

# Smart Sensors: Analysis of Different Types of IoT Sensors

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**Abstract—** Internet of Things (IoT) is a revolutionary technology. It is revolutionizing our world with trillions of sensors and actuators by creating a smart environment around us. In scientific research, sensors are considered as a prospective field. Ubiquitous sensing abilities offer shared information to develop a common operating picture. IoT sensors are efficiently used in various IoT applications for creating a smart environment. This paper presents several IoT sensors and also explains various sensor based IoT applications. Furthermore, after analyzing different sensor applications, this article enlightens which IoT application requires which type of sensor. In the future, this work will serve as the basis for further research work in the related area.

**Keywords—** IoT sensors; types of IoT sensors; sensor applications; IoT and sensors, IoT sensor types.

## I. INTRODUCTION

Internet of Things (IoT) connects all, animate and inanimate things that lead to revolutionary changes. Objects are connected using different network media. The main objective of IoT is to make things more dynamic and convenient. IoT domain significantly increased the number of smart things/devices. It enables many objects (devices) to act as smart things. Objects enabled with IoT technology have been embedded with smart capabilities through the use of various tools and technologies like sensors, RFID and many other forms of embedded computing [1]. IoT technology has led people to pervasive connection and smart services. It is now being deployed widely in various smart applications and creates a wide range of business opportunities [2].

IoT is comprised of various areas including cloud, mobile devices, virtualized environments, sensors, Radio Frequency Identification (RFID), and Artificial Intelligence [3]. Also, various intelligent services are offered in IoT based networks that have led to the cloud-based IoT networks [4].

In this smart environment of IoT, devices can exchange information and provides many convenient services. For example, echo enabled Alexa devices and many other IoT enabled smart devices provides many facilities to the owner like turning on/off indoor and outdoor electronic devices such as lights, water heater, washing machine, AC, and etc. remotely and hand free [5]. Devices such as Echo Spot and Alexa make audio-video calls, play music, watch videos, watch news bulletins, see the calendar, to-do lists, traffic management, view social media accounts like Facebook photos, watch kids from outside, control lights, switches and much more. These devices use far-field voice recognition and connect to Alexa echo devices; that works using a cloud-based

voice service. Amazon's new "Tap to Alexa" feature enables speech and hearing impairment. Users trigger common "Alexa" tricks with the only tap on the screen without conversation. It is more helpful for people with a disability like blind and deaf. Such devices are used in IoT enabled environments for entertainment, listening to music, to explore nearby places, to set a timer, news updates, weather updates and etc. These devices are available in the market with screen and without screen. Without screen, devices provide only audio services and with screen devices also provide services with a display. IoT smart environment is really affecting human life.

In any smart application, sensors are very important. It detects any physical/chemical change and after processing the collected data sensors automate the application/devices to make it smart. IoT integrates various types of sensors, devices and nodes having the capability to communicate with each other without intervention of human [6]. In any IoT application, sensors bring the physical world very close to the digital world that can be implemented by leveraging fog computing.

This paper presents various types of sensors in IoT like proximity sensors, temperature sensors, humidity sensors, chemical sensors, position sensors, motion sensors, pressure sensors, and etc. Different types of sensors are used by various IoT applications to create an IoT enabled smart environment. This paper analyzes several sensors based IoT applications and explains which IoT application requires which type of sensor.

The rest of the paper is structured as follows: In section 2, we briefly introduce the enabling technologies in IoT. Section 3, presents different types of sensors and briefly explains their use in different application areas to create a smart environment and finally, section 4 concludes the paper.

## II. INTERNET OF THINGS (IoT)

In the IoT field, various resource constraints devices communicate in the network using RFID (Radio Frequency Identification Devices) which is a fast-growing technology that allows automated identification of items having RFID tags. These RFID tags are integrated circuits having an antenna. An RFID reader, through the radio interface, communicates with these RFID tags. Fig. 1 shows how IoT works using various technologies including RFID that identifies and tracks data of things, sensors play the role of collecting and processing of data for detecting changes in physical things, smart-tech enhances network power by developing the capabilities in network and nanotech that

enable smaller things to connect and interact with other things in the network [7].

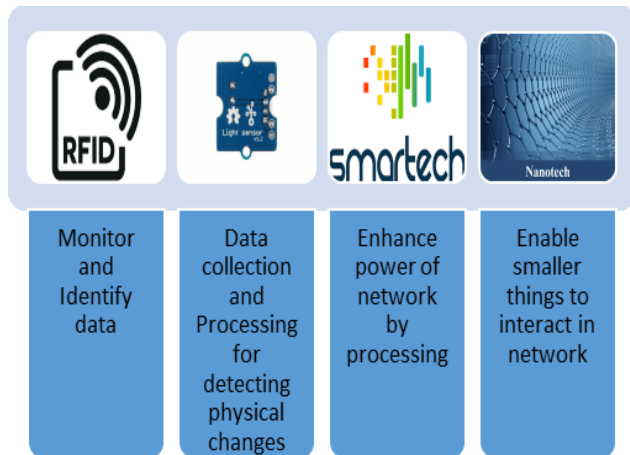


Fig. 1. IoT working with enabling Technologies

Communication with such devices can be done directly, hands-free, remotely over the Internet. This way of communication is known as an intelligent communication system. This system can be used in various areas of networks such as Home Area Networks (HAN), Personal Area Networks (PAN) and Metropolitan Area Networks (MAN) and devices can be interconnected within hybrid structures also; formed of multiple network types.

Such interconnected networks provide benefits to many end users, companies, organizations (government and private) in various applications. Things/Objects work autonomously within a network. The things/devices are having the capability of data delivery, data access and authorization of cloud-based resources for data extraction and collection.

### III. TYPES OF SENSORS

Sensors play an important part in the automation of any application by measuring and processing the collected data for detecting changes in physical things. Whenever there is a change in any physical condition for which a sensor is made, it produces a measurable response. Fig. 2 shows sensing elements and the corresponding electrical signal.

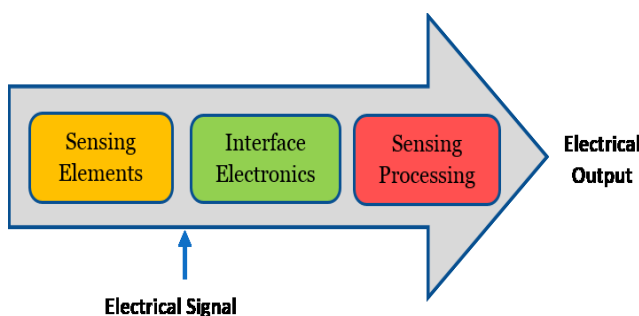


Fig. 2. Sensing elements and corresponding electrical signal

There are different types of sensors which can range from very simple to complex. The classification of sensors can be based on their specifications, its conversion method, type of material used, its sensing physical phenomenon, properties

that what it measures, and the application field. Fig. 3 depicts various types of sensors in IoT which are explained below.

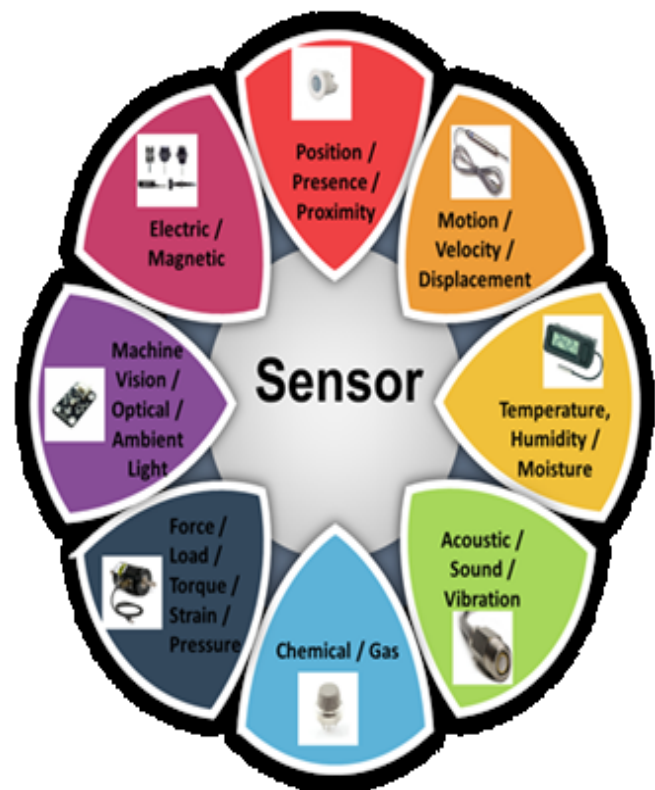


Fig. 3. Different types of IoT sensors

#### A. Proximity Sensors

The position of any nearby object can easily be detected with proximity sensor without any physical contact. By emitting electromagnetic radiation such as infrared, it finds the presence of an object by simply looking for any variation in the return signal. There are different types of proximity sensors like Inductive, Capacitive, Ultrasonic, Photoelectric, Magnetic and etc. targeting different applications. This particular type of sensor is mostly used in applications demanding security and efficiency. Various application areas of this type of sensors are object detection, counting number of items, measuring the amount of rotation, for positioning of objects, material detection, measuring movement direction, parking sensors and etc. Proximity sensors have the best use in many types of industries [8, 9].

#### B. Position Sensors

The position sensor detects the presence of human or objects in a particular area by sensing their motion. It can be used in home security to enable the owner to track the doors and windows of rooms and appliances from anywhere. It let them know the open or closed status at all times and can track the intruders in their absence. It can be used in health care monitoring for monitoring the position of patients, nurses and doctors in a hospital [10], in agriculture for detecting the position of cattle [11].

#### C. Occupancy Sensors

Occupancy Sensor or sometimes called presence sensor detects the presence of human or objects in a particular area. It can be used for remote monitoring through various parameters like temperature, humidity light, and air. A

similar application of this type of sensor is given by authors in [12].

#### D. Motion Sensors

A motion detector is a device used to sense all the kinetic and physical movement in the environment. An application for monitoring homes in the absence of homeowner can make use of motion sensors and whenever motion is detected the photos or videos can be uploaded on the server. Authors in [13] used the motion detection sensor for home security. The python script is executed in the proposed approach to detect the motion and this application takes continuous snapshots till motion is detected and also captures videos from the start of motion till the end of a motion.

#### E. Velocity sensors

It is a sensor that calculates the rate of change in constant position measurement and position values at known intervals. Velocity sensor may be linear or angular. A linear velocity sensor detects the speed of an object along a straight line whereas angular velocity sensor detects how fast a device rotates. It can be used in smart city applications for intelligent vehicle monitoring [14, 15].

#### F. Temperature sensors

Temperature sensors are helpful in detecting the physical changes in one's body by measuring heat energy. Authors in [16] used temperature sensors for the monitoring of environmental conditions of the surroundings. The data collected is then sent to the cloud using Wi-Fi for the analysis. This is all done through android smartphone. A similar type of sensor is also used by the authors in [17] for smart agriculture and enable farmers to increase their overall yield and product quality by getting real-time live data of their land.

#### G. Pressure Sensors

Pressure sensors sense the amount of force and convert it in signals. This type of sensors can be used in health monitoring [18].

#### H. Chemical Sensors

A chemical sensor is an analytical device used to measure the chemical composition of the environment. Air quality monitoring can be done using a wireless chemical sensor network by monitoring chemical plumes in the environment [19].

#### I. Humidity Sensors

A humidity sensor measures air temperature as well as moisture and signals the humidity in the environment. Authors in [17] used humidity sensors for smart agriculture and enable farmers to increase their overall yield and product quality by getting real-time live data of their land. A similar application is proposed by [20] where the collected data is sent to the open source platform, Thingspeak.

#### J. Water Quality Sensors

Water quality sensors are used for Ion monitoring. Water quality is measured by water quality sensors. Researchers in [21] presented a design of a low-cost system by measuring temperature, PH, turbidity, conductivity, dissolved oxygen of the water and monitored the water quality in the IoT scenario.

#### K. Infrared Sensors

Infrared Sensors emits or detect infrared radiations in order to sense some characteristics of certain objects. They

can also measure heat emission. This type of sensors can be used for home automation for monitoring and controlling home appliances like turning On/OFF lights [22]. It can also be used for smart security [23], waste collection systems [24], smart parking [25].

#### L. Gyroscope Sensors

Gyroscope sensors detect any tilt or angular movement in the object by measuring angular velocity. It is widely used in 3D mouse games, for the training of sportspersons, robotics, industrial automation and many more [26].

#### M. Optical Sensors

Optical sensors are useful in detecting the electromagnetic energies like light. Being passive to all forms of electrical interfaces, these are widely used in IoT applications like in digital cameras. Optical sensors are good for IoT applications related to energy, health, environment, oil refineries, chemical, industries, aerospace and etc. [26].

#### N. Chemical Sensors

Sensors which response by sensing any chemical reaction, chemical substance or a set of chemicals is known as chemical sensors. This type of sensors can be used for detecting environmental events, building health, agriculture conditions, and etc. [27].

### IV. SENSOR APPLICATIONS FOR A SMARTER WORLD

Sensors are used in almost every area so as to create a smart IoT environment. Various researchers are working in the area of IoT sensors. In this section, we have presented some of the applications of IoT sensors.

#### A. Smart Cities

Different types of sensors are used in a smart environment to create a smart city, it includes:

1) *Smart parking*: this area of smart city deals with monitoring and smartly parking of vehicles in the city by finding proper parking spaces.

2) *Structural health*: by monitoring the different conditions like material conditions and amount of vibrations of buildings, bridges, monuments, and roads, it is possible to suggest improvements to be made well on time [28].

3) *Smart noise handling*: Sound monitoring can be done to prevent any type of mishappening in the bar area and crowded zones in real time. For intelligent monitoring of vehicle noise in the smart environment of IoT, a system is proposed in [29].

4) *Smart traffic management*: Monitoring of vehicles and congestion on any route can be used to suggest and optimize driving and walking routes at a real time.

5) *Smart waste management*: Trash collection routes can be optimized by detecting levels of waste in different containers. Furthermore when smart waste management is combined with smart traffic management then routes can be suggested to the waste container vehicles for the collection of waste, according to the level of wastes and traffic congestion.

6) *Smart lighting*: Turning on/off street lights according to the weather conditions and requirements (whenever a vehicle pass through the way) results in saving a huge amount of energy. This intelligent and adaptive lightning is

successfully implemented by various researchers in this area both on roads and at homes.

7) *Smart roads*: highways can be made smart highways or intelligent highways when timely warning messages and routes can be given according to climate conditions and unexpected events such as traffic congestion or accidents or catastrophic conditions.

#### B. Smart Environment/ Smart Earth

When sensors are used in monitoring environmental conditions then it adds to the development of the country to a great extent. Worldwide, earth monitoring is gaining interest and is challenging too. This is all because of the harsh operating conditions and high deployment and maintenance difficulty level [30]. Some such applications of sensors in creating smart environment are discussed in the following section:

1) *Forest fire detection*: Alert zones can be defined and warnings can be given on time when sensors monitor the preemptive fire conditions and combustion gases.

2) *Air pollution*: Sensors can be used to monitor and control the emissions of harmful and toxic gases of factories and vehicles. This, if handled timely can protect the environment to a great extent. Some such applications in this area are given by researchers in [30].

3) *Catastrophic early detection*: Monitoring earth vibrations, density, moisture in the soil, and etc., it is possible to identify danger well on time for any landslide or earthquake.

#### C. Smart Water

Monitoring water quality, its ground level, pollution level and any sort of leakages in containers can save water. Some such smart sensors can be used for applications in the proper management of the water [31].

1) *Water leakages*: For this water pressure can be measured on outside tanks and pipes so that timely leakages can be protected.

2) *Controlling pollution level of the sea*: Additions of harmful or any sort of leakages or wastes to the sea can be monitored through sensors to prevent the sea water.

3) *Smart swimming pool*: The conditions of a swimming pool can be monitored through sensors and timely management can be carried out in this direction.

4) *River floods*: Monitoring the level of water and its variations from time to time in rivers, dams and reservoirs is essentially an important task.

#### D. Smart Metering

Meters can be used to smartly monitor different parameters of things in IoT like energy consumption; water, oil or gas level; silos stock calculation and solar energy plants. By monitoring different parameters and controlling according enhances the performance to a great extent. Various researchers in this area have developed systems which use sensors to monitor day to day life things [32].

#### E. Smart Security:

Sensors can be deployed in various areas to ensure security in the surroundings. Some such applications where

sensors play a major role in providing security is discussed in the following section:

1) *Smart Perimeter Access Control*: A smart perimeter around some specific areas can be made with sensors and alarms can be implemented to alert the entry of non-authorized people in restricted areas. An intelligent intrusion system attached at door, named ADXL 345 accelerometer is designed by the authors in [31].

2) *Smart explosive detection*: Detection of harmful gas levels, radiation levels, and leakages can be done smartly with the use of sensors. Sensors can be attached to the walls or containers at factories, mines, and industries where there is a danger of any leakage exists.

#### F. Smart Retail

Monitoring and controlling stocks, purchases, payments and etc. in retail industry can also be done with the help of sensors. The intelligent advice and suggestions can be given in the shopping according to the choices, habits, preferences and other contributing factors of every customer [32].

#### G. Smart Transport

Quality of shipping conditions can be improved by monitoring the amount of vibrations and strokes. Items can be traced easily using GPS like systems [28].

#### H. Smart Agriculture

Sensors are widely used in numerous agriculture applications for various purposes like detecting the amount of moisture in the soil, monitoring climate conditions and automatic sprinkling water and pesticides to the crop. Sensors, when attached to the ground soil, can detect the moisture in the soil and according to the humidity in the air and temperature appropriate amount of watering can be done.

1) *Meteorological Station Network*: Sensors detect the weather conditions in the environment and forecast the snow falling, ice formation, rain, and drought. So proper management can be made timely to prevent any kind of damage to the crops. An application model is presented by the authors in [33] which detects the humidity, moisture in soil, rainfall, pH value of soil, temperature and seed recognition. Another study in [34] used a drone for smart agriculture.

2) *Golf Courses*: The selective sprinkling in only dry zones reduce the required amount of water. This ultimately improves the production of fruits, vegetables and crops, and their quality. Water sprinkling in IoT agriculture is presented in [35], it is a case of vertical farming.

3) *Compost*: Intelligently sensing humidity and temperature levels for the prevention from fungus and other microbial contaminants is essentially an interesting area in creating smart agriculture.

#### I. Smart Homes

Sensors attached to different things at home for creating a smart environment includes intelligently switching on/off appliances, detecting intruders, detecting the amount of ingredients used in cooking. This is done by sending alerts and resulting in a better lifestyle. Some applications in smart homes are as follows:

1) *Remote Control Appliances*: Intelligently switching on/off appliances make the life easy and safe by preventing from accidents and it also saves energy.



2) *Intrusion Detection Systems*: Intruders can be detected by the sensors at the entry and timely report can be sent to the concerned authorities. This makes life safe and easier as a person can watch their home from anywhere without worry. This can be implemented when entry is allowed only after proper validation and door open only for the authorized persons. Authors in [36] presented an intrusion detection system which senses motion in door and intimates the owner through a message.

3) *Energy and Water Saving*: Advice given to control the consumption of water and electricity is possible with the help of sensors.

#### J. Smart Health

IoT changed the life of a human to a great extent. Smart health or e-health is one such example where sensors can be worn by patients at home, at work or at hospitals. These sensors detect the conditions of a person and in any abnormal conditions, it sends alerts to the concerned. Smart bands worn by patients and doctors at hospitals helps to manage the treatment of the patients. Monitoring vital signs of old peoples, controlling medical equipment, vaccines and organic elements can be made with the use of sensors. Warnings can be given to people about their wrong habits, health conditions and even exposure to the UV sun rays. To monitor the overnight anomalous events of patients in a hospital, a NIGHTCare platform is proposed by [37]. Sensors are attached to the patient's clothes. A similar study in [38], u-healthcare monitoring also uses sensors for the monitoring of patients. For rural e-health monitoring, a low-cost model is presented in [39]. For monitoring the physiological parameters, a wearable sensor is presented by the authors in [40]. Whereas, a study in [41] proposed a wearable smart shoe insole. It detects the temperature and humidity of a person wearing the shoe insole.

#### V. ANALYSIS OF IOT APPLICATIONS AND SENSORS

Sensors are used in all IoT applications. After analyzing different types of sensors and smart applications of IoT, this section suggests the type of sensors required in an IoT application to create a smart world. A single application may use more than one sensor. Table 1 shows which type of sensor is used for a particular IoT application.

TABLE I. IOT APPLICATIONS AND TYPES OF SENSORS USED IN IT

IoT Applications	Type of Sensors
Smart City	Velocity, Light, Accelerometer, Position, Temperature, Proximity, Humidity, Pressure, Infrared
Smart Environment	Light, Temperature, Humidity, Chemical, Gyroscope, Bio Sensors, Chemicals, Accelerometer, Optical
Smart Water	Temperature, Humidity, Occupancy, Water Quality
Smart Building	Light, Accelerometer, Chemical, Gyroscope, Magneto
Smart Health	Light, Gyroscope, Biosensors, Chemicals, Magneto, Accelerometer, Pressure
Smart Home	Light, Gyroscope, Biosensors, Chemicals, Magneto, Accelerometer, Temperature, Proximity, Position, Infrared
Smart Transport	Gyroscope, Pressure, chemicals, Magneto, Accelerometer, Temperature, Motion, Infrared
Smart Security	Light, Gyroscope, Chemical, Magneto, Accelerometer, Temperature, Infrared
Smart Agriculture	Temperature, Humidity, Water Quality, Chemical, Proximity, Position

Smart Retail	Light, Gyroscope, Chemical, Magneto, Accelerometer, Pressure, Position
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#### CONCLUSION

Internet of Things (IoT), is revolutionizing our world by creating a smart environment around us. In any IoT based smart application, sensors play a key role in the automation of application by making it smarter to respond without any human intervention. This paper presents various types of sensors in IoT enabled smart environment. IoT sensors can be effectively used for health, water, transport, home appliances, garbage, agriculture, cattle, and etc. In any particular smart application, IoT integrates various types of sensors having the capability to communicate with each other wisely and remotely. This paper analyzes different IoT sensors and sensor-based IoT applications and enlightens which sensors are used in different IoT applications. In the future, this study will help us to develop a sensor based IoT application.

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