IoT Smart Sensors in Healthcare Applications: A Review

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Abstract: **IoT in healthcare is the key player in providing better medical facilities to the patients and facilitates the doctors and hospitals as well. Sensors and web based or mobile based applications which communicate via network connected devices and helps to monitor and record patient's health data and medical information. The sensing devices and objects in IoT sense and collect relevant information which later on can be processed, analyzed for better decision making. Thus allows the physical objects in real-world to connect together to deliver computation based performance. This paper discusses the various types of sensors used in healthcare field. The healthcare IoT have many applications including remote monitoring, early prevention, chronic disease management, elderly care, medical treatment for institutionalized patients etc. It allows us to establish intelligent connections assuring an effective healthcare system.**

Keywords: **Internet of Things (IoT), Smart Healthcare, IoT healthcare Architecture and Sensors**

1.INTRODUCTION

A sensor is an object whose purpose is to detect events or changes in its environment, and then provide a corresponding output. A sensor is a type of transducer; sensors may provide various types of output, but typically use electrical or optical signals. Sensors are used in everyday life to measure blood glucose level,temperature, oxygen etc. which helps the people to know about their health status. A sensor's sensitivity indicates how much the sensor's output changes when the input quantity being measured changes.
Internet of Things (IoT) is a interconnection of devices, applications, sensors and network connectivity that helps to collect and share data. IoT in healthcare (Shubham Banka et al 2018, S.M. Riazulislam et al 2015) enables to closely monitor the person's health using various sensors with different parameters. It helps the doctors and caretakers to remotely monitor the patient's health and provide medical help and medications on time. Smart sensors(Cheena Sharma et al 2017) can be wearable, implantable and shares the health data to connected devices and aids in decision making.

2.IOT SMART HEALTCARE ARCHITECTURE

The architecture of IoT Cloud based monitoring of patients health in hospitals/home(Amir-Mohammad Rahmani et al 2015) was shown in the below fig 1.Patients equipped with wearable or implantable sensors in their body will monitor and measure various health parameters and unusual health patterns. It makes more accurate information about them, these signals are transmitted to the connected devices.

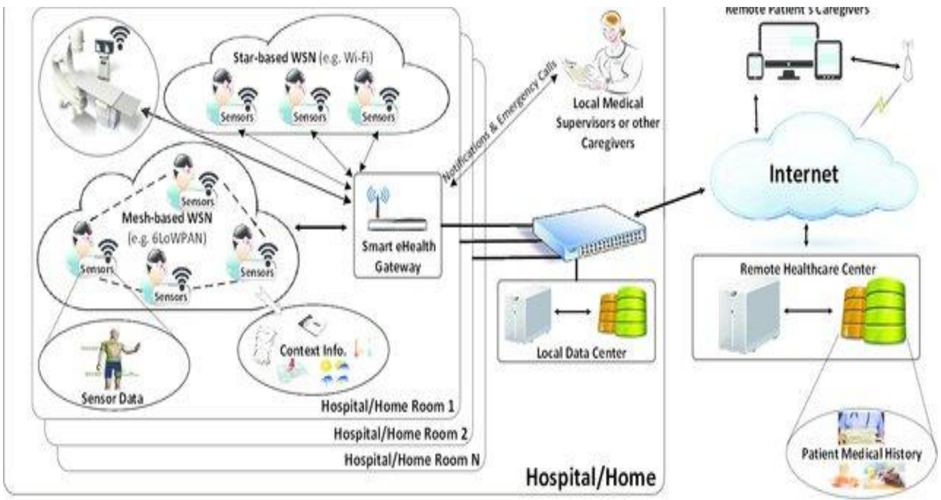

Fig. 1: IoT Cloud based Smart Healthcare Monitoring Architecture

The smart e-Health gateway collects data from different networks performs protocol conversion and provides services like data aggregation and filters only relevant data.The data sent to the backend system was processed and securely stored in remote health care center.

3.SMART SENSORS FOR HEALTHCARE

This section discusses different types of sensors used in monitoring person's health was shown in fig 2.

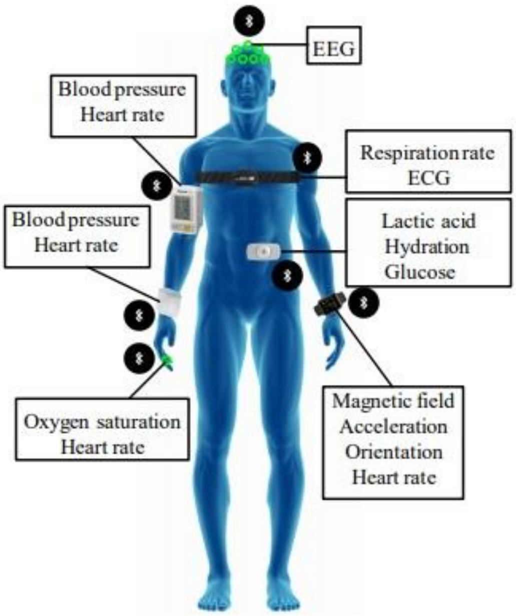

Fig. 2: Smart Sensors in Human Body

Temperature Sensors: Human body temperature is measured using digital thermometers kept in rectum, ear, forehead, armpit, inside mouth or wearable sensors on skin. Normal human body temperature is 98° F. Change in body temperature is an indication of alert message for various chronic diseases.

Pulse Oximetry Sensor : Pulse Oximeters are low cost non-Invasive medical sensors(Alekya R,2020) used to continuously measure the Oxygen saturation (SPO2) of haemoglobin in blood. It displays the percentage of blood that is loaded with oxygen. The unit tests the oxygen saturation level of the human body and monitors the difference in the skin blood flow associated with the cardiac cycle. The pump oximeter, containing an image detector and light-emitting diodes (LEDs), is connected to the finger or ear. The red light sent or carried back into the human body tests infrastructure. The distinction between the level of the installation and the amount of deoxygenated hemoglobin helped to measure oxygen saturation. It is used to calculate the heart rate as Photo Plethysmo Graph (PPG).

Blood Pressure Sensors: Blood Pressure (BP) is one of the important vital signs. It is the pressure exerted by the circulating blood on the walls of blood vessels. Blood Pressure is expressed as the ratio of the systolic pressure(Ahmed Al-Qatatsheh et al 2020, Dena Ettehad et al 2016) over diastolic pressure. Mercury sphygmomanometer is being used for measuring blood pressure. In this, the height of the column of mercury is considered for measuring the blood pressure. With the advance in technology devices for measuring blood pressure through the non-invasive oscillometric method are being developed and one such device is the Blood Pressure Sensor.

Electrocardiogram Sensor: It measures the electrical activity of the heart. It is called as ECG sensor(Quan Dong et al 2021). Heart rate refers to the speed of the heartbeat. It is typically measured in beats per minute. Heart rate is measured to detect bradycardia (slow heart rate), tachycardia (fast heart rate) or arrhythmia (irregular heart rate and rhythm), any of which can indicate illness. The number of pulsations is counted to find the heart rate. In a hospital setting, heart rate is measured continuously using an electrocardiograph(ECG). A waveform that monitors the heart continues to function and provides time information. There is also restricted readiness for automation for ECG calculation based on wireless sensor devices.

Electromyography (EMG) Sensor: Electromyography (EMG) measures muscle response or electrical activity in response to a nerve's stimulation of the muscle. The test is used to help detect neuromuscular abnormalities. The muscle research works by looking at the muscle's electrical signals. For all electric signals EMG is the spatio-temporal DRM. The EMG signal(Yi-Da Wu 2021) therefore provides an efficient way to monitor human muscles' activities.

Force Sensors: Noninvasive pressure sensors **(**Fokko Pieter Wieringa et al 2017) can precisely measure pressure at critical points in the system, such as directly upstream of the blood pump, at the dialyzer inflow, and right before the blood is returned to a patient's venous system. Ensuring blood is maintained at the proper pressure at all points in the process can be critical to preventing damage to the patient's circulatory system or to the dialysis machine itself. Monitors and regulate the dial sate flow on the outside of the dialysis filter to enable the filter to capture contaminates within the blood. Improve treatment efficiency and reduce the time it takes to remove fluid from the peritoneum Board mount pressure sensors are typically used on the blood side of the dialysis equipment to monitor and regulate blood flow to and from the patient during the dialysis procedure. Failure to control this blood flow may cause the patient severe discomfort and potential heart failure.

Airflow Sensors: Mass air flow sensors contain a thermal sensor and a heating source. Once gas begins flowing through the heating source, it transports the heat away, which changes the temperature difference between the heating source and the thermal sensor. This change is used to determine the energy required to maintain the sensor at the same temperature(Subrahmanyam Maddirala et al 2016), which is then interpreted into a value. This value is transmitted through a communication interface to calculate flow.

Humidity Sensors: The humidity sensor in the medical ventilator is helpful in conveying warm and wet air, making the patient feel comfortable. When the water is introduced into the air stream, it must be monitored and controlled in real time. When the patient exhales, the air flow sensor sends a signal to inform the sleep ventilator to reduce the speed of the ventilator fan lest the patient feel uncomfortable of "fighting" the machine. The humidity sensor(Subrahmanyam Maddirala et al 2016) is used to monitor the humidity of the air and accurately measure the dew point and absolute humidity or moisture content to provide the patient with humidity appropriate air.

Continuous Glucose Monitoring Sensor: A continuous glucose monitor (CGM) uses a filament coated in glucose sensing enzymes to detect glucose in the interstitial fluid (the fluid between your cells). As a wearable sensor, a CGM automatically detects and measures glucose levels 24 hours a day.A CGM sensor(Anuradha Yadav 2018) can be used continuously for several days or weeks — the exact duration will vary by manufacturer. Implantable CGM sensor options offer months-long wear, as they are embedded below the skin in a larger capsule, versus the thinner filament in other CGM sensors.The sensor then works with a transmitter that sits above the skin to send data to a receiver or smart device. The transmitter allows you to wirelessly view your current glucose level and trends, or you can be notified when it’s time to replace the sensor.

Pyroelectric Sensor: A pyroelectric sensor is used to measure IR radiation emitted from a moving object within its Area of Detection (AoD). It has two slots made of the same materials that are sensitive to the IR radiation. When there is no motion, the differential IR level between the two slots is equal to zero, because both slots have the same amount of charge, corresponding to the ambient light. If the IR radiation is intercepted in one of the slots due to motion, then PIR slot a has more IR level change than slot b, generating a positive differential charge. On the other hand, when the moving object exits the AoD of the PIR sensor(Tong Liu et al 2011), the level of IR radiation of the second slot b will be higher than that of slot a, generating a negative differential charge

Heart rate Sensor: When people are not exercising, the heart rate is at rest so the heart will pump the lowest amount of blood. Same goes when people are sitting, relaxing or not doing something that require much energy, the heart rate normally range from 60-100 in beat per minute. But it might be differed when running and exercising. Reading of human heart rate can be read by the sensor(Priyanka Kakria et al 2015) which uses LED and light detector to detect the variation of human blood causes by the heartbeat. When the LED covered by human skin (finger) some of the light from LED will reflect and being received by the light detector and some will be absorbed by the blood. The output from the light detector is in the form of electrical signal which proportional to the heart rate. The signal then filtered by using two stage of high pass-low pass circuit. Comparator circuit will convert to digital pulses which then are fed up to the microcontroller. Microcontroller analyzes and calculates the heart rate.

4.DISCUSSION ABOUT APPLICATIONS OF SENSORS IN MEDICAL DEVICES

Sensors embedded in medical devices are used to improve patient care(Rodolfo S et al 2019), comfort, enhance healthcare professionals’ performance and reduce healthcare costs as given below.

4.1 Anesthesia Delivery Machines

Patient benefits: Anesthesia machines are used during medical operations, to put the patient in an induced sleep and provide pain relief. The machine provides supported breathing and monitors the vital signs of the patient, measuring blood pressure, heart rate, and others. Also, the patient receives a reliable and constant supply of gases and vapor.

Sensors Used:

Airflow – measures the air, oxygen, and nitrous oxide flow to ensure airflow is delivered to the patient in the right amount.

Pressure – monitors patient breathing, detects when the patient inhales and exhales, allowing air/oxygen to be delivered more efficiently and effectively.

Oxygen – measures and controls the oxygen concentration level of the air mixture delivered to the patient.

Temperature – monitors and controls the temperature of the air delivered to the patient.

Humidity – monitors and controls the moisture content of the air delivered to the patient.

Magnetic – improves motor efficiency, reducing power consumption, noise and vibration.

4.2 Ventilators

Patient benefits: Ventilators help patients who are breathing insufficiently or are physically unable to breathe, during an operation or within an intensive care or high dependency unit. Ventilators are also used during treatment for serious lung diseases or infections which affect normal breathing.

Sensors Used:

Airflow – measures air and oxygen flow so the correct amount is delivered to the patient.

Oxygen – measures and controls the oxygen concentration level of the air mixture delivered to the patient.

Pressure – monitors patient breathing, detects when the patient inhales and exhales, allowing air/oxygen to be delivered more efficiently and effectively.

Temperature – monitors and controls the temperature of the air delivered to the patient.

Humidity – monitors and controls the moisture content of the air delivered to the patient.
Magnetic – improves motor efficiency, reducing power consumption, noise and vibration.

4.3 Oxygen Concentrator
Patient benefits: Oxygen concentrators are used to help patients with respiratory illnesses or lung disease. Patients who have difficulties in absorbing oxygen into the bloodstream benefit from the oxygen concentrators enhanced response time, minimized oxygen waste, and improved portability.
Sensors Used:
Airflow - measures air and oxygen flow so the correct amount is delivered to the patient.
Oxygen – measures and controls the oxygen concentration level of the air mixture delivered to the patient.
Pressure – monitors patient breathing, detects when the patient inhales and exhales, allowing air/oxygen to be delivered more efficiently and effectively.
Temperature – monitors and controls the temperature of the air delivered to the patient.
Humidity – monitors and controls the moisture content of the air delivered to the patient.
Magnetic – improves motor efficiency, reducing power consumption, noise and vibration.

4.**4 Dialysis Machine**
Patient benefits: Hemodialysis machine treatments replace some kidney functions by removing waste and fluid from the bloodstream via diffusion and osmosis of solutes and fluid across a semi permeable dialysis membrane.
Sensors Used:
Pressure – monitors blood flow to and from the patient and controls the flow dialysate to ensure blood is cleaned thoroughly and efficiently. If blood pressure is not controlled, the patient could become critically ill
Force/Magnet – detects the presence/absence of a fresh dialysate cartridge before the machine can be used.
Thermistor – provides temperature measurement for enhanced control across the dialysis membrane.
Barcode – ensures the right treatment is administered to the right patient

4.5 Infusion Pumps
Patient benefits: Infusion pumps are used to deliver fluids, medicines, or nutrients to patients. Fluids and medicines are delivered intravenously directly into the bloodstream and nutrients are delivered directly into the stomach. Infusion pumps are commonly used in hospitals, but smaller portable infusion pumps are now being used to treat patients at home.
Sensors Used:
Force – monitors the delivery of fluids, detects blockages, and determines when the bag containing fluids needs to be changed.
Magnet – ensures correct placement of tube carrying fluids and controls pump speed.
Switches – door control and operator on/off controls
Barcode – ensures the right treatment is administered to the right patient by reading the barcodes on the IV bag and the patient's wrist band.

4.6 Hospital Hardware
Patient benefits: Patients who receive efficient treatment and have a comfortable experience in the hospital can have a better chance of recovery and the time they spend in the hospital is reduced. As an example, smart hospital beds contain various sensors that can detect and correct or adjust the position, to improve patients' comfort. Sensors control the position and elevation of the bed and regulate the pressure within different zones of the mattress to stimulate blood flow and improve patient recovery times.
Sensors Used:
Humidity – maintains temperature and humidity levels in incubators and microenvironments
Magnetic – enables locking/unlocking of medication dispensing cabinets
Magnetic/basic switches – enables precise position control within hospital beds
Position sensors – monitors backrest elevation within hospital beds
Pressure – improves patient comfort and stimulates blood flow to improve patient recovery times
Pressure – accurately measures blood pressure
Thermistor – monitors the incubator system's temperature
Thermostat – controls or limits temperature
Barcode – enables patient tracking via a mobile device or scans labels for patient confirmation and clinician information.

5. CONCLUSION
In today's busy world most of the elderly people are living alone with no caretaker besides them. IoT sensors either invasive, non-invasive, wearable, implantable was a gift for aged people and aids them in monitoring their health and stores the information to remote servers. By using such monitoring systems, the healthcare professionals can monitor, diagnose, and advice their patients from a remote location at all the time and doctor or patient can access report through online. IoT smart healthcare architecture based on cloud allows systems to work together using smart sensors, connection methods, internet protocols, databases, cloud computing and analytic as infrastructure was presented. This paper also discussed a variety of sensors and its usage in medical devices.

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