

# AN OVERVIEW OF VARIOUS SENSORS AND THEIR USES

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**ABSTRACT:** Sense organs are vital to human body. Sensors of electronics world behave exactly like the sense organs of the human body. Best known sensors of microphones was invented in 1951. Some rudiments, various types of sensors used have been reviewed. Classification of sensors based on various application areas, various sensor network architectures have been studied. Finally the latest advancements and future scope of the research to be carried out has been mentioned.

**KEY WORDS:** Sensors, wearable, components architecture WSN, future trends advances in sensor technology, actuator, transducer, and mathematical tools

**INTRODUCTION:** A sensor is a device that produces an output signal after sensing a physical phenomenon. In the broadest sense, a sensor is a device, machine, or subsystem that detects situation; makes changes in the environment and sends the information to other electronic communication equipment or a computer processor. Sensors are always used with other electronics equipment. Sense organs are the vital parts of human body which are responsible for “response to stimulus” action. When there is an external stimulus to our body, there will always be a reaction to the action. Brain is the superior power which takes the decision accordingly. Sensors of the electronic world also behaves exactly like the sense organs of our body. Sensors are sophisticated device which senses, detects and responds accordingly. It’s a type of transducer, which has electrical signals or optical signals. The explicit input could be moisture, pressure, heat, light or pressure.

Sensors are the objects such as touch-sensitive elevator buttons or lamps which brighten or turn dim when touching the base. One example is the touch screen mobiles we use in daily life.

With advances in micro machinery and easy-to-use microcontroller platforms, the uses of sensors have expanded beyond the traditional parameters like temperature, pressure and flow measurement.

The output is generally a signal that is converted to a human-readable display, at the sensor location and transmitted electronically over a network for further processing. Some of the synonyms for sensors are photo-conductive cell, electric eye, magic eye, mine detector, sensing element, trace detector, detector, and photocell.

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

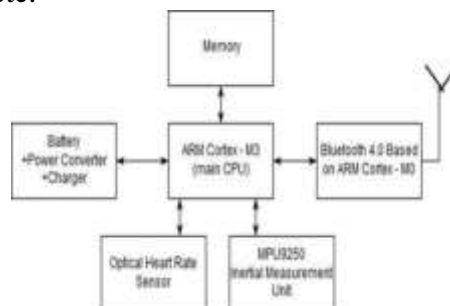
There is another device called the **Actuator** which is a device that converts the electrical signals into the physical characteristics. It takes the input from the system and gives output to the environment. For example, motors and heaters are some of the commonly used actuators. Actuators are the devices which performs action.

Also another device called **transducer** is a physical device that alters the physical attributes of given *non-electrical signals* to form an electrical signal that can be measured easily. Transducer is the one which converts one form of energy to another, which happens in the Speaker or the microphone etc. This process of conversion of energy in the transducer is referred to as transduction. Transduction takes two

steps to complete. Firstly, it senses signals and then strengthens them for the cause of further processing. Transducers comprise three main components. These are 1. Signal conditioning / processing device, 2. Input device, and 3. Output device. The input devices are designed to accept and measure quantities and then sends them as proportional analog signals for processing and conditioning the devices. The conditioning device then modifies filters and sends the signal to output devices in an easily-understandable format. A transducer is also capable of converting electrical signals into physical quantities for the sake of creating an actuator. As soon as this process takes place, the transducer ceases to be a sensor. It may be noted that, a piezoelectric transducer is capable of being used for sensing and actuation purposes.

Thus Sensors and transducers are used for measuring physical quantities such as temperature, light, displacement, heat, etc. These physical devices are quite diverse in nature in the sense that functionality should not be confused. We have tried to touch upon the various points of difference between sensors, actuator and transducers.

**WEARABLE SENSORS:** Wearable sensors are integrated devices which help monitor health and provide clinically relevant data for care. Wearable sensors can be used in measuring motor-related symptoms such as balance, gait, and spasticity symptoms. Designing patient friendly sensors which can be easily placed on the hips, knees, and legs will allow the development of more digital *biomarker* systems, that can continuously monitor patient activity and improve patient care. Higher level programs combine the parameters of the body like heart rate, temperature and movement into measures of the duration, and quality. Sensors and algorithms combine to help wearable devices measure step counts, calories burned and oxygen levels etc.



*Wearable sensors block diagram*

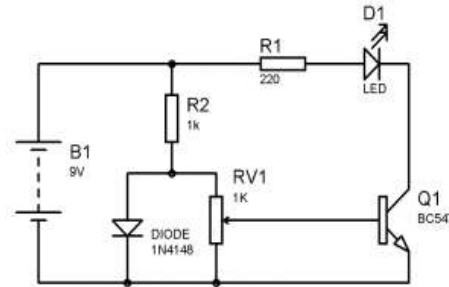
**WHAT DO THE SENSORS DO?** One of the best-known sensors is the microphone invented in 1951, which converts sound energy to an electrical signal that can be amplified, transmitted, recorded, and reproduced. Thus Sensors are used in our everyday lives. The common mercury thermometer is a very old type of sensor used for measuring body temperature. Colored mercury in a closed tube is used and this chemical has a consistent and linear reaction to changes in temperature. By marking the tube with temperature values, we can look at the thermometer and see what the temperature is. The precision may be somewhat limited due to the visual clarity of the scale markings.

Some thermometers are useful in the electric oven, or outside the kitchen window. So, temperature sensors have been invented to measure temperature and other physical phenomena and to provide an output that we can display, store, and analyze.

Let's learn more about the most common and popular sensors in use today.

**TYPES OF SENSORS:** In the following we learn about different types of sensors and their uses, as well as detectors and transducers. Some of them are Vision and Imaging Sensors, Temperature Sensors, Radiation Sensors, Proximity Sensors, Pressure Sensors, Position Sensors, Photoelectric Sensors, Particle Sensors, Motion Sensors, Metal Sensors, Level Sensors, Leak Sensors, Humidity sensors, Gas and Chemical Sensors, Force Sensors, Flow Sensors, Flaw Sensors, Flame Sensors, Electrical Sensors, Contact Sensors, Non-Contact Sensors.

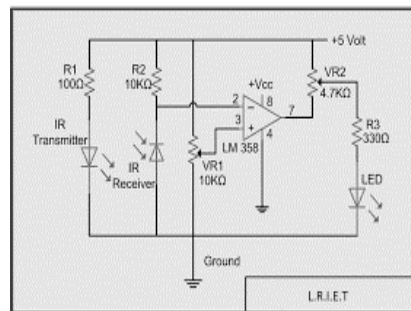
**Temperature Sensor Circuit:** A simple temperature sensor with the circuit can be used for switching on or off the load at a specific temperature which is detected by the temperature sensor . The circuit consists of a battery, thermistor, transistors, and relay which are connected.



Temperature Sensor Circuit

The relay is activated by the temperature sensor by detecting the desired temperature. The relay switches on to the load connected to AC or DC. This circuit is used for controlling the fan automatically based on temperature.

**Infra-Red (IR ) Sensor Circuit:** A simple IR sensor circuit is used in our day-to-day life as a remote control for a TV. It consists of IR emitter circuit and IR receiver circuits.

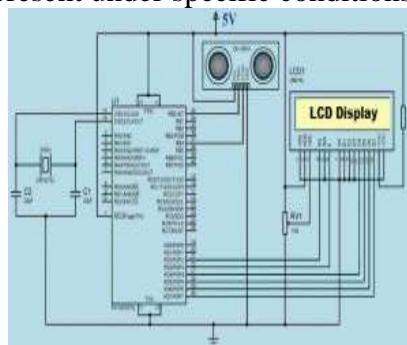


IR Sensor Circuit

This IR emitter circuit is used as a remote by the controller emitting infrared light. This infrared light is transmitted to IR receiver circuit which interfaces to the device like a TV or IR remote-controlled robot, based on the commands received, the TV or robot is controlled.

**Ultrasonic Sensor:** A transducer that works on the principle similar to the sonar or radar and estimate attributes of the target by interpreting is called an ultrasonic sensors or transceivers. There are different types of sensors that are classified as active and passive ultrasonic sensors that can be differentiated based on the working of sensors.

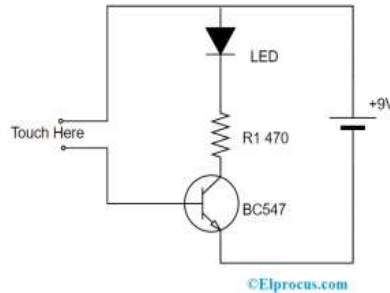
The high-frequency sound waves generated by active ultrasonic sensors are received back by the ultrasonic sensor for evaluating the echo. Thus, the time interval taken for transmitting and receiving the echo is used for determining the distance to an object. But, passive ultrasonic sensors are just used for detecting ultrasonic noise which is present under specific conditions.



Ultrasonic Sensor with Circuit

This ultrasonic module shown here consists of an ultrasonic transmitter, receiver and a control circuit. The practical application of an ultrasonic sensor with the circuit can be used as an ultrasonic distance sensor circuit as given below.

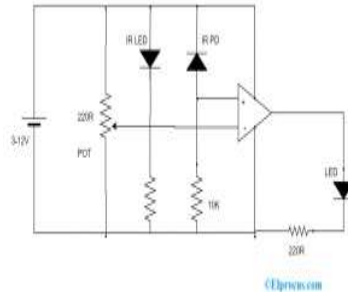
**Touch Sensor Circuit:** This circuit is a simple application of a touch sensor consisting of a 555 timer operated on mono-stable mode, touch sensor or plate, LED, battery, and basic electronic components.



*Touch Sensor Circuit*

In the normal state the touch plate is not touched and the LED remains in the off state. If once the touch plate is touched and a signal is given to the 555 timer. By sensing the signal received from the touch plate, the 555 timer activates the LED and thus the LED glows indicating the touch made to the touch sensor or plate.

**Proximity Sensors:** This is an IoT sensor which identifies the existence or non-existence of the surrounding object. Then it converts the detected signal into the form which is understood by the user, It may be a simple electronic device that gets without contact with them.

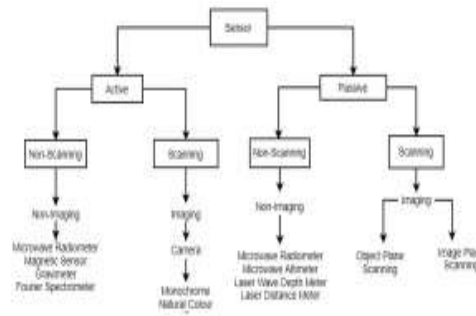


*Proximity Sensor Circuit*

We find the application of proximity sensors in the retail domain, where they can find out the movement and association that exists between the product and the consumer. Using this proximity sensor users, can receive quick notifications of discount updates and exclusive offers of interesting products and other domain in automobiles. When you reverse a car, you will be getting sounds if any obstacle is found. Here is the experience of the proximity sensor. There are many other types of proximity sensors and they are: Capacitive sensors, Inductive sensors, Photoelectric sensor.

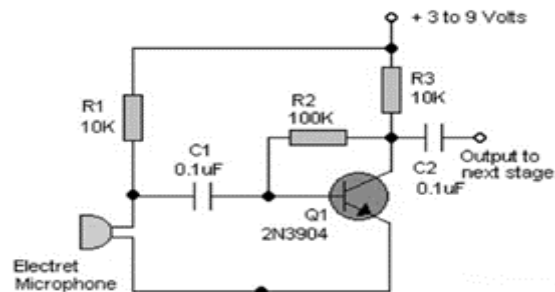
**Passive Sensors:** These sensors collect radiation which is either radiated or reflected by the surrounding locations or object. The most crucial example of a passive sensor is reflected sunlight. And the other examples are radiometers, charge-coupled objects, infrared, and film camera work. The classification of sensors in remote sensing is given below.

**Sound Sensor:** These sensors are usually microphone devices that are used to know the sound and deliver the corresponding level of voltage based on the detected sound level. With the implementation of a sound sensor, a small robot can be directed to navigate



Types of Sensors in Remote Sensing

depending on the level of the received sound. When compared with light sensors, the design process of sound sensors, is somewhat complicated. This is because sound sensors deliver very minimal voltage difference and this has to be amplified to provide measurable voltage variation. The sound sensor switching circuit is shown below:



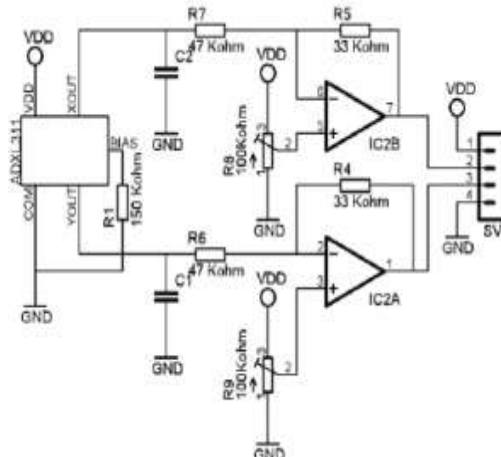
Sound Sensor

**Acceleration Sensor:** This type of sensor is employed in calculating angular and acceleration values. An accelerometer is used for the calculation of acceleration. There exist two types of forces that show the impact on an accelerometer and those are:

*Static Force* – This is the frictional force that exists between any two objects. With the calculation of gravitational force, one can know the tilting value of the robot. This calculation is helpful for robotic balancing, or to know either the robot has a driving motion on uphill or on a flat edge.

*Dynamic Force* – This is measured as the amount of acceleration that is necessary for the movement of an object. The calculation of dynamic force through an accelerometer defines either the velocity or speed rates for what the robot is having motion.

These accelerometer sensors are available in multiple configurations. The type of selection is dependent on the requirement of the industry. A few of the parameters that are to be checked in before proper sensor selection are bandwidth or type of output either digital or analog or the total number of axes, and the sensitivity. The following picture shows the schematic diagram of an acceleration sensor.





**Chemical Sensor:** These sensors are used in various industries to find any kind of changes in the liquid or to detect any air chemical variations. These are implemented in bigger towns and cities, because it is important to look for changes and ensure safety for the population. The most generally used chemical sensors are Electro-chemical gas type, Chemical FET, Chemi-resistor, Non-dispersive IR, pH glass electrode type, Zinc oxide nanorod, Fluorescent chloride type.

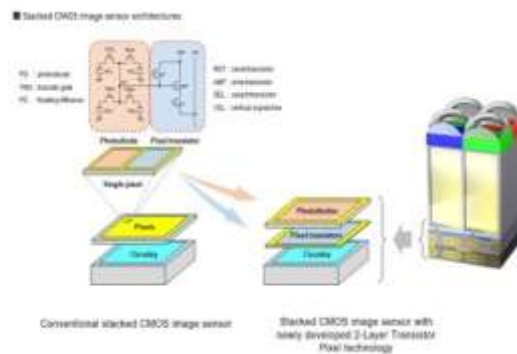
Gas molecules from the sample are adsorbed on an electro-catalytic sensing electrode, after passing through a diffusion medium, and are electrochemically reacted at an appropriate sensing electrode potential. This reaction generates an electric current which is directly proportional to the gas concentration. This current is converted to a voltage meter. The diffusion limited current,  $i_{lim}$ , is directly proportional to the gas concentration as per the equation,  $i_{lim} = \frac{nFADC}{\delta}$ . Here  $i_{lim}$  is the diffusion limited current in amps,  $F$  is the Faraday constant (96,500 coulombs),  $A$  is the reaction interfacial area in  $cm^2$ ,  $n$  is the number of electrons per mole reactant,  $\delta$  is the diffusion path length,  $C$  is the gas concentration in moles/ $cm^3$ , and  $D$  is the gas diffusion constant, representing the product of the permeability and solubility coefficients of the gas in the diffusion medium.

**CLASSIFICATION OF SENSORS:** There are certain features which have to be considered when we choose a sensor. They are 1. Accuracy, 2. Environmental condition – usually has limits for temperature/ humidity, 3. Range – Measurement limit of sensor, 4. Calibration – Essential for most of the measuring devices as the readings change with time, 5. Resolution – Smallest increment detected by the sensor, 6. Cost, 7. Repeatability – The reading that varies is repeatedly measured under the same environment. *The sensors are classified based on the criteria:*

1. Primary Input quantity (Measurand)
2. Transduction principles (Using physical and chemical effects)
3. Material and Technology
4. Property
5. Application

Transduction principle is the fundamental criteria which are followed for an efficient approach. Usually, material and technology criteria are chosen by the development engineering group.

A) *Classification is based on property* Temperature – Thermistors, thermocouples, RTD's, IC and many more, or Pressure – Fibre optic, vacuum, elastic liquid based manometers, LVDT, electronic. Or Flow – Electromagnetic, differential pressure, positional displacement, thermal mass, Level Sensors – Differential pressure, ultrasonic radio frequency, radar, thermal displacement, Proximity and displacement – LVDT, photoelectric, capacitive, magnetic, ultrasonic. Biosensors – Resonant mirror, electrochemical, surface Plasmon resonance, Light addressable potentiometric. Image – Charge coupled devices, CMOS, Gas and chemical – Semiconductor, Infrared, Conductance, Electrochemical. Acceleration – Gyroscopes, Accelerometers. Others – Moisture, humidity sensor, Speed sensor, mass, Tilt sensor, force, viscosity.



CMOS image sensor of SONY with 2-layer transistor pixels

Surface Plasmon resonance and Light addressable potentiometric from the Bio-sensors group are the new optical technology based sensors. CMOS Image sensors have low resolution as compared to charge coupled devices. CMOS has the advantages of small size, cheap, less power consumption and hence are better substitutes for Charge coupled devices. Accelerometers are independently grouped because of their vital role in future applications like aircraft, automobiles, etc and in fields of videogames, toys, etc. Magnetometers are those sensors which measure magnetic flux intensity B (in units of Tesla or As/m<sup>2</sup>).

B) *Classification based on Application like:*

Industrial process control, measurement and automation or

Non-industrial use –Aircraft, Medical products, Automobiles, Consumer electronics, other type of sensors.

C) *Sensors can be classified based on power or energy supply requirement of the sensors:*

*Active Sensor* – Sensors that require power supply are called as Active Sensors. Example: LiDAR (Light detection and ranging), photoconductive cell.

*Passive Sensor* – Sensors that do not require power supply are called as Passive Sensors. Example: Radiometers, film photography.

D) *In the current and future applications, sensors can be classified into groups as follows:*

*Accelerometers* – These are based on the Micro Electro Mechanical sensor technology. They are used for patient monitoring which includes pace makers and vehicle dynamic systems

*Biosensors* – These are based on the electrochemical technology. They are used for food testing, medical care device, water testing, and biological warfare agent detection.

*Image Sensors* – These are based on the CMOS technology. They are used in consumer electronics, biometrics, traffic and security surveillance and PC imaging.

*Motion Detectors* – These are based on the Infra Red, Ultrasonic, and Microwave / radar technology. They are used in videogames and simulations, light activation and security detection.

E) *Classification based on analog or digital sensors.* Analog sensors such as potentiometers and force-sensing resistors are widely used, even now. They are used in manufacturing of machinery, airplanes and aerospace, cars, medicine, robotics and many other aspects of our day-to-day life. For an analog sensor, signal has to be processed, or used in digital equipment. It needs to be converted to a digital signal, using an analog-to-digital converter.

A good sensor is sensitive to the measured property, insensitive to any other property likely to be encountered in its application, and it does not influence the measured property. It may be noted that most of the sensors have a linear transfer function.

A digital sensor is an electronic or electrochemical sensor, where data is digitally converted and transmitted. Sensors are often used for analytical measurements, e.g. the measurement of chemical and physical properties of liquids. Typical measured parameters are pH value, conductivity, oxygen, redox potentials, and others. Such measurements are used in the industrialized world and give vital input for process control. Sensors of analogue type were used in the past, but today more and more digital sensors are used.

All types of sensors can be basically classified into analog sensors and digital sensors. But, there are a few types of sensors such as temperature sensors, IR sensors, ultrasonic sensors, pressure sensors, proximity sensors, touch sensors, level sensors and smoke & gas sensors which are frequently used in most electronics applications.

*There are many types of sensors that have been invented to measure physical phenomenon:*

\* Thermocouples, RTDs and Thermistors used for measuring temperature

\* Strain gages are used to measure strain on an object, e.g. pressure, tension, weight, etc.,

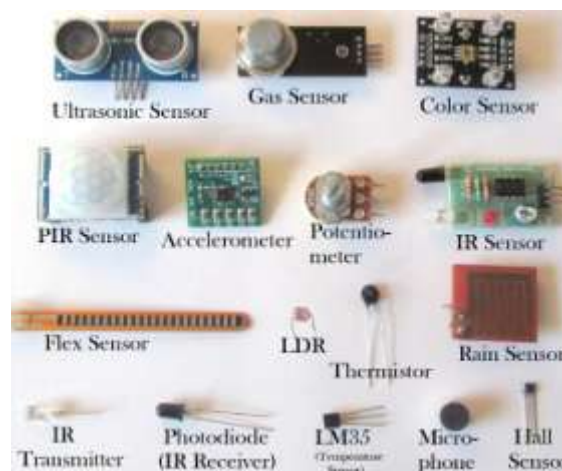
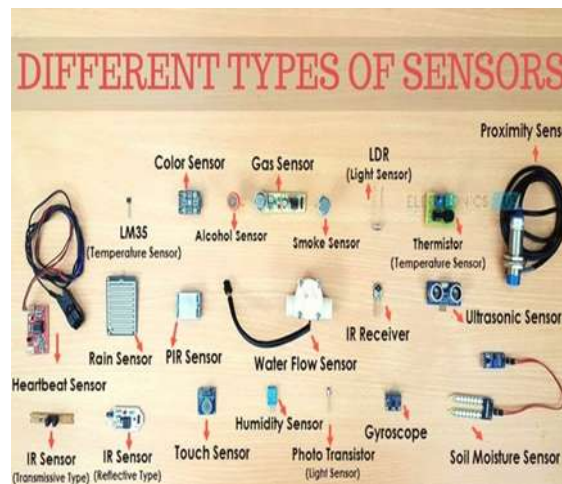
\* Load cells for measuring weight and load

\* LVDT sensors are used to measure displacement in distance

\* Accelerometers sensors measuring vibration and shock

- \*Microphones used for capturing sound waves.
- \*Current transducers are used for measuring AC or DC current.
- \*Voltage transformers are used for measuring high voltage potentials.
- \*Optical sensors are used to detect light, transmit data, and replace conventional sensors.
- \*Camera sensors are used to capture single and continuous 2D images.
- \*Digital sensors are used for discrete on/off counting, linear and rotary encoding, position measurements,
- \**Positioning sensors* (GPS) are used to capture the longitudinal, latitudinal position based on GPS, GLONASS, and other satellite positioning systems. Different GPS sensors with different accuracy are available.

Depending on the type of sensor their electrical output can be a voltage, current, resistance or some electrical measurement which varies over time. Some of the sensors are available with digital outputs, whereby the output is a series of bytes of scaled or un-scaled data. The output of these analog sensors is typically connected to the input of a signal conditioner.



**SENSORS OF ANDROID PLATFORM:** Most of the Android-powered devices have built-in sensors which measure motion, orientation, and various environmental parameters. These sensors are capable of providing raw data with high precision & accuracy, and are useful when you wanted to monitor three-dimensional device movement and positioning. One can also monitor changes in the ambient environment near the device. a) In a situation where in a game might track readings from a device's



gravity sensor to infer complex user gestures and motions, rotation, or swing. b )A weather application may use to measure temperature sensor and humidity sensor to calculate and report the dewpoint. c )A travel application might use the geomagnetic field sensor and accelerometer to report a compass bearing. It is interesting to learn about some specialized sensors like Motion Sensors, Position Sensors, Environment Sensors, API Demos (OS – Rotation Vector Demo). The Android platform supports three broad categories of sensors:

**Motion sensors**-- These sensors measure acceleration forces& rotational forces alongthe three axes. This category includes accelerometers, gravity sensors, gyroscopes, and rotational vector sensors.

**Environmental sensors** -- These sensors measure various environmental parameters, such as ambient air temperature, pressure, illumination, and humidity. This category includes barometers, photometers, and thermometers.

**Position sensors** --- These sensors measure the physical position of a device. This category includes orientation sensors and magnetometers.

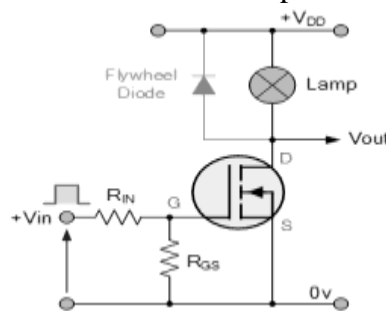
One can also access sensors available on the device and acquire raw sensor data by using the Android sensor framework. This provides several classes and interfaces which help us perform a wide variety of sensor-related tasks. Also we can determine an individual sensor's capabilities like maximum range, power requirements, and resolution.

**SENSORS FOR VARIOUS PURPOSES:**

**Chemical sensor** - Chemical sensor is a self-contained analytical device which can provide information about the chemical composition of the environment.

**Biosensor** - In biomedicine and biotechnology, sensors which detects and analyses, biological component, such as cells, protein, nucleic acid or biomimetic polymers, are called biosensors. **Neuro-morphic sensors**-are sensors which physically mimic structures and functions of biological neural entities.

**MOS sensors** --Metal (MOS) technology originates from the MOSFET (MOS field-effect transistor, or MOS transistor) invented by Mohamed M. Atalla and DawonKahng in 1959, and demonstrated in 1960. MOSFET sensors are the MOS sensors were later developed, and they have since been widely used to measure physical, chemical, biological and environmental parameters.



*Basic MOSFET working principle*

**Biochemical sensors** - A number of MOSFET sensors have been developed, for measuring physical, chemical, biological and environmental parameters. The earliest MOSFET sensors include the open-gate field-effect transistor (OGFET) introduced by Johann Essen in 1970, the ion-sensitive field-effect transistor (ISFET) invented by Piet Bergveld in 1970, the adsorption FET (ADFET) patented by P.F. Cox in 1974, and a hydrogen-sensitive MOSFET demonstrated by I. Lundstrom, M.S. Shivaraman, C.S. Svenson and L. Lundkvist in 1975. The ISFET is a special type of MOSFET with a gate at a certain distance in which the metal gate is replaced by an ion-sensitive membrane, electrolyte solution and reference electrode. The ISFET is widely used in biomedical applications, such as the detection of DNA hybridization, biomarker detection from blood, antibody detection, glucose measurement, pH sensing, and genetic technology.

**Image sensors** -- *Image sensor, Charge-coupled device, and Active-pixel sensor which make use of MOS technology; which is the basis for modern image sensors, The charge-coupled device (CCD) and the CMOS active-pixel sensor (CMOS sensor), used in digital imaging and digital cameras. Willard Boyle and George E. Smith developed the CCD in 1969, while working on MOS process, they realized that an electric charge was the analogy of the magnetic bubble and that it could be stored on a tiny MOS capacitor. The MOS active-pixel sensor (APS) was developed by Tsutomu Nakamura at Olympus in 1985.*

The CMOS active-pixel sensor was later developed by Eric Fossum and his team in the early 1990s. MOS image sensors are widely used in optical mouse technology. The first optical mouse, invented by Richard F. Lyon at Xerox in 1980, used a 5 μm NMOS sensor chip. Since the first commercial optical mouse, the IntelliMouse was introduced in 1999. It may be noted that most of the optical mouse devices use CMOS sensors.

**Monitoring sensors** - Lidar sensor on iPad Pro - MOS monitoring sensors are used for house monitoring, office and agriculture monitoring, traffic monitoring (including car speed, traffic jams, and traffic accidents), weather monitoring, defense monitoring, and monitoring temperature, humidity, air pollution, fire, health, security and lighting. MOS gas detector sensors are used to detect carbon monoxide, sulfur dioxide, hydrogen sulfide, ammonia, and other gas substances. Other MOS sensors include intelligent sensors and wireless sensor network (WSN) technology.

**HISTORY OF SENSORS:** Water quality problems had occurred well before the two world wars, and in fact in the early days of the industrial revolution, around 1800. Before the wars, water pollution concerns were mainly related to pathogens such as [cholera and typhoid](#) and other diseases that were widespread in densely packed cities. Water treatment thus focused on eliminating such pathogens. After the Second World War, the Chemical Revolution focused on microbial water safety caused were largely ignored by governments and there were severe consequences of chemical pollutants in water for a long time. Public health departments went to regulators in 70's to include chemical parameters in water regulations. Actually history of electrochemical sensors started with the development of the glass electrode in 1906 and Optical sensor technology was boosted with the development of the first laser in 1960.

Name	Application Domains	Environmental Influences	Detection Range	Processing Complexity	Unobtrusiveness
Capacitive proximity sensing	Indoor localization, smart appliances, physiological sensing, gestural interaction	Electric fields, conductive objects	Near distance (< 10cm)	Few high dynamic range data sources	Visible integration possible
Capacitive touch sensing	Smart appliances, physiological sensing, gestural interaction	Electric fields, conductive objects	Touch	Few binary sensors	Thin cover above electrodes
RGB cameras	Indoor localization, smart appliances, physiological sensing, gestural interaction	Occlusion, external lights	Far distance (> 10m)	Complex image processing based on resolution	Pinhole lenses
Infrared cameras	Indoor localization, physiological sensing, gestural interaction	Occlusion, external infrared light	Medium distance (< 5m)	Complex image processing based on resolution	Infrared source and camera
Ultrasound sensing	Indoor localization, smart appliances, gestural interaction	Acoustic occlusion, absorbing materials	Medium distance (< 5m)	Few low dynamic range data sources	Emitter and sensors with exposed pinhole speaker, microphone
Microphone arrays	Indoor localization, smart appliances, physiological sensing	Environmental noise, absorbing materials	Medium distance (< 5m)	Very high dynamic range data sources	Exposed pinhole microphones
Radiofrequency sensing (RF)	Indoor localization, smart appliances, gestural interaction	Other RF devices	Far distance (> 10m)	Few low dynamic range data sources	Hidden emitters and sensors possible

In 1958, WHO included nitrate in its International Standards for Drinking Water, thereby specifically monitoring the risk of elevated nitrate levels (50-100 mg/L) causing methemo-globinemia in infants under one year of age.

In 2000 's remote power supplies have become more and more affordable allowing for the placement or deployment of sensor technologies at locations where no grid-power is available. More and more sophisticated big data analysis tools enabled monitoring data of high spatial-temporal resolution. The development of drone technologies also promoted the application possibilities of sensor technologies for water quality monitoring.

Electronic and electrochemical sensors are typically one part of a measuring chain. A measuring chain comprising the sensor itself, a cable and a transmitter. In the traditional analog systems, the sensor converts the measuring parameter (e.g. pH value) into an analog electrical signal. This analog electrical signal is connected to a transmitter via a cable.

The transmitter transforms the electrical signal into a readable form (display, current outputs, bus data transmission, etc.).

The sensor and the cable often are not connected permanently, but through electrical connectors. This classical design with



*Historical timeline of the discovery of various sensors and their development with respect to materials (green), sensor technologies (blue), and biotechnology (black).*

connectors and transmission of small currents through a cable has the drawbacks: a) Humidity and corrosion of the connector falsify the signal. b) The cable must be shielded and of very high quality to prevent the measuring signal from being altered by electromagnetic noise. c) The sensor can only be calibrated or adjusted when installed, because the influence of the cable (length, osmic resistance, impedance) cannot be neglected. d) The cable length is limited.

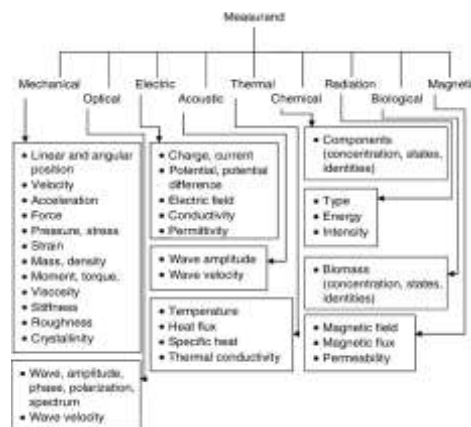
**VARIOUS TYPES OF SENSORS BASED ON APPLICATION AREAS:** There are numerous types of sensors, based on application area. They all are classified based on their input signals. Few of the most commonly used sensors are pressure sensors, proximity sensors, light sensors, optical sensors, position sensors, humidity sensors, flow sensors, heat or temperature sensors, speed sensors etc.

More specifically they are 1.Acoustic, sound, vibration; 2. Automotive; 3. Automatic transmission speed sensor; 4. Chemical, 5. Electric current, electric potential, magnetic, radio; 6. Environment, weather, moisture, humidity; 7. Flow, fluid velocity; 8. Ionizing radiation, subatomic particles; 9. Navigation instruments; 9. Position, angle, displacement, distance, speed, acceleration; 10. Optical, light, imaging, photonPressure; 11. Force, density, level; 12. Thermal, heat, temperature; 13.

Proximity, presence, Sensor technology; 14. Speed sensor - Speed sensors are machines used to detect the speed of an object, usually a transport vehicle.



Review of sensors and developments



SENSORS AND MEASURANDS

**COMPONENTS OF SENSORS:** A sensor node is made up of four basic components:

**i. Sensing Unit:** Sensors usually composed of two subunits namely sensors and Analog-to-Digital convertors (ADC's). Also Analog signals produced by sensors based on observed phenomenon are converted to digital signals by ADC, and then fed into processing unit.

**ii. Processing Unit:** It manages the procedures that make the sensor node collaborate with other nodes to carry out assigned sensing tasks. It is generally associated with a small storage unit.

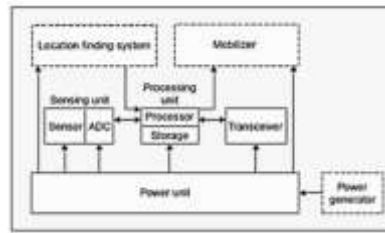
**iii. Transceiver:** It connects the node to the network.

**iv. Power Unit:** The wireless sensor networks focus more on power conservation than 'Quality of Service (QoS)'. It is one of the most important components of a sensing node. Power units may be supported by power scavenging units such as solar cells. A sensor node can only be equipped with limited power source (<0.5 Ah, 1.2 V). There are some other sub-units that are application dependent:

**v. Location finding system:** It is commonly required because most of the sensor network routing techniques and sensing tasks require knowledge of location with high accuracy.

**ii. Mobilizer:** It may sometimes be needed to move sensor nodes when it is required.





**MATHEMATICAL TOOLS & MODELING OF SENSOR NETWORKS:** There is a growing use of sensor networks in monitoring, controlling, efficient management of the network structure and optimization of its operation. Due to the wide range of sensor network applications in the situations related to fire risk monitoring, air quality assessment, traffic control, etc., it is important to have universal network performance analysis tools, which will be used in many network operating conditions. We need to keep track of different parameters determining the intensity of the traffic and also for different network topologies.

It seems desirable to use mathematical tools and models like **stochastic modeling methods or statistical techniques**. The use of these mathematical tools can affect the more *effectiveness and efficiency* of the network, improvement of transmission quality and better organization of network operation.

Mathematical and analytical methods can greatly support and improve the process of network topology, control, queue processing of individual nodes and routing protocols. A special task is the mathematical modeling and development of *energy-saving algorithms* in sensor networks. Mathematical and statistical methods are used in the analysis of network disturbances like fading, breakdowns, etc., can be removed.

Advanced mathematical modeling techniques for design, analysis and performance evaluation of sensors and actuators, in the measurement of parameters play a great importance. There is a great use of numerical finite element (FE) modeling technique for the analysis and design of sensors and actuators. This technique improves performance of torque of motor actuator and a robust capacitive sensor.

An analytical solution for a rectangular-shape sensor and applying of Gauss Conservation of Charge (GCC), and Ohm laws along with Laplace's equation  $\nabla^2 V(x, y, z, t) = 0$ , gives the electric potential distribution. This helps us to calculate the *fringe capacitance* in a 2D domain area. The calculated capacitance drastically decreases the fringe phenomena while object moves toward the polymeric sensor. This model also helps us to calculate the change of capacitance under the influence of sensor resistivity. We can observe the range of  $10^3$  to  $10^5 \Omega.m$ , of the initial capacitance which varies from 0.045pF to 0.024 pF. In an airplane, sensors for angular velocity and acceleration are placed at specific locations to estimate the velocity.

If you are building a really long wind turbine blade, some physical properties of the system need to be estimated, using sensors and these sensors need to be placed at optimal locations to make sure the structure does not fail. This is nontrivial and that's where our mathematical framework comes in. Mathematical tools used for a good estimate of the gravity direction when using a pair of non-orthogonal inclinometers whose measurements are affected by zero-mean Gaussian errors.

These tools consist of: (1) the analytical derivation of the gravity direction expectation and its covariance matrix, and (2) a continuous description of the geoid model correction as a linear combination of a set of orthogonal surfaces. The accuracy of the statistical quantities is validated by extensive Monte Carlo tests and the application in an Extended Kalman Filter.

**Mathematical tools for optimization of Energy Consumption:** In the design and development of Wireless Sensor Networks (WSNs), one of the main challenges is to achieve maximal battery life-time, in the presence of the constrained energy resources. The stochastic optimization method based on



genetic algorithm is used to minimize the energy consumption of the wireless sensor nodes depending on the frequency of the transmitted data.

Spatial information in broadband array signals is embedded in the relative delay with which sources illuminate different sensors. Therefore, second order statistics, on which cost functions such as the mean square rest, must include such delays. Typically a *space-time covariance matrix* therefore arises, which can be represented as a Laurent polynomial matrix. The optimization of a cost function then requires extending the utility of the eigenvalue decomposition from narrow-band covariance matrices to the broadband case of operating in a space-time covariance matrix.

Polynomial matrices help to formulate broadband multi-sensor problems, and find solutions to these formulations by means of generalizing narrowband solutions. This typically requires the application of polynomial matrix decompositions. Important future developments also target the estimation of space-time covariance, since the statistics typically have to be estimated from finite data sets, and interesting new applications where the polynomial approach permits solutions which could not be possible in the area of impulse response modeling.

Game Theory provides a mathematical tool for the analysis of interactions between the agents with conflicting interests, hence it is a suitable tool to model some problems in communication systems, particularly in the case of wireless sensor networks (WSNs), where the prime goal is to minimize energy consumption than high throughput and low delay.

We can find the signal-to-noise ratio (SNR) for light detection and range (LiDAR) of unmanned autonomous vehicles based on the predetermined probability of false alarms under various intentional and unintentional influencing factors. The focus of this study is on the relevant issue of the safe use of LiDAR data and measurement systems within the “smart city” infrastructure. A synthetic approach as a mathematical tool, used for designing a resilient LiDAR system on the physics of infrared radiation is based on the Bayesian theory, and the Neyman–Pearson criterion. Further it is used in a predetermined threshold for false alarms, the probability of interference in the analytics, and the characteristics of the LiDAR’s receivers. The result is the analytical solution to the problem of calculating the allowed SNR; while stabilizing the level of “false alarms”, in terms of background noise caused by a given type of interference.

A data topology optimization algorithm based on local tree reconstruction for heterogeneous wireless sensor networks is proposed for data transmission in wireless sensor networks that are easily affected by external instabilities.

The network often faces some unstable external factors that influence the process of transmission. These influences many times will reduce the efficiency of data transmission. A safe and reliable data transmission model for the complex network environment, which combines the actual requirements, ensures safe and reliable data transmission. The model considers energy, node distance, data redundancy and link security in the node path selection method and presents an intelligent, secure, efficient, and robust data transmission path using a robust optimization algorithm based on ant colony algorithm. The algorithm is a fast converging global optimization algorithm with stronger robustness.

**BASIC ARCHITECTURE OF SENSORS:** Architecture consists of three modules: (i) the Sensor Interface Module (SIM), (ii) the Communication Module (CM) and (iii) the Measuring Engine Module (MEM). Each module provides specific functionalities and interacts with the other modules.

As an Open specification based on Open Source protocols the Architecture is the way to go for prototyping IoT hardware. The Goals are system capable of running for years off a coin cell battery; Low cost and simple to build and design modules; Open to allow others to contribute and use it; Small form factor

Further the Key Features of this Architecture are Based on open source and well documented projects; Easy to make compatible sensors; Fast to prototype a working system; Small and rugged enough to go to production with; Low cost hardware ; Simple to make your own sensors

The design of the architectural framework should fulfil the following criteria:

**Heterogeneity**—Support the connection of sensor and actuator modules possessing diverse functionality and capabilities.

**Autonomy**—Support the autonomous discovery of the capabilities of networked modules, and the autonomous configuration of these modules based on their discovered capabilities.

**Pose/Geometry Determination**—Support the determination of the absolute or relative *pose* (position and orientation) of individual modules, and by extension the overall geometry of a set of connected modules.

**Assumption of a Collective Identity**—Facilitate the assumption of a collective identity by successfully connected modules, based on their capabilities and relative positions and orientations.

**Process Distribution**—Support the splitting and distribution of a complex task among a group of networked modules.

**Resource Management**—Manage the hardware resources on each module in an efficient, intuitive, and simple manner.

**Scalability**—Maintain reliable operation with an increasing number of connected sensor and actuator modules.

**Robustness**—Adapt automatically to the addition, removal, or failure of modules in real-time.

**Modular sensing systems are often composed of a number of sensors and possibly actuators of diverse types.** Enabling intercommunication among these transducers, in a manner facilitating easy re-configurability, is often problematic due to the various analog and digital interfaces, through which communication must take place. Therefore, facilitating interoperability between the devices often requires interface-specific solutions, when reconfiguration of large sensor-actuator systems is required.

One approach aims to simplify the assembly of multi-sensor systems, the aspects of which are utilized in the design of the software architecture. A number of implementations of reconfigurable modular sensing systems exist in which smart sensor and actuator components may be combined. .

The **basic module used to construct modular sensing systems is the *transducer interface module* (TIM)**. Each is capable of a single sensing or actuation function, and is uniquely identified by a 64-bit address.

A modular sensing system may consist of two other types of modules significant to the software architecture. These modules perform tasks unrelated to sensing and actuation; instead of supporting the inter-operation of a group of TIMs.

#### 1. Administration Module

An *administration module* is used by the system user to detect and manage TIMs within its vicinity. It possesses only a power supply, a microcontroller, and a transceiver. It may be integrated into a complete computer system, with a small, self-contained console and a user interface. Administration modules may also act as a sink for transducer readings and as a gateway for communication with a larger network, such as the Internet.

#### 2. Interconnect Module

*Interconnect modules* are built to assuming one of a variety of non-standard shapes, and are used to provide angular and translational offsets between connected TIMs which would otherwise not be possible due to the cubical shape of the TIMs. They possess only a microcontroller and module connectors, and draw power from the TIMs to which they are connected. The nature of the offset provided by a particular interconnect module is stored in its TEDS, and may be accessed through its module connectors.

#### 3. Software Architecture Stack

The software architecture is a distributed architecture based on the *Open Systems Interconnection* (OSI) and consists of six layers (one of which is divided into two sub-layers) as shown in Figure. The use of a *distributed* architecture ensures that no single point of failure exists within a modular sensing system and also facilitates architecture scalability. This is not the case in *centralized* architectures, in which a

single point of failure is often introduced that can also limit scalability in large systems where communication between nodes mostly occurs through this point..



Software architecture stacks.

The use of a layered architecture model allows the implementation of any layer to change independently of the others, since the implementation of each layer is encapsulated from the layer above, to which it provides service. This information-hiding technique also facilitates a more robust software architecture, and makes each of the architecture layers easier to implement, modify, and debug. The function of the software architecture are,

- a. *Module Hardware* :Contains the physical components of a module needed for execution of the operating system, sensing and actuation functionality, as well as wired and wireless communication.
- b. *Real-Time Operating System/Device Drivers*: Provides resource management functionality and an environment for concurrent task execution.
- c. *Communication Layer*: Provides an interface to the wireless transceiver driver that automatically accounts for transmission problems such as packet loss and synchronization. This layer also provides an interface through which modules may communicate using their face connectors.
- d. *Middleware Layer*: Provides the commands and services through which the member TIMs comprising a *logical module* may interact and communicate with each other in order to achieve a specific goal. A logical module is an abstraction of one or more collaborating TIMs.
- e. *Virtual Machine*: Provides a platform-independent execution environment for the algorithms utilized in the composition layer. Platform independence is facilitated through the use of a compact implementation of Sun Microsystems’ *Java Virtual Machine* [21].
- f. *Composition Layer*: Encompasses one or more *logical module template classes* that provide the intelligence necessary for a group of collaborating TIMs to behave as a logical entity. Each template algorithm is accompanied by a *logical module template TEDS* that describes the basic characteristics of a logical module entity derived from on it.

**Real-Time Operating System( RTOS ):** The software architecture utilizes a *real-time operating system* (RTOS), which enables it to be implemented in a modular fashion through the concurrent execution of various *tasks*. As a result, the management of the hardware resources of a module, as well as the development and debugging of the software architecture, is greatly simplified. Tasks are implemented as independent functions that appear to be running simultaneously, but are actually sharing the execution time of the microcontroller through the use of *scheduling* mechanisms, implemented within the operating system.

In an RTOS there is a concurrent executing of tasks, which may be scheduled using either a *pre-emptive* scheduling policy or a *cooperative* scheduling policy. In pre-emptive scheduling, CPU time is automatically shared between tasks based on their assigned priority;but in cooperative scheduling each task maintains control of the CPU until it explicitly yields control. Pre-emptive scheduling is advantageous since it prevents execution of long-running low-priority *background* tasks from blocking shorter, higher-priority *foreground* tasks.Thus improving of the system response and speed to external events. In the popular *TinyOS* and RTOS, which utilizes a cooperative scheduler, all tasks must run to completion. Long-running background tasks are therefore prohibited, and care must be taken to ensure that each task completes in a reasonable amount of time.

Standard background tasks executed upon startup and initialization of a TIM are the *network communication task*, which performs various duties related to communication on the various wireless data channels; the *face communication task*, which manages the communication of the TIM with others physically connected to its faces and calculates their relative *pose* (position and orientation); the *administrative interface task*, which allows the system user to monitor and administrate any physical module, or logical group of modules, within the modular sensing system; and at least one *message handler task*, which process messages received by a TIM related to its local hardware or a logical module of which it is a member.

The real-time operating system chosen for use in the software architecture presented herein is *TNKernel*. This RTOS was chosen because it is free, open source, compact, well documented, and contains a priority-based pre-emptive task scheduler. TNKernel also makes provisions for message passing and synchronization between concurrently executing tasks.

**File System:** A *file system* is a set of data structures that facilitates the storage, organization and retrieval of files from a data storage device. A file system is employed within the software architecture to provide an efficient, high-level interface to information and algorithms stored on SD flash cards that determine the identity and behavior of a particular module in a network. These SD flash cards are formatted with the *FAT32* (32-bit File Allocation Table) [23] file system and initialized with a standard file structure. The FAT32 file system was chosen since it is widely supported, stable, and lightweight.

A standard file structure is utilized to ensure that the software architecture is able to locate and access the files necessary for its operation consistently, from predictable locations. This execution is irrespective of the underlying hardware. Access to these files by the users of the system is also made more convenient. The file structure designed for this purposes consists of four directories as well as up to four different types of files.

*These directories and files are described below.*

**Template Class Directory**—the *template class directory* is the directory in which the Java classes, termed the *logical module template classes*. These classes provide the platform-independent intelligence that enables connected TIMs to collaborate with each other and operate as a logical entity.

**Module TEDS Directory**—The *module TEDS (Transducer Electronic Data Sheet) directory* *teds* consists of one or more text files termed *module TEDS*, each possessing the extension *.teds*. These files identify and describe the characteristics and digital data format of the transducers associated with a particular physical TIM in the form of a list of *property-value pairs*. The usage of a text format instead of a binary format enables the TEDS to be specified in an easily human-understandable and easily modified form.

**Template TEDS Directory**—The *template TEDS directory* *tmpl* consists of zero or more text files termed *template TEDS*, each associated with one template class, that identify and describe the characteristics of a combination of collaborating TIMs known as a *logical module*. Template TEDS also specifies various *roles* that may be fulfilled by a particular class of TIMs within the logical entity. Template TEDS are specified using the same format as module TEDS and possess the same mod extension.

**ARC4 Key File**—The *ARC4 key file* *key.rc4* stores the variable-length *key* required by the *Alleged Rivest Cipher 4* (ARC4) cryptographic stream cipher [24] utilized by the software architecture for the secure transmission of packets. Modules are only able to communicate with others that are utilizing the same key.

**Network Identifier File**—The *network identifier file* *net.id* stores the 5-byte *network identifier* used to indicate that a particular TIM is a member of a network of TIMs possessing the same network identifier. Packet transmissions from modules with different network identifiers are completely ignored, thus reducing packet processing overhead



**SENSOR NETWORK ARCHITECTURE** is called *Wireless Sensor Network (WSN)*. It can be used in various places like schools, hospitals, buildings, roads, etc., and also for various applications like disaster management, security management, crisis management, etc.

The most common wireless sensor network architecture follows the OSI architecture Model. The architecture of the WSN includes five layers and three cross layers. These layers of the WSN are used to accomplish the network and make the sensors work together in order to raise the complete efficiency of the network. We learn some

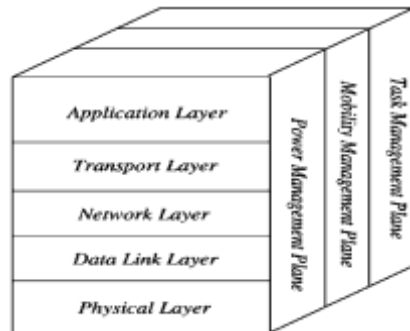
*Types of wireless sensor networks and WSN topologies*

**Types of WSN Architectures:** The architecture used in WSN is sensor network architecture. This kind of architecture is applicable in different places such as hospitals, schools, roads; buildings. It is used in different applications such as security management, disaster management & crisis management, etc. There are two types of architectures used in wireless sensor networks which include the following. A) Layered Network Architecture, and B) Clustered Architecture.

**Layered Network Architecture:** Here the arrangement of network nodes can be done into concentric layers. Layered Network Architecture makes use of a few hundred sensor nodes and a single powerful base station. Network nodes are organized into concentric Layers. It comprises five layers as well as 3 cross layers which include the following.

The five layers in the architecture are 1. Application Layer; 2. Transport Layer; 3. Network Layer; 4. Data Link Layer; 5. Physical Layer

The three **cross layers** are Power Management Plane; Mobility Management Plane; Task Management Plane. These three cross layers are mainly used for controlling the network as well as to make the sensors function as one in order to enhance the overall network efficiency.



Wireless Sensor Network Architecture

**Application Layer:** The application layer is liable for traffic management and offers software for numerous applications that convert the data in a clear form to find positive information. Sensor networks arranged in numerous applications in different fields such as agricultural, military, environment, medical, etc.

**Transport Layer:** The function of the transport layer is to deliver congestion avoidance and reliability where a lot of protocols intended to offer this function are either practical on the upstream. These protocols use dissimilar mechanisms for loss recognition and loss recovery. The transport layer is exactly needed when a system is planned to contact other networks.

Providing a reliable loss recovery is more energy-efficient and that is one of the main reasons why TCP is not fit for WSN. In general, Transport layers can be separated into Packet driven, Event-driven. There are some popular protocols in the transport layer namely STCP (Sensor Transmission Control Protocol), PORT (Price-Oriented Reliable Transport Protocol and PSFQ (pump slow fetch quick).

**Network Layer:** The main function of the network layer is routing, it has a lot of tasks based on the application, but actually, the main tasks are in the power conserving, partial memory, buffers, and sensor don't have a universal ID and have to be self-organized.

The simple idea of the routing protocol is to explain a reliable and redundant lanes, according to a convincing scale called a metric, which varies from protocol to protocol. There are many existing



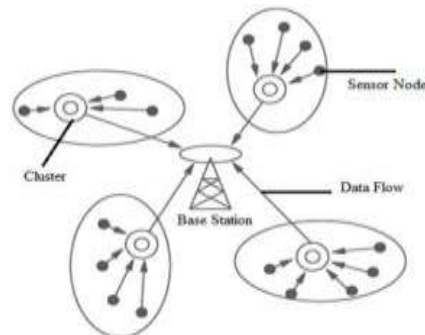
protocols for this network layer, they can be separated into; flat routing and hierarchal routing or can be separated into time-driven, query-driven & event-driven.

**Data Link Layer:** The data link layer is liable for multiplexing data frame detection, data streams, MAC, & error control, confirm the reliability of point–point (or) point– multipoint.

**Physical Layer:** The physical layer provides an edge for transferring a stream of bits above the physical medium. This layer is responsible for the selection of frequency, generation of a carrier frequency, signal detection, Modulation & data encryption. IEEE 802.15.4 is suggested as typical for low rate particular areas & wireless sensor networks with low cost, power consumption, density, the range of communication to improve the battery life. CSMA/CA is used to support star & peer to peer topology. There are several versions of IEEE 802.15.4.V.

The main benefits of using this kind of architecture in WSN is that every node involves simply in less-distance, low- power transmissions to the neighboring nodes due to which power utilization is low as compared with other kinds of sensor network architecture. This kind of network is scalable as well as includes a high fault tolerance.

**Clustered Network Architecture:**In Clustered Network Architecture, Sensor Nodes autonomously clubs into groups called clusters.In this kind of architecture, separately sensor nodes add into groups known as clusters which depend on the “Leach Protocol” because it uses clusters. The term ‘Leach Protocol’ stands for “Low Energy Adaptive Clustering Hierarchy”. The main properties of this protocol are



*Clustered Network Architecture*

**Properties of Leach Protocol:** 1. it is a 2-tier hierarchy clustering architecture. 2. It is a distributed algorithm for organizing the sensor nodes into groups called clusters. 3. The cluster head nodes in each of the autonomously formed clusters create the Time-division multiple access (TDMA) schedules. 4. It makes use of the concept called *Data Fusion* which makes it energy efficient.

Clustered Network Architecture is a very useful sensor network because of the property of Data Fusion. Inside each cluster, each node communicate with the cluster head to gather the information. This kind of network architecture is extremely used due to the data fusion property. In every cluster, every node can interact through the head of the cluster to get the data. All the clusters will share their collected data toward the base station. The formation of a cluster, as well as its head selection in each cluster, is an independent as well as autonomous distributed method.

The advantage of using *Layered Network Architecture* is that each node participates only in short-distance, low power transmissions to nodes of the neighboring nodes, because of which power consumption is less as compared to other sensor network architecture. It is scalable and has a higher fault tolerance.

All the clusters which are formed share their gathered information, to the base station. The cluster formation and selection of cluster head inside each cluster is an independent and autonomous distributed process.

### Characteristics of Wireless Sensor Network

The characteristics of WSN include the following:

The consumption of Power limits for nodes with batteries  
 Capacity to handle node failures  
 Some mobility of nodes and Heterogeneity of nodes  
 Scalability to a large scale of distribution  
 Capability to ensure strict environmental conditions  
 Simple to use  
 Cross-layer design

**Advantages of wireless sensor networks:** The advantages of WSN include Network arrangements which can be carried out without immovable infrastructure; Apt for the non-reachable places like mountains, over the sea, rural areas, and deep forests; Flexible if there is a casual situation when an additional workstation is required ; Execution pricing is inexpensive; It avoids plenty of wiring; It might provide accommodations for the new devices at any time, It can be opened by using centralized monitoring.

**Wireless Sensor Network Applications--** Wireless sensor networks may comprise many different types of sensors like low sampling rate, seismic, magnetic, thermal, visual, infrared, radar, and acoustic, which are clever to monitor a wide range of ambient situations. Sensor nodes are used for constant sensing, event ID, event detection & local control of actuators. The applications of wireless sensor networks (WSN) mainly include health, military, environmental, home, & other commercial areas. WSN s are also used in Military Applications, Health Applications, Environmental Applications, Home Applications, Commercial Applications, Area monitoring, Health care , monitoring, Environmental/Earth sensing, Air pollution monitoring, Forest fire detection, Landslide detection, Water quality monitoring, Industrial monitoring



WSN Application

It is all about what is a wireless sensor network, wireless sensor network architecture, characteristics, and applications.

**WIRELES SENSOR NETWORKS ARCHITECTURE:** The device architecture is fundamental and affects many other factors in the system. For example, power supply affects the life span; it also affects transmission range, memory, and processing unit, which in turn can affect the algorithms that can be executed on the device, etc.

Wireless sensor networks (WSNs) have taken a giant leap in scale, expanding their applicability to a large variety of technological domains and applications, ranging from the Internet of things (IoT) for smart cities and smart homes to wearable technology, healthcare applications, underwater, agricultural and environmental monitoring and many more.

Wireless sensor networks (WSN) are also data measurement and gathering networks based on small hardware (HW) units which are capable of sensing, monitoring their surroundings. The sensed data are transmitted directly or by relay via other sensors to some sink or server. The ultimate objective of such a configuration is to provide control over an area where the network is deployed.

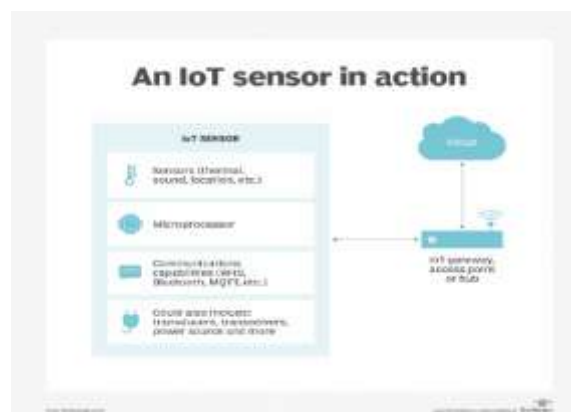
The characteristics of WSN being that, they can be composed of a few to hundreds and thousands of sensors; the monitored terrain can range from a small coverage area to a vast realm; the sensed variables of interest of the surroundings are diverse (e.g., weather parameters, acceleration, pollution); and the sensors can have different characteristics (e.g., size, computational power, energy source).

Many sensor platforms are application-oriented. Occasionally, their suggested architecture can be applied to other applications. However, their design and evaluation are typically aimed at a specific one. Hence, in many cases, both hardware and software technological developments are introduced for effective functioning. One of the most common tasks of WSN is the obvious one of monitoring a terrain. There are sensor nodes which, detects the presence of water on home floors and provide an early warning of water leaks. The system is based on LoRa technology and can collect various measurements, such as humidity, ambient temperature, soil moisture, and temperature, and enables a farmer to access all of the information necessary to achieve efficient irrigation management of crops in real time.

The energy source is a battery attached to the sensor platform. It is utilized to provide power to all the required operations, e.g., wireless transmission, computation, memory, etc. The battery properties (e.g., technology used and size) can determine its lifespan as well as several other properties, e.g., transmission range. An alternative approach to overcome the battery hurdle is to embed a mechanism that harvests energy. Many studies have explored different energy sources which can supplement energy such as solar, vibration, wind, motion, electromagnetic etc.

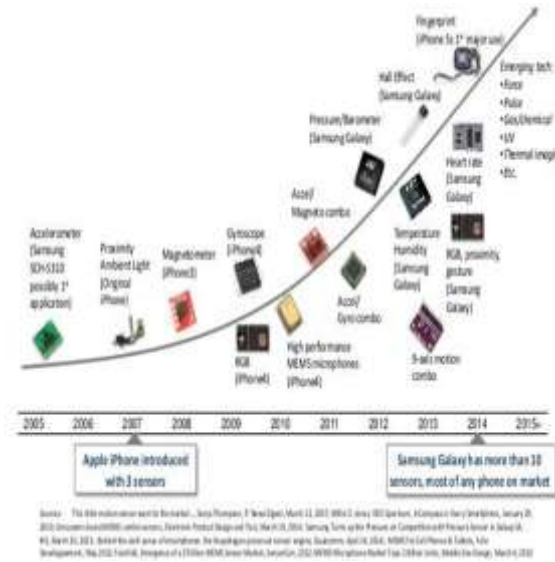
The architecture that relies on low-power wide-area network (LPWAN) protocols and provide a long-range communication system with limited data to transmit and focuses on three layers of data management in IoT networks, communication, storage and processing. Also LPWAN helps in deployment of IoT Data management for *smart home and smart cit*. The raw data reaches a central or distributed computing platform, where it undergoes transformation and evolves into rich and structured valuable information for higher-layer applications.

Sensors play a pivotal role in the internet of things (IoT). They make it possible to create an ecosystem for collecting and processing data about a specific environment, so that it can be monitored, managed and controlled more easily and efficiently. IoT sensors are used in homes, in automobiles, on airplanes, in industrial settings and in other environments. Sensors bridge the gap between the physical world and logical world, acting as the eyes and ears for a computing infrastructure further analyzes and acts upon the data collected from the sensors.



An IoT network architecture for *wildlife monitoring systems (WMS)*, is one in which animals exhibit sparse mobility, which results in sporadic wireless links. Here data forwarding enhancement that adopts the flood-store-carry-and-forward paradigm, in order to send data to the sink, the nodes disseminate it, among themselves until it reaches the sink. Specifically, each node stores the data needing to be conveyed, waits for connectivity with other nodes, and distributes the data to them, and they repeat the same process.

While STFT was utilized for the noise preprocessing, the classification of noise levels and events was performed by convolutional neural networks (CNNs). Researchers used several previously published networks and carried out afrequency-domain analysis, classification by statistical methods was accomplished (Gaussian mixture model).



*IOT sensors from embedded to pervasive*

**DESIGN ISSUES OF WIRELESS SENSOR NETWORK ARCHITECTURE:** The design issues of wireless sensor network architecture stresses mainly on Energy Consumption; Localization; Coverage; Clocks, Computation; Cost of Production; Design of Hardware; Quality of Service and Energy Consumption.

In WSN, power consumption is one of the main issue. As an energy source, the battery is used by equipping with sensor nodes. The sensor network is arranged within dangerous situations so it turns complicated for changing, otherwise recharging batteries. The energy consumption mainly depends on the sensor nodes operations like communication, sensing & data processing. Throughout communication, the energy consumption is very high. So, energy consumption can be avoided at every layer by using efficient routing protocols.

**Localization:** For the operation of the network, the basic, and critical problem is sensor localization. So sensor nodes are arranged in an ad-hoc manner, so they don't know about their location. The difficulty of determining the sensor's physical location once they have been arranged is known as localization. This difficulty can be resolved through GPS, beacon nodes, localization based on proximity.

**Coverage:** The sensor nodes in the wireless sensor network utilize a coverage algorithm for detecting data as well as transmit them to sink through the routing algorithm. To cover the whole network, the sensor nodes should be chosen. The efficient methods like least and highest exposure path algorithms as well as coverage design protocol are recommended.

**Clocks:** In WSN, clock synchronization is a serious service. The main function of this synchronization is to offer an ordinary timescale for the nodes of local clocks within sensor networks. These clocks must be synchronized within some applications like monitoring as well as tracking.

**Computation:** The computation can be defined as the sum of data that continues through each node. The main issue within computation is that it must reduce the utilization of resources. If the life span of the base station is more dangerous, then data processing has to be completed at each node before data

transmitting toward the base station. At every node, if we have some resources then the whole **computation should be done at the sink.**

**Production Cost:** In WSN, the large number of sensor nodes is arranged. So if the single node price is very high then the overall network price will also be high. Ultimately, the price of each sensor node has to be kept less. So the price of every sensor node within the wireless sensor network is a demanding problem.

**Hardware Design:** When designing any sensor network's hardware like power control, micro-controller & communication unit must be energy-efficient. Its design can be done in such a way that it uses low-energy.

**Quality of Service:** The quality of service or QoS is nothing but, the data must be distributed in time. Because some of the real-time sensor-based applications mainly depend on time. So if the data is not distributed on time toward the receiver then the data will turn useless. In WSNs, there are different types of QoS issues like network topology that may modify frequently as well as the accessible state of information used for routing can be imprecise.

**Structure of a Wireless Sensor Network:** The structure of WSN mainly comprises various topologies used for radio communications networks like a star, mesh, and hybrid star. These topologies are discussed below in brief.

**Star Network:** The communication topology like a star network is used wherever only the base station can transmit or receive a message toward remote nodes. There is a number of nodes are available which are not allowed to transmit messages to each other. The benefits of this network mainly comprise simplicity, capable of keeping the power utilization of remote nodes to a minimum.

It also lets communications with less latency among the base station as well as a remote node. The main drawback of this network is that the base station should be in the range of radio for all the separate nodes. It is not robust like other networks because it depends on a single node to handle the network.

**Mesh Network:** This kind of network permits to the transmission of the data from one node to another within the network that is in the range of radio transmission. If a node needs to transmit a message to another node and that is out of radio communications range, then it can utilize a node like an intermediate to send the message toward the preferred node.

The main benefit of a mesh network is scalability as well as redundancy. When an individual node stops working, a remote node can converse to any other type of node within the range, then forwards the message and to the preferred location. Additionally, the network range is not automatically restricted through the range among single nodes; it can extend simply by adding a number of nodes to the system.

The main drawback of this kind of network is power utilization for the network nodes that execute the communications like multi-hop are usually higher than other nodes that don't have this capacity of limiting the life of battery frequently. Moreover, when the number of communication hops increases toward a destination, then the time taken to send the message will also increase, particularly if the low power process of the nodes is a necessity.

**Hybrid Star – Mesh Network:** A hybrid among the two networks like star and mesh provides a strong and flexible communications network while maintaining the power consumption of wireless sensor nodes to a minimum. In this kind of network topology, the sensor nodes with less power are not allowed to transmit the messages. This permits to maintenance least power utilization.

But, other network nodes are allowed with the capability of multi-hop by allowing them to transmit messages from one node to another on the network. Usually, the nodes with the multi-hop capacity have high power and are frequently plugged into the mains line. This is the implemented topology through the upcoming standard mesh networking called ZigBee.

**Structure of a Wireless Sensor Node:** The components used to make a wireless sensor node are different units like sensing, processing, transceiver & power. It also includes additional components that depend on an application like a power generator, a location finding system & a mobilizer. Generally, sensing units include two subunits namely ADCs as well as sensors. Here sensors generate analog



signals which can be changed to digital signals with the help of ADC, after that it transmits to the processing unit.

Generally, this unit can be associated through a tiny storage unit to handle the actions to make the sensor node work with the other nodes to achieve the allocated sensing tasks. The sensor node can be connected to the network with the help of a transceiver unit. In the sensor node, one of the essential components is a sensor node. The power-units are supported through power scavenge units like solar cells whereas the other subunits depend on the application.

A wireless sensing nodes functional block diagram is shown above. These modules give a versatile platform to deal with the requirements of wide applications. For instance, based on the sensors to be arranged, the replacement of signal conditioning block can be done. This permits to use of different sensors along with the wireless sensing node. Likewise, the radio link can be exchanged for a specified application.

**RECENT ADVANCES IN SENSOR DESIGN:** Recent advances of sensor technologies have been powered by high-speed and low-cost electronic circuits, novel signal processing methods, and advanced manufacturing technologies. The synergetic interaction of new developments in these fields provides promising technical solutions like increasing the quality, reliability, and economic efficiency of technical products. An overview about the significant developments of methods, structures, manufacturing technologies, and signal processing characterizing today's sensors and sensor systems is available

The recent advances of sensor technologies have been powered by high-speed and low-cost electronic circuits, novel signal processing methods and innovative advances in manufacturing technologies. The synergetic interaction of new developments in these fields allow completely novel approaches increasing the performance of technical products. Innovative sensor structures have been designed permitting self-monitoring or self-calibration.

The rapid progress of sensor manufacturing technologies allows the production of systems and components with a low cost-to-performance ratio. Among microsystem manufacturing technologies, surface and bulk micromachining are increasingly winning recognition. The potential in the field of digital signal processing involves new approaches for the improvement of sensor properties. Multi-sensor systems can significantly contribute to the enhancement of the quality and availability of information. For this purpose, sophisticated signal processing methods based on data fusion techniques are more effective for an accurate computation of measurement values or a decision than usually used threshold based algorithms. In this state-of-the-art lecture we give an overview of the recent advances and future development trends in the field of sensor technology.

We focus on novel sensor structures, manufacturing technologies and signal processing methods in individual and multi-sensor systems. The predominantly observed future development trends are: the miniaturization of sensors and components, the widespread use of multi-sensor systems and the increasing relevance of radio wireless and autonomous sensors.

**FUTUREOF SENSOR TECHNOLOGY:** The first key trend is the miniaturization. Sensors are proliferating across countless applications, as we move to an increasingly connected world. Many of those applications require multiple sensors in a small way with no reduction of performance – and very low power requirements. The second is digitization. With so many applications playing in the IoT space, the shift to digitalization is required for intelligent sensors. Besides capturing sensing data, and interpreting that data for a variety of applications. A new concept called **Sensor fusion** represents the third major trend. With the trend towards digitization, multi-sensor integration is directly related to IoT proliferation and the expectation that everything is connected. The need to capture multiple types of measurement in extremely small packages is pushing the development of multi-sensing elements. These three trends sometimes overlap along with a need for higher performance at lower costs.

Many of our sensors include temperature at a minimum and we see the need to add other types of sensor. We now have tri- and quad-sensor designs that reduce cost and complexity for our customers. The breadth of our product range coupled with our application expertise allows us, to leverage our portfolio to overcome design obstacles and drive an innovation in sensor fusion.

We see four main growth markets for sensors today. A) One is in pressure sensing. The need to sense pressure is growing. Target applications include wearables and medical devices, drones, home appliances, industrial applications and transportation. Many of these applications also call for temperature sensing. B) Condition monitoring for industrial and automotive machinery, along with the high-power batteries that are now being used to supply power, represent important growth markets for temperature sensing. Temperature sensing in wearables for healthcare is another important sector. C) The third key area is force sensing, with applications in aerospace, medical instruments, appliances, elevators and a new generation of high-power electric motors. D) Finally, we see a growing need for position sensing in applications as diverse as money-handling systems, industrial equipment, automotive systems and medical devices.

Sensing technology is evolving in line with *advancements in process automation*, resulting in more capable and better-networked sensing devices. Sensors are being deployed in industries including those in oil and gas, petrochemicals, chemicals, electric power, pulp and paper, pharmaceuticals, food, iron and steel, water supply and waste-water treatment, and metal, among others. Industrial advancements have paved way for an exclusive class of sensors. As the transition to digitalization accelerates, the need for greater process automation, an enhanced ability to detect abnormalities and predictive maintenance capabilities are driving an unprecedented adoption of sensing technology.

**Some Challenges:** Despite miniaturization, today's sensors are extremely powerful and receptive. They have low failure rates, and consume less power than ever before. In the near future, enterprises can expect greater miniaturization and further advances in electronics from sensors, available for lower prices. Improved capabilities which ensure that they consume less power, greater responsiveness, and a higher tolerance to failure.

Many process related companies have already installed sensors and digitized operations for process control. They have connected major processes in their plants, and can detect, report, and analyze data to achieve higher levels of process efficiency.

The next challenge is to derive value from sensemaking, not mere sensing. Achieving increasingly profitable and sustainable operations requires more fully utilizing high-fidelity plant data, which has been gathered more extensively.

The swift evolution of the Industrial Internet of Things (I.I.o.T.) will further expand and complement its application and scope. I.I.o.T sensors monitor a range of attributes including temperature, vibration, pressure, and water-quality. These sensors are connected to solutions which leverage edge, fog, and cloud computing resources to monitor and manage asset performance and energy efficiency.

Further advances in sensing technology will not be limited to sensing devices. By converging intelligent sensing with artificial intelligence (AI) and machine learning (ML), it will support agile decision-making and drive performance optimization.

With the growing demand for smart products, and the acceleration of digitization within organizations, the role and importance of sensors will continue to grow.

*Recent developments in smart sensor technology are as follows:*

Smart lighting sensor solutions for smart cities

e-Health Sensor Shield

Encryption libraries – AES/RSA cryptography for sensor networks

3G connectivity to ZigBee, Wi-Fi, and Bluetooth sensors

Smartphones and Android devices detected by smart sensors

Why are smart sensors gaining importance? And how have they convinced people to track that data for them?

*Advantages of smart sensor systems compared to basic sensors are as follows:*

High reliability and high performance

Minimum interconnecting cables

Easy to design, use, and maintain

Scalable, flexible system

Small, rugged packaging

Minimum cost

Smart sensors enhance the applications in the areas 1. Communication, 2. Self-calibration. 3. Computation, 4. Cost effectiveness and 5. Multi-sensing

Smart sensors are also an important and integral element in the **Internet of Things (IoT)**, and as components of a wireless sensor and actuator network (**WSAN**), smart sensors not only provide digital data but can also provide other information. Therefore smart sensors play an important role in modern technology. From navigation systems in cell phones and smart wearable systems for health monitoring to autonomous driving, demand is rapidly growing. Smart sensors, including signal conditioning, embedded functions, and digital interfaces, are increasingly being adopted by the mobile phone, consumer, and industrial markets, therefore gradually replacing basic sensors. In the near future sales of about 40 billion units are expected.

**CONCLUSION:**It looks that there may not be any system in life, whether it is an engineering or medical which can be designed without a sensor. To create applications for smart environments, we can select from a huge variety of sensors that measure environmental parameters or detect activities of different actors within the premises. Capacitive proximity sensors use weak electric fields to recognize conductive objects, such as the human body

Among recent technologies, the smart sensor technology is in the spotlight because of its potential, significance, and wide range of application areas. These new systems are believed to have potentially new generation of detection capability and self-awareness, which are key components of future intelligent systems. Smart sensors, which work as part of micro-electro-mechanical systems, work with an increasingly diverse and highly accurate input. Complex multilayered operations such as collecting raw data, adjusting sensitivity and filtering, motion detection, analysis, and communication are the main functions expected of intelligent sensors. They are used in all areas of life, from HVAC systems to traffic management, air conditioning systems, and agriculture. Another important study is for Wireless Sensor Network for Animal Monitoring, Design and Implementation of Farm Monitoring and Security System, Wildlife Animal Tracking System using GPS and GSM

Several researchers have been working on the comparison and improving the existing technologies; of course with advancement of miniaturization, AI, IOT, Block chain and Cloud concepts, more and more efficient sensors are being developed. Some of the emerging devices are the **quantum sensors**. One should concentrate on improving the biosensors, integrated biosensors for high accuracy. Levitated force sensors which challenge the theory of dark energy, ultrasonic sensors, and high capacity sensor sheet with valuable resistance electrodes. It would be interesting to make a comparative study of various types of designs of a sensor meant for the same purpose for a maximal efficiency.

#### REFERENCES:

1. Stephan Weiss Mathematical Tools for Processing Broadband Multi-Sensor Signals. Proceedings of the 6th World Congress on Electrical Engineering and Computer Systems and Science (EECSS'20) Prague, Czech Republic - August 2020.
2. Sensors Overview; **Android Developers**
3. Introduction to Transducers, Sensors, and Actuators Participant Guide; Southwest Center for Microsystems Education (SCME) University of New Mexico- 2011.

4. Mohamed M. Atalla and Dawon Kahng The **MOSFET** (metal-oxide-semiconductor field-effect transistor), also known as the MOStransistor at Bell Labs in **1959**,
5. Marija Cundeva-Blajer<sup>1</sup> and Mare SrbinovskaMathematical Tools for Optimization of Energy Consumption in Wireless Sensor NetworksJournal of Physics: Conference Series, Volume 1065, Issue 21
6. Andrew C. Lyle and Michael D. NaishA Software Architecture for Adaptive Modular Sensing Systems, , MDPI, Sensors **2010**, 10(8), 7514-7560; <https://doi.org/10.3390/s100807514>.
7. Modular Sensor Architecture, Pure Engineering LLC 2020, Sensor Network Architecture, 2020; Geeksforgeeks
8. Stig Anton NielsenArchitecture in the Making; Architecture as a Making Discipline and Material Practice;EmbeddedSensors  
Jason Hill, Robert Szewczyk, Alec Woo, Seth Hollar, David Culler, KristoferPisterSystem Architecture Directions for Networked Sensors
9. Wireless Sensor Networks Architecture, Encyclopedia, scholarly community .
10. GalipAydin,IbrahimRizaHallac,and BetulKaraku.Architecture and Implementation of a Scalable Sensor Data Storage and Analysis System Using Cloud Computing and Big Data Technologies , Journal of sensors Research Article HINDAWI Open Access. Volume 2015 , ID 834217 <https://doi.org/10.1155/2015/834217>
11. Tarikul Islam; S.C.Mukhopadhyay; NagenderSuryadevaraSmart Sensors and Internet ofThings: A Postgraduate Paper; November 2016; IEEE Sensors Journal PP(99):1-1, .
12. AamirShaikh and SirajPathan,Research on Wireless Sensor Network Technology; International Journal of Information and Education Technology, Vol. 2, No. 5, October 2012.