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INTERNET OF THINGS: SMART SENSORS, SMART APPLICATIONS AND SUPPORTIVE TECHNOLOGIES FOR AUTOMATION

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ABSTRACT:

Internet of Things (IoT) refers to the linking of computing devices also known as nodes for communication through wireless sensor networks. It automates the world processes with billions of sensors and actuators. IoT is evolving with each passing day. Sensors are used as a node for sensing and collecting data. A sensor is an electronic component that detects and responds to some type of input from the physical environment. Sensors are used to detect motion, pressure, temperature, moisture, sensitivity and many other physical quantities. The journey from smart applications to smart world is possible due to smart sensors. In this paper, we have precisely reviewed the sensors with their specifications and uses in smart applications. A wide range of smart applications are discussed along the sensors that bring the applications in working. Furthermore, an internet of things taxonomy has been created in context of sensors to smart applications. We also elaborated the IoT enabling technologies like wireless sensor networks, data analytics, cloud computing etc for better understanding of researchers.

INTRODUCTION

Internet of Things is an emerging technology that refers to the millions of physical computing devices of world that are integrated with each other for collecting and sharing data for communication[1]. Due to invention and availability of super-cheap computing chips, microcontrollers, the ubiquity of cloud, wireless networks, it's possible to turn anything, from something as small as a pill to something as big as an aero plane, into a part of the IoT. The internet of things term is first time referred by Kevin Ashton 1999 to describe a system where the Internet is connected to the physical world via ubiquitous sensors. Industry 4.0 refers to the 4th revolution of industry that leads to intelligent networking of machines and processes for industry with the help of information and communication technology and Internet of Things[2]. A sensor is device or a module that can detect changes happening around its surrounding like heat etc. A sensor by itself is useless but whenever we use it in an electronic system or device, it always plays in an important part. A sensor can measure all the physical environment activities and convert it into an electrical signal. A few common sensors that are mostly used in daily life are photovoltaic sensors, temperature sensors, pressure sensors, motion sensors and many more. Sensors are usually made or developed in a way so that they have a small effect on what is measured. By changing the size of sensor and making them smaller in size often enhance their quality and may introduce many interesting advantages which may improve the quality of the device to which they are integrated. This may make them affordable and easy to fit in small devices.

In this modern era of technology sensors have brought revolutionary change in the field of technology. They have totally changed the human life by making everyday tasks convenient and easy-to-access. A good sensor always follow or obey rules[3] and are sensitive to the measured property. Sensors are being used in different sectors like gas sensing, motion detection[4], assembly modeling [5], smart cities, traffic automation etc. Now-a-days, every device is equipped with some sensors, from smart phones to cars, laptops and in home lamps which can be dimmed and brightened by touching the base of lamp. Sensors have revolutionized the industry 4.0 by bringing an automation to commonly used devices. With the advancement in the micromachinery and with easiness in the utilization of microcontroller platforms, the utilization of sensor has expanded beyond its conventional boundaries or fields of temperature, pressure or flow measurement[6]. Sensors are also being used for security monitoring purposes. Now-a-days, researches are being made on smart homes, energy monitoring [7], smart gardening [8], sports [9] and on development of smart cities which all are greatly impacted by IoT and sensors. They are also playing an important role for the security and safety of important building and objects. In the near future, we will be surrounded in technologies consisting of sensors. Sensor are playing vital role in advancement of medical field or human health. With sensors we can monitor health of person such as heartbeat[6], blood pressure[10], temperature[6], movement detection[4], respiration[11] and many other body parameters. They are also used monitoring condition of bones[12]. Sensors are making our life easy in many ways. Sensors are playing an important role in artificial intelligence too. Because the increasing demand of people for affordable or

accurate information in today's world has increased, the demand of disposable sensors has also increased to fulfil the former need. Using this type of sensor, critical information can be obtained by anyone, at anyplace or at any time, without any problem[3]. Now-a-days, cars are being designed using sensors and AI technology which are totally automatic and work even without drivers. Sensors are developed according to the need of people such as chemical sensor which is self-analytical device which is used to give information about the chemical of its environment and surrounding[13]. Recently, many MOSFETs have been developed for measuring chemical, physical, environmental and biological parameters[14].

Rest of the paper is categorized in four sections. Section 2 presents the sensors with categorization and taxonomy. Section 3 discusses the different smart applications of IoT while the section 4 elaborates the IoT supporting technologies. Finally, section 5 concludes the research.

SENSORS IN IOT

IoT is one of the most discussed topics in the field of technologies. Now-a-days everything is connected to the internet. This era is known as the era of modernization and Industrial revolution 4.0. IoT has played an important role in deployment of new technologies. Sensor is a device that detects the changes in its surrounding. Sensor by itself is a useless device but it can play an important role when it is connected in an electronic system. Sensors measure different phenomena such as pressure, temperature etc. A good sensor is always based on three features:

- It is sensitive to measurable phenomenon.
- It is not sensitive to other physical phenomenon.
- It does not change the recorded values during measurement.

Sensors have been in use for long time but after the advent of Internet of Things, sensors have evolved to a completely new level. IoT platforms function and deliver various kinds of data and intelligence using different sensors. It serves to collect and share data with whole network of various connected devices. All this collected data make it possible for devices to work autonomously. Sensors can be classified into different categories depending on the different properties they have. Some of the most common classification of sensors are:

Direct Sensors

Direct sensors are those sensors which convert a non-electrical input to an electrical output with multiple intermediate processes.

Indirect Sensors

Indirect sensors are those sensors that have multiple conversion stages to convert the measured signals into an electrical signal.

Active & Passive Sensors

Passive sensors do not require or need an external source of power while monitoring an environment, while Active sensors needsuch electrical source to work.

Analog & Digital Sensors

Continuous signals are generated by analog sensors while discrete signals are produced by digital sensors.

We classified different sensor on the basis of field where they are used such as health, industrial etc.

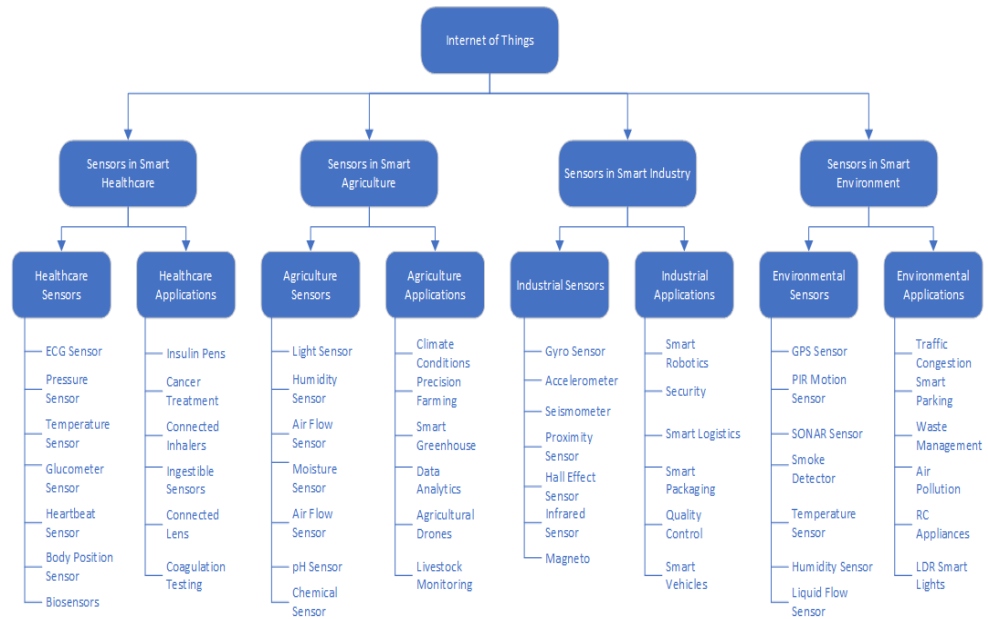


Figure 1. Internet of Things Taxonomy with Sensors and Smart Applications

Table 1 Sensors in Healthcare with Functionality

Health Sensors			
Sr	Name	Description	Specs
1	Temperature Sensor	It is used to check the temperature of human body or other objects.	<ul style="list-style-type: none"> ▪ Accuracy: 0.5° at 25°C ▪ Range: -55° to +150°C ▪ Voltage: 4 to 30 volts
2	NTC Thermistor Sensor	It is common type of temperature sensor to measure surface temperature[15].	<ul style="list-style-type: none"> ▪ Excellent long-term stability. ▪ Flow/Reflow soldering possible
3	Medical Pressure Sensor	Medical pressure sensor is used to control the pressure level in oxygen tank and also flow of oxygen being delivered to patient.	<ul style="list-style-type: none"> ▪ Shelf Life: 5 years ▪ Pressure: -50 to 300 mmHg ▪ Calibration: 97.5 to 102.5 mmHg
4	Heart rate Sensor	It is the sensor which is used to measure rate of patient’s heartbeat.	<ul style="list-style-type: none"> ▪ Biometric Pulse Rate Detection ▪ Voltage: +3.3V to 5V
5	Body position sensor	It consists of triple axis accelerometer that is used to measure the patient’s position.	<ul style="list-style-type: none"> ▪ Voltage: 1.65V to 5.5V dc. ▪ Temperature: -40°C to 85°C ▪ Actuation: Monopolar
6	Glucometer sensor	It is the sensor which help patient or user to measure approximate concentration of glucose in blood.	<ul style="list-style-type: none"> ▪ Range: 20-600 mg/dL ▪ Precision: up to 4% ▪ Test Time: 5s

7	ECG sensor	It is the sensor which is used to measure electrical activity of heart.	<ul style="list-style-type: none"> ▪ Range: $\pm 1.5\text{mV}$ ▪ CMRR: 110dB ▪ Consumption: $\sim 4\text{mA}$
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Table2.Sensors in Agriculture with Functionality

Agricultural Sensors			
Sr	Name	Description	Specs
1	Location Sensor	It is used to locate a particular thing. In agriculture, it is used to determine the location of crops.	<ul style="list-style-type: none"> ▪ Temperature: -40°C to $+85^{\circ}\text{C}$ ▪ RoHS Compliant ▪ Thin Type: 2.1mm ▪ Pb Free Soldering: 260°C
2	Optical Sensor	This sensor converts light rays into an electronic signal. It is used to measure physical quantity of light.	<ul style="list-style-type: none"> ▪ Temperature: -30°C to $+70^{\circ}\text{C}$ ▪ Voltage: 2.4V to 3.6V ▪ RoHS and Halogen free compliant
3	PIR Sensor	It is commonly used in security alarms to monitor motion and automatic lighting applications.	<ul style="list-style-type: none"> ▪ Power supply: 5V-12V ▪ Sensitivity range: up to 20 feet ▪ Output: Digital pulse high (3V)
4	pH Sensor	It is used to measure the PH of water and soil.	<ul style="list-style-type: none"> ▪ Response time: 90% in 1 sec ▪ Accuracy: ± 0.2 pH units ▪ Temperature: 5 to 80°C
5	Soil Moisture Sensor	It is used to detect the level of moisture present in the soil. It measures the volumetric content of moisture in the soil [16].	<ul style="list-style-type: none"> ▪ Voltage: 3.3V to 5V ▪ Dry Soil: 0~300 ▪ Humid Soil: 300~700 ▪ Water: 700~950
6	Air Flow Sensor	It is used to measure air permeability in the soil.	<ul style="list-style-type: none"> ▪ Flow Range: ± 200 SCCM ▪ Pressure Range: ± 5 mbar ▪ Response Time: 1 ms typ.
7	Leaf Wetness sensor	It is the sensor which is used to measure water loss in plants by real-time monitoring the moisture level in plant leaves.	<ul style="list-style-type: none"> ▪ Temperature: 0 to 50°C ▪ Protection Index: IP 67 ▪ Dry Output: 0.25 V approx. ▪ Wet output: 0.4 V approx.
8	Humidity sensor	It is the sensor which is used to detect the level of moisture in the air.	<ul style="list-style-type: none"> ▪ Humidity Accuracy: $\pm 5\%$ RH ▪ Measurement Range: 20-90% RH ▪ Temperature Accuracy: $\pm 2^{\circ}\text{C}$

9	Light sensor	It is the sensor which is used to detect presence of sunlight in atmosphere.	<ul style="list-style-type: none"> ▪ Measurements: 0.01 lux to 83 k lux ▪ Temperature: -40°C to +85°C
10	Rain Sensor	It is used to detect rain. It is used in automatic irrigation system. It causes irrigation system to shut down in case of rain.	<ul style="list-style-type: none"> ▪ Minimum Wet Area: 0.05 cm² ▪ OFF-delay (active):<5 min ▪ Temperature: -15 to +55 °C
11	Soil Temperature Sensor	It is the sensor which is used to measure temperature of soil[17].	<ul style="list-style-type: none"> ▪ Temperature: -40° to +60°C ▪ Accuracy: 0.1 °C ▪ Response Time: less than 10 sec

Table 3.Sensors in Smart Homes with Functionality

Smart Homes			
Sr	Name	Description	Specs
1	Heat sensor	It is the sensor which is used to detect changes in heat. It can be used to detect fire opening.	<ul style="list-style-type: none"> ▪ 0.5°C Ensured Accuracy at 25°C ▪ Voltage: 4 V to 30 V ▪ Range: -55°C to 150°C
2	Motion sensor	It is the sensor which is used to detect the motion of any object at particular place.	<ul style="list-style-type: none"> ▪ Power supply: 5V-12V ▪ Sensitivity range: up to 20 feet ▪ Output: Digital pulse high (3V)
3	Magnetic door sensor	It is the sensor which is used to control home door.	<ul style="list-style-type: none"> ▪ Distance: 15mm max ▪ ABS enclosure ▪ Voltage: 200 V dc
4	Smoke Sensor	It is the sensor which is used to detect smoke in home in case of fire.	<ul style="list-style-type: none"> ▪ Detection Zone: 300 - 10000ppmm ▪ Characteristic Gas: 1000ppmm ▪ Response Time:<10s
5	Gas Sensor	It is the sensor which is used to detect gases in the room.	<ul style="list-style-type: none"> ▪ Detection Gas: Combustible gas and smoke ▪ Concentration:300-10000ppm
6	Video Sensor	It is the sensor which describes the technique of digital image analysis.	<ul style="list-style-type: none"> ▪ Mp and 720p (16:9) Images ▪ Linear Range Capture ▪ DR-Pix Technology ▪ On-chip Phase-locked Loop (PLL)Oscillator
7	TouchSensor	It is the sensor which operates on touching. It can be used in security mechanisms.	<ul style="list-style-type: none"> ▪ Voltage: 2.0V~5.5V ▪ Response time: 220ms ▪ Auto calibration
8	Alarm Sensor	It is a sensor that detects the event which is not part of any normal activity.	<ul style="list-style-type: none"> ▪ Magnetic test feature ▪ Intelligent Data Evaluation
9	Ultrasonic Sensor	Distance between objects is measured by ultrasonic sensor using ultrasonic rays.	<ul style="list-style-type: none"> ▪ Range: 2cm to 4m ▪ Measuring Angle: 15 degrees ▪ Voltage: 5V dc

Table 4.Sensors in Industry with Functionality

Industrial Sensors			
Sr	Name	Description	Specs
1	Seismometer Sensor	It responds to ground motion such as caused by the earthquake, volcano eruption etc.[18].	<ul style="list-style-type: none"> ▪ Sensitivity: 3200 V/ms⁻¹ ▪ Dynamic Range: 148 dB @ 1 Hz ▪ Linearity:>90 dB ▪ Damping:70% of critical
2	Gyroscope Sensor	It is the sensor which is used for measuring or maintaining orientation and angular velocity.	<ul style="list-style-type: none"> ▪ Voltage: 1.95 V to 3.6 V ▪ Full-scale Range: up to ±4000 dps ▪ Sensitivity: 0.0625°/s
3	Accelerometer Sensor	It is used to measure acceleration force. It is useful in sensing vibration.	<ul style="list-style-type: none"> ▪ 3-axis sensing ▪ Low power: 350 μA ▪ 10,000 g shock survival
4	Proximity Sensor	It is able to detect the presence of object with physical contact in a defined range of distance.	<ul style="list-style-type: none"> ▪ 16-bit Resolution Threshold ▪ NPN and PNP Modes ▪ Programmable Hysteresis
5	Hall Effect Sensor	It is the sensor which is used to measure the magnitude of the magnetic field.	<ul style="list-style-type: none"> ▪ Sensitivity: ±10% ▪ Voltage: 2.5 to 38 V ▪ Temperature: -40 to 125°C

SMART APPLICATIONS IN IOT

Sensors in Smart Healthcare

As we all know that health is one of the important sector. Sensors and IoT have brought huge changes in this sector. Now people can detect different changes and abnormalities in their body even at home. People can check their heartbeat, blood pressure and glucose level at home without going to a doctor. Different sensors are used in medical care devices. We can make many wearables using sensors [19].

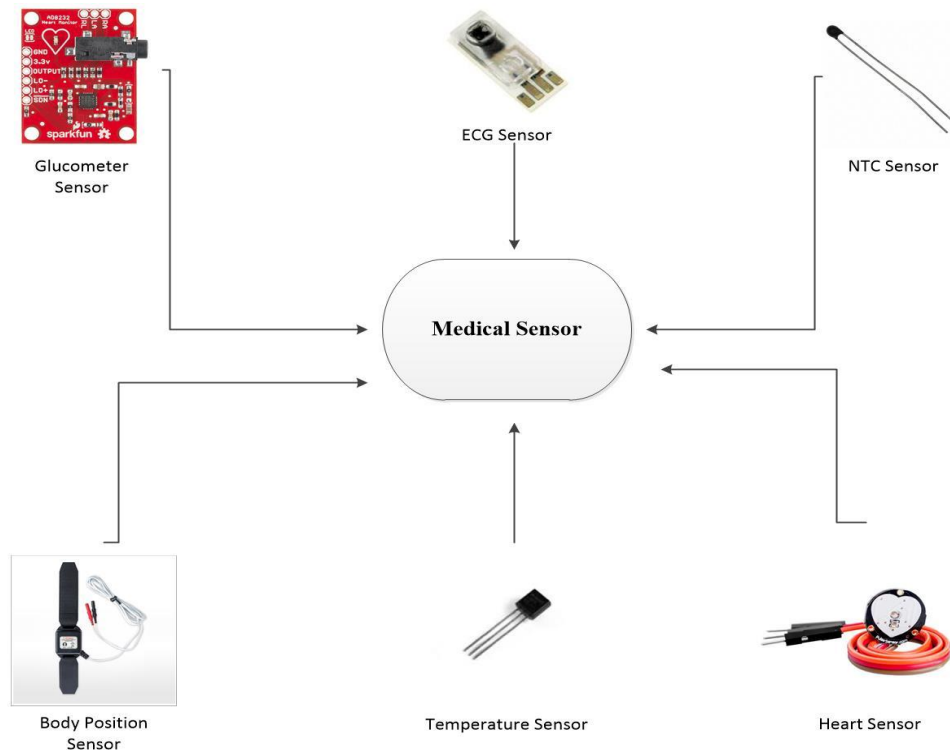


Figure 2.Sensors in Smart Healthcare

Sensors in Smart Agriculture

Agriculture is also a crucial sector. Most of the population of the world depend directly or indirectly on agriculture. After the advent of sensors in this sector, agricultural activities have totally changed. Now the sensors have made the agriculture smart. Using sensors, we can improve the quality of yield. We can increase the quantity and quality of our crops by using modern sensors and IoT in mechanical processes, threshers and harvesters to automate the processes. Sensors can help monitor the growth of crops. Wireless sensors have connected agriculture to the internet[8].

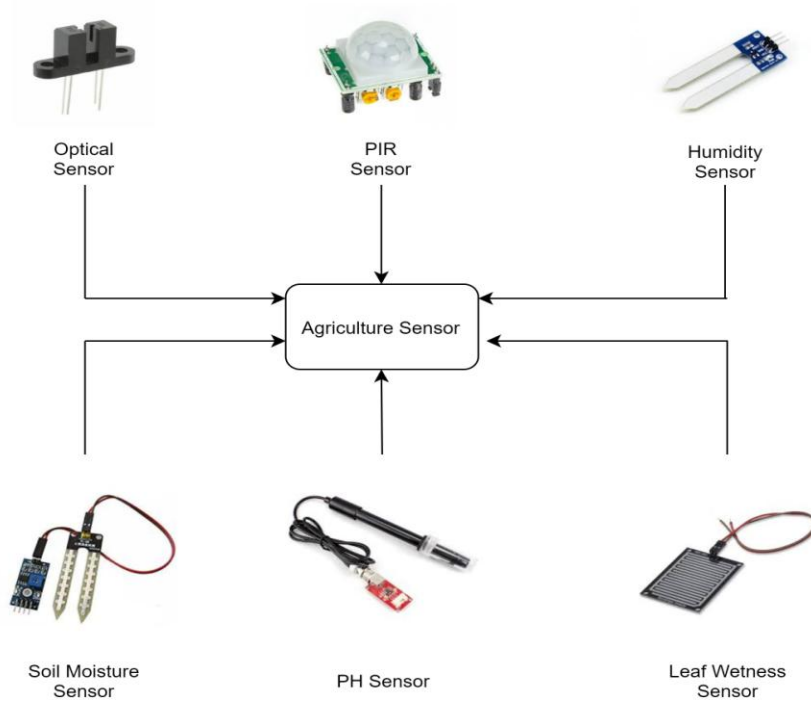


Figure3.Sensors in Smart Agriculture

Sensors in Smart Environment

Some years back, thinking of smart homes seemed an imagination or a dream that can never be achieved but, with introduction of different sensors in environmental sector, this dream came true. Smart homes are now truth. By using different sensors and IoT we can turn our normal home into a smart home [13]. We can control home appliances and electrical devices using latest technologies like Infrared, Gesture, Human Motion and Voice recognition.

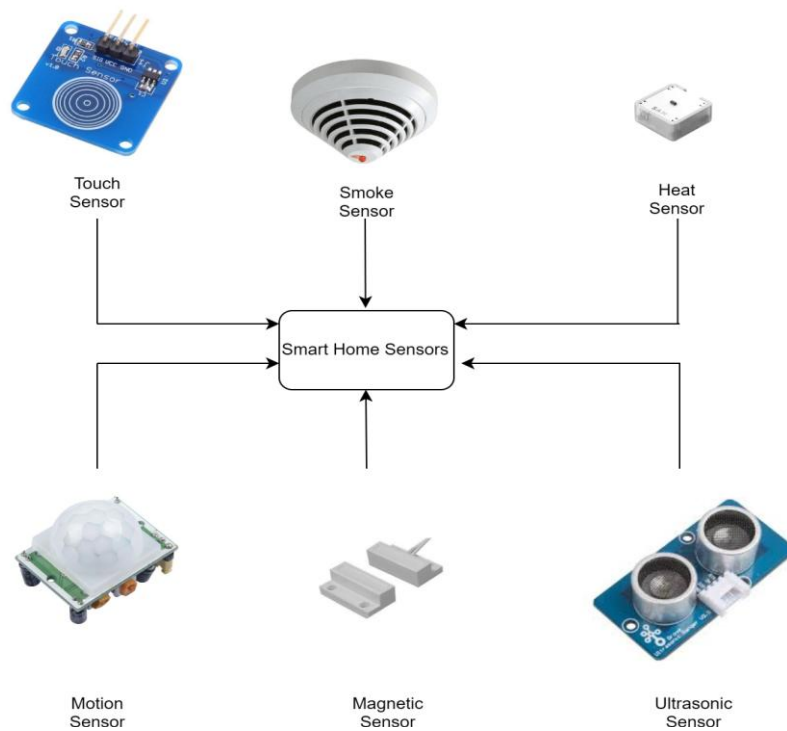


Figure 4.Sensors in Smart Environment

Sensors in Smart Industries

Industries plays an important role in the growth of a country. After the invention of sensors, the industries have been revolutionized in a great manner. Every industry has evolved by welcoming automation in its processes which otherwise required hard human labor and excessive time to complete a task[20]. But thanks to IoT, these crucial and complex processes and tasks are now carried out automatically by sensor based devices and automated tools in a very little time with little effort. Smart phones and automobiles are the best example of these industries.

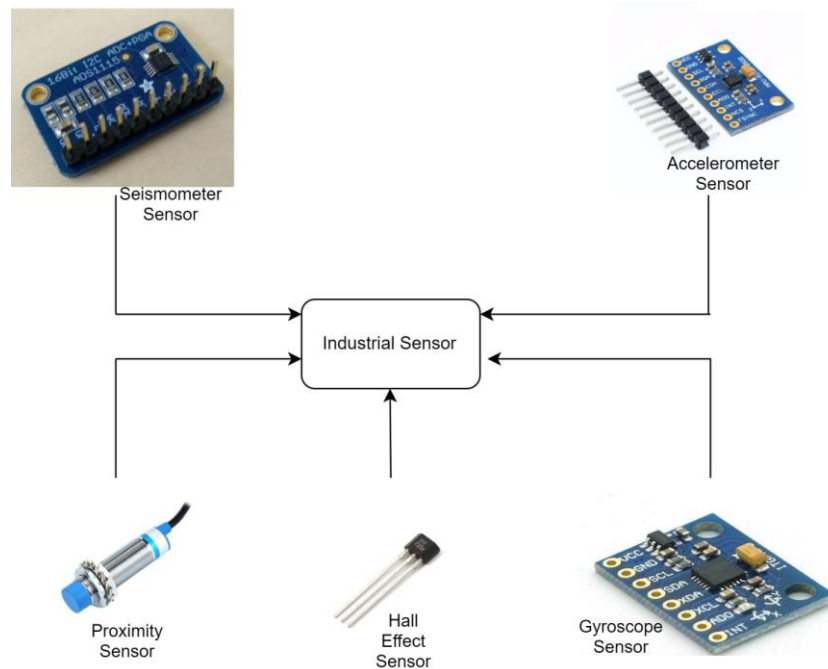


Figure 5. Sensors in Smart Industry

IOT ENABLING TECHNOLOGIES

Wireless Sensor Network

A wireless sensor network consists of devices with different sensors connected to them[21]. These are used to monitor the environmental and physical conditions in the surrounding. A wireless sensor network also consists of number of nodes, routers and coordinators. Several sensors are also attached to the end nodes. Main objective of the router is to transfer data packets from end nodes to coordinator. Coordinator collect data from all nodes and it also acts as a gateway that connects WSN to the internet. Here below are some of the WSNs used in IoT systems:

- Smart Grid uses WSN for monitoring the grid at various points.
- Surveillance system uses WSN for collecting surveillance data.

Communication protocols act as the backbone of the IoT systems[22]. They also enable network connectivity. Devices exchange data over the network with the help communication protocols. Number of protocols often describes different features of single communication. In IoT, we use different types of protocols. Some of them are:

- Message Queuing Telemetry Transport (**MQTT**) Protocol
- Constrained Application Protocol (**COAP**)
- Advance Message Queuing Protocol (**AMQP**)

Big Data Analytics

It is the process in which we collect, organize and analyze the large sets of data into the useful information[23]. Using big data analytics, organization can understand the information contained within the large amount of data and it may also help them to better understand the data which is important to enhance business. There are many examples of big data generated by IoT system. Some of them are given below:

- Data generated by sensors in IOT system e.g. Earthquake Monitoring System.
- Data generated by IoT system for location or vehicle tracking e.g. Global Positioning System (GPS).

Embedded Systems

An embedded system is refers to built-in integration of software with hardware[24]. Sometime embedded systems are independently implemented and sometime integrated as a sub-components of large systems. Mostly embedded systems are used in real time computing systems where sensed data is transmitted over cloud for further data processing. Latest embedded systems are implemented with state of the art microcontrollers. They are used in automotive, industry, agriculture, medical and education.

Cloud Computing

Cloud computing refers to being able to access computer resources such as storage, softwares or infrastructure via internet rather than traditional computer systems[25],[26]. It has three models.

- Software-as-a-service (**SaaS**)
- Platform-as-a-service (**PaaS**)
- Infrastructure-as-a-services (**IaaS**)

They are important to IoT because they allow any user with a browser or internet connection to transform smart objects as an actionable intelligence.

Artificial Intelligence

Artificial Intelligence (AI) is ability of computer system to take decision and perform task intelligently by taking decision itself on the basis of given dataset or training[27]. Digital machines are trained with datasets to make them intelligent. Now AI is essential part to IoT systems, development, enabling outstanding features and operations to give competitive edge in business performance. AI and IoT is the future of technologies.

CONCLUSION

Internet of things revolutionizing the world drastically by moving manual processes to automatic process. It is future of today's computing. Sensors,

actuators and other supportive technologies helping IoT in creation of smart world. This paper presents the different type of sensors with their functionalities and specification. After that, a taxonomy has been created in reference of smart sensors to smart applications. Internet of things smart applications are discussed with sensors which are specifically used for building that applications. Furthermore, internet of things enabling technologies are elaborated with their support purpose. This research work will help other researcher in selecting appropriate sensors and supportive technologies while developing internet of thing based systems.

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