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Smart Sensors: Analyzing Efficiency of Smart Sensors in Public Domain

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ABSTRACT

The paper gives the brief idea of smart sensors, structure and its application. Smart sensor as compare to other sensors can sensor anything with the special computing devices connected with each other in sensor network. These smart sensors first convert the digital signals to analog signals and then communicate the message to the device. Now a days smart sensors are used almost everywhere around us but very few people know its working and future applications. So here is a small review on smart sensors. This paper will help you gain knowledge and its applications in daily life.

***Keywords**:* Smart Sensor Network, Internet of Things, Energy Efficiency, Data Transmission, Logistics, Intelligent Transportation System, Optical Sensors, Health Monitoring

I. INTRODUCTION

The word “smart” has been often applied to various sensor products. Its meaning has been expanded by the continuous arrival of new and improved concepts in technology. The sensor machines those have latest technologies and improved concepts are changing the meaning of smart sensors. The smart sensor is the embedded IC which help to control any device wirelessly, remotely and automatically manipulate tasks based on data set received,thus they are embedded in most products used in day to day.Therefore the smart sensors have capability such as wireless communications, embedded timers, memory, predefined functions based on program fed, and embedded microprocessor to take independent decisions.A sensorproducesome intelligent output when connected to some interfacing hardware are known as smart sensors.(Bhatt A. K. and Pant D)[1].

Sensor+ Interfacing Hardware= Smart Sensor

Rapidly changing In the design crisis in the 1980s, technological advances led to such chip complexities that the duration of chip design reached the same time interval as the product life cycle (31). The design has been accelerated with so-called silicon-compilers on ever-higher levels of abstraction. In the initial phase, the abstraction of the production was not mature. The individual technologies required their own compiler. Every process change resulted in a corresponding fine-tuning. Meanwhile, the complexity of digital design became manageable by integrated design automation. Standard systems can be programmed with almost no manufacturing skills with the help of hardware description languages like VHDL and Verilog (32). Full- or semi-automatic tools for design synthesis map high-level specifications into a net list consisting of electronic components from a technology library that can be obtained from foundries. There are software packages that enable the automatic generation of hardware blocks for specific architectural elements such as memory. The diversity of architecture elements and the large set of interfacing options that accompanies them make it difficult to provide a fully automated design flow for rapid prototyping.The production aspects are abstracted into geometric design rules. The automatic verification of these design rules ensures that a chip can be manufactured with respectable yield. Design tools for placement and routing transfer the net list into a geometric layout of the embedded system. There are also software tools available that support the insertion of test paths into hardware modules and generate test pattern for the chip verification. Ultimately, the fabrication data for the mask set can be generated from the verified layout[2].

In 1983, Daniel Gajski and Robert H. Kuhn introduced the Y-chart as taxonomy for the design automation of electronic systems (Figure 12) (33). This design model is today the most commonly used reference in the design of digital systems (34). The Y-chart consists of three axes that are arranged as a two-dimensional Y shape, which is where the name comes from. The axes symbolize three perspectives on the circuit to be designed. The functional view represents the behaviour of a circuit. Typically, hardware description languages are applied. The structural view corresponds to the logical structure of a circuitry with components and their connections. The geometric view, often referred to as a physical view, maps the execution of all elements through real devices, including the spatial arrangement of material layers.It is

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basically combination of a sensor and an interfering circuit. Smart sensors are also used in logic function and two-way communication. The global smart-sensors market is expected to expand at a CAGR of 18% during the forecast period 2016-2023.

Rising demand for smart sensors in smart cities and healthcare industry contributes to the growth of the global smart sensor market in the forecast period. They are majorly deployed in medical diagnosis, biomedicine, health monitoring and biometrics. Smart sensors are today integrated with healthcare devices, used to monitor and control health conditions by providing sensory information about patient's health on time.

Fig. 1: Digital Thermometer.

The main difference between the traditional sensors and smart sensors is that, the smarts ones have wider intelligence ability when compared to the traditional sensors. The common function of a normal sensor is to sense information and then transform it in the form of electrical signals. The normal sensors have three crucial parts which are

- Sensing element (Transistor, Capacitors, Photo Diode etc.)
- Conduction of signals and processing
- Sensor Interface

The specific input could be light, heat, motion, moisture, pressure, or any one of a great number of other environmental phenomena. Smart sensors are information sensors. These integrate sensors and circuits to process information obtained from the environment without a significant human interference. The output is a signal that is converted to human readable display at the sensor location or it is transmitted electronically over a network for reading or further processing.Thus smart sensors help us to make lives easier. Detailed information about smart sensors is given in paper below.[1].

II. STRUCTURE OF SMART SENSOR

The basic block diagram of a smart sensor is given in the figure-2.

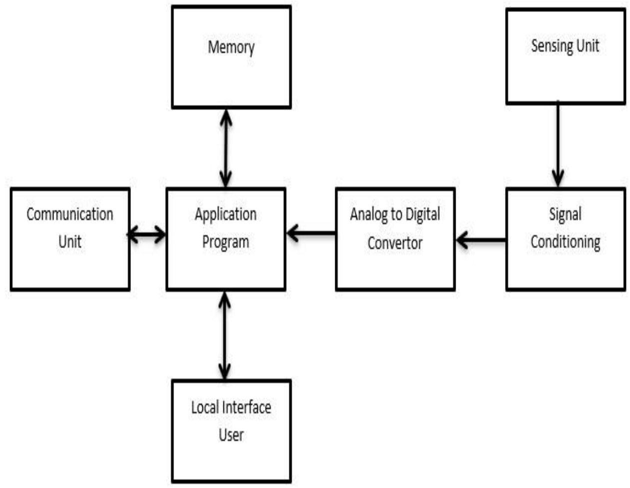

Fig. 2: Structure of Smart Sensor

According to above block diagram smart sensor is a collection of sensors interconnected with each other by communication network. Changes in parameters are sensed by sensing unit, digital signals are generated by signal conditioning circuitry in form of electrical signals. Analog to digital conversion is performed by converters like A2D or D2A and this input is given to application programs that study data, manipulate it and gives feedback to sensor for further operation. Task processing is done by processor and stored by memory unit.

The structure of smart sensor consists of 5 main components:

- Communication unit: It includes transceivers and forwards queries and data to and from central module. Communication with base station or sensors or sinks in WSN is done by transceivers.
- Memory: It is used as storage media for storing data or task processing.
- Battery: It is the source of energy.
- Transceiver: It interacts with the environment and data.
- Central unit: It is in the form of microprocessor which manages the tasks.

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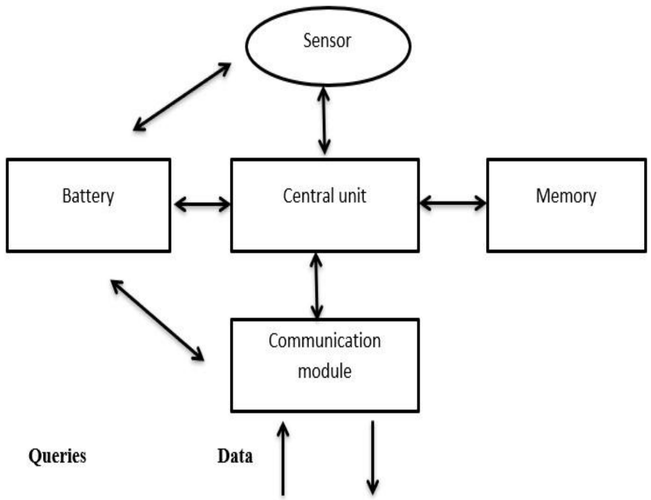

Fig. 3: Major Components of Sensor

The micro-hardness values as observed during testing.

III. ARCHITECTURE OF A SENSOR

These may be briefly defined as:

- Sensing element/transduction element
- Amplifier
- Sample and hold
- Analog multiplexer
- Analog to digital converter (ADC)
- Offset and temperature compensation
- Digital to analog converter (DAC)
- Memory
- Serial communication
- Processor

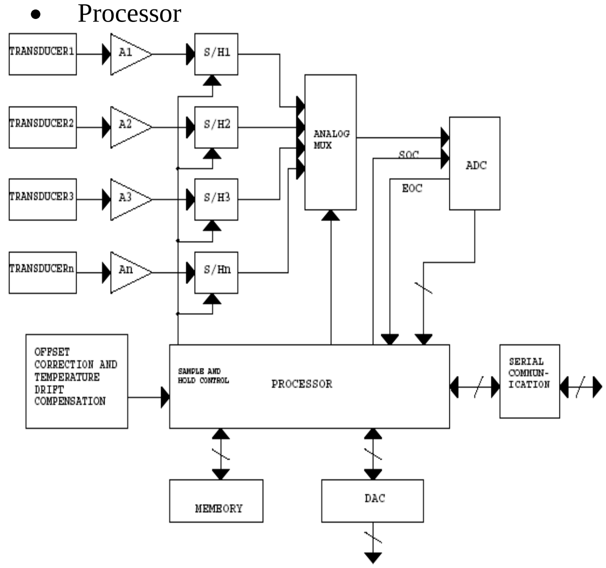

Fig. 4: Architecture of Smart Sensor

IV. SMART SENSOR

The sensors are categorized based on their activity, hardware structure, functionality, and many parameters:

Optical Sensor: An optical sensor converts light rays into an electronic signal and sends it to a processing unit that manipulates it based on some predefined functions and code modules and responds to the device for further operation .The measurements possible by different optical sensors are temperature, Velocity Liquid level, Pressure, Displacement (position), Vibrations, Chemical species, Force radiation, pH- value, Strain, Acoustic field and Electric field. Some of these are infrared sensors, LDR, LASER (Light Amplification by Stimulated Emission Radiation).

Infrared detector array: An infrared sensor is an electronic device, that sense IR rays in order to sense activities of surrounding environment. An IR sensor can measure the heat of an object as well as detects the motion .These types of sensors measures only infrared radiation, rather than emitting it that is called as a passive IR sensor. Some examples are flame analyzers, radiation sensors, moisture analyzers.

Accelerometer: Accelerometer sensor is used to measure the acceleration exerted on the sensor. Usually the acceleration is given in two or three axis-vector components that make up the sum/net acceleration. You can probably think of a few already—glass breakage detector, video game remote controls, or even electronic bubble levels for when you are trying to hang a picture frame on the wall.

Integrated multi sensor: Integrated multi sensors are used to perform some specific operations using a combination of multiple sensors of different domain and operation controlled via single integrated platform.

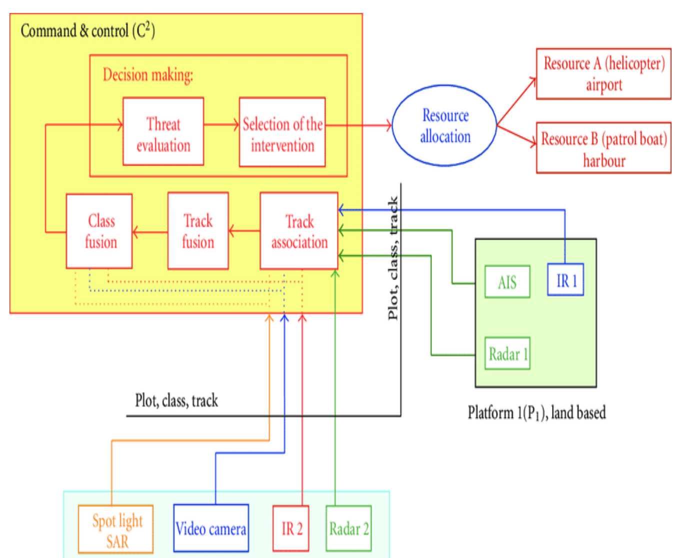

Fig. 5: Integrated Multi Sensor

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There are some more types of smart sensor based on their functionality, technology, and hardware structure. Thus some of such kinds of sensors are:

Temperature: A temperature sensor is a chip, usually an RTD (resistance temperature detector) or a thermocouple, that is used to collect the data about temperature from a particular source and converts data into understandable form for devices or an observer. Temperature sensors are used in many applications such as HV and AC system environmental controls, food processing units, medical devices, chemical handling and automotive under the hood monitoring and controlling systems, etc.

Humidity: A humidity sensor (or hygrometer) senses, measures and reports the moisture and temperature of air. Humidity sensors work by detecting changes in electrical currents or temperature in the air.

Pressure: A pressure sensor is a device which senses pressure and converts it into an analog electric signal whose magnitude relies upon the pressure applied. Since they convert pressure into an electrical signal, they are termed as pressure transducers.

Touch: A touch sensor is a type of equipment that captures and records physical touch or embrace by a device and object. It enables a device or object to detect touch, typically by a human operator. A touch sensor is also called a touch detector.

Motion: Motion sensor is a device that detects physical movement on a device or within an environment. It has the ability to detect and capture physical and kinetic movements in real time.

Occupancy: An occupancy sensor indoor motion detecting device used to detect the presence of a person to automatically control lights or temperature or ventilation systems.

Water: A water detector is electronic device that is designed to detect the presence of water for purposes such as to provide an alert in time to allow the prevention of water leakage.

Position: Position sensors are basically sensors for measuring the distance travelled by the body starting from its reference position. How far the body has moved from its reference or initial position is sensed by the position sensors and often the output given as a fed back to the control system which takes the appropriate action.

Light: Light sensors are more commonly known as “Photoelectric Devices” or “Photo Sensors” because the convert light energy (photons) into electricity (electrons).

IV. DISCUSSION: OPTICAL HEART RATE SENSOR

Most wearables with heart rate monitors today use a method called **Photoplethysmography (PPG)** to measure heart rate.[3] PPG is a technical term for shining light into skin and measuring amount of light that is scattered by blood flow. That’s an over simplification, but PPG sensors are based on the fact that light entering body will scatter in a predictable manner as the blood flow dynamics change, such as changes in blood pulse rates (heart rate) or with changes in blood volume (cardiac output).

PPG sensors use four primary technical components to measure heart rate:

Optical emitter – Generally made up of at least 2 LED’s that send light waves into the skin. Because of wide differences in skin tone, thickness, and morphology associated with a diversity of consumers, most state-of-the-art OHRM’s use multiple light wavelengths that interact differently with different levels of skin and tissue.

Digital Signal Processor (DSP) – The DSP captures the light refracted from the user of the device and translates those signals into one’s and zero that can be calculated into meaningful heart rate data.

Accelerometer – The accelerometer measures motion and is used in combination with the DSP signal as inputs into PPG algorithms.

Algorithms – The algorithm processes signals from the DSP and the accelerometer to motion-tolerant heart rate data, but can also calculate additional biometrics such as VO2, calories burned, R-R interval, heart rate variability, blood metabolite concentrations, blood oxygen levels, and even blood pressure.

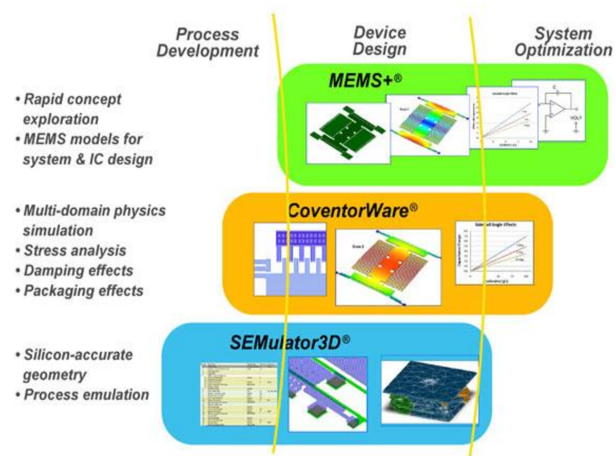

Fig. 6: MEMS based OHRS

The MEMS sensor has played an eminent role in Optical heart rate sensor operation and also in other appliances using pulse and heartbeat masuring techniques.

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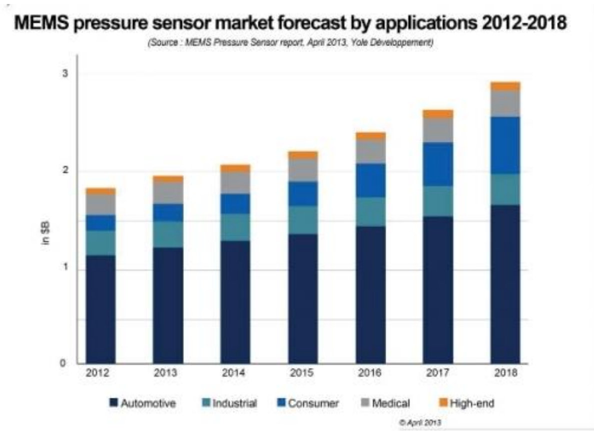

Table 1: MEMS pressure sensor usage forecast

ROHM Semiconductor BH1790GLC Optical Heart Rate Sensor

ROHM Semiconductor BH1790GLC Optical Heart Rate Sensor is a photodiode designed to measure pulse waves, which are changes in the volume of a blood vessel that occur when the heart pumps blood. Pulse waves are detected by measuring the change in volume using an optical sensor and green LED. The BH1790GLC Optical Sensor features an optical filter optimized for pulse wave detection. This filter minimizes the effects of ambient light and increases the sensitivity and accuracy of the sensor block.

Circuit Diagram

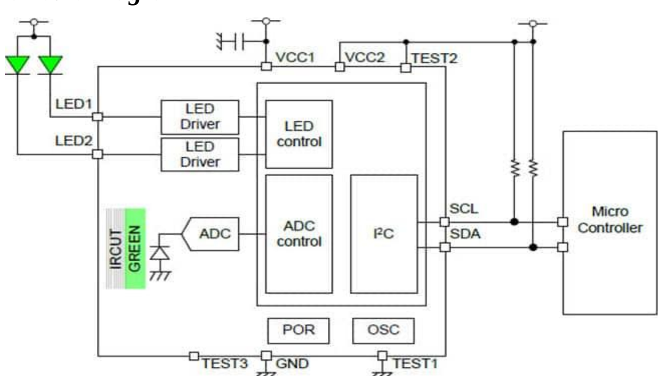

Fig. 7: Circuit diagram of OHRS

Technical Specifications

- Optical filter offers excellent wavelength selectivity
- Built-in IR-Cut Filter
- Corresponds to 1.8V I2C Interface
- Low power consumption
- Analog supply voltage range: 2.5V to 3.6V
- I/O supply voltage range: 1.7V to 3.6V
- Current consumption: 200µA
- Operating temperature range: -20ºC to +85ºC
- Package size: 2.8mm x 2.8mm x 0.9mm

Control and Operation

The graph shows control and operation of OHRS and defines its efficiency in public domain based on various factors:

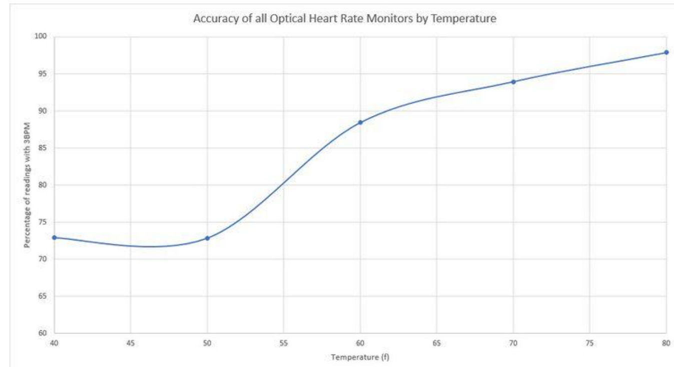

Table 2:Accuracy of optical heart rate sensor by Temperature

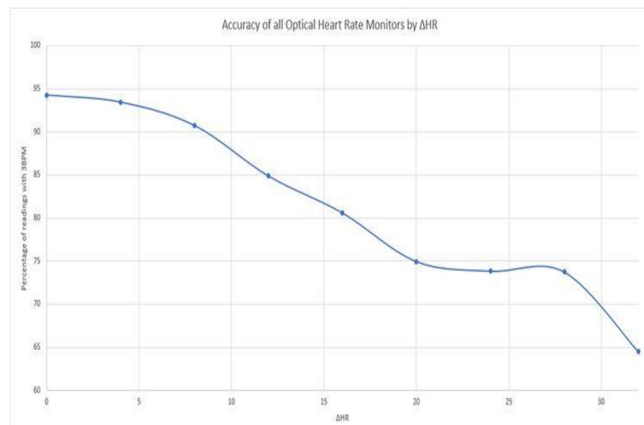

Table 3: Accuracy of optical heart rate sensor by HR

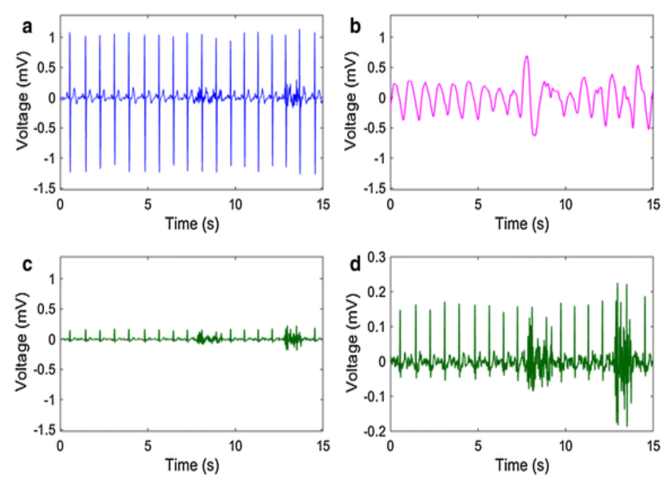

Table 4:Measurement of data by OHRS

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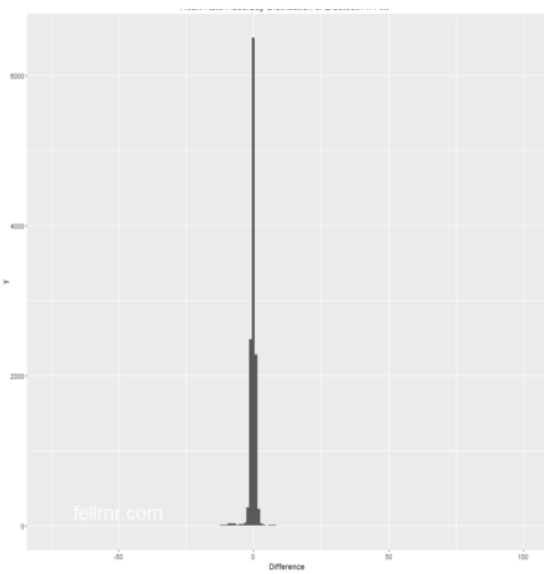

Table 4:Accuracy of OHRS in bluetooth transmission

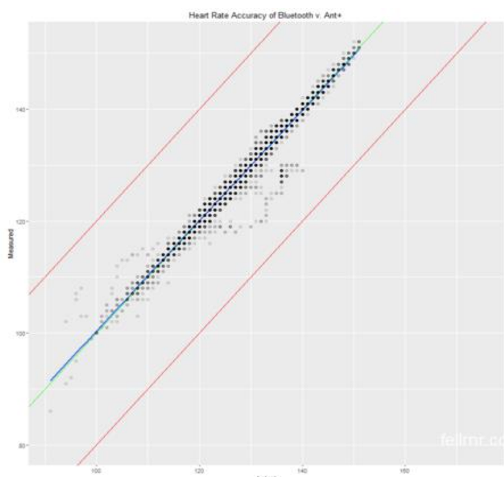

Table 6:Average accuracy of OHRS by bluetooth

Smart Sensors with Self-Diagnostics and Repair Capabilities

Smart sensors can also be well-suited to safety-critical applications like detection of hazardous gas, fire or intruders. Conditions in these environments can be harsh, and the sensors can be difficult to access for maintenance or battery replacement - yet high reliability is critical. A team at the Lab-STICC Research Center, University of South-Brittany, has been developing a solution which improves reliability by using dual probes and hardware which can self-diagnose and repair itself.

The paper, **entitled 'On-line self-diagnosis based on power measurement for a wireless sensor node'**, describes a node that pinpoints an internal failure and takes corrective action to improve reliability and energy-efficiency. This will reduce node's vulnerability and alleviate maintenance costs. The design brief recognizes the limitations of such sensors; restricted battery autonomy, energy harvesting subject to unreliable energy source behaviours, limited processing and storage resources, and a need for wireless communication.

The node was equipped with two sensors; during normal operation, the first captured environmental data while the second was only activated by users to verify the obtained data. If the first sensor were failed, the node's reliability was downgraded, while battery power was being wasted on supplying the non-functioning sensor. However, if the node was disconnected the first sensor and switched to the second, then no energy was wasted and node reliability was maintained.

Accordingly, the project's objective was to develop a novel self-diagnostic based on functional and physical tests to detect a hardware failure in any component of the wireless sensor node. This method can identify exactly which node component has failed, and indicate suitable remedial action.

V. TECHNOLOGICAL IMPLICATIONS AND FUTURE SCOPE

Not only now but smart sensors have many future implications too and some of these may be defined as:

Traffic Monitoring and Controlling

A smart sensor is deployed roadside in developed countries that makes possible to collect live data and to monitor vehicles speed limit. Apart from this a simple traffic signal system could also tell us about the upcoming objects.

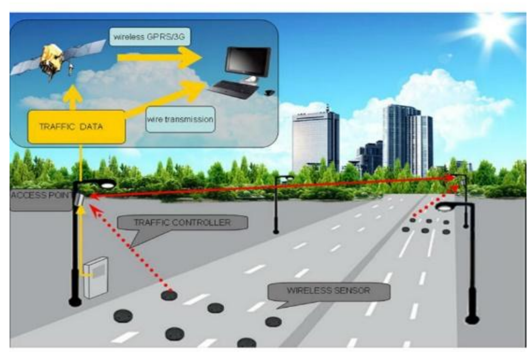

Fig. 8: Traffic monitoring system

Home

A smart sensor device would help an individual to control his/her house appliances from anywhere outside the house. It also helps the person tocheck the security and to control the appliances. It helps to make his home smart.

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Fig. 9: Smart Home

Remote Control System

These days controlling any devices are very common and it helps a person to control the device from any distance and from anywhere. A common example of remote control system is televisions,we can control our television by simply using the remote control.

Fig. 10: Security Remote Control

Biometric System

The biometric systems used to capture the digital image of biometrics (fingerprint, heartbeat, retina, etc.) pattern. The captured image is called a live scan. This live scan is digitally processed and stored for matching.


Fig. 11: Fingerprint Sensor

Industries

In industries machines and equipment are monitored and controlled for pressure, temperature, capacity, humidity level etc. These sensors help to manufacture or for packing purpose.


Fig. 12: Capacity Monitoring System

Security and Alarm

The smart sensors are also used in alarms in many places for security purpose. One of the very common sensors used in industries, public places is fire alarm it detect the smoke and then alert everyone.

Fig. 13: Wireless Security Alarm System

Health Care

Smart sensors are also used in health care as wearable such as digital watches, implanted or wear clothes, used in sensing signs of heart failure, stroke, etc.


Fig. 14: Pulse Oximeter

There are many more system introduced which uses IOT and artificial intelligence for developing smart sensors. These smart sensors are used in smartly sensing everything which many times we can’t sensor or notice. It helps us to live more comfortably.

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VI. CONCLUSION

In recent technology, wireless sensor network is been highlighted on it because of its unbeatable potential and wide range of application area. These smartsensors have made our lives much more easy andcozy. The future with these sensors will make our lives smarter than today. This paper is mainly focused on smart sensors and its existing usage in various fields. The future of smart sensors is not limited to this there are many more to come.

The concept of Industry 4.0 will remain unchanged for a long time. More smart sensors are expected to come to market, and wireless communication will continue to provide the needed connection to those sensors and diagnostic and other connected equipment. The application of smart sensors in manufacturing is extensive and is becoming more so every day. Some of the many monitored parameters include motion, acceleration, air quality, color, current, flowforce,gyroscopesimage, pressure, fluid level, photoelectric, proximity, pressure, humidity, strain, and more. We are, indeed, witnessing a revolution in smart manufacturing thanks to smart sensors.

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