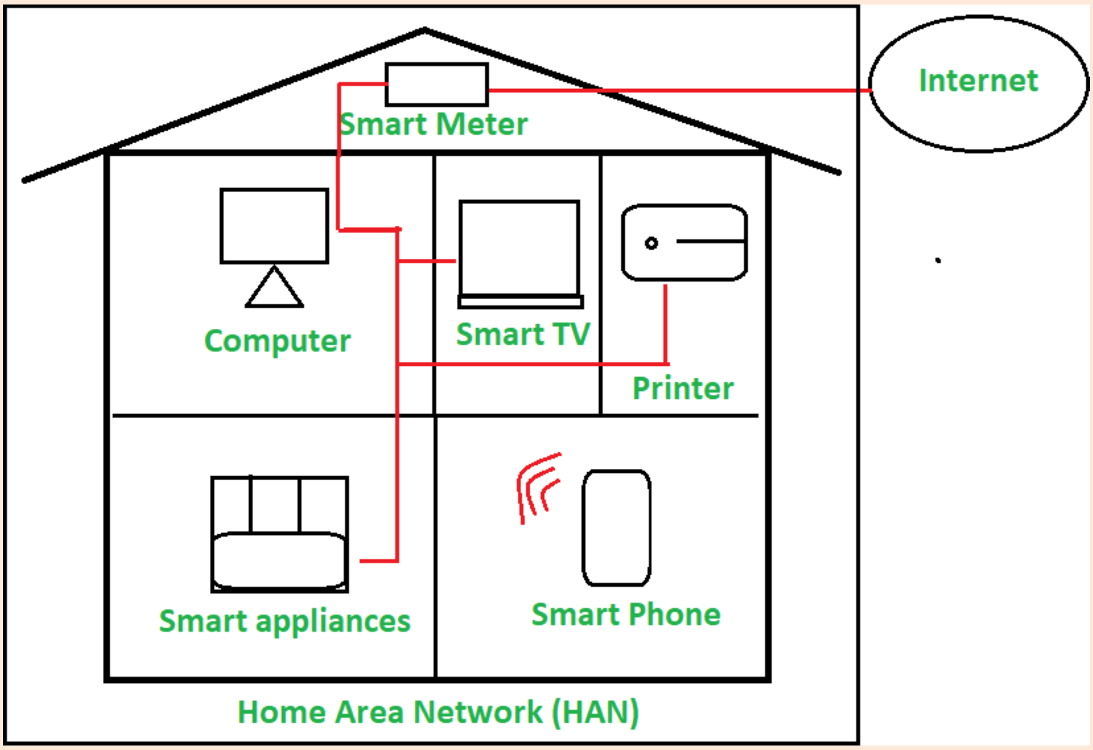
Settingupofasmarthomerequiresthefundamentaltechnologyincludingprotocolsandallthe hardware and software. Besides, you need smart devices that can be connected to the internet on the home network. For example, cameras, motion sensors, LED lights, devices with built-in web servers, etc. These are readily available online or at electronics improvement stores.

Beforebuyingsuchproducts,onehastomakesurethatalldevicesusethesametechnology.If two devices use different technologies, say one uses X10 while other uses Z-Wave, then it requiresabridgingdeviceaswellasalotoftechnicalexpertise.Itisusuallyrecommendedthat oneshouldseekprofessionalhelpwhiledesigningasmarthome.TechnicianswithCEA-Comp TIA Certification are considered to be more proficient in installing and troubleshooting the home networking equipment.

The cost of home automation depends on how smart the home is. The users can either keep it basic with jut intelligent lighting or add high-tech security systems. One has to decide where toplacethenodestohaveaneffectiveroutingrangeandplantheasitmayrequirerenovation or rebuilding of certain portions of the house.

HomeAreaNetwork(HAN)

- Home Area Network (HAN)is a network in a user's home where all the laptops, computers, smartphones, and othersmart appliances and digital devices are connected into a network.
- This facilitates communication among the digital devices within a home which are connected to the Home network.
- Home Area Network may be wired or wireless. Mostly wireless network is used for HAN.
- Example – Thinkaboutahomewherecomputers,printers,gamesystemsandtablets,smartphones, other smart appliances are connected to each other through wired or wireless over a network is an example of Home Area Network.



InfrastructureofHAN:

- AmodemisusedwhichisprovidedbyanISPtoexposeEthernettoWAN.Inhomes they come in DSL modem or cable modem.
- ArouterisusedtomanageconnectionbetweenHomeAreaNetwork(HAN) and Wide Area Network (WAN).
- Awirelessaccesspoint isusedfor connectingwirelessdigital devicestothenetwork.
- SmartDevices/DigitalDevicesareused toconnecttotheHomeAreaNetwork.

<u>Smart Home benefits</u>

1. Managingall ofyourhome devicesfrom one place.
2. Flexibilityfornewdevicesandappliances.
3. Maximizinghome security.
4. Remotecontrol of home functions.
5. Increasedenergyefficiency.
6. Improvedappliancefunctionality.whenentertainingguests.
7. Homemanagementinsights.
8. Customizeas Perour Convenience.
9. Higherqualityoflife.

10. Notificationsincase oftrouble.

11. Costsavingsin thelongrun.

12. Smarthomesmaybesuitablefordisabledandoldpersons.

Smart Home issues

1. Significantinstallationcosts.
2. Reliableinternetconnectioniscrucial.
3. Technologicalproblemsinconnectedhomes.
4. Maintenanceandrepairissues.
5. Compatibilityproblemsbetweendevices.
6. Technologymaybecome outdatedsoon.
7. PowerOutageMayhamper theSystem operations.

UNIT-10SMARTCITIES

- Asmartcityisanurbansystemwhichusesinformation&communicationtechnology (ict) to make infrastructure more interactive, accessible and efficient.
- NeedforSmartCities arosedueto
  - Rapidlygrowingurbanpopulation.
  - Fastdepletingnaturalresources.
  - Changesinenvironmentandclimate.

CharacteristicsofSmartCities

Ithasbeensuggestedthatasmartcity(alsocommunity,businesscluster,urban agglomeration or region) uses information technologies to:

1. Makemoreefficientuseofphysicalinfrastructure(roads,builtenvironmentandother physical assets) through artificial intelligence and data analytics in order to support a strong and healthy economic, social, cultural development.
2. Engageeffectivelywithlocalgovernanceofficialsbyuseofopen innovation processes and e-participation, improving the collective intelligence of the city'sinstitutionsthroughe-governance,withemphasisplacedoncitizenparticipation and co-design.
3. Learn,adaptandinnovateandtherebyrespondmoreeffectivelyandpromptlyto changing circumstances by improving the intelligence of the city.

SmartcityFrameworks

The creation, integration, and adoption of smart city capabilities require a unique set of frameworks to realize the focus areas of opportunity and innovation central to smart city projects.Theframeworkscanbedividedinto5maindimensionswhichincludenumerous related categories of smart city development

1. Technology framework

A smart city relies heavily on the deployment of technology. Different combinations of technologicalinfrastructureinteracttoformthearrayofsmartcitytechnologieswithvarying levels of interaction between human and technological systems.

Digital:Aservice-orientedinfrastructureisrequiredtoconnectindividualsanddevicesina smart city. These include innovation services and communication infrastructure.

Intelligent: Cognitive technologies, such as artificial intelligence and machine learning, can be trained on the data generated by connected city devices to identify patterns. The efficacy andimpactofparticularpolicydecisionscanbequantifiedbycognitivesystemsstudyingthe continuous interactions of humans with their urban surroundings.

Ubiquitous: A ubiquitous city provides access to public services through any connected device.U-cityisanextensionofthedigitalcityconceptbecauseofthefacilityintermsof accessibility to every infrastructure.

Wired: The physical components of IT systems are crucial to early-stage smart city development.WiredinfrastructureisrequiredtosupporttheIoTandwirelesstechnologies centraltomoreinterconnectedliving.Awiredcityenvironmentprovidesgeneralaccessto continually updated digital and physical infrastructure. The latest in telecommunications,robotics,IoT,andvariousconnectedtechnologiescanthenbedeployed to support human capital and productivity.

Hybrid:Ahybridcityisthecombinationofaphysicalconurbationand avirtualcityrelated to the physical space. This relationship can be one of virtual design or the presence of a critical mass of virtual community participants inaphysical urban space. Hybrid spaces can serve to actualize future-state projects for smart city services and integration.

Informationcity: Themultiplicityofinteractivedevicesinasmartcitygeneratesalarge quantity of data. How that information is interpreted and stored is critical to Smart city growth and security.

2. Humanframework

Smart city initiatives have measurable positive impacts on the quality of life of its citizens andvisitors.Thehumanframeworkofasmartcity–itseconomy,knowledgenetworks,and human support systems is an important indicator of its success.

Creativity: Arts and culture initiatives are common focus areas in smart city planning. Innovationisassociatedwithintellectualcuriosityandcreativeness,andvariousprojectshave demonstrated that knowledge workers participate in a diverse mix of cultural and artistic activities.

Learning: Since mobility is a key area of Smart city development, building a capable workforcethrougheducationinitiativesisnecessary.Acity'slearningcapacityincludesits education system, including available workforce training and support, and its cultural development and exchange.

Humanity: Numerous Smart city programs focus on soft infrastructure development, like increasingaccesstovoluntaryorganizationsanddesignatedsafezones.Thisfocusonsocial and relational capital means diversity, inclusion, and ubiquitous access to public services is worked in to city planning.

Knowledge: Thedevelopmentofaknowledge economy is centraltoSmart city projects.Smartcitiesseekingtobehubsofeconomicactivityinemergingtechandservice sectors stress the value of innovation in city development.

3. Institutional framework

The smart community’s movement took shape as a strategy to broaden the base of users involved in IT. Members of these Communities are people that share their interest and work inapartnershipwithgovernmentandotherinstitutionalorganizationstopushtheuseofITto improve the quality of daily life as a consequence of different worsening in daily actions.

4.Energy framework

Thecityhasasmarterenergyinfrastructure.Employmentofsmarttechnologiesenablesthe more efficient application of integrated energy technologies in the city allowing the development of more self-sustaining areas or even Positive Energy Districts that produce more energy than consume.

A smart city is powered by "smart connections" for various items such as street lighting,smartbuildings,distributedenergyresources(DER),dataanalytics,andsmart transportation.

5.DataManagement framework

Smart cities employ a combination of data collection, processing, and disseminating technologiesinconjunctionwithnetworkingandcomputingtechnologiesanddatasecurity and privacy measures encouraging the application of innovation to promote the overall quality of life for its citizens and covering dimensions that include: utilities, health, transportation, entertainment and government services.

<u>ChallengesinSmart cities</u>

The Chere are several challenges that exist in the implementation of smart cities. The developmentofsmartCityconfrontsseveralchallengesfromthetechnologicalperspective.

Security and privacy: Preserving privacy of citizens and end users is a big concern Since mostofmostoftheframeworksrequirecollectingdatafromthecitizens.Thedatacollected can be exposed to attacks, vulnerabilities and multi-tenancy which include the risk of data leakage.

Heterogeneity:ltinvolvestheintegrationofvaryinghardwareplatformsandspecifications. Various radio specifications and software platforms need to be integrated. Accommodating vary1ng user requirements is another challenging task in smart city.

Reliability: There can be unreliable communication in smart cities due to vehicle mobility. Delivery failures are still significant in smart cities. There can be delay in receiving data due tomobilityofdeployednodes.Distributionofdevicescanaffectmonitoringtasksalso.Legal and social aspects: The legal aspects of smart cities include services based on user provided information which is subject to local or international laws. Social issue is that individual and informed consent is required for using humans as data sources.

Big data: Challenges related to Big data include storage, management, fusion, consistency trustworthiness and 3V's (Volume, Velocity and Variety). In a smart city context, this becomes more significant. Transfer, storage and maintenance of huge volumes of data are expensive Data cleaning and purification of data is time consuming. Analytics on gigantic data volume is process intensive. On-device and embedded intelligence to support light-weightartificialintelligenceonloTandresource-constraineddevicesthatbuildthesmartcity infrastructure is yet another challenge.

Sensor networks: Choice of appropriate sensors for individual sensing tasks and energy planning is crucial. Device placement and network architecture is important for reliable e to-endIoTimplementation.Communicationmediumandmeansplayanimportantroleseamless function of IoT in smart cities.

Data Fusion

- Enormousvolumeofdatais producedperiodically in asmart city environment.
- Challengesincludemakingtheavailable/incominglargedatavolumepreciseand accurate.
- QualityofdataprecisionandaccuracyaffectsthequalityofdecisionmakinginIoT-enabled smart cities.
- Datafusionenablesoptimumutilizationofmassivedatagatheredfrommultiple sources, and across multiple platforms.

Multi-sensorData Fusion

- Combinesinformationfrommultiplesensor sources.
- Enhancestheabilityofdecision-makingsystemstoincludea
- multitudeofvariablespriortoarrivingata decision.
- Inferencesdrawnfrommultiplesensortypedataisqualitativelysuperiortosingle sensor type data.
- Informationfusiongeneratedfrommultipleheterogeneoussensorsprovidesforbetter understanding of the operational surroundings.

ChallengesinData Fusion

Imperfection	InaccurateoruncertainWSNsensordata
Ambiguity	Outliers,missingdata
Conflicts	Samesensortypereportsdifferentdataforthesamelocation.
Alignment	Ariseswhensensordataframesareconvertedtoasingularframepriortotransmission
Trivialfeatures	Processingoftrivialdatafeaturesmaybringdowntheaccuracyofthewholesystem

DataFusionOpportunitiesinIoT

- Collectivedataisrichininformationandgeneratesbetterintelligencecomparedtodata from single sources.
- Optimalamalgamationofdata.
- Enhancingthecollectiveinformationcontentobtainedfrommultiplelow-power,low-precision sensors.
- Enableshidingofcriticaldatasourcesandsemantics(usefulinmilitaryapplications, medical cases, etc.).

Smart Parking

Smart Parking is a parking strategy that combines technology and human innovation in an efforttouseasfewresourcesaspossiblesuchasfuel,timeandspacetoachievefaster,easier and denser parking of vehicles for the majority of time they remain idle.

BenefitsofSmartParking:

- Shortensparkingsearch timeof drivers.
- Reducestraffic congestion.
- Reducespollutionbykeepingunnecessarilylingeringvehiclesofftheroads.
- Reducesfuel consumptionandcosts.
- Increasesurban mobility.
- Shorterparkingsearchtimeresults inmoreparked time,andhence,morerevenue.

Howdoesasmartparkingsystemwork?

Asmartparkingsystemisaneffectivesolutiondevelopedagainsttheproblemofon-andoff- street parking. For understanding how a smart parking system works, it is essential to comprehendtheinformationaboutthevariouselementsthatcontributetothedevelopmentof an intelligent parking system.

Sensors: Sensors are embedded within the roads and grounds to provide the parking operatorsknowledgeaboutconsumerbehaviourandwhetherornotasuitableparkingslotis available.

Cameras: Camerasattachedtothehighpointviewsneartheparkinglotallowtheoperators to perceive the dimension and movement of the vehicle.

Parkingmeters: Parkingmeterisanintermediatebetweentheoperatorandtheuser.It provides authorization and payment information to the operator.

CentralServer: Asthenamesuggests,acentralserverisresponsibleforcommunicating with sensors, cameras and mobile applications.

ParkingManagementsoftware: Typicallyassociatedwithinteractionwithstakeholdersas it provides them with real-time information pertaining to the parking process.

IoT based Smart Parking Mobile Apps: With regard to the process, a mobile app contributestotheprocessingoftransactions.All-in-all,mobileappsareresponsiblefor allowingthe userto identify thespaces onthestreets andslots availableinthe garages.

Nowthatwe'reawareofthethingsworkinginthebackground,youmustknowhowsmart parking system works:

Input: Sensors,camerasandparkingmeterscollectandtransfertheinformationaboutthe vehicle and the surroundings to the parking operators.

Processing: Once,theinformationabouttheparkingslotandconsumer'svehicleisreceived, the central server securely stores this information and informs the stakeholders about the granting of the slot.

Output: The underlying software or application processes the data received from the aforementioneddevicesandreservesaparkingspotfortheconsumer.Iftheconsumerhas previously booked the parking space, the software guides the driver to the same.

EnergyManagementinSmartCities

- Energy Management in Smart Cities involve Energy efficient solutions like Lightweightprotocols,Schedulingoptimization,Predictivemodelsforenergy consumption, Cloud-based approach, Low-power transceivers and Cognitive management framework
- EnergyharvestingsolutionsincludeAmbientenergyharvesting,RFsources,Wind, Sun, Heat and Vibration.
- InDedicatedenergyharvesting,EnergysourcesintentionallydeployednearIoT sources.
- AmountofenergyharvesteddependsonSensitivityoftheharvestingcircuit,Distance between the device and source and Environment.

UNIT-11

IndustrialIoT

The industrial internet of things (IIoT) refers to the extension and use of the internet ofthings(IoT)inindustrialsectorsandapplicationswithastrongfocusonmachine-to-machine (M2M) communication, big data, and machine learning, the IIoT enables industries and enterprises to have better efficiency and reliability in their operations**.**

IIoT requirements

- IoTendrequirementistheconsumerconvenienceandIIoTendrequirementisthe return on investment.
- IoTfocusesonmanaginghomeapplianceswhichincreaseconsumerconvenienceby saving resources such as electricity.
- IIoT focuses on critical systems such as health care, aerospace, factory machinery automationandconnectingmachinesandpeopletogetheralongwithdataanalytics.
- IIoTwants theuptime tobehigherand downtimeof businessoperations tobelesser.

Designconsiderations

TouseanIoTdeviceforindustrialapplications,thefollowingdesignobjectivesaretobe considered

- Energy:Timeforwhichthe IoTdevicecanoperatewithlimitedpowersupply.
- Latency:Timerequiredtotransmitthe data.
- Throughput:Maximumdatatransmittedacrossthenetwork.
- Scalability:Numberofdevicessupported.
- Topology:Communicationamongthedevices,i.e.,interoperability.
- SafetyandSecurity:Degreeof safetyandsecurityoftheapplication.

Applications of IIoT

Thekeyapplicationareasof IIoTare:

1. **Manufacturingindustry:**

   Thedevices,equipment,workforce,supplychain,workplatformareintegratedand connected to achieve smart production. This will lead to –

   - reductioninoperationalcosts
   - improvementin theproductivityof the worker
   - reductionintheinjuriesattheworkplace
   - resourceoptimizationandwastereduction
   - end-to-endautomation.

2. **HealthcareServiceindustry:**
   Patientscanbecontinuouslymonitoredduetotheimplantedon-bodysensors.This has led to –
   - improvedtreatmentoutcome
   - costshasreduced
   - improveddisease detection
   - improvedaccuracyinthe collectionofdata
   - improveddrugsmanagement.

3. **Transportation& logistics:**

Toimprovesafety,efficiencyoftransportation,IntelligentTransportationsystem(ITS)is developed which consists of connected vehicles. ITS provides –

   a. Vehicle–to –sensorconnectivity
   b. Vehicle– to – vehicleconnectivity
   c. Vehicle–to–internetconnectivity
   d. Vehicle–to–road infrastructure

- In IIoTscenariothephysicalobjectsareprovided with
  - barcodes
  - RFID tags
  - hence,real-timemonitoringofthestatusandlocationofthephysicalobjects from destination to the origin, across the supply chain is possible.
- Securityand privacyof thedata shouldbemaintained.

4. **Mining:**
   Topreventaccidentsinsidethemines-RFID,Wi-Fi andotherwirelesstechnologies are used, which
   - providesearly warningofanydisaster
   - monitorsair-quality
   - detectsthepresenceof poisonousgases insidethemines
   - oxygenlevelinsidethemines.

5. **Firefighting:**
   Sensornetworks, RFIDtags areused to perform
   - automaticdiagnosis
   - earlywarningofdisaster
   - emergencyrescue
   - providesreal-timemonitoringHence,improvespublicsecurity.

BenefitsofIIoT

Byharnessing IoTand advanced analyticstechnologies,manufacturerscan:

- Increaseproductivityanduptime.
- Improveprocess efficiencies.
- Accelerateinnovation.
- Reduceassetdowntime.
- Enhanceoperational efficiency.
- Createend-to-endoperationalvisibility.
- Improveproductquality.
- Reduceoperatingcosts.
- Optimizeproduction scheduling.
- Improveoverallequipmenteffectiveness (OEE).

Challenges ofIIoT

- The primary challenges in IloT include identification of objects or amount things, managehugeofdata,integrateexistinginfrastructuresintonewIloTinfrastructure and data enabling storage.

- Thereareseveralsafetychallengeswhichincludeworkerhealthandsatety,regulatory compliance, environmental protection and optimized operations.

- Challengesrelatedtohazardsincludehandling,storingorusinghazardoussubstances, oxygen deficiency, radiation and physiological stress.

- Theproblemsrelatedtostandardizationareinteroperability,semanticinteroperability, security and privacy and radio access level issues.

- OtherimportantconcernsrelatedwithIloTareinformationsecurityand dataprivacy protection. The devices or things can be tracked, monitored and connected. So there are chances of attack on the personal and private data.

- ThoughlloTprovidesnewopportunities,newfactorsmaycausehindranceinthepath to success such as lack of vision and leadership, lack of understanding of values among management employees, costly sensors and inadequate infrastructure.

DifferencebetweenIIOTandIOT:

IIOT	IOT
It focuses on industrial applications such as manufacturing,powerplants, oil&gas, etc.	Itfocusesongeneralapplicationsranging from wearables to robots & machines.
Itusescriticalequipment&devicesconnectedovera network which will cause a life-threatening or other emergency situation on failure therefore uses more sensitive and precise sensors.	Itsimplementationstartswithsmallscale level so there is no need to worry about life-threatening situations.
Itdealswithlargescalenetworks.	Itdealswithsmallscale networks.
Itcanbeprogrammedremotelyi.e.,offersremoteon- site programming.	Itofferseasyoff-site programming.
Ithandlesdata rangingfrom mediumto high.	Ithandles very highvolume of data.
Itrequiresrobustsecuritytoprotectthedata.	Itrequiresidentityandprivacy.
Itneedsstringent requirements.	Itneedsmoderaterequirements.
Ithavingverylong-life cycle.	Ithavingshortproductlife cycle.
Ithashigh-reliability.	Itislessreliable.

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