B20CS4103
Internet of Things
Lecture Notes
Department of Computer Science and Engineering
SRKR Engineering College (Autonomous)

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Unit-3 Syllabus:

Part-1
Basic Building blocks: IOT Physical devices and Endpoints: Basic building blocks of an IOT device. **Sensors, Participatory sensing, RFIDs:** Sensor Technology, Participatory sensing, Industrial IOT and Automotive IOT, Actuator, Radio Frequency Identification technology.

Part-2
Programming with Arduino: Features of Arduino, Components of Arduino board, Arduino IDE, programming Elements, Case Studies: Traffic control system, DHT Sensor with Arduino, Servo Motor Interface with Arduino.

UNIT – 3 (Part-1)

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IOT Physical devices and Endpoints

Basic building blocks of an IOT device

What is an IoT Device?

A "Thing" in Internet of Things (IoT) can be any object that has a unique identifier and which can send/receive data (including user data) over a network (e.g., smart phone, smart TV, computer, refrigerator, car, etc.).

IoT devices are connected to the Internet and send information about themselves or about their surroundings (e.g. information sensed by the connected sensors) over a network (to other devices or servers/storage) or allow actuation upon the physical entities/environment around them remotely.

IoT Device Examples

- A home automation device that allows remotely monitoring the status of appliances and controlling the appliances.
- An industrial machine which sends information about its operation and health monitoring data to a server.
  A car which sends information about its location to a cloud-based service.

- A wireless-enabled wearable device that measures data about a person such as the number of steps walked and sends the data to a cloud-based service.

Sensing

Sensors can be either on-board the IoT device or attached to the device. Examples, temperature, humidity, light intensity sensors.

Actuation

IoT devices can have various types of actuators attached that allow taking actions upon the physical entities in the vicinity of the device. Examples, a relay switch, servo motor.

Communication

Communication modules are responsible for sending collected data to other devices or cloud-based servers/storage and receiving data from other devices and commands from remote applications.

Analysis & Processing

Analysis and processing modules are responsible for making sense of the collected data.

Generic Block Diagram of a Single Board Computer (SBC)

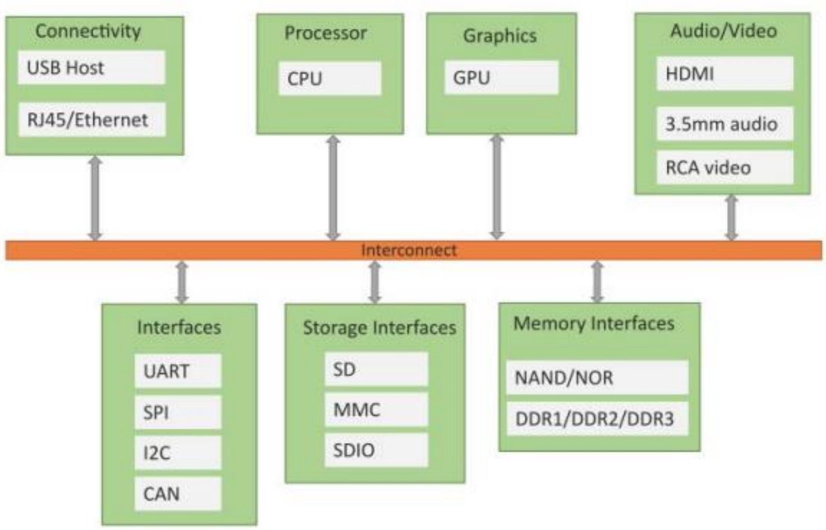


Fig: Generic Block Diagram of a Single Board Computer (SBC)

Sensors, Participatory sensing, RFIDs

Sensor Technology

- Sensor technology is a technology used for designing sensors and associated electronic readers, circuits and devices.
- A sensor can sense a change in physical parameters, such as temperature, pressure, light, metal, smoke and proximity to an object.
- Sensors can also sense acceleration, orientation, location, vibrations or smell, organic vapors or gases.
- A microphone senses the voice and changes in the sound, and is used to record voice or music.
- A sensor converts physical energy like heat, sound, strain, pressure, vibrations and motion into electrical energy.
- An electronic circuit connects to the input at a sensor. The circuit receives the output of the sensor. The output is according to the variation in physical condition.
- A ***smart sensor*** includes the electronic circuit within itself, and includes computing and communication capabilities.
- The circuit receives energy in form of variations through currents, voltages, phase angles or frequencies.
- Analog sensors measure the variations in the parameters with respect to a reference or normal condition and provide the value of sensed parameter after appropriate calculations.
- Sensors are electronic devices that sense the physical environment

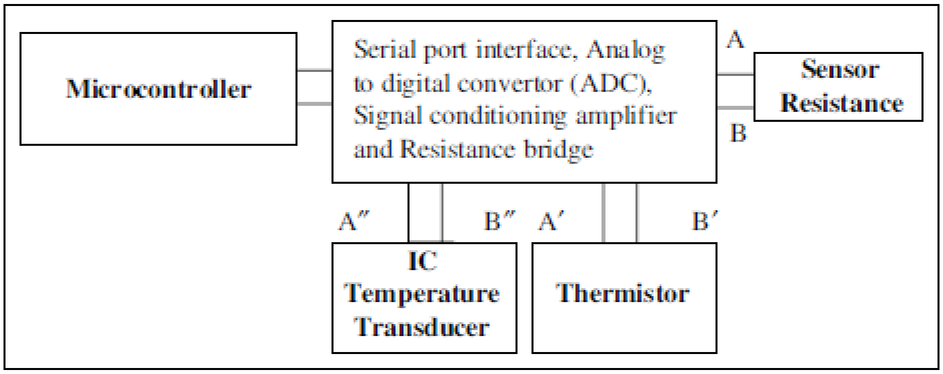
Analog Sensors

- Analog sensors use a sensor and an associated electronic analog circuit. Analog sensors generate analog outputs as per the physical environmental parameters, such as temperature, strain, pressure, force, flex, vapors, magnetic field, or proximity.
- Resistance of the sensing component may show measurable changes with surrounding pressure or strain or magnetic field or humidity.
- Resistance of a pressure sensor increases on pressure which creates a strain on the sensor.
- A flex sensor, for example, of 2.2 inch or 4.5-inch length, shows that its resistance across the sensor strip increases on flexing due to a changed path and deflection of the sensing resistor.

- The measurement of analog output from a sensor circuit is performed as follows—
- the sensor output is given to the input of a signal conditioning-cum-amplifying circuit (SC).
- The SC output is the input to an Analog-to-Digital Converter (ADC).
- The ADC gives a digital output; for example, 8 or 12 bits.
- This output is read using a microcontroller.
- Microcontroller reading and computation gives the value of the sensed parameter value and shows the physical condition around the sensor.

Example of Analog Sensor: Reading Temperature from Resistance Sensor

Figure shows how an analog sensor and a sensing resistor with associated electronics enables the sensing and measuring of temperature.



The working principle of temperature sensor is “A resistor in the form of a wire or a component can be a part of the electronic circuit. Ohm’s law states that resistance remains constant only as long as physical conditions remain the same. The resistor functions as a sensor when its value changes measurably within the required temperature range for sensing.”

Microcontroller serial port connected to sub-circuits—serial port interface, ADC, signal conditioning amplifier, resistance bridge and sensor resistance outputs A and B. Alternatively circuit connects to a thermistor output at A’ and B’ or IC based temperature-transducer output at A’’ and B’’. A transducer induces current or voltage. The output changes as per a change in the physical energy at input. An IC-based circuit for a temperature-transducer induces current in the output according to the heat energy, represented by the temperature. Microcontroller is a computing device which reads the input at its ports, saves the reading in memory and then the reading is used for computations and communication.

The measurements can be first made using two standard or reference temperature points, such as 0°C and 100°C. An equation or table can be prepared for the sensing component resistance R values as a function of the temperature T in °C. When changes are linearly related to the change in the physical environment then the equation is used. When changes are nonlinearly or exponentially related to the change in the physical environment, then use of the table is preferred.

Example of Analog sensor: Capacitive sensor (Touch sensor)

Working principle of capacitive sensor (two cases)

1. When a metal part is present in the vicinity of a parallel plate capacitor, the capacitance C changes and proximity distance is sensed.
2. When a finger reaches near a screen, and the screen has a metallic grid at its base, then C will change depending upon the touched position or C varies with time when the finger is approaching towards the vicinity to a menu item on the screen.

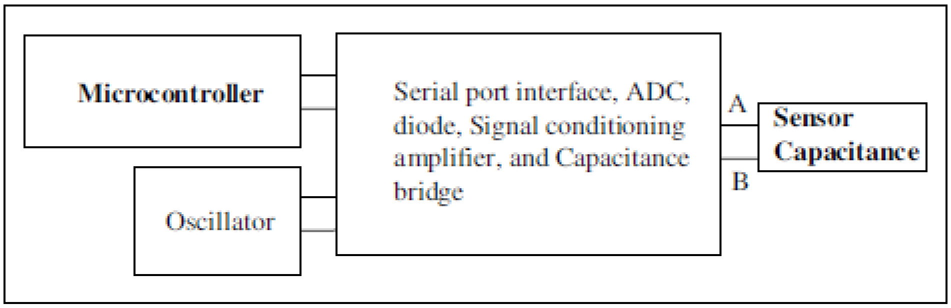


Figure: Capacitive sensor with microcontroller

Figure shows a circuit using a capacitance bridge. The bridge consists of the sensing capacitor (object) and three fixed (standard) capacitors. The figure shows a microcontroller based electronic circuit with port connected to four sub-circuits, serial port interface, ADC, signal conditioning amplifier, diode and capacitance bridge.

Serial Port Interface

A serial port interface with the ADC has an advantage that the ADC 8 or 10 or 12-bit output is input to the interface, and the interface sends the input to the serial port at the microcontroller.

Analog to Digital Converter

A microcontroller may consist of an in-circuit ADC or multiple inputs ADC. It processes the digital output from the in-circuit ADC. Alternatively, a port accepts the digital input consisting of 1s and 0s through an external ADC. An 8-bit port accepts the 8-bit input which corresponds to 0 to 255 decimal (255_d). Assume an ADC is of 8 bits. [$2^n - 1 = 255d$] Then ADC digital output = V_{in} X $255_d/V_{ref}$, because V_{ref} is the maximum input which can be applied to the ADC which gives maximum digital output, 11111111_b, which means 255_d.

Sampling ADC

Sampling means that an ADC accepts input signals at specified periodic intervals and converts them into digits. The interval is set as per the signal frequency and other needs. The applications of sampling ADC are many. For example, while recording voice or music, the sampling ADC receives signals from the microphone for the recording sensor.

Signal Conditioning Amplifier

An SC amplifies the signal at the input as well as adds or subtracts an offset voltage in such a way that minimum V_{in} (min) and maximum V_{in} (max) values of the sensed physical parameter equal to 0 V and V_{ref}, respectively, at the SC outputs.

Digital Sensors

Digital sensor uses the sensor and an associated electronic digital circuit to read 1s and 0s.

A digital sensor uses the sensor and has an associated electronic circuit which gives digital output. The output 1 or 0 (1s and 0s) is read through a port in a microcontroller. This circuit can be used for sensing a sudden change in specific physical state or condition.

Example of Digital Sensor: An environment ambient condition sensor at a streetlight

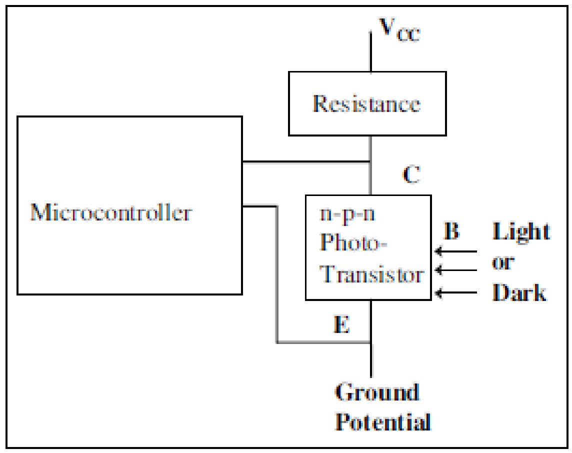
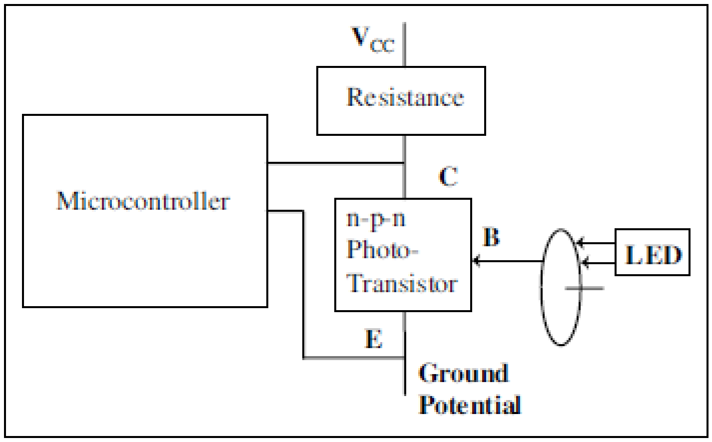


Figure: An environment ambient condition sensor at a streetlight

An environment ambient condition sensor at a streetlight senses the ambient light condition using a phototransistor, FPT. FPT detects the environment ambient light intensity above a threshold. The circuit gives 1 in output when ambient light intensity is below threshold and gives 0 in output ambient light intensity is above threshold.

Example for Digital Sensor: IR-LED (light emitting diode or infrared LED) and phototransistor (FPT) to detect rotating wheel position.

A rotating wheel gives two outputs 1 or 0, when it has a pair of LED or IR-LED (light emitting diode or infrared LED) and phototransistor (FPT) is on two sides of a slot in the wheel. Figure shows the circuit. The circuit gives 1 in output when a slot of rotating wheel reaches near the FPT on completing a rotation and gives 0 in outputs till that is revolving towards the completion of the next revolution. The light to FPT does not block till the wheel completes the revolution.



Examples of Sensors

Temperature

A component called thermistor, shows larger changes in resistance within narrow environment temperature range (120°C to –90°C). A Negative Temperature Coefficient (NTC) thermistor shows negative temperature coefficient which means a drop in the resistance value with rise in temperature. A Positive Temperature Coefficient (PTC) Resistance value of a PTC resistor rises with rise in temperature. A thin wire of platinum or other metallic alloys shows linear changes with its temperature. These can be used for sensing temperature and measuring the values over very wide ranges of temperatures, say (0–1600°C).

Humidity

Humidity is measured in percentage. It is the relative percentage ratio (RH%) of content of water vapors in air compared to one in a situation of maximum possible water vapor content for the air temperature at the instance of measurement. Greater than 90% humidity signifies it is a rainy day. A capacitor sensor shows change in capacitance as a percentage of relative humidity changes. Readily available humidity sensors show output voltage proportional to RH%

Distance

Infrared (IR) sensor is useful for a 0.15 m to 0.8 m range of object. IR sensor works on the principle that when a narrow beam IR LED sends radiation at an inclined angle, the nearby phototransistor FPT receives the reflected radiation after travelling two times the object distance. The reflected radiation delay (= 2 X 3.3 ns per m) between transmitted and reflected signal is proportional to the distance. The distance can be measured for object from 0.1 m to 0.8 m. Above 0.8 m, the reflected intensity may be insufficient for detection and below 0.15 m, the time interval is less than 1 ns, which inhibits the detection.

Alternatively, ultrasonic sensors send the pulses. The frequencies of ultrasonic waves are of few kilocycles. The detection of echo from ultrasonic pulses and an associated circuitry generate a signal proportional to the distance. Ultrasonic wave delay is 2 X 3 millisecond/meter in air as the speed of sound in air is 330 m/s. Long-range distances and any obstacles nearby can be detected using ultrasonic sensors. These sensors are used in industrial automation, ail tracks and oil pipeline faults.

Light

a photoconductor can be used to detect light in the vicinity. The sensor shows a drop in resistance with surrounding light. Alternatively, the p-n junction photodiode or phototransistor can be used to measure incoming radiation intensity incoming from a particular direction.

Acceleration

A Micro-Electro-Mechanical Sensor (MEMS) detects linear accelerations a_x, a_y and a_z along three axes x, y and z, respectively. An MEMS moves when a mass moves along a direction. A mechanical movement has three components. The variations cause the variation in three capacitance values, C_x, C_y and C_z. The value of each C depends on the space between two plane surfaces, which varies on acceleration along an axis.

An accelerometer sensor is used in new generation mobile phones. The display screen image and menu items rotate and align horizontally or vertically on detecting the three components using the sensor when it rotates along with the phone.

Vibrations and Shocks

Alternatively, MEMS may use piezoelectric effect in place of capacitive change effects. The effect observed in certain specific materials is accumulation of electric changes on surfaces due to mechanical compression of the piezoelectric material. The rate of change of number of charges with time implies a flow of current. Vibrations create repeated compression and decompression. An associated electronic circuit generates output according to the intensity of vibrations. The circuit also senses the mechanical shocks. A user initiates the vibrations or shocks, or the device shakes when it falls, then the in-built sensor in the mobile senses these changes and the system takes action as programmed.

Angular Acceleration and Change in Direction (Angle)

Gyroscope is a sensor which measures the change in angular velocity (angular acceleration) and the change in direction (angle). An application takes measurements using a gyroscope or accelerometer and the system initiates actions as programmed. For example, mobile gaming application uses in-motion gestures of a player when deploying a gyroscope.

Orientation and Direction Compass

A gyroscope can be used as an electronic compass or a digital compass as it shows the change in direction (angle). Alternatively, a digital compass can also be used. A compass shows the directions—North, South, East and West. It also shows the direction in which an object is inclined. The compass is a very simple device used for navigation. It has a magnetic strip which aligns towards the Earth's magnetic north under the influence of the Earth's magnetic field.

Magnetic Sensors/Magnetometer

A magnetometer present in a device enables three-dimensional interactions between a tiny magnet M1 in the device and a nearby iron magnetized piece M2 without touch. It uses the magnetic field created in the environment of the device. The magnetometer is also used as an orientation, proximity and distance sensor for iron or steel objects in industrial automation. One application also identifies presence of iron or steel objects and switches off the phone upon detection. Another application monitors the changes in magnetic fields of M1 and identifies the gestures of the user.

Electric Current

Alternating Current (AC) is detected by a miniature transformer and its associated circuitry. A Direct Current (DC) flows in one direction at all instances. It detects using a sensor circuit, which detects the magnetic field by flowing current. Readily available electric current i and voltage v or power (product of i and v) are used. They can connect to the microcontroller using its associated circuitry. The computation can be done in the microcontroller. A wireless transmitter can transmit the data through Wi-Fi to the utility company.

Sound

A microphone is used to sense sound. A readily available electronic board with a microphone connects to the microcontroller, which can control an actuator for actions based on the sensed sound, or recognize the voice and then take required action, such as dialing a number using the Sensing the Things

Reading Barcodes

A barcode is a representation of data. The data relates to the object where the printed code strip is attached. The code is read by an optical scanner. An electronic device reads the output for a port of microcontroller or computing device or computer. The scanner has a light source. When it is switched on, the light impulses pass through a lens and focuses on the black and white spaces of the barcode. The light source can be laser based or LED based.

Reflected light sensor or CCD (Charge Coupled Device) detector at the scanner along with an associated decoder circuit converts the optical impulses into electronic pulses and analyses the barcode’s image data. The resolution commonly used is of dimension 0.33 mm of the printed code. The sensor sends the contents of the barcode as 1s and 0s at the input port of the computing device.

QR Code

QR code is an abbreviation for Quick Response Code. It was first used in automotive industry. Its applications are product identification, tracking, marketing and document management. The QR code uses standardized encoding modes, such as numeric, alphanumeric, byte/binary or other. The code stores the data efficiently and is extendable. It is now popular in industries other than the automotive industry. It is read faster and the data stored is more than that using a standard Universal Product Code (UPC).

The QR code consists of black square dots arranged in a square grid format on a white background. The required data is at patterns in both horizontal and vertical components of the image. A scanner or camera reads the code and the data is processed using an error-correction method called Reed Solomon method. The processing takes place till the process results in appropriate interpretation of the data.

Motion Sensors for Moving Objects

Motion or speed is measured in m/s. The sensor measures delay between successive reflected IR light pulses. An LED source is an IR light source and a phototransistor is an IR sensor. Alternatively, ultrasonic wave echoes can be used to sense the motion of light. The sensor measures the delay between successive echoes.

Pressure Sensors

Pressure P is measured as force per m2. Pressure can be sensed in a number of ways. The sensor is called pressure transducer, pressure transmitter, pressure sender or pressure indicator. Piezometer pressure transducer uses a piezoelectric object between two surfaces. The compression creates electric charges on the opposite surfaces of the object. The flow of charges generates current and voltages, which provide the measure of pressure.

Environmental Monitoring Sensor

Environment parameters are temperature, humidity, barometric pressure and light. A collective use of these parameter sensors enable monitoring of the environment. The data of these sensors adapts to the requirement and sends communication on the Internet to the cloud or web for the environment monitoring applications. For example, light environment on the streets monitors the lights

Location Data

Determining location of an object means finding its distance from several fixed locations which are in multiple directions and also measuring the intensity of light or IR or ultrasonic waves enables computations for a location, in case the source location intensities and attenuation per meter is known.

GPS

Location determination can be done using a Global Positioning System (GPS), also known as Geographical Positioning System. A user can receive the location from a service provider. The service provider finds the GPS location through signals from satellites. The service provider finds the user location with respect to the service provider through its base stations.

Camera

Camera is an image sensor. The camera uses CCD, which consists of a large number of pixels, exposed to the light from the image. It accumulates charges on each of the pixel present at a large number of horizontal and vertical coordinates. The charge accumulation is as per the intensity of light at the corresponding pixel coordinate in the image. Colored camera has set of R, G and B (Red, Green and Blue) light intensity components at each pixel coordinate. The camera generates a file from the R, G and B intensities at each image pixel. The file gets saved in the memory after compression in jpg or gif or any other standard format.

LIDAR

LIDAR (Light + Radar) [Laser Imaging, Detection and Ranging] sensors and laser 3D imaging technology enables remote sensing and imaging. It finds distances by throwing light using laser on target. The sensor senses the reflected light which enables computations of distance.

Laser 3D Imaging

3D imaging is feasible using laser 3D imaging technology. The technology uses both scanning and non-scanning systems. 3D gated viewing laser radar is a non-scanning system using pulse laser and fast gated camera.

Participatory Sensing

Information collected from sensors of multiple heterogeneous sources can lead to knowledge discovery after analytics and data visualization. A web source defines Participatory Sensing (PS) as “sensing by the individuals and groups of people contributing sensory information to form a body of knowledge”. Deborah Estrin, University of California, Los Angeles now at Cornell University, defines participatory sensing as, “Participatory sensing is the process whereby individuals and communities use evermore-capable mobile phones and cloud services to collect and analyses systematic data for use in discovery.”

A participant of a PS process can be sensors used in mobile phones. Mobile phones have camera, temperature and humidity sensors, an accelerometer, a gyroscope, a compass, infrared sensors, NFC sensors, bar or QR code readers, microphone and GPS. Mobiles communicate on the Internet the sensed information with time, date and location stamps.

Applications of PS include retrieving information about weather, environment information, pollution, waste management, road faults, health of individuals and group of people, traffic congestion, urban mobility, or disaster management, such as flood, fire, etc. Participatory sensing has many challenges such as—security, privacy, reputation and ineffective incentives to participating entities.

Figure (a) shows the sources of data in the PS process for IoT applications. Figure (b) shows the phases of a PS process. Phase 1 is coordination, in which the participants of a PS process organize after identifying the sources. Next two phases, i.e. phases 2 and 3 involve data capture, communication and storage on servers or cloud. Next two phases, i.e. phases 4 and 5 involve PS data processing and analytics, visualization and knowledge discovery. Last phase, i.e. phase 6 is for initiating appropriate actions.

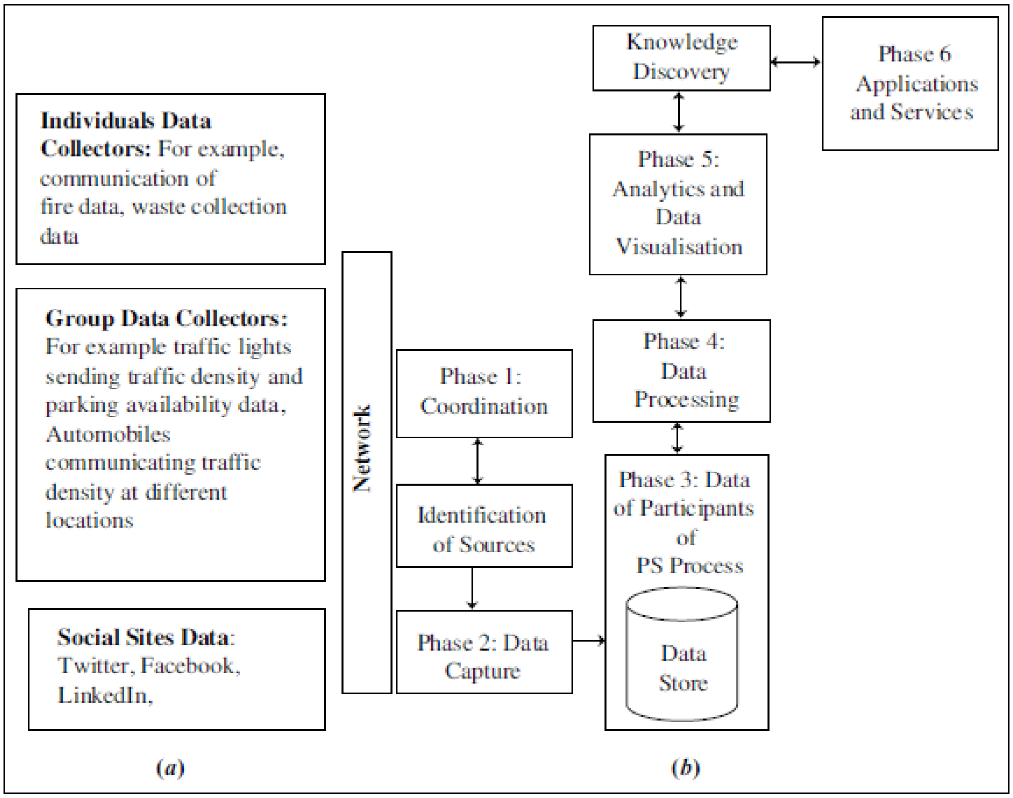


Figure 7.9 (a) Sources of data in the PS processes and (b) Phases of a participatory sensing process for IoT applications and services

Industrial IoT

Industrial Internet of Things (IIoT) involves the use of IoT technology in manufacturing. IIoT involves the integration of complex physical machinery M2M communication with the networked sensors and use of software, analytics, machine learning and knowledge discovery. Example of the functions of IIoT are refining the operations for manufacturing or maintenance, or refining the business model of an industry. IIoT applications are in the manufacturing, railways, mining, agriculture, oil and gas, utilities, transportation, logistics and healthcare services. Similarly, IIoT finds applications in predictive maintenance of aircraft parts, gas pipelines and machines used in production.

Industrial Internet Consortium (2014) is body which has been founded for creation of standards, open interoperability and the development of architectures for Industrial Internet of Things (IIoT).

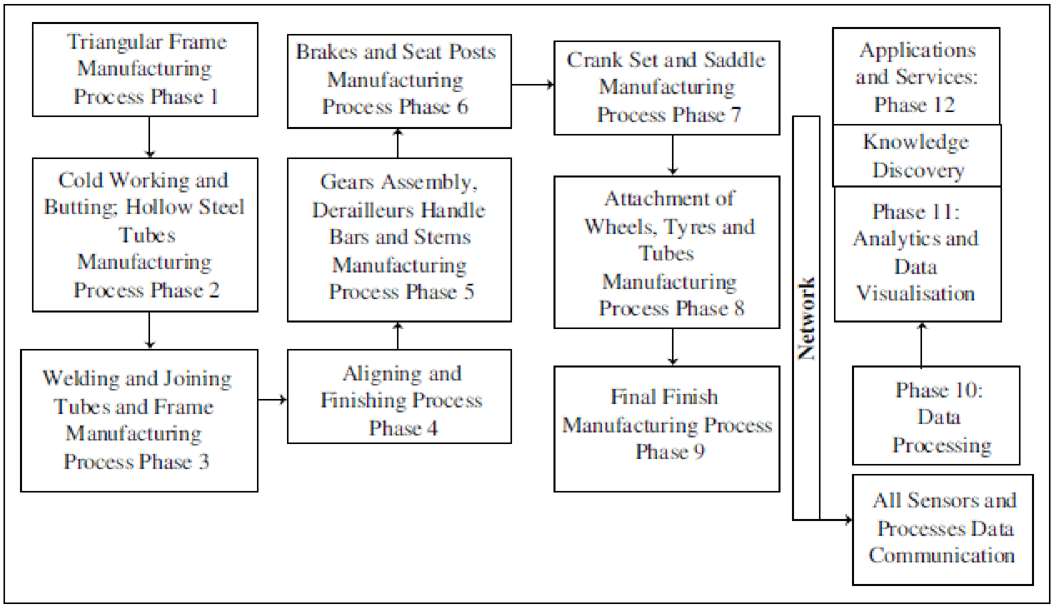


Figure 7.10 IIoT phases in the bicycle manufacturing process

Automotive IoT

Automotive IoT enables the connected cars, vehicles-to-infrastructure technology, predictive and preventive maintenances and autonomous cars.

Connected Cars Technology

Automotive vehicles can drive through roads with little or no effort at all. A connected car with the combination of GPS tracking and an Internet connection enables applications

such as:

1. Display for driver that enables driving through the shortest route, avoiding the congested route, etc.
2. Customization of functioning of the vehicle to meet the driver's needs and preferences
3. Get notifications about traffic
4. Protecting cars against theft
5. Weather and enrooted destinations
6. Keeping a tab on driver's health and behavior.

Vehicle-to-Infrastructure Technology

Automotive IoT enables Vehicle-to-Infrastructure (V2I) technology. A vehicle communicates with other vehicles, the surrounding infrastructure and a Wi-Fi LAN. Examples of V2I applications are:

- Alerts and warnings for forward collision
- Information about blind spots

- Notification about a vacant parking space
- Information about traffic congestion on route to destination
- Stream live music and news.

Predictive and Preventive Maintenances

Figure 7.11 shows Internet of connected car components for predictive and preventive maintenances of automobile by a service center.

Consider Internet of connected automotive components (Example 5.2). A number of sensors for statuses and conditions of components are used. Examples are engine movements unit, axle, steering unit, brake linings, wipers, air conditioners, battery, tyre movements, coolant and shockers. The statuses and conditions data are needed for predictive maintenance. A component embeds computing hardware and for ultrasonic sensors, IR sensors, sound sensors, seat alignment sensors, height sensors, driver acceleration sensors at start, during running and driver braking characteristics and road friction, and microphone sensors. The sensors capture the data for noise, vibration and harsh driving and actions of the vehicle.

The sense data communicates in real-time or stores and transmit when the automobile reaches a Wi-Fi node. The service center application schedules maintenance alerts and predicts the failures and alerts for the actions.

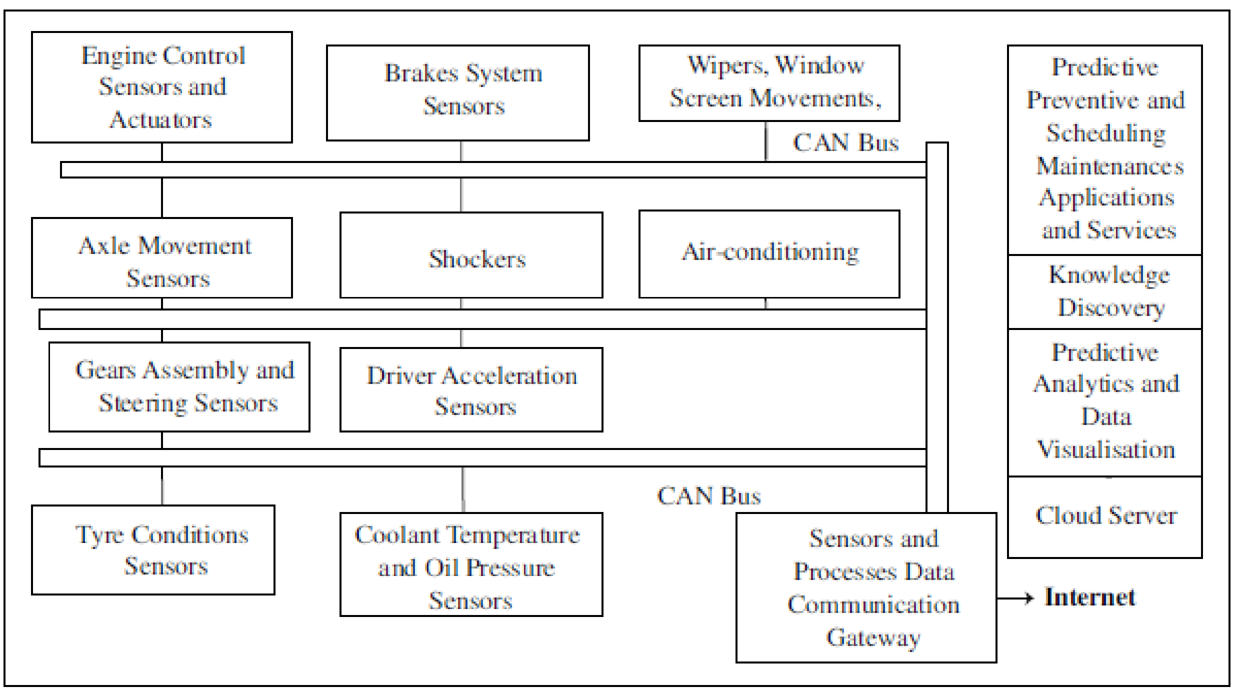


Figure 7.11 shows Internet of connected car components for predictive and preventive maintenances of automobile by a service center

ACTUATOR

An actuator is a device that takes actions as per the input command, pulse or state (1 or 0), or set of 1s and 0s, or a control signal. An attached motor, speaker, LED or an output device converts electrical energy into physical action. Examples of applications of actuators are:

- Light sources
- LEDs
- Piezoelectric vibrators and sounders
- Speakers
- Solenoids
- Servomotor
- Relay switch
- Switching on a set of streetlights
- Application of brakes in a moving vehicle
- Ringing of alarm bell
- Switching off or on a heater or air-conditioner or boiler current in a steam boiler in a thermal plant.

Light Source

Traffic lights are examples of function of light sources as actuators controlled by the inputs.

LED

LED is an actuator which emits light or infrared radiation. Uses of different color LEDs, RGB (Red-Green-Blue) LEDs, intensity variation of LED and colors, graphic and text display using big screens are actions which are controlled using the inputs. RGB LED has three inputs to control, i.e. R, G and B components and thus the composite color. Pulse width modulated pulses control the LED light emission intensity. A microcontroller is used for generating PWM outputs.

Piezoelectric Vibrator

Piezoelectric crystals when applied in varying electric voltages at the input generate vibrations.

Piezoelectric Speaker

A piezoelectric speaker enables synthesized music tunes and sounds. The appropriately programmed pulses generate the music, sounds, buzzers and alarms when they are the input to the speaker. A microcontroller is used for generating PWM outputs for actions using speakers.

Solenoid

A solenoid is an actuator consisting of a number of cylindrically wound coils. The flow of current creates a magnetic field in proportion to the number of turns in the solenoid and the current in it. If a shaft made of iron is placed along the axis, then its motion can be controlled by the input current, pulses and variations of current with time. It can create a sharp forward push, backward push and repeated to and fro motion. It can also create rotator motion from linear motion by using a Cam.

Motor

A motor can be DC (direct current controlled) or AC (alternating current controlled). IO modules are readily available to receive the control digital inputs of 1s and 0s and deliver high currents. The dc or ac rotates the motor. A cam also converts rotator motion into linear motion when it rotates using a motor.

Servomotor

Servomotor is a geared DC motor for applications such as robotics. It rotates the shaft of a motor. The shaft of the motor can be controlled and positioned or rotated through 180° +90°) degrees. The shaft's angular position is controlled through 180°, between –90° and +90° degrees.

Relay Switch

An electronic switch can be controlled by the input 1 or 0 from the port pin of a microcontroller or through a push button switch and battery. The current flows through the switch or voltage applies through the switch depending upon the input state 1 or 0.

A relay switch makes mechanical contact when the input circuit magnetizes with a control circuit and pulls a lever to make the contact. The current flows through the switch or voltage applies through the switch depending upon the input state 1 or 0 from the port pin of a microcontroller or through a push-button switch and battery.

Radio Frequency Identification technology

RFID IoT Systems

A tag enables identification of an object at different locations and times. A product, parcel, postal article, person, bird, animal, vehicle or object can have a tag or label in order to make the identification feasible.

The reader circuit of an ID can use UART or NFC protocol to identify the tag, when the RFID tag is at a distance less than 20 cm. An active NFC device/mobile generates an RF field which induces the currents in RFID and generates enough power for RFID. Using that power, the RFID transmits the identification of tag contents.

Passive device drives power from the electrical current induced in its antenna by the incoming RF signals from a reader or hotspot, and then transmits the tag information back. The active device has an in-built power source (battery) and transmits the information on its own.

A hotspot consists of a wireless transceiver or Wi-Fi transceiver for Internet connectivity. It receives signals from a number of RFID tags in an organization and transmits the data to the web server over the Internet. The hotspot connects to the Internet for IoT services, applications and business processes. A mobile or wireless nearby the device can also function as a hotspot.

RFIDs form an IoT network. They connect to the Internet and then to an IoT server. An IoT server consists of RFID identity manager, device manager, data router, analyzer, storage and database server and services.

Principle of RFID

A tag is an electronic circuit which transmits its ID using RF signals. The ID transmits to a reader, then that transmits along with the additional information to a remote server or cloud connected through the Internet. The additional information is as per the application. For example, for a tracking application, it is location and time-stamped data along with the ID.

RFID IoT Network Architecture

Consider a model for Internet of RFIDs. Following are the capabilities of the layers and data interchange in the ITU-T reference model.

Layer 1: Device and gateway capabilities are present in the RFID physical device cum RFID reader which acquires the ID data, and communicates the enriched data according to a wireless protocol to an access point (AP).

Layer 2: Transport and network capabilities are present at access network consisting of APs and Internet connectivity to servers.

Layer 3: Services and application-support layer capabilities at server are RFID device's registry, ID management, RFIDs data routing to server or data center, data analysis for the time-series device presence and device tracked positions.

Layer 4: Services and applications of RFIDs are tracking, inventory control of goods and business processes; for example, supply-chain management.

RFID IoT Applications

Examples are tracking and inventory control of goods, supply chain systems, business processes such as for payment, leasing, insurance, and quality management, access to buildings and road tolls or secured store center entries, and devices such as RFID based temperature or any other parameter sensor. New applications of RFID network have been found in designing a factory, protecting a brand and anti-counterfeiting measures.

Components of an RFID System

Figure 7.15 shows the components needed in a system for IoT applications and services.

The components of an RFID system are:

RFID is a tiny chip which functions as a tag or label onto an object. The chip is one of three types—passive, active and battery powered passive (battery switches when reader is nearby).

A transceiver is in-built at the chip. It communicates in a range 10 cm to 200 m according to the chip. The chip does UART communication to the reader either using RF link or does NFC communication to the reader within 20 cm range; standard frequency range used can be between 120 kHz to 150 kHz, 13.56 MHz, 433 MHz, higher when using UHF and microwave frequencies. Transceiver using RF frequencies recommended by Regulator has the data transfer rate of 115 kbps using carrier RF signals from 915 MHz to 868 MHz, 315 MHz or 27 MHz.

A nearby RFID reader for receiving ID uses the transceiver within it. It receives the header which consists of 1 start byte, then 10-byte ID and then one end byte when using the UART protocol. Hotspot, mobile or computer with wireless transceiver or Wi-Fi transceiver transmits and receives signals from the RFID tag.

Data processing subsystem: A reader associates a data processing subsystem which consists of a computing device and a middleware and provides connectivity to the Internet, directly or through a gateway which includes a data adaptation sublayer. The subsystem is a backend system. A reader circuit may send data directly or through a computer, mobile or tablet to the Internet. The computations for transmission (of the contents information of tagged device) are usually little. Example of a reader is SparkFun SEN-08419 for prototype developments.

Middleware: Middleware are software components used at the reader, read manager, data store for the transaction data store and APIs of the applications.

Applications and services and other associated applications software use the data store at the cloud or web server.

Issues

The issues are:

Design issue: Designing a unique ID system needs a standard global framework.

Security issue: A tag is read only. It can thus interact with any reader and thus allows automated external monitoring. A tag can thus be tracked without authority. A privacy issue arises when a tag and reader need not to be authenticated before their use. Full implementation of privacy and security needs data processing at the tag and reader with access encryption and authentication algorithms. Another issue is that the RFID system can be vulnerable to external virus attacks.

Cost issue: RFID tag and reader become costly with data processing and security enhancing technology.

Protection issue: The tag needs protection from the adverse weather condition which may damage the tag.

Recycling issue: Recycling of the tags can be an environmental concern.

Active life issue: Active RFID, which consists of battery, has limited life of up to 2 to 4 years.

Review Questions for Unit-3 Part-1:

Straight Questions

1. Discuss about the basic building blocks of IoT.
2. Explain about participatory sensing.
3. Explain sensor technology with examples.
4. Detail Industrial IoT with an example.
5. Explain IoT for Automotive with an example.

6. Summarize various sensors and actuators.
7. Explain the role of RFID in IoT.

Probable Questions

1. Differentiate analog and digital sensors with suitable examples.
2. State the working principle of the following sensors
    a. Temperature
    b. Distance
    c. Pressure
    d. Camera
3. Discuss a case study on Industrial IoT (IIoT).
4. Explain the role of Internet of connected car components for predictive and preventive maintenances of automobile by a service center.
5. Give some examples of actuators, differentiate sensors and actuators.
6. Summarize the issues of RFID.
7. Explain the components of RFID.

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