UNIT-5

UNITVIOTSYSTEMDESIGN 9

Basic building blocks of an IoT device – Raspberry Pi – Board – Linux on Raspberry Pi – Interfaces– ProgrammingwithPython–CaseStudies:HomeAutomation,SmartCities,EnvironmentandAgriculture.

PART-A

1.Whatisan EmbeddedSystem Design?

A system designed with the embedding of hardware and softwaretogether for a specific function with a larger area is embedded system design.

2. What are the ElementsofEmbeddedSystems

- Processor
- Microprocessor
- Microcontroller

Digitalsignalprocessor

3. Write the Types ofEmbeddedSystems

- Stand-AloneEmbeddedSystem
- Real-Time Embedded System
- NetworkedAppliances

Mobiledevices

4.What are the ChallengesinEmbeddedSystemDesign

- Environmentadaptability
- Power consumption
- Area occupied
- Packagingand integration
- Updatinginhardwareand software
- Security

There are various challenges the designers face while testing the design like Embeddedhardware testing, Verification stage, Validation Maintainability

5. Write Embedded SystemDesign Examples

- Automaticchocolatevendingmachine(ACVM)
- Digitalcamera
- Smartcard
- Mobilephone
- Mobilecomputer..etc.

6. What are sensors?: Sensor used for sensing the change in environment condition and it generate the electric signal on the basis of change in environment condition. Therefore it isalso called as transducers for providing electric input signal on the basis of change in environment condition.

7. Define Application specific integrated circuit (ASIC) is an integrated circuit designed to perform task specific operation inside an embedded system

8. What are Embedded System processors?

Processors are the major part in embedded systems that take response from sensors in digital form and processing of this response to produce output in real-time processing environmentis performed using processors.

9. Write the Typesofgeneralpurposeprocessor

- Microprocessor
- Microcontroller
- Digitalsignalprocessor
- Analogsignalprocessor

10.What are Threemain componentsofEmbeddedsystems?

1. Hardware
2. Software
3. Firmware

11. Write theDisadvantagesofEmbeddedSystem

- Highdevelopment cost.
- Time-consumingdesignprocess.
- Asitisapplication-specificlessmarketavailable.

12.**Write theAdvantagesofEmbedded System**

- Enhancedreal-timeperformance.

13.What IndustrialAutomation

-

Itisone of the areaswhere the quality ofproductsis an essentialfactor fora more significant investment return. Anyone can **re-engineer**products and their packaging to provide superior performance in**cost**and **customer experience**with IoT applications

14.Write the applications of IOT in Healthcare

Healthcare do real-time monitoring with the help of smart devices. It gathers and transfers health datasuch as blood pressure, blood sugarlevels, weight, oxygen, and ECG. Thepatient can contact the doctor by the smart mobile application in case of any emergency

15. Write the applications of IOT in SmartRetail

IoT applications in retail give shoppers a new experience. Customers do not have to stand in long queues as the checkout system can read the tags of the products and deduct the total amount from the customer's payment app with IoT applications' help.

16. Write the applications of IOT in Smart SupplyChain

Customers automate the delivery and shipping with a smart supply chain. It also provides details of real-time conditions and supply networks.

17. Write the applications of IOT in SmartGrid

The smart grid is the IoT that attends to energy systems. Utility companies use smart grid technologies to find energy efficiencies through various means, including monitoring energy consumption, predicting energy shortages and power outages, and gathering data on how differentindividuals andcompanies useenergy

18. Write the applications of IOT in SmartFarming

Farmers can minimize waste and increase productivity. The system allows the monitoring of fields with the help of sensors. Farmers can monitor the status of the area.

Internet-connected devices go from 5 million to billions in just one year. Business Insider Intelligence estimates 24 billion IoT devices will install and generate more than 300 billionin revenue in the future.

19. What is MQTT Protocol?

ThisIoT based Home Automation Project uses MQTT protocol for exchanging data between serverandclient.

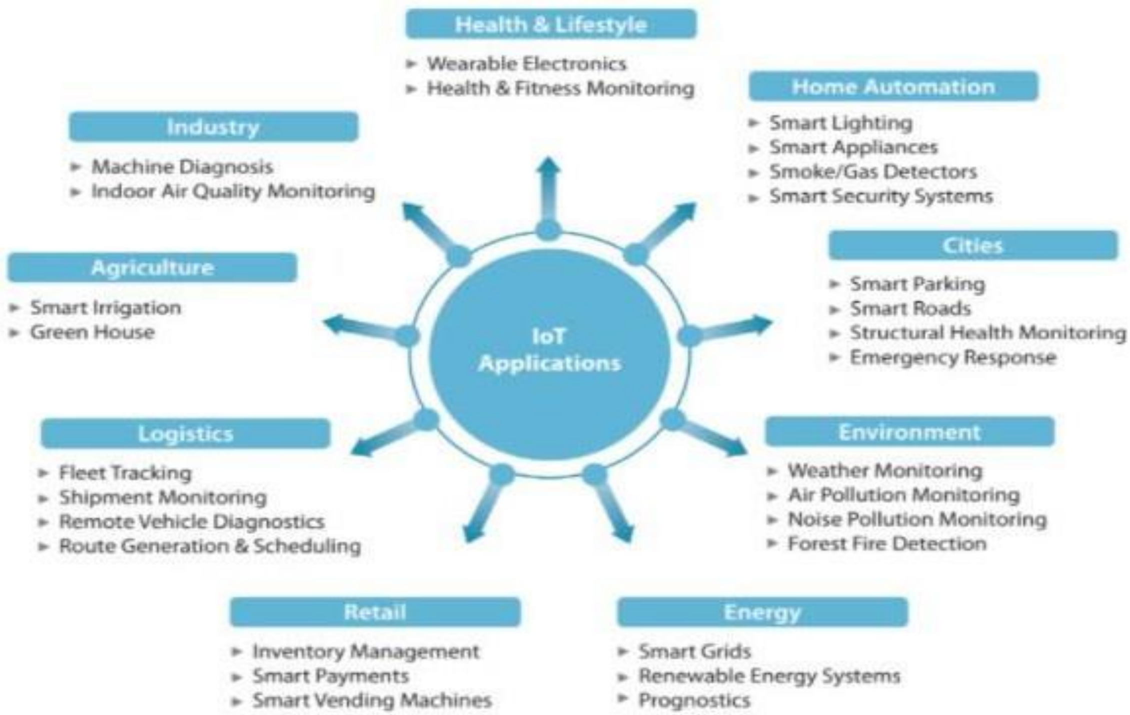
20. Define SignalConditioning Unit.

Thissensor isacost-effectiveboardusedtomeasuretheelectricalactivityoftheheart. This electrical activity can be charted as an ECG or Electrocardiogram and output as an analogreading

PART-B

BasicbuildingblocksofanIoTdevice

The Internet of Things denotes the connection of devices, machines, and sensors to the Internet.AnIoTsystemcomprisesfourbasicbuildingblocks:sensors,processors,gateways,andapplica tions. This article will thoroughly discuss what each component of the IoT architecturerepresents.



ThearchitectureofIoTcomponents:

1. **Sensors**convertanon-electricalinputtoanelectricalsignal.Sensorsareclassifiedintotwotypes:activeandpassivese nsors. Whereasactivesensorsuseand emittheirownenergy to collect real-time data (ex.: GPS, X-ray, radars), passive sensors use energyfrom external sources (ex: cameras). Additionally, sensors differentiate themse lves byposition,occupancy,andmotion,velocityandacceleration,force,pressure,flow, humidity,light, radiation,temperature,etc.
2. **Processors**arethebrain,themainpartoftheIoTsystem.Theyprocesstherawdatacapturedb ythesensorsandextractvaluableinformation.Examplesofprocessorsaremicrocontrollers andmicrocomputers.
3. **Gateways** are the combination of hardware and software used to connect one network to another.GatewaysareresponsibleforbridgingsensornodeswiththeexternalInternetorWorld WideWeb.Thefigurebelowdepictshowusinggatewaysworks.

4. **Applications**provide auserinterfaceandeffectiveutilizationofthe

datacollected.Thefigureaboveillustratessomeexamplesof IoTapplications.

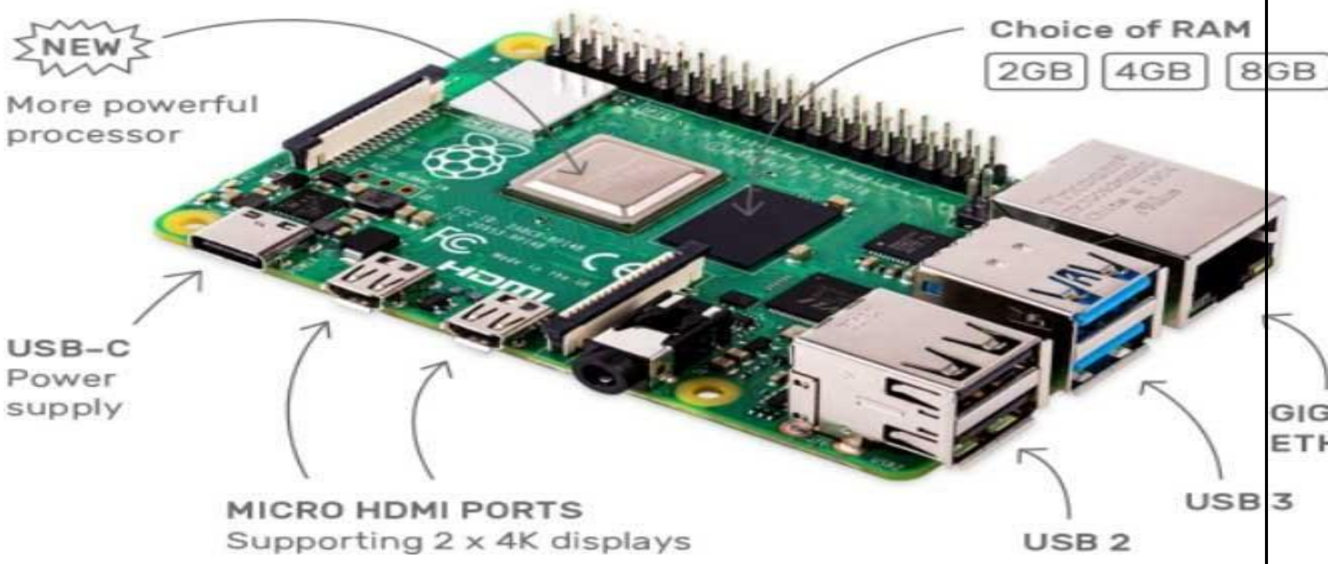
In summary, the IoT architecture comprises four basic building blocks: sensors, processors,gateways, and applications. Sensors are responsible for converting a non-electrical input to anelectricalsignal;processors–handle‖thesignals;gatewaysareused to connectanetwork to another,and,ultimately,anapplicationoffersauserinterfaceandeffectiveutilizationofthedatacollected.

WhatIsARaspberryPi?

- TheRaspberryPiisafullyintegratedcomputer(palmtop)mounted onacircuitboardmeasuring approximately7 cmx5.5cm.
- It is a small, capable device that enables people of all ages to scan a computer and learnto edit in languages such as Scratch and Python. It can do everything you would expect adesktopcomputertodo,frombrowsingonlineandplayinghigh-definition video,creatingspreadsheets,word processing,and playinggames.
- TheRaspberryPihastheabilitytointeractwiththeoutsideworldandhasbeen usedinmanydigitalmakerprojects,frommusicmachinesandparentalfinderstoweatherstationsa ndtweetingbirdhouseswith infra-red cameras.WewanttoseetheRaspberryPiused bychildren alloverthe worldtolearn howtoplanandunderstandhowcomputerswork.

HistoryOfRaspberryPi

- One-board Raspberry Pi computers have been developed in the United Kingdom by theRaspberry Pi Foundation to promote basic computer science teaching in schools anddevelopingcountries.
- Theoriginalmodelbecamemorepopularthanexpected,sellingoutofitstargetmarketforuseas robots.Includesperipherals(suchaskeyboardsandmice)orcases.UKReliefSocietyregisteredint heUK(No.1129409), May2009.
- SupportedbytheUniversityofCambridgeComputerLaboratoryandtechnologyfirmBroad comm.
- RaspberryPiHardwarehasbeen upgradedwithseveralversionsthatincludememorycapacityvariationsandperipheralcompatib ledevicesupport.



ImportantComponentsOfHardware

- TheRaspberryPihasaBroadcomBCM2835systemonchip (SoC),which includestheARM1176JZF-S 700 MHz processor, which was later upgraded to Broadcom BCM2711,Quad-coreCortex-A72 (ARMv8)64-bitSoC1.5GHz.
- Originallyshippedwith256megabytesofRAM,laterupgradedto4GB.
- Doesnotincludeabuilt-in harddisk,butusesanSDcardforbootandlong-termstorage.
- OSSupport:Linux-based(Fedora,Raspbian,Debian,ArchLinuxARM,etc..).

PlanningLanguages

- Bydefault,itsupportsPythonasalanguageofinstruction.
- Any integratedARMv6language canbeused with RaspberryPi.
- Automaticallyinstalledin RaspberryPi:
    - CorC++ orJavaorRubyorScratch

Application

- Canbeusedtomakehigh-endcomputers.
- RaspberryPiMedicalDeviceShield.
- SolarRaspberryPiPowerPack.
- VoiceCraftedCoffeeMachine.
- RaspberryPiDynamicBikeHeadlightPrototype.
- IoTBasedSmartApplication.

RaspberryPiInterfaces

Raspberry Pi is most popular SBC(Single Board Computer). We can used Raspberry Pi as an IoTdeviceandIoTGateway.InthisarticlewediscussRaspberryPiInterfaces.Interfacesusedforconnecti ngSensorsand actuators.

WhatisRaspberrypi?

The Raspberry Pi is a low cost, **credit-card sized computer** that plugs into a computer monitoror TV, and uses a standard keyboard and mouse. It is a capable little device that enables peopleof all ages to explore computing, and to learn how to programin languages like Scratch andPython.It'scapableofdoingeverythingyou'd expectadesktop computerto do,frombrowsingthe internet and playing high-definition video, to making spreadsheets, word-processing, andplayinggames.‖

IfyouknowaboutRaspberryPimore,Visitthis:***RaspberryPiTutorials***

Ifyouhave aRaspberryPiandyou wanttosetupforusein Headlessmode,VisitThis :***Raspberry PiHeadlessModeSetup***

Raspberrypihas***Serial,SPIand I2C***interfacesfordatatransfer.

Serial : The Serial interface on Raspberry Pi has receive (Rx) and transmit (Tx) pinsforcommunicationwithserialperipherals.

SPI : Serial Peripheral Interface (SPI) is a synchronous serial data protocol used forcommunicating with one or more peripheral devices. in an SPI connection, there are five pins onRaspberryPiforSPIinterface:

- **MISO(Masterinslaveout)**–Masterlineforsendingdatato theperipherals.
- **MOSI(Masteroutslavein)**–Slavelineforsendingdatatothemaster.
- **SCK(SerialClock)**–Clockgeneratedbymastertosynchronizedatatransmission
- **CE0(ChipEnable0)**–Toenableordisabledevices
- **CE0(ChipEnable1)**–Toenableordisabledevices

I2C:

The I2Cinterface pinsonRaspberryPiallowyou toconnecthardwaremodules.I2Cinterfaceallowssynchronousdatatransferwithjusttwo pins– **SDA(dataline)**an**SCL(ClockLine)**.

WHATISAPYTHONPROGRAM?

Python isa very useful programming languagethathasan easy to read syntax,andallowsprogrammers tousefewerlinesof codethan wouldbepossible inlanguages such asassembly,C,orJava.

ThePythonprogramminglanguageactually startedas a scripting language forLinux.Pythonprogramsare similar to shell scripts inthatthe files containa seriesof commandsthatthecomputerexecutesfromtoptobottom.

Comparea"helloworld"programwritteninCtothesameprogramwritteninPython:

Unlike Cprograms, Pythonprogramsdon'tneedtobe compiledbefore runningthem.However,youwillneedtoinstallthePythoninterpreteronyourcomputertorunthem.ThePythoninterpreterisaprogramthatreadsPythonfilesandexecutesthecode.

ItispossibletorunPythonprogramswithoutthePythoninterpreterinstalledthough.ProgramslikePy2exeorPyinstallerwillpackageyourPythoncodeintostand-alone executableprograms.

WHATCANAPYTHONPROGRAMDO?

Like shell scripts, Python canautomatetaskslikebatchrenamingand movinglargeamountsoffiles.ItcanbeusedjustlikeacommandlinewithIDLE,Python'sREPL(read,eval,print,loop)function.However,therearemoreusefulthingsyoucandowithPython.Forexample,youcanusePythontoprogramthingslike:

- Webapplications
- Desktopapplicationsandutilities
- SpecialGUIs
- Smalldatabases
- 2Dgames

Python also hasalargecollection of libraries, which speedsup the developmentprocess.Thereare libraries for everythingyou can think of–gameprogramming, renderinggraphics,GUIinterfaces,webframeworks, andscientificcomputing. Many(butnotall)ofthethingsyoucandoinCcanbedoneinPython.Pythonisgenerallysloweratcomputations than C, butitseaseofusemakes Pythonanideal languageforprototypingprogramsanddesigningapplicationsthataren'tcomputationallyintensive.

HOWTOWRITEANDRUNAPROGRAMINPYTHON

We'llonly coverthebasicsof writingandexecutinga Pythonprogram here, butagreattutorialcoveringeverythingaprogrammerneedstoknowaboutPythonisthebookLearningPython5thEd.(O'Reilly)byMarkLutz.

INSTALLINGANDUPDATINGPYTHON

Python2andPython3comepre-installedonRaspbianoperatingsystems,buttoinstallPythononanotherLinuxOSortoupdateit,simpl commandprompt:

yrunoneofthesecommandsatthe

commandprompt:

`sudoapt-getinstallpython3`

InstallsorupdatesPython3.

`sudoapt-get installpython`

InstallsorupdatesPython2.

OPENINGTHEPYTHONREPL

To access the Python REPL (where you can enter Python commands just like the commandline)enter`python`or`python3`dependingonwhichversionyouwanttouse:

EnterCtrl-DtoexittheREPL.

WRITINGAPYTHONPROGRAM

To demonstrate creating and executing a Python program, we'll make a simple "hello world"program. To begin, open the Nano text editor and create a new file named hello-world.py byenteringthisatthecommandprompt:

`sudonanohello-world.py`

EnterthiscodeintoNano,thenpressCtrl-XandYtoexitandsavethefile:

```
#!/usr/bin/python

print"Hello,World!";
```

AllPythonprogramfileswillneedtobesavedwitha".py"extension.Youcanwritetheprogramin anytexteditor such asNotepad orNotepad++, justbe sure to save the filewitha".py"extension.

RUNNINGAPYTHONPROGRAM

To runtheprogram without makingitexecutable, navigate to thelocation whereyou savedyourfile,andenterthisatthecommandprompt:

`pythonhello-world.py`

MAKEAPYTHONFILEEXECUTABLE

MakingaPythonprogramexecutableallowsyoutoruntheprogramwithout entering`python`beforethefilename.Youcanmakeafileexecutablebyenteringthisatthe commandprompt:

```
chmod+xfile-name.py
```

Nowtoruntheprogram,allyouneedtoenteris:

```
./file-name.py
```

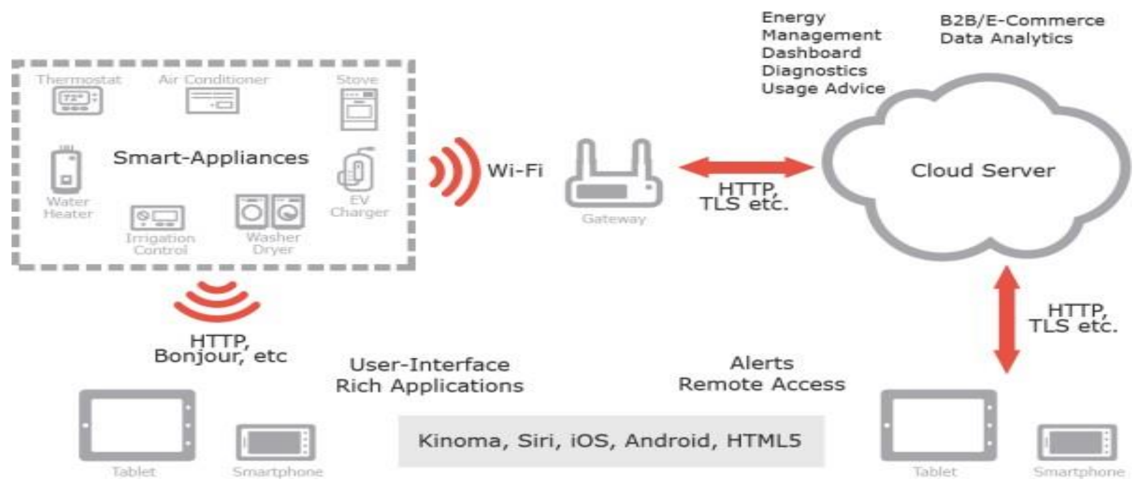
HerearesomeadditionalresourcesthatwillhelpyoumakethemostoutofprogramminginPython:

- CompletelistofPythonsyntax
- ThePythonPackageIndex(PyPi)
- InstallingPythonpackagesontheRaspberryPi

Casestudies:

HOMEAUTOMATION

IoT home automation is the ability to control domestic appliances by electronicallycontrolled, internet-connected systems. It may include setting complex heating andlighting systems in advance and setting alarms and home security controls, allconnectedbyacentralhubandremote-controlledbyamobileapp.



The rise of Wi-Fi‘s role in home automation has primarily come about due tothenetworked nature of deployed electronics where electronic devices (TVsand AVreceivers, mobile devices, etc.) have started becoming part of thehome IP networkand due the increasing rate of adoption of mobile computingdevices (smartphones,tablets,etc.),seeaboveFigure.

Thenetworkingaspectsarebringingonlinestreamingservicesornetworkplayback, while becoming amean to control of the device functionality over thenetwork.Atthesametimemobiledevicesensurethatconsumershaveaccesstoa portable ‗controller‘ forthe electronics connected to the network. Both types ofdevicescanbeusedasgatewaysforIoTapplications.

In thiscontext many companiesare consideringbuilding platformsthat integratethebuildingautomationwithentertainment,healthcaremonitoring,energymonitoringandwirelesssensormonitoringinthehomeandbuildingenvironments.

IoTapplicationsusingsensorstocollectinformationabouttheoperatingconditionscombinedwithcloudhostedanalyticssoftwarethatanalyzesdisparatedata points will help facility managers become far more proactive aboutmanagingbuildingsat peakefficiency

THREELEVELSOFHOMEAUTOMATION

1. **Monitoring:**

Description: Monitoring is the foundational level of home automation. It involvesthe ability to observe and track the status and conditions of various devices andsystemswithinthehome.

Characteristics:

SensorsandDevices:Implementationofsensorstomonitorenvironmentalconditions,security,energyusage,andmore.

Alerts and Notifications: Receive notifications or alerts based on monitored events.For example, receive a notification if a door is left open or if there's a suddenchangeintemperature.

Remote Viewing: Access real-time data andstatusupdates remotely through amobileapporwebinterface.

2. **Control:**

Description:Thecontrollevelbuildsuponmonitoringbyallowinguserstoactivelymanageandmanipulateconnecteddevicesandsystemswithinthehome.

Characteristics:

RemoteControl:Enableuserstoremotelycontrol devicesandsystems.Thisincludes turning lights on/off, adjusting thermostat settings, or locking/unlockingdoors.

Manual Input: Users have direct control through interfaces such as mobile apps,voicecommands,ordedicatedcontrolpanels.

Customization: Users can set preferences and customize the behavior of devicesbased on their needs. For instance, adjusting the brightness and color of smartlights.

3. **Automation:**

Description: Automation representsthe highest level of sophisticationin homeautomation.Itinvolvescreatingpredefinedscenariosorrulesthattriggerautomated actionsbasedoncertainconditionsorevents.

Characteristics:

Scenes and Routines: Users can define scenes or routines that involve multipledevices. For example, a "Good Morning" routine might turn on lights, adjust thethermostat,andstartthecoffeemaker.

Event Triggers: Automation rulescan be triggeredby specificevents,such asmotiondetection,adooropening,orascheduledtime.

AdaptiveBehavior: Intelligentautomationthatlearnsfrom userbehaviorandadjusts settings over time without explicit user input. For example, learning whentoadjust thethermostat basedonoccupancypatterns.

SMARTHOMEAUTOMATION

All smart home devices can communicate using openHAB.11. HAB drives from**Home Automation Bus**. The developer deploys Java and OSGi services and usestheopensourcedevelopmentenvironmentanddeploymentplatform.Itsaccompanying cloud platform is **my.openHAB** provides communication betweenthat with the cloud. **The my.openHAB cloud-connector also provides REST andcloud-basedservices.**

Figure12.7showsarchitecturallayersinopenHABdevelopmentenvironment. A service in figure refers to service capabilities, which can be calleduponwheneverneeded.Thefigureshowsthefollowing:

1. **CoreopenHABobjects**—RESTserviceandrepository;baselibrary

2. **openHABadd-onobjects**—Itemprovider,protocolbindings,automationlogics,userinterfacesandlibraries

3. **OSGiframeworkservices**—Configurationadministration,eventadministrationservice,declarativeservices,logback,runtimeandHTTPservices

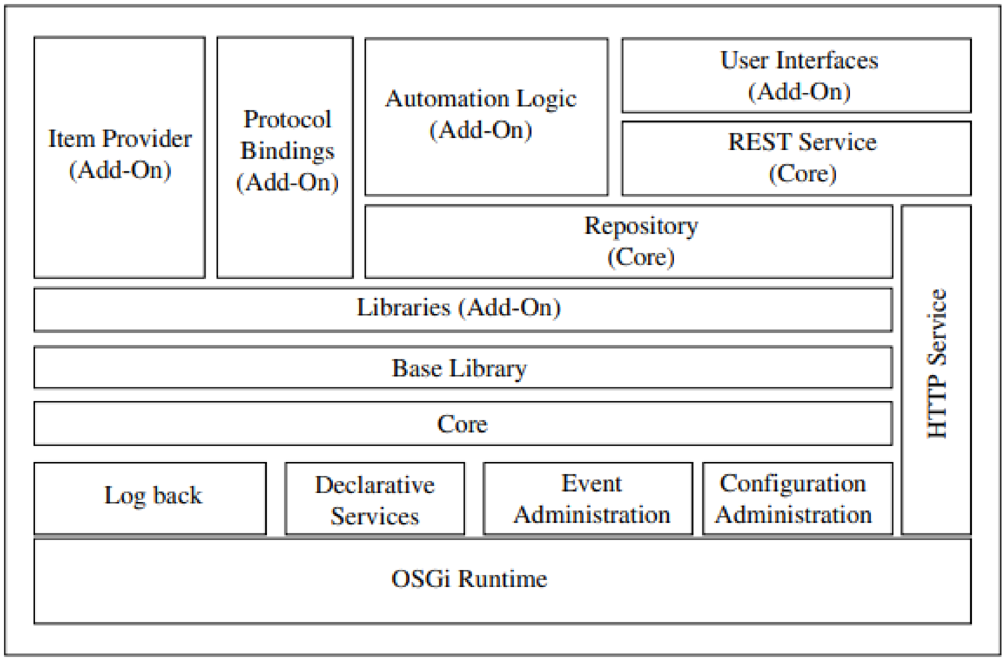


Figure 12.7 Architectural layers in openHAB development environment

4. **OpenHAB**deployseventadministrationserviceofOSGiwithpub/submode.
5. A stateful repository is for querying and for use by **automation logics**. Somefunctions are stateless and do not depend on previous action(s). Remainingactionsarestateful and dependent on previouschain of actions. State ofitemsinrepositoryisaspertheactions.

Two domains and their high-level service capabilities in the home automationsysteminIoTarchitecturereferencemodelare:

1. Deviceand Gateway Domain: Assumethatthe system deploysj lightingdevices, each with a proximity sensor. Automation logic provides that if no changeis found in proximity due to presence of person(s) then the devices switch off.Assumethatthesystemalsodeployskintrusionsensorsandlappliances.Automationl ogicprovidesonintrusion,communicatetrigger(s)toalocal orremote web-service as per configuration setting at the configuration administrationserviceofOSGiframework.

2. Application and Network Domain: Applications and network domain deploysapplications and services and have high-level capabilities. Domain ArchitecturalReferenceModel.

Figure 12.8 shows the data-flow diagram and domain architecture referencemodel for homeautomation lighting,appliancesand intrusion monitoringservices.

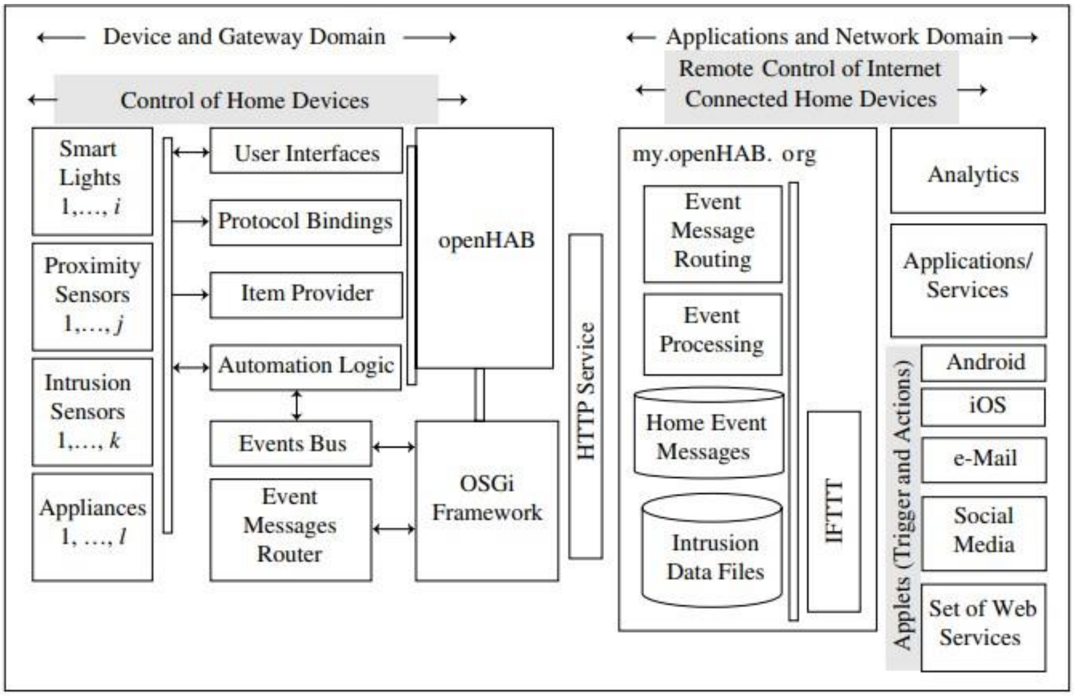


Figure 12.8 Data-flow diagram and domain architecture reference model for home automation lighting, appliances and intrusion monitoring services

Figure shows that openHAB has an event bus. The bus is asynchronous. Theeventbusrefersto a communication busfor all protocol bindings. The bindingslinktothehardware.TheeventbusisthebaseserviceofopenHAB.

Example of the event is command, which triggers an action or a state change ofsome item or device. Another example of event is **status update** which informsabout astatuschangeofsomeitemordevice.

For example, in response to a command. The openHAB service is **integration-hubbetweensuchdevicesandbindingsbetweendifferentprotocols**usedfornetworkingthehomedevices,OSGiandHTTPservice.

Usually just one instance of openHAB runs on a central coordinator (computer) athome. Event Administration Service of OSGi service is used for remote services.SeveraldistributedopenHABinstancescanconnectanddeploytheeventbus.

SMARTCITY

- Smartcityapplicationsandservicesconnectpeople,process,dataandthings.
- A smart city can be defined as a vision which integrates multiple ICT andIoTsolutionsinasecurefashiontomanageacity‘sassetssuchasinformation systems,schools,libraries,transportation systems,hospitals,power plants, water supply networks, waste management, law enforcementandothercommunityservices.
- Sectors that have been developing smart city technology include governmentservices,transportandtrafficmanagement,energy,healthcare,water ,innovativeurbanagricultureandwastemanagement.

Smart-citysolutionsintegrateanumberofcityservicesandcanincludethefollowing:

1. Smartparkingspaces
2. Smartstreetlightingsandsmartlightingsolutions
3. Smarttrafficsolutions
4. Smartwatermanagement,
5. Smartconnectedbikeshareservices
6. Smarthealthservices
7. Smartstructures
8. Smartcitysystemintegrator

Four-layer architectural framework developed at CISCO cloud IoT for a city.Layersconsistsof:

(i) devicesnetworkanddistributednodes,
(ii) distributeddatacapture,processingandanalyzing,
(iii) datacentersandcloudand
(iv) applications,suchaswastecontainersmonitoring.

Figureshowsdata-flowdiagramanddomainarchitecturereferencemodelforthesmartcityapplicationsandservices.

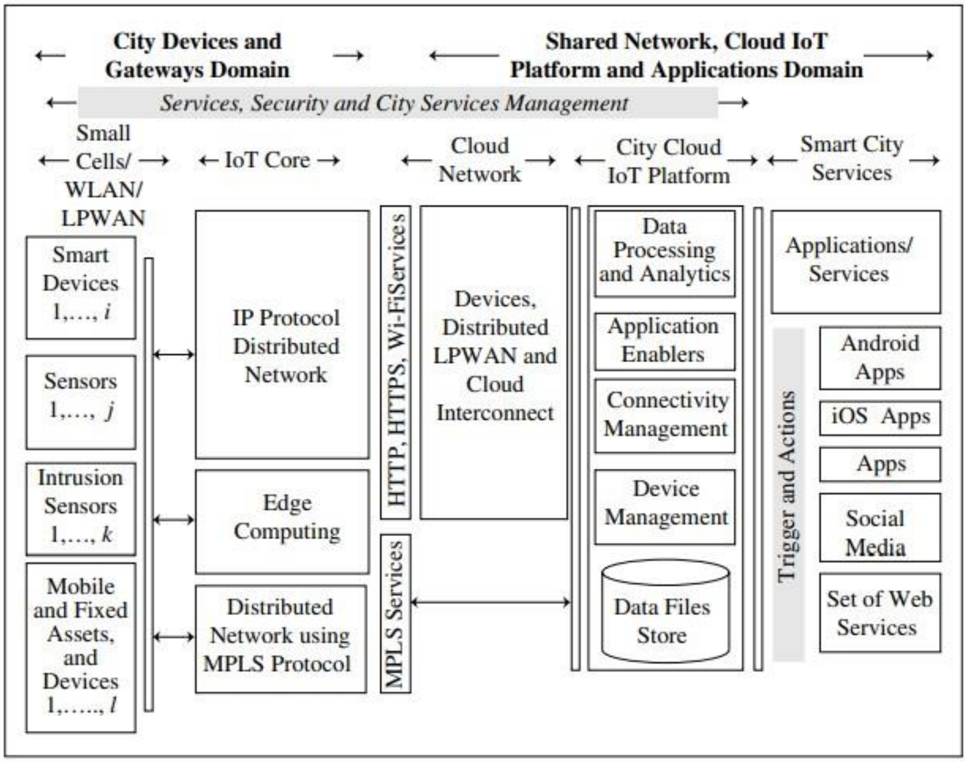


Figure 12.9 Data flow diagram and domain architecture reference model for the smart City Applications and Services

Twodomainsare

(i) CitydevicesandGatewaysdomain,

(ii) sharednetwork, cloudIoTplatformandapplicationsdomains.

- Services,securityandcityservicesmanagementarecross-domainfunctions.
- Assume the edge sensorsand devicesconsist of, say i-smart devices,j-sensors, k-intrusionsensorsandl-mobileandfixedassetsanddeviceswhereasi,j,kandlcanbeverylargenumbers.
- Theedgesensorsanddeviceswirelessly connectwithinsmallcells;systems connectwithWLAN(WirelessLAN).TheycommunicateusingLPWAN.
- Thedistributednetworkofedge-computingsystemsconnectsusingIPprotocolsorusingtheMultiprotocolLabelSwitching(MPLS).
- TheMPLSassignsthelabelstodatapacketsandforwardthelabelstocity cloud IoT platform. City cloud IoT platform collects messages, triggers,alertsanddatafilesat datastore.
- Theplatform does device and connectivity management functions, applicationenablerfunctions,anddataprocessingandanalytics.

- The platform generates triggers which follows actions, such as connect tosocial media, set of web services, applications, iOS apps and Android apps.Theplatformconnectstoanumberofcityapplicationsandservices.
- Smart city applications and services can deploy CISCO IoT, IOx and Fog.This is because of usages of shared networks and distributed access pointnodes,andthe needof an ecosystem withability totransform sensor dataandperformthecontrolfunctionswithinthedistributednetworknodes.
- This enables development of applications, such as site asset management,energymonitoring,andsmartparkinginfrastructureandconnected cities.

SMARTCITYPARKING

A growing problem in citiesis of vehicular traffic congestion and parking spaces.A modern city, therefore, provides a number of multilevel parking spaces whichspreadalloverthecity.

A driverneeds a mobile app. Significantfuel saving can resultfrom provisioningof smart parking spaces in a city. **A smart parking-service should enable thefollowing:**

1. Guidesthedriversfortheavailableparkingslotsandspaces

2. Provides a mobile app, and the app assists a driver and enables him/her to obtain theappropriateparking-slot informationremotely.

3. Publishesmessagesinrealtimeforavailableslotsandalertsforslotunavailabilityat theparkingutility

4. Consists of a central supervisory control and monitoring system (CSS) whichconnects the edge sensors and devices, accurately senses the slots available foroccupancy of vehicles in real time, and predicts the expected availability time incaseofnon-availabilityofslots

5. Optimizestheusagesofparkingspacesandreachingtime

6. Providesdisplayboardsatroadtrafficjunctionsforstatusofavailability

7. Providesgoodparkingexperiencetousers

8. Addsvalueforallparkingstakeholders,driversandserviceproviders

Sensors play vital role in the smart parking. The application is ranked as topmostamongsensor-applicationsforasmarterworld.

Figure12.10showsdata-flowdiagram,domainsandarchitecturereferencemodel forsmart parkingapplicationsandservices.

Thefigureshowsfourlayersattwodomains.

- **Parking spaces are at layer 1**. They are sensed using coordinators at eachlevel in multilevel parking spaces. An actuator for the light at each slot isused. Lighting control module at the coordinator actuates the parking spacelights. The lightings can be switched on and off as per requirement for eachspace.
- **A Parking Assistance System (PAS) is at layer 2.** This includes CCS andthreemodulesformonitoring,controlanddisplay.
- Layers 1 and 2 communication protocols are ZigBee, LWM2M and UDP.The CSS maintains a real-time database of time-series data of the parkingspaces.
- **The systemconnectslayer 3,whichincludesthe SMSgatewayandcloud IoTplatform.**

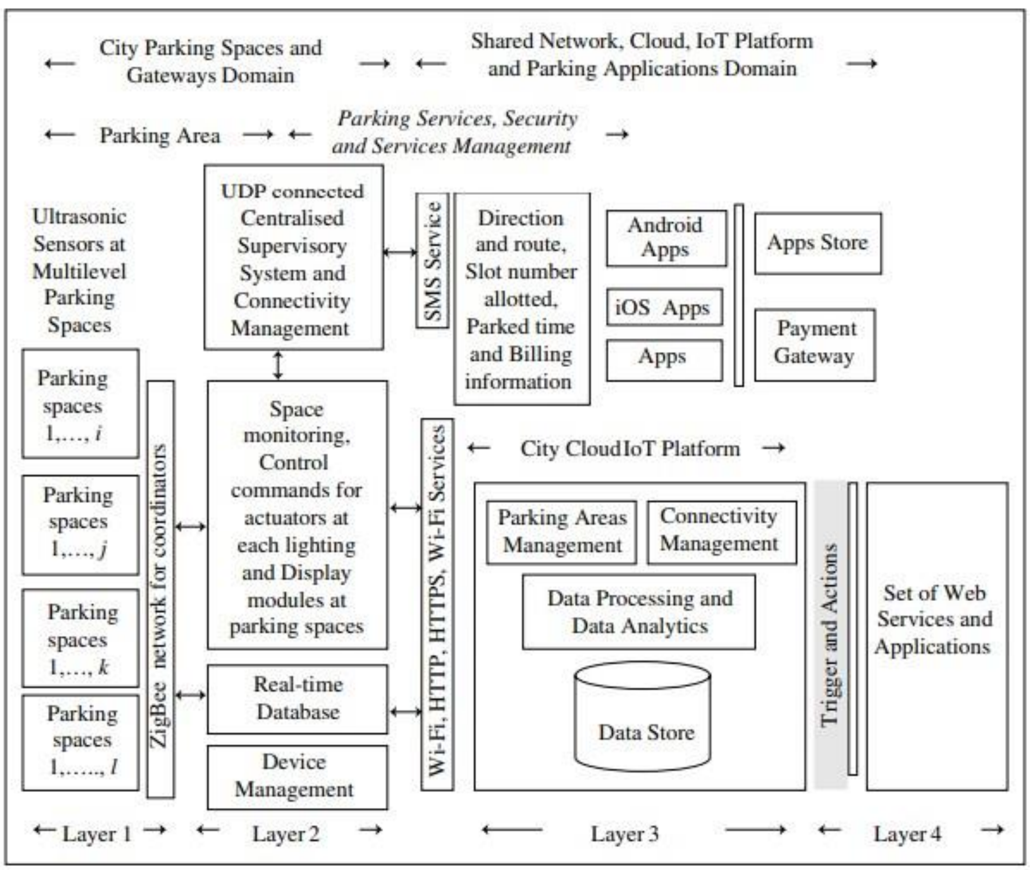


Figure 12.10 Data flow diagram, domain architecture reference model and four layers for the design of smart parking applications and services

Layer2connectsCSSwithallcoordinators.Layer2includesareal-timetime-seriesdatabase.

Layer 2 also connects with three modules for (i) displaying, (ii) space monitoringand(iii)controlcommandsforactuatorsforeachparkingslot.

Layer 3 consists of SMS gateway and City cloud IoT platform that connects CSS,modulesanddatabaseusingtheWi-Fi,HTTPandHTTPSservices.

The platform has data store, data processing and analytics, and parking areas andconnectivity management modules. The CSS sends the UDP packets using MPLSandusesaSMSservicetocommunicatewiththemobileapp.

TheSMSservicecommunicatesparkinginformation.Apacketprovidesinformation such as slot available, slot allocated, time parked, billing informationanddirectionalandparkingspaceroutedetailstotheuser‘smobilephone.

Theuserdownloadsa PASappfrom theAppstore.Theuser‘smobilealsoconnectstoapaymentgatewayforparkingservicebill payment.

Layer 4 web services connect the cloud data store, and use the PaaS cloud fortheanalytics.

HardwarePrototypeDevelopmentandDeploymentdescribedsensorsforultrasonicpulsedetectors.

When a car parking slot is occupied, then the parked car reflects back ultrasonicpulses to the source. The sensor measures the reflected directional intensity anddelay period for the reflections. The coordinator updates the parked slots status oneach alert from a circuit. The sensor associated circuit at coordinator alerts the CSSfor status change and generates time-series messages from the sensor data andcommunicatestotheCSSforsavingatthereal-timedatabase.

Figure 12.11 shows the design principle for a set up for identifying vacant spacesand slot IDs using ultrasonic pulses and back reflections to the transceiver (emitterandsensors)at thecoordinator.

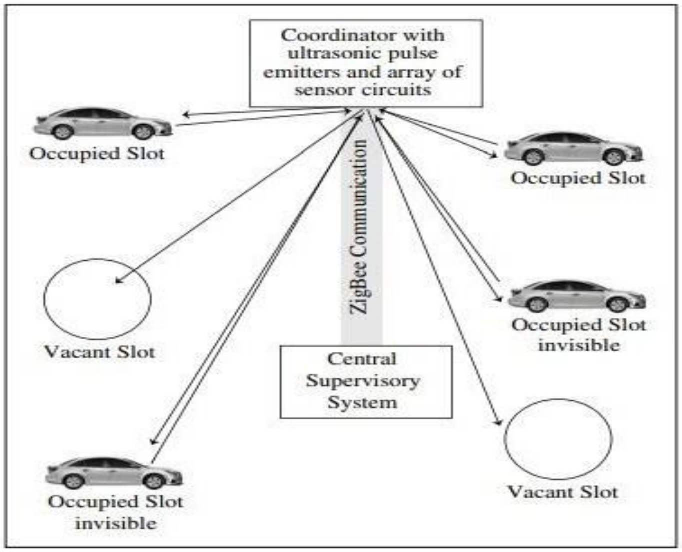


Figure 12.11 Design principle for the set up for identifying vacant spaces using ultrasonic pulses and back reflections from cars to the transceiver at the coordinator

SMARTENVIRONMENT

SmartEnvironment-MonitoringEnvironmentmonitoringreferstoactionsthatarerequiredforcharacterizingandmonitoringthequalityoftheenvironment.

Asmartenvironmentmonitoringsystemshouldenablethefollowing:

1. Preparationsforassessmentofenvironmentimpact
2. Establishthetrendsinenvironmentalparametersandcurrentstatusoftheenvironment
3. Interpretationofdataandevaluateenvironmentalqualityindices
4. Monitortheair,soilandwaterqualityparameters
5. Monitorharmfulchemicals,biological,microbiological,radiologicalandotherparameters

WeatherMonitoringSystem

Asmartweathermonitoringsystemshouldenablethefollowing:

1. Each**measuringnode**forweatherparametersisassignedanID.Eachlamppostdeploysawirelesssensornode.EachnodemeasurestheT,RHandotherweatherparametersatassignedlocations.AgroupofWSNscommunicatesusingZigBeeandformsanetwork.Eachnetworkhasanaccesspoint,whichreceivesthemessagesfrom

eachnode.Theydepictedinterconnectionsbetweennodes,coordinators,routersandaccesspoints .Eachaccesspointassociatesagateway.

2. The**nodescommunic**atetheparametersuptotheaccesspointusingWSNsatmultiplelocations.

3. ForwardandstoretheparametersonanInternetcloudplatform

4. Publishes weather messages for the display boards at specific locations in the city andcommunicatestoweatherAPIatmobileandwebusers

5. Publishesthemessagesinrealtimeandsendalertsusingaweatherreportingapplication6.Analyz eandassesstheenvironmentimpact.

7.Enablesintelligentdecisionsusingdataandhistoricalanalyticsreportsatcity cloudweatherdatastore

Twodomainsandtheirhigh-levelservicecapabilitiesintheweathermonitoringservicesinIoTarchitecturereferencemodelare:

1. Deviceand Gateway Domain: Assumethatthesystemdeploysmweather-sensorembedded devices, each with a location-data sensor and n access-points for the WSNs. Asensornodedoesminimumrequiredcomputations,gatherssensedinformationandcommunicates withotherconnectednodesinthenetwork

Adataadaptationlayerforthedata,messages,triggersandalertsdoesthemaincomputations and puts the result in real time updated database. The items identified forcommunicationfromgatewayarequeriedfromthedatabase.

TheitemscommunicatefromgatewayusingnetworkprotocolsandHTTP/HTTPSservices**.**

(i) **Devicesubdomain:**HardwareWSNboardconsistsofsensorsforweatherparameters.Abo ardexampleisWaspmote.

(ii) **GatewaySubdomain:**Theparametersandalertscommunicatetoalocalorremoteweb service, time-and location-stamping service, itemprovider,protocolbindingsand6LowPAN/IP v6modulesasperconfigurationsettingattheconfigurationadministrationserviceofOSGifr amework.Thebindingsbetween

ZigBeeLANs,6LowPANandLPWANandIP v6protocolsareusedfornetworkingofthedevices,WSNs,OSGiwiththeHTTP/HTTPSservices.

2. Application and Network Domain: Applicationsandnetworkdomaindeploystheapplicationsandservicesandhashigh-levelcapabilities,suchanalytics,datavisualization,display-boardfeeds,weatherreportingapplication

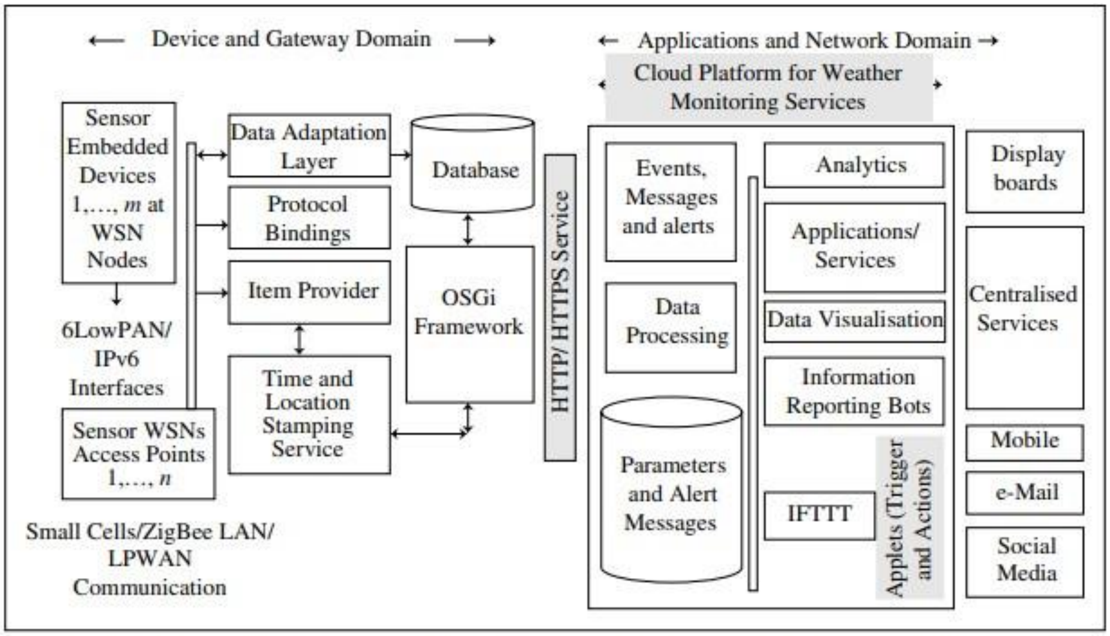


Figure 12.12 Data-flow diagram and domain architecture reference model for the WSNs based monitoring services

Devices Hardware Design and Code Development Environment, Development, Debugging and Deployment

DevicesHardwareDesignandCodeDevelopmentEnvironment,Development,DebugginganDeployment

A microcontroller circuitconsists ofmemory, overtheairprogrammability (OTP)andtransceiver associated with each sensor or node. Theweather monitoring circuit deployssensorsforT,RHandatmosphericpressure(Patm)andmayincludesolarvisibleradiation, wind speed and direction, and rainfall.Hardware design of the sensor and WSNnodecanuseArduinoboardwithZigBeeshield.

WeatherReportingBot

Abotisanapplicationthatrunsautomatedorsemi-automatedscriptsaforspecificsetoftasksandcommunicatestheresultsovertheInternet.Abotgenerally performsthetask

whicharesimpleandstructurallyrepetitive,suchasa,weatherreportingbot.Theword ‗bot' is derided from the word robot. A bot can communicatewith an API using InstantMessaging(IM)orInternetRelayChat(IRC)ortoTwitterorFacebook.

A bot can also chat and give responses to the questions from user API. The bot uses theweather parameters and generates the alert messages from the database and messages forforecastbyacloudanalyticsservice

A mobile app can display the report in two succeeding frames

repeatedly.Thefirstframeshowstheweatherconditionofthecurrentday,as:

1. Firstline:conditionsuchasclear,rain,partlyrain,cloudyorpartlycloudy

2. Secondline,firstparttextgivesthedaycurrentTandfourorfivespaces

3. Secondline,secondparttextgivessuperscriptedtextforthemaximumTexpectedandsubscripted textforminimumTexpected,followedbyfourorfivespaces

4. Secondline,thirdparttextgivessuperscriptedtextforcurrentRH%valueandsubscriptedtextfor wind-speedinkmph(kilometerperhour).

Thus,firstreportingframedisplaysthecurrentconditionandday'sforecastforTmaxandTmin.Secondf rameshowstheforecastfortoday,tomorrowanddayafterforweatheras:
1. Firstline:–SatSunMon‖

2. Secondlineshowsa symbolwhich is completelyunfilled circlefor sunny, or cloudimagewith sun forpartly cloudy, orcloud sign forfully cloudy below each day Sat,SunandMon.

Afterthesign,asuperscriptedwordgivesmaximumT,andasubscriptedword,theminimumexpecte donthatday.Thus,forecastforthreedaysisreported,viz.today,tomorrowanddayafter.Exampleofcr eatingaweatherbotisSlackweatherbotAPI.

ThebotusesthecodesgivenaFarnciskimsite.

TheAPIisanode.jsmoduleforthebot.ItdisplaysSecondframeshowstheforecastfortoday,tomorrowan ddayafterdaysforweather,forexampleasfollows:

1. Firstline:BotnameCurrentRuntime(suchas09:15A.M.)

2. Secondlineshows–ConditionforCityName,PlaceName,CurrentTime,Standard (suchasIST,GMT)

3. Thirdlineshows–Today(suchasSAT):T,condition(suchassunny,partlycloudy, cloudyorrain)‖

4. Fourthlineshows–Tomorrow(suchasSUN)Current:T,condition‖

5. Fifthlineshows–Dayafter(suchasMON)Current:T,condition‖

AirPollutionMonitoring

A growing problem for all residents is airpollution from cars, toxic gases generated infactories and farms, such as carbon monoxide (CO). Pollution needsmonitoring and toensurethesafetyofworkersandgoodsinsidechemicalplants.

Themonitoringdoesthefollowingtasks:

1. Monitoring andmeasuring levelsofCO, a gasdangerousabove50 –100 ppm level;carbondioxide(CO2),agascauseswhichgreenhouseeffect;andozone(O3),agasdangerousabove0.1mg/perkgairlevel,forcontrollingairpollution

2. Monitoring and measuring levels of hydrogen sulfide (H2S), a highly toxic gas. It is agreenhousegassoitsincreasemaycontributetoglobalwarmingaswell.

3. Monitoringandmeasuringlevelsofhydrocarbons,suchasethanol,propane.

4. Measure T, RH and Patm parameters for calibrations of sensed gaseous parameters ofeachnode

5. Investigateairqualityandtheeffectsofairpollution.

6. ComputeAirQualityIndex(AQI)fromtheparameters,suchashourlyordailyaveragesofairpollutantconcentration,particulatematter(suchasdustorcarbonparticle)

7. Compute source and spatial dispersion of pollutants asa function of day conditions,wind-speed and direction, air temperature and air temperature gradientwith altitude andtopographyusinganalytics.

8. Datavisualization

9. Reportthepollutionstatustomonitoringauthorities

Sensors play a vital role in air-quality monitoring. The application has eleventh rankingamongsensor-applicationsforasmarterworld.

Adata-flowdiagramanddomainarchitecturereferencemodelforairpollutionmonitoringservicesaresimilartoFigure12.12.

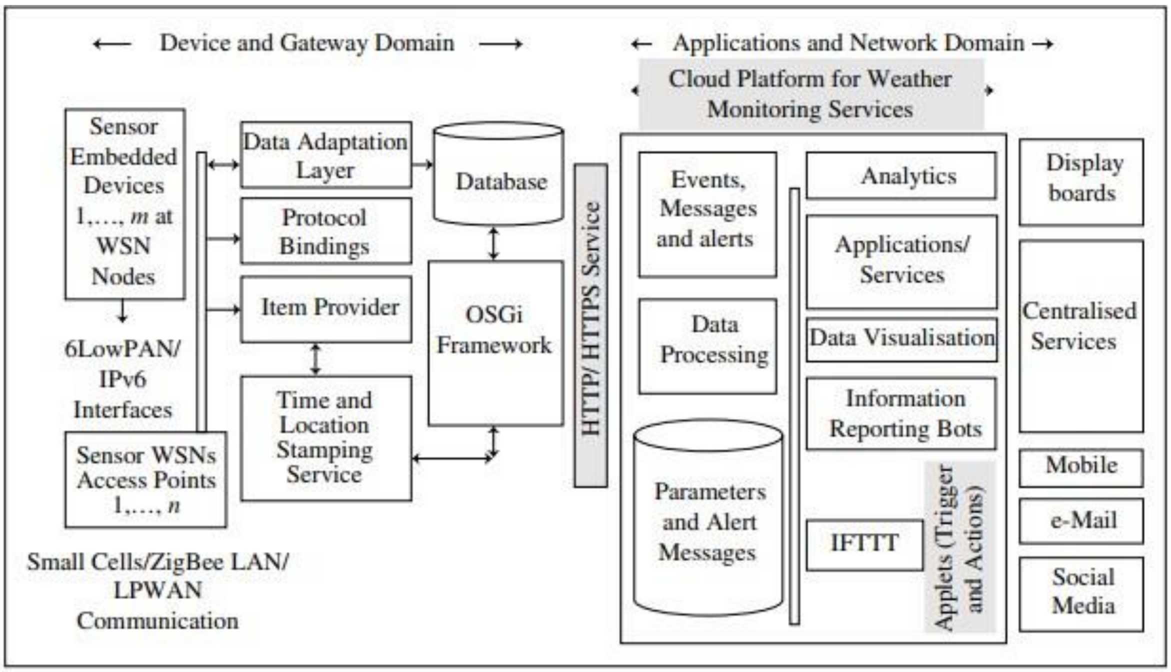


Figure 12.12 Data-flow diagram and domain architecture reference model for the WSNs based monitoring services

Twodomainsand theirhigh-levelservicecapabilitiesin theairqualityandpollutionmonitoringservicesinIoTarchitecturereferencemodelare:

1. DeviceandGatewayDomain: Assumethatthesystemdeploysmgassensorembedded devices at each WSNwith a location-data sensor and n access-points for theWSNs**(Figures7.17).**

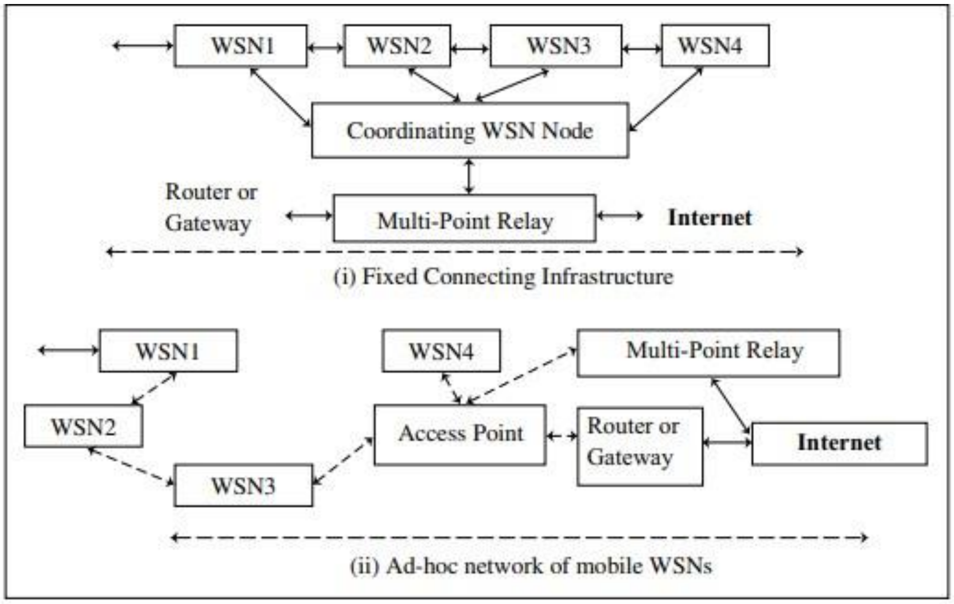


Figure 7.17 Architecture for connecting WSN nodes: (i) Fixed connecting infrastructure of WSN nodes, coordinators, relays, gateways and routers and (ii) Mobile ad-hoc network of moving WSNs

Thedata-adaptationlayeratgatewaydoestheaggregation,compactionandfusioncomputations for each sensor node data.The queries gather sensed information from thedatabase and the items selected communicate using HTTP/HTTPS/MPLS services. WSNboardIOportsconnectthesensorsforgaseous,particulatematterandweatherparameters. Each sensor node is configured by assigning a node ID.A node ID maps withtheGPSlocation foundearlierfrom GPSmodulesatthedataadaptation layeratthegateway.

A sensorID isconfigured foreach sensorat thenode. Each sensorassociated circuit isalsoconfiguredforfrequencyofmeasurementseverydayandintervalbetweentwosuccessivemea surements.Thesensorcircuitisconfiguredtoactivateonlyformeasurementdurationatameasuring instancefollowedby long inactiveintervals.

An exampleisWaspmoteboardwhich canbeusedwith sensors suchas citypollutionCO,NO, NO2, O3,SO2and dustparticlessensorsandair-quality finding sensorsforSO2,NO2,dust particles, CO, CO2, O3and NH3.TheArduinoor EclipseIDE canbeusedtodevelopcodesfortheWaspmote.

2. TheApplicationsandNetworkDomain: Theapplicationsandnetworkdomaindeploystheappli cationsand servicesandhavehigh-levelcapabilities, suchasevents,messages,alertsanddataprocessing,databases,applicationsandservices,analytics, data visualization,display-boardfeeds,pollutionreportingapplicationsandservices,andIFTTT triggers and actions.The cloud platform can beTCUP,AWS Io T, IBMBlue mixorNimbits.

ForestFireDetection

A bigproblem forcountrieswithlargeforestareasisforestfires. A firemonitoringservicedoesthefollowingtasks:

1. UsesOTPfeaturesforprogrammableWSNsandgateways
2. MeasuresandmonitorstheT, RH,CO,CO2and infrared light (firegenerated)intensityinrealtimeatpresetintervals
3. Each WSNuploadstheprogram and presetmeasured intervalsoft1(say, 300s)eachandthepresetmeasuredintervalsoft2(say,on1or5s)onsensedparametersvaluesexceeding thresholdscan instantaneously triggerthefire-alarmalgorithm
4. Configuresthedata-adaptationlayerswithcalibrationparameters
5. CommunicatestheWSNmessagesatthepresetintervalstotheaccesspointassociatedforspecificnetworkarea
6. Communicatesalerts,triggers,messagesanddataatdata-adaptationlayerusinganuploadedprogramatassociatedgateway
7. Uploadsconnectivityprogramsforgateways
8. Runsatthedata-adaptationlayerthefaultyorinaccessiblesensorsatperiodicintervals
9. Integratesdatawiththenodelocationsfoundfrommappingwithnode IDs,compute, and activate thealarmsusing an algorithm, input-sensed and calibratedcoefficients
10. Processesthelayerdataanddatabaseinformation,andcommunicatesinstantaneously tonearest mobiles and fire-fighting services near theaccess pointgateway
11. Updatesthedatabaseandcommunicatestoacloudplatform,suchasNimbits,my.openHAB, TCUP,AWSorBluemixplatform

12. Modifiesthepresetmeasured intervalstot2on activation ofthefirealarm aftervaluechangesabovetheconfiguredthresholdvalues
13. Usesanalyticstoevaluatereliabilityindexofthepreset,thresholdandconfigurationvaluesan dneedtoupdatealarm-algorithmandifneedsimprovementthenuploadnewalgorithms
14. Usesanalyticstogenerateandcommunicatetopologicalmapsforthecurrently fireinfected forest area and reachability maps for fire-fighting service equipment‘sSensorsplayavitalrolein forest-firemonitoring.

Theapplicationhastenthrankingamong50sensor-applicationsforasmarterworld.

Figure 12.13 shows a data-flow diagram anddomain architecturereferencemodel forthemonitoringservice.

The figure shows thatthe servicedeploysm embedded-sensordevices at each of nWSNassociatedwithxaccesspoints.

Deviceand gateway domain functions in thefire monitoringservice forforests inIoTarchitecturereferencemodelisasfollows:

A lookup tableenablesmapping oftwoentities.Location-data stampingusessensorIDs at a lookup table. Data adaptation of each sensor is at the layer. Data aggregates,compactsand fuses, computes, gatherssensed information and thealgorithmsusethatfor alarmand faulty sensor identification andconfiguration management.Data store atthe database, updates in real time. The alerts and messages communicate to Io T cloudplatform. Hardware WSN board and sensors can use Waspmote board.24 Each WSNcommunicatestoaccesspointsusingamultiprotocolwirelessrouter

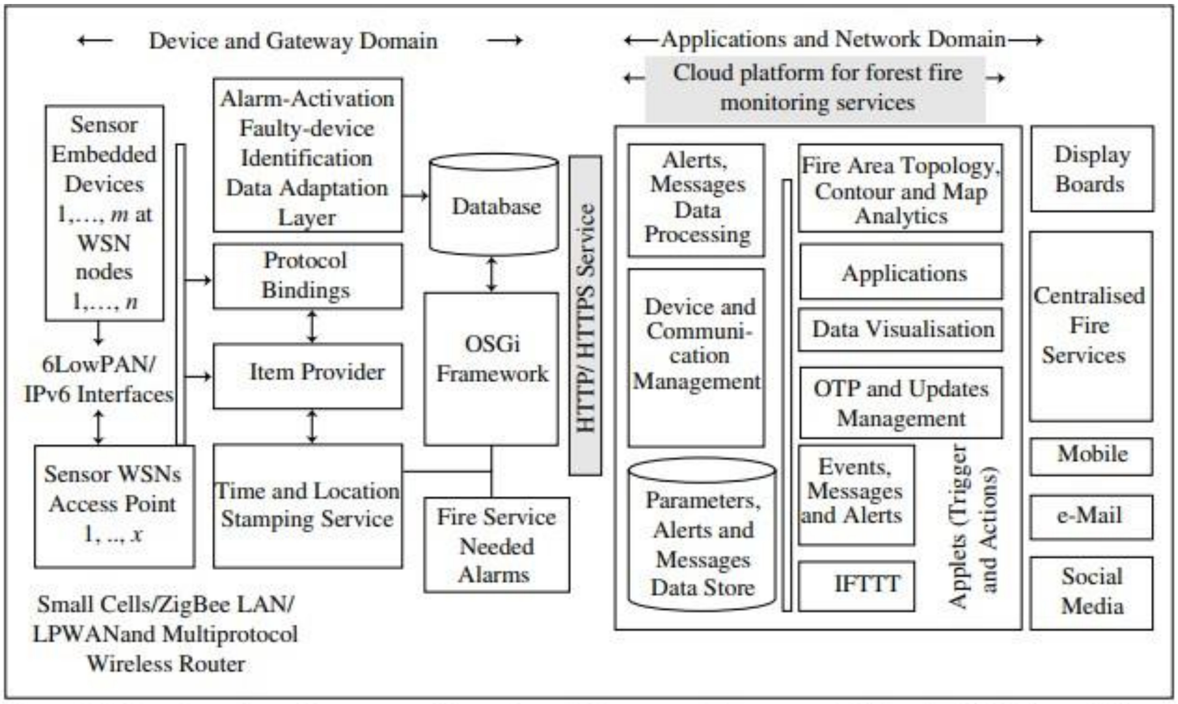


Figure 12.13 Data flow diagram and domain architecture reference model for the WSNs based Forest Fire monitoring service

SMARTAGRICULTURE

Followingsectiondescribestwoapplicationsviz.,smartirrigationincropfieldsandsmartwinequalityenhancing

SmartIrrigation

Smartirrigationdeployssensorsformoisture.

Asmartirrigationmonitoringservicedoesthefollowingtasks:

1. Sensorsformoistureandactuatorsforwateringchannelsareusedinsmartirrigation.

2. Usessoilmoisturesensorswitha sensorcircuitry boardwitheachoneinstalled atcertaindepthinthefields.

3. Uses an array of actuators (solenoid valves)which are placed along thewater channelsandthatcontroldeficienciesinmoisturelevelsabovethresholdsduringagivencropperiod.

4. Usessensorsplaced atthreedepthsformonitoring of moisturein fruitplantssuchasgrapesormango,andmonitorsevapotranspiration(evaporationandtranspiration)

5. Measuresandmonitorsactualabsorptionandirrigationwaterneeds

6. Each sensor board is in a waterproof cover and communicates to anaccess point usingZigBeeprotocol.AnarrayofsensorcircuitsformsaWSN.

7. Access point receives thedataand transfers it toan associatedgateway.Dataadapts atthegatewayandthencommunicatestoacloudplatform usingLPWAN.

8. ThecloudplatformmaybedeployedsuchasNimbits,my.openHAB,AWSorBluemix. 9. Analytics at the platform analyses the moisture data and communicates to theactuatorsofwaterirrigationchannelsasperthewaterneedsandpasthistoricaldata

10. Measurements at the sensors are at preset intervals and actuators activate at analysedrequiredvaluesoftheintervals.

11. The platform uploads the programs to sensors and actuators circuitry and sets presetmeasurement intervals ofT1(say, 24hour) eachand thepreset actuation interval of t2(say,on120hour)

12. Sensedmoisturevalueswhenexceedpresetthresholdsthentriggerthealarm

13. Analgorithmuploadsandupdatestheprogramsforthegatewaysandnodes.

14. Runs at thedata-adaptation layer and finds thefaulty or inaccessiblemoisturesensorsatperiodicintervals

15. OpensourceSDKandIDEareusedforprototypingthemonitoringsystem

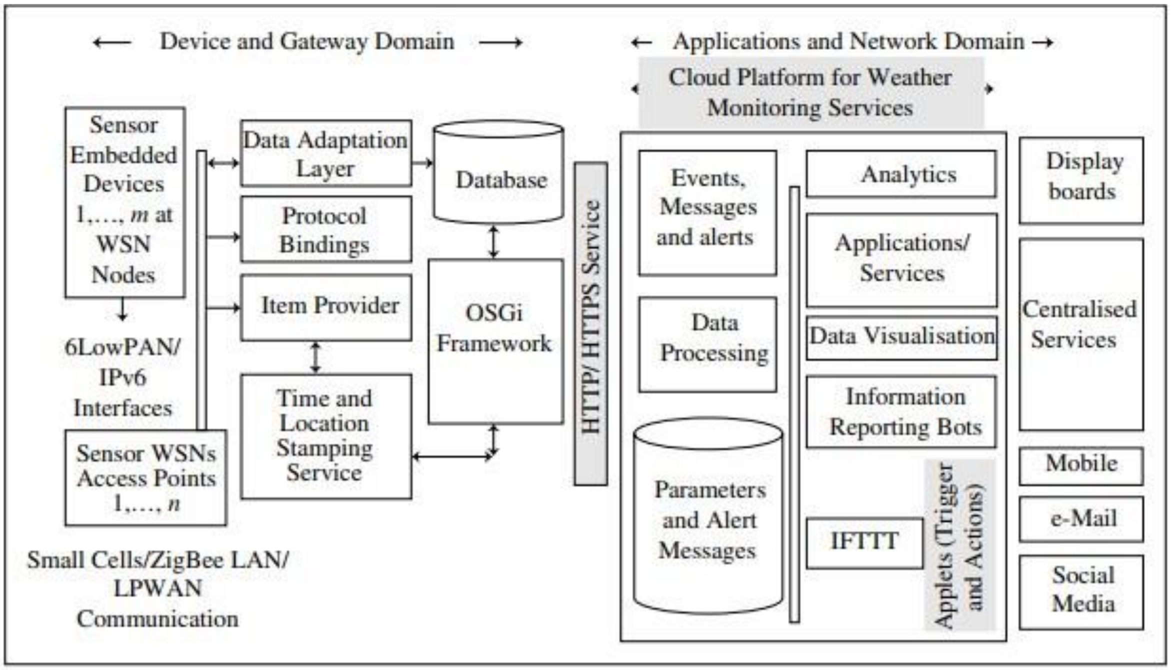


Figure 12.12 Data-flow diagram and domain architecture reference model for the WSNs based monitoring services

SmartWineQualityEnhancing

The sensors monitor the soil moisture and trunk diameter in vineyards. Themonitoringcontrolsthesugarcontentingrapesandhealth ofgrapevines. Data-flow diagramanddomainarchitecturereference-modelforthemonitoringservicearesimilartoonesshownin**Figure12.12.**

DeviceandGatewayDomain

AWSNmeasuresmoistureandotherparametersandhasanID.EachnodeisaWSN.Each WSNmeasuresatassigned placesin acrop orvineyardatcertaindepth(s)insidethe soil. Sensors at three equally spaced depthsare used for thevineyard grapes sugar-control.

Agroup of WSNscommunicate among themselves using ZigBeeand forma network.Each network hasan accesspoint,which receivesthemessagesfrom each nodeusingLPWAN.**Figures7.17showtheWSNs**.Theyshow interconnectionsbetweennodes,coordinators, routersandaccesspoints. Eachaccesspointassociatesagateway.EachgatewaycommunicatestothecloudusingLPWAN

ENERGY

EnergyIoTapplicationsforsmartenergysystems:

a). SmartGridb).RenewableEnergySystemsc).Prognostics

SMARTGRIDS

Smartgridtechnology providespredictiveinformation andrecommendationstoutilize,their suppliers,andtheir customersonhowbest tomanagepower.

Smartgridcollectsthedataregarding:

- Electricitygeneration
- Electricityconsumption
- Storage
- Distributionandequipmenthealthdata

• By analyzing the data on power generation, transmission and consumption ofsmartgridscanimproveefficiencythroughouttheelectricsystem.Storagecollection and analysisof smartsgridsdata in the cloud can helpin dynamicoptimizationofsystemoperations,maintenance,andplanning.

• Cloud-based monitoring of smart grids data can improve energy usage levelsviaenergyfeedbacktouserscoupledwithreal-timepricinginformation.

• Condition monitoring data collected from power generation and transmissionsystemscanhelpindetectingfaultsandpredictingoutages.

RENEWABLEENERGYSYSTEM

• Due to the variability in the output from renewable energy sources (such as solarand wind), integrating them into the grid can cause grid stability and reliabilityproblems.

• IoT based systems integrated with the transformer at the point of interconnectionmeasuretheelectricalvariablesandhowmuchpowerisfedintothegrid

• Toensurethegridstability,onesolutionistosimplycutofftheoverproductions.
• Communicationsystemsforgridintegrationofrenewableenergyresources[IEEE Network, 2011] -provided the closed-loop controls for wind energy systemthatcanbeusedtoregulatethevoltageatpointofinterconnectionwhichcoordinate windturbineoutputsandprovidesreactivepowersupport.

PROGNOSTICS

• IoTbasedprognosticreal-timehealthmanagementsystemscanpredictperformance of machines of energy systems by analyzing the extent of deviation ofasystemfromitsnormaloperatingprofiles.

• In the systemsuch aspower grids,real timeinformationiscollectedusingspecializedelectricalsensorscalledPhasorMeasurementUnits(PMU)

• Analyzingmassiveamountsofmaintenancedatacollectedfromsensorsinenergysystemsandequipmentcanprovidepredictionsforimpendingfailures.

• OpenPDC is a set of applications for processing of streaming time-series datacollectedfromPhasorMeasurementsUnits(PMUs)inreal-time.

ApplicationsofIoTinLogistics

ImplementationofIo Tinlogisticsindustrycanboosttheconstituentsofthesepillarsandhelpthelogisticsindustry augment by leap andbounds. Below aresomeoftheadvantagesthataconventionallogisticscompanycanenjoyfromtheapplicationofInternetofThings.

1) **LocationandRouteManagement**:

Trucksarethelifelineofanylogisticscompany.IntheUSalone,morethan70%ofallthegoodsare transportedbytrucks.Infact,around95%ofallthemanufactured

goodsatonepointaretransportedvia trucks.Logisticsandfleetcompanieshencerequiresystemsthatcanhelpthemmanagetheirtruckoperations.

Thelocation and routemanagementsolutionofIo T forlogisticsindustry ishencequitepopular.Thissolution enablesa logisticsmanagertomonitorthelocation oftheirtrucksin real-time.Byusing GPStracking systemsandgeofencing techniques,theroutetakenbythetruckscanalsobemonitoredfromremotelocations.Thisfurther helpsthelogisticscompaniestotrack driveractivitiesand ensuretimelycargodelivery.

Moreover,thereal-timealertsystemofthesevehicletrackingsolutionsalarmmanagersaboutany anomaly likethunderstormsoraccidenton a freewayviapushnotificationsthatmayaffectthestatusofshipment.

Thesefeaturesactasanassistantforlogisticscompaniesandassistintheplanningandmanagementofdeliveryschedules.Time-delayingbarriersareinstantlyidentifiedandmitigatedthatresult instreamlined businessprocessesandcent percentcustomersatisfaction.

2) **InventoryTrackingandWarehousing**

IoTinlogisticsotherthanprovidingfleetmanagementservicesalsofacilitatesthe

storageofgoodsand managementofstock levels.Ina logisticsecosystem, itenablesa company to haveclear-cuttransparencyinitsvariousoperations,furthersupportinginseamlessinventoryorganization.

RFIDtagsand sensorsallow companiestoeasilykeep track oftheirinventoryitemsalongwiththeirstatusandposition.Inotherterms,IoTfacilitatesthedevelopmentofasmartwarehousesystemthatallowsacompanytopreventlosses,ensure safe storage of goods,andefficientlylocatetheitemsinneed.Furthermore,italsohelpscompaniestorevamptheirwarehousingoperations,resultinginthereductionoflaborcostsandanincreaseinefficiencyduetolessmanualhandlingerrors.

3) **CBMandBreakdownPrevention:**

IoTapplicationsinlogisticssegmentarenotonlylimitedtothemonitoringandmanag ementofassets.However,itsmostbeneficialapplicationistheidentificationofbottlenecksthat may result in the breakdown of these assets. Internet of Things hashelpedindustriestojumponpredictivemaintenanceandcondition-basedmaintenanceinsteadofdependingonscheduledinspectionprocedures.

Bymeasuringandanalyzingparametersthatdefinetheperformanceofthetrucks,companiescanpredictpatternsrelatedtocommontruckbreakdown.Similarly,real-timealertsystemscanbeusedtogainalertsaboutprobableunexpectedmalfunctionsthatcanbepreventedviacondition-basedmaintenance.

Thesepredictiveapplicationsof IoTwillhelpcompaniestoidentifydefects before theybecomecatastrophic.Logisticscompanieswillbeabletoimprovetheirdecision-makingprocessesandcreateeffectiveinspection/repairstrategies.Moreover,thesepreventiveinsightsabouttheirassetswillhelpcompaniesreducerisksanddowntimethatwillfurtherresultinseamlessprocessexecutionandtimelydeliveryoperations.

4) IoTandBlockchainforDigitalBOL:

Applications of Io T in logistics industry when blended with the technology of Blockchain createa digital Bill of Lading (BOL) that creates whole new transparency in thesupplychains.ThisBOLallowsacompanyanditscustomerstotracethetransportationcycleoftheproductsbeingshipped.

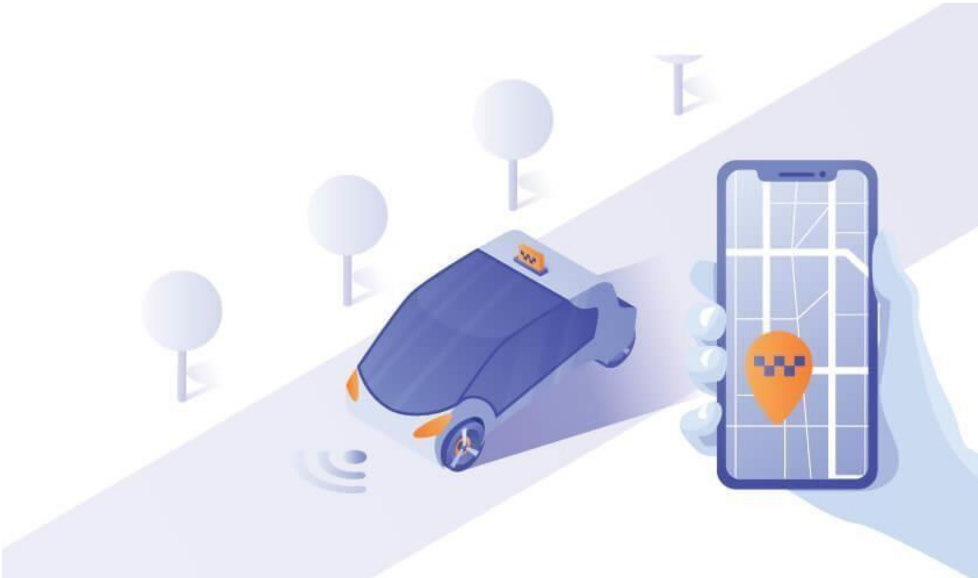
Theamalgamationofboththesetechnologies hasresultedinthecreationofsmartcontractsolutions(BOL being oneofitsmany constituents)that enablemonitoring ofall the stagesbetween the originof thegoodsand their finaldelivery inthe customer‘shands.SensorsandGPStrackersplayacrucialroleinthissolutionaswell.Bothpartie scanmeasuretemperature,humidity,location,andotherparametersfrom

remotelocationsin real-timeduring theshipmentandmakesurethat all theconditionsofthecontractarefulfilled.

AsdataisstoredinaBlockchain,theprobabilityofdatatheftorcyber-attackisconsiderablyreduced.Hence, transactionsareinstantly released fromthecustomer‘saccountifallthe pre-described conditions comply. The customer can also cancel the contract if thecontractis breached due to reasons like spoiled cargoor delivery delay.This maintains atwo-wayauthorityoverthecontractspecificationsfurtherenforcingthesecurity,transparency,andtraceabilityofthesupplychain.

5) **AutonomousandSelf-DrivingCars:**

Logisticsmanagersarenotonlyresponsibletomanagethemanagementofassetsbeingtransported.Theyarealsosupposed toensurethesafetyoftruckersand thecargobeingshipped.Thiscanbeaccomplishedbytheimplementationofself-



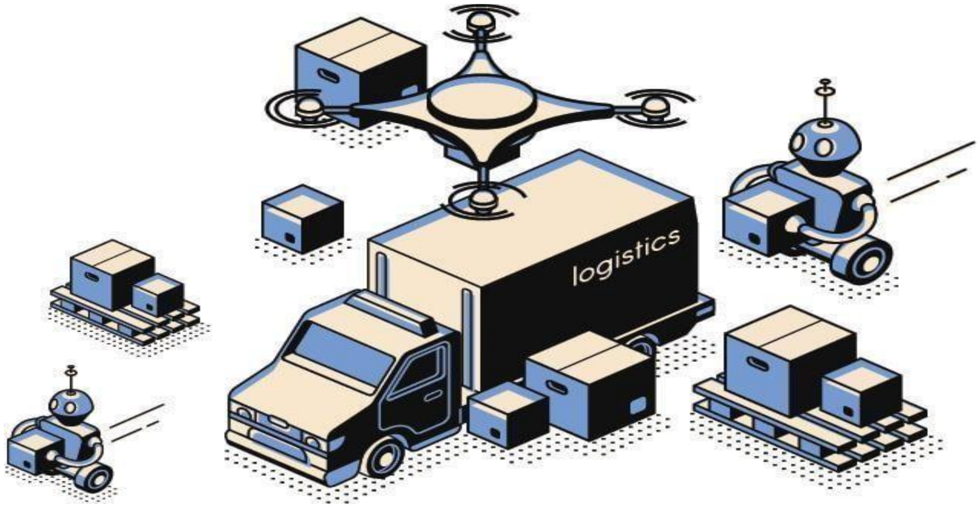
drivingvehicles.

The hypeofautonomous and self-driving vehicles is atanall-timehigh.Intelligenttechnologieslikeartificial intelligenceand machinelearning arebeingblendedbyconnectedinfrastructuresformedbytheInternetofThings.Usingsuchinfrastructures of IoT inlogisticswillbethefirststepforbusinessestoincludetheconceptofautonomousvehicles.Datacorrespondingtovariousshipmentparameterswillbeanalyzedandprocessedto developsmartdrivingroutesanddirections.Logisticswillhencebeabletoreducetheiroperation costs,minimizecaraccidents,andensuretimelycargodeliverybasedontrafficconditions.

6) **Drone-BasedDelivery:**

UnmannedAerialVehicles(UAVs)ordronesarethenewmediumtodeliverpackages. Theirpotential lies strongly in the field of retail, logistics, agriculture, ande-commerce. Amazon, oneof theBig 4tech companies in theworld has alsounveiledtheuseofdronesfordeliveringordereditemstopeoplelocatedinremoteareas.

Drones applications and implementation of Internet of Things in logistics can ensureautomatedprocess execution and quick delivery of goods. The market of drones baseddeliverysystemsisgrowingatarapidrateandisexpectedtoreachamarketvaluation



of

$11.2billionbytheendof2020.

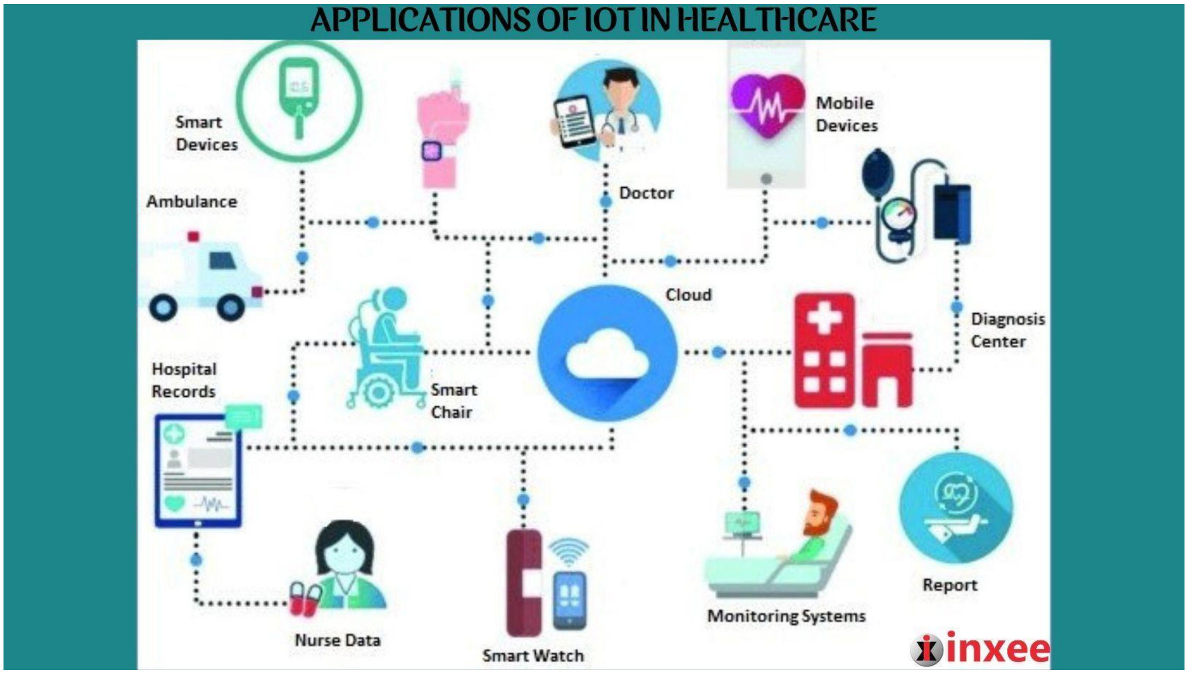
IoTinHealthandlifestyle

Io T devices offer a number of new opportunities for healthcare professionals tomonitorpatients,aswellasforpatientsto monitorthemselves.By extension,thevarietiesofwearableIo Tdevicesprovideanarrayofbenefitsandchallenges,forhealthcareprovidersandtheirpatientsalike.

Remotepatientmonitoring

Remotepatientmonitoring is themost common application of Io T devices for healthcare.Io Tdevicescanautomaticallycollecthealthmetricslikeheartrate,bloodpressure,temperature,andmorefrompatientswhoarenotphysicallypresentinahealthcarefacility, eliminating theneed forpatientstotraveltotheproviders, orforpatientstocollectitthemselves.

When an Io T device collects patient data, it forwards the data toa software applicationwherehealthcareprofessionalsand/orpatientscanview it.Algorithmsmay beused toanalyzethedata inordertorecommendtreatmentsorgeneratealerts.For example,anIo T sensor that detects a patient‘s unusually low heart rate may generate an alert so thathealthcareprofessionalscanintervene.



A majorchallengewith remotepatientmonitoringdevicesisensuring thatthehighlypersonaldatathattheseIoTdevicescollectissecureandprivate.

Glucosemonitoring

Forthemorethan30millionAmericanswithdiabetes,glucosemonitoringhastraditionally been difficult. Notonly isitinconvenienttohavetocheck glucoselevelsandmanually record results,butdoingsoreportsapatient‘sglucoselevelsonlyat theexact timethetest isprovided.Iflevelsfluctuatewidely, periodictesting may notbesufficienttodetectaproblem.

Io Tdevicescanhelpaddressthesechallengesbyprovidingcontinuous,automaticmonitoring ofglucose levels in patients. Glucose monitoring devices eliminate the need tokeeprecordsmanually,andtheycanalertpatientswhenglucoselevelsareproblematic.

Challenges include designing an IoT devicefor glucose monitoring that:

- Issmallenoughtomonitorcontinuouslywithoutcausingadisruptiontopatients
- Doesnotconsumesomuchelectricitythatitneedstoberechargedfrequently.
- Thesearenotinsurmountablechallenges,however,anddevicesthataddressthempromiseto revolutionizethewaypatientshandleglucosemonitoring.

Heart-ratemonitoring

Likeglucose, monitoring heart rates can be challenging, even forpatientswhoarepresentin healthcare facilities. Periodic heart rate checks don‘t guard against rapid fluctuations inheart rates, and conventional devices for continuous cardiac monitoring used in hospitalsrequirepatientstobeattachedtowiredmachinesconstantly,impairingtheirmobility.

Today,avarietyofsmallIo T devicesareavailableforheartratemonitoring, freeingpatientstomovearoundastheylikewhileensuringthattheirheartsaremonitoredcontinuousl y.Guaranteeing ultra-accurateresultsremainssomewhatof a challenge,butmostmoderndevicescandeliveraccuracyratesofabout90percentorbetter.

Handhygienemonitoring

Traditionally, there hasn‘t been a good way to ensure that providers and patients inside ahealthcare facility washed their hands properly in order to minimize the risk of spreadingcontagion.

Today,manyhospitalsandotherhealthcareoperationsuseIoTdevicestoremindpeopletosanitizeth eirhandswhentheyenterhospitalrooms.Thedevicescanevengiveinstructionsonhowbesttosanitiz etomitigateaparticularriskforaparticularpatient.

A majorshortcoming isthatthesedevicescan only remind peopletoclean theirhands;they can‘t doit for them. Still, research suggeststhat thesedevicescan reduceinfectionratesbymorethan60percentinhospitals.

Depressionandmoodmonitoring

Information aboutdepression symptomsand patients‘generalmood isanothertypeofdatathathastraditionallybeendifficulttocollectcontinuously.Healthcareprovider smight periodically ask patients how they are feeling, but were unable to anticipate suddenmoodswings.And,often,patientsdon‘taccuratelyreporttheirfeelings.

–Mood-aware‖IoTdevicescanaddressthesechallenges.Bycollectingandanalyzing data such as heart rate and blood pressure, devices can infer information about a patient‘smental state. Advanced Io T devices for mood monitoring can even track data such as themovementofapatient‘seyes.

Thekeychallengehereisthatmetricslikethesecan‘tpredict depression symptomsorother causes for concern with complete accuracy. But neither can a traditional in-personmentalassessment.

Parkinson’sdiseasemonitoring

InordertotreatParkinson‘spatientsmosteffectively,healthcareprovidersmustbeabletoassesshow theseverityoftheirsymptomsfluctuatethroughtheday.

Io T sensors promise to make this task much easier by continuously collecting data aboutParkinson‘ssymptoms.At thesametime, thedevicesgivepatientsthefreedom togoabout their livesin their own homes, instead of having to spend extended periods in ahospitalforobservation.

OtherexamplesofIoT/IoMT

WhilewearabledeviceslikethosedescribedaboveremainthemostcommonlyusedtypeofIoTdeviceinhealthcare,therearedevicesthatgobeyondmonitoringtoactuallyprovidingtreatment,oreven–living‖inoronthepatient.Examplesincludethe following.

Connectedinhalers

Conditionssuchasasthma or COPD often involveattacksthat comeon suddenly,withlittle warning.Io T-connected inhalers can help patientsby monitoring the frequency ofattacks,aswellascollectingdatafromtheenvironmenttohelphealthcareprovidersunderstandwhattriggeredanattack.

Inaddition,connectedinhalerscanalertpatientswhentheyleaveinhalersathome,placing them at risk of suffering an attackwithout their inhaler present, orwhen theyusetheinhalerimproperly.

Ingestiblesensors

Collecting data from inside thehumanbody is typicallya messyandhighlydisruptiveaffair.Nonoenjoyshavingacameraorprobestuckintotheirdigestivetract,forexample.

Withingestiblesensors,it'spossibletocollectinformationfromdigestiveandothersystems in a much less invasiveway. They provide insights into stomach PH levels, forinstance,orhelppinpointthesourceofinternalbleeding.

These devices must be small enough to be swallowed easily. They must also be able todissolveorpassthrough thehumanbody cleanly on theirown. Severalcompaniesarehardatworkoningestiblesensorsthatmeetthesecriteria.

Connectedcontactlenses

Smartcontactlensesprovideanotheropportunityforcollectinghealthcaredatainapassive,non-intrusiveway.They couldalso, incidentally, includemicrocamerasthatallowwearerseffectivelytotakepictureswiththeireyes,whichisprobablywhycompanieslikeGooglehavepatentedconnectedcontactlenses.

Whetherthey'reused toimprovehealth outcomesorforotherpurposes, smartlensespromisetoturnhumaneyesintoapowerfultoolfordigitalinteractions.

Roboticsurgery

BydeployingsmallInternet-connectedrobotsinsidethehumanbody,surgeonscanperform complexprocedures thatwouldbedifficult tomanageusinghumanhands.Atthe same time, robotic surgeries performed by small Io T devicescan reduce the size ofincisionsrequiredtoperformsurgery,leadingtoalessinvasiveprocessandfasterhealing.