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Sensor Based IoT Industrial Healthcare Systems

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Abstract*—The bright capability of showing up Internet of things (IoT) advancements for well being gadgets and sensors assumed an essential need in the new era of Healthcare industry for secure patient care. The information is gathered by using various sensor node. It has been observed that there is an utter need for the automated healthcare system for the patients in need or elderly incapable or unhelped people. This paper discuss a Healthcare Industrial Internet of Things (Health IoT) monitoring model for the benefit of under helped intensive care patients and the solution for seamless connectivity of different systems through internet anticipating providing specific service and information for doctors such as in real time. This work is an extension of work for proposed IoT application in industrial health care system. The initial idea for a research problem was to search/find the business models of startups in Flanders that responsible for development an Internet of Things application in health care for industrial system. Using a popular business model framework [6] X. Yang et al, the Business Model Ontology this could give an insight into the suitable business models which are used for the Internet of Things in health care system.*

***Keywords*—** *HealthI IoT, body sensor network, Low power network, hydra middleware.*

I. Introduction Sensors and IoT

IoT platform is an ambitious approach in Healthcare Industry, which effectively connects body sensor network with the communication network. In order to manage the complexity of such systems, interworking solutions that can reuse established technologies seamlessly with healthcare network. from choosing of right sensors to sending the error free patient data with the help of right wireless connectivity technology can be relatively challenging to healthcare industry. IoT to healthcare industry provide automation and analytics system, which utilizes sensing, networking, data and technology to deliver complete Health IoT system. The high flexibility and ability to work in any infrastructure enhances the application of IoT in various other industries as well.

In a wireless sensor network, tens, hundreds, or even thousands of sensor nodes are scattered and deployed throughout a physical environment for the desired data collection. Each device should be capable of monitoring-sensing-and/or displaying transmitting -actuating-information. A sensor node is capable of gathering sensory information, processing it in some manner, and communicating with other nodes in the network

One of the challenges of Health Industry are the distribution of accurate and real time information of patients. IoT application in healthcare industry enhances facilities and professional practice it brings out into the home, office, or social space. IoT allows individual in monitoring to their own health and allow service provider to deliver better treatment. However, there are many other challenges in designing an IoT based healthcare system includes security, authentication and exchanging data. This paper devoted for selecting a right sensors and communication network for monitoring patients three main vital sign for improving their health condition remotely. And design a seamless communication channel for healthcare network by providing a solution for heterogeneous devices used in Health IoT system.

II. Related Work Done: Literature Review

In the paper [1] LED based PPG (photo plethysmo graphy) sensors are used to measure pulse rate and to improve accuracy an accelerometer is used to check for motion and to further reduce the effect of motion a two different LED light intensities is used. Another pressure type sensor is used in [3] to measure a pulse rate, it is flexible to use but highly sensitive to any other source of pressure. Nasal sensor which is used for respiratory rate count are used in paper [4] based on thermistor is also highly sensitive to another source of temperature, although this techniques works well. Electrocardiography (ECG) enable respiratory sensor used in [5] to obtain respiratory rate, but it is not a long wearable as causes skin allergies. In paper [4] author used microphone but this is also highly inflicted by external noises. Fiber-optic sensor used elastic substrate in [5] here author suggested that it is 95% accurate and longtime wearable but has also susceptible to noise

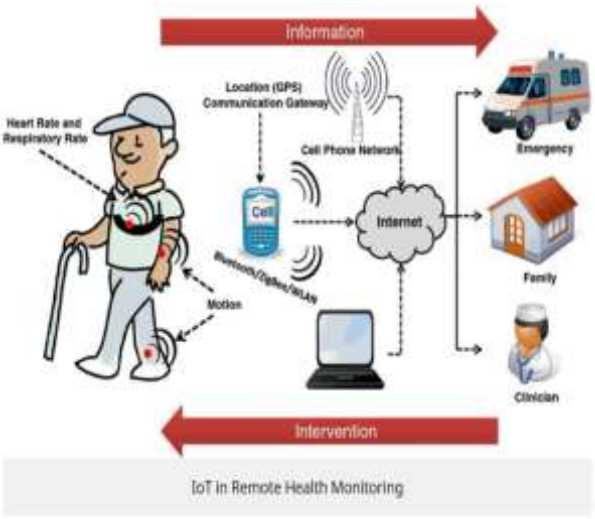

Fig. 1. IoT in Healthcare:Anushree Priyadarshin

In body area network a central node act as a center of the star topology with all sensors linked with it. In paper [11]author suggests BLE communicate up to 150m in an open area, sufficient for healthcare system WBAN . It also has a low latency rate of 3ms and in paper [12] its provide high data rate of 1 Mbps. In [4] Carolina Varon et al. "presents a methodology for the automatic detection of sleep apnea from single-lead ECG. Methods: It uses two novel features derived from the ECG, and two well-known features in heart rate variability analysis, namely the standard deviation and the serial correlation coefficients of the RR interval time series. The first novel feature uses the principal components of the QRS complexes, and it describes changes in their morphology caused by an increased sympathetic activity during apnea. The second novel feature extracts the information shared between respiration and heart rate using orthogonal subspace projections. Respiratory information is derived from the ECG by means of three state-of-the-art algorithms, which are implemented and compared here. All features are used as input to a least-squares support vector machines classifier, using an RBF kernel. In total, 80 ECG recordings were included in the study. Results: Accuracies of about 85% are achieved on a minute-by-minute basis, for two independent datasets including both hypopneas and apneas together. Separation between apnea and normal recordings is achieved with 100% accuracy. In addition to apnea classification, the proposed methodology determines the contamination level of each ECG minute. Conclusion: The performances achieved are comparable with those reported in the literature for fully automated algorithms. Significance: These results indicate that the use of only ECG sensors can achieve good accuracies in the detection of sleep apnea. Moreover, the contamination level of each ECG segment can be used to automatically detect artifacts, and to highlight segments that require further visual inspection"[4].

In [13], for long distance communication author suggested that Health IoT over other two standards of low power network- narrow band (LPN.NB-IoT) can operate in LTE bands . Due to high receiver sensitivity it covers the area up to 15 km with high speed explained in paper [14]. 3rd generation partnership project(3GPP) S3 security scheme is used by NB-IoT including other security features like authentication, securing user and device identity and data integrity proposed in paper [15]. The author Mainetti, L.; Patrono, L.; Vilei, A. discussed the Evolution of wireless sensor networks towards the Internet of Things and A survey. In Proceedings of the Soft COM International Conference on Software, Telecommunications and Computer Networks.

In [16] authors P. Castillejo et al describe "Applications based on Wireless Sensor Networks for Internet of Things scenarios are on the rise. The multiple possibilities they offer have spread towards previously hard to imagine fields, like e-health or human physiological monitoring. An application has been developed for its usage in scenarios where data collection is applied to smart spaces, aiming at its usage in fire fighting and sports. This application has been tested in a gymnasium with real, non-simulated nodes and devices. A Graphic User Interface has been implemented to suggest a series of exercises to improve a sportsman/woman s condition, depending on the context and their profile. This system can be adapted to a wide variety of e-health applications with minimum changes, and the user will interact using different devices, like smart phones, smart watches and/or tablets" [16].

III. Body Sensor Network for Health Care

These days the use of wearable sensors, namely wireless for monitoring patient health. Wearable sensor nodes measure physiological conditions of patient. There are some recommended sensors like pulse sensor, respiratory sensor and sensor to measure body temperature which are primarily important to monitor the vital sign of any patient for determining their health conditions. The central node see figure2 preferably a smart phone which receives data from other sensor nodes will process the all collective information, may apply some decisions and forward to an external location which could be any wide area network base station like LPWAN.

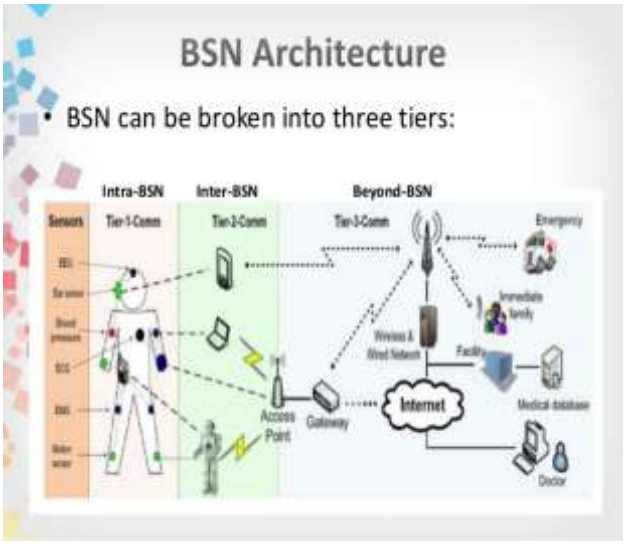

Fig. 2. Body Sensor Network: Thivyapriyaa Baskaran

A. Pulse Sensors

Most ordinarily read fundamental sign heartbeat is utilized to distinguish an extensive variety of crisis conditions, for example, heart failure, aspiratory embolisms and vasovagal syncope. Heartbeat can be perused from chest, wrist, ear cartilage, fingertip and more. Ear cartilage and fingertip readings provide high accuracy in measurement however are not much wearable. Chest worn is wearable yet wrist sensors are by and large thought to be most agreeable for long wearable framework.

It is viable to utilize PPG sensors for beat detecting. these have ceaselessly been turned out to be valuable for estimating more exact heartbeat rate as compare to other sensors like, ultrasonic and Radio Frequencies sensors .

LED operated PPG sensors are one of type which transmits light into the Artery and the amount of light which is not absorbed by the blood are receive by the photodiode. This amount of change in light is recorded and thus pulse rate can be examined. In [1], PPG sensors are

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used to measure pulse rate and blood oxygen in one small wrist-wearable sensor. The accuracy of pulse reading is affected by the motion of the person so, an accelerometer is used to check for movement. However, this device is not entirely suitable during high motion of individual as it does not record pulse and goes into a low power state. Improving the accuracy of pulse sensor during high movement such as when person is seizing or suffering cardiac issues during exercise would be taken care off. In [2] two different LED light intensities are used by PPG Sensor's to reduce the effect of motion. The use of photodiode to compare the amount of received light and improvement in signal quality is seen as effect of motion on PPG sensor are greatly reduced through this technique. The internet of things has applied in healthcare, from remote monitoring to smart sensors and medical device integration. The number of connected devices and the huge amount of data they collect can be transmitted to hospital IT as shown in Figure 3.

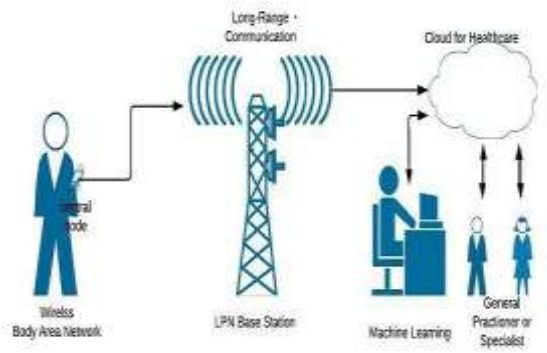

Fig. 3. General model for Health IoT [1]

B. Respiratory Rate for Sensors Data

Respiratory monitoring is useful for determining various conditions such as asthma attacks, apnea episodes, lung cancer hyperventilation due to panic attacks, obstruction of the airways, tuberculosis and more. The various research works has been done to developed a sensor for measuring respiratory rate due to its importance in various health conditions.

The thermistor based nasal sensor, as used in [3]. AS air exhaled is warmer than the room temperature. This sensor effectively uses t

he rise and fall in temperature to measure the respiratory rate. This technique works reasonably well but accuracy is again compromised by other temperature sources fluctuations and it is not comfortable to wear. ECG derived respiration (EDR) is used in [4] this method works reasonably well to detect respiratory rate but has certain drawbacks like this is not wearable for long time as ECG contacts would likely to cause irritation to the skin and ECG contacts are need to replaced regularly. In [5] uses a Microphone to detect respiratory rate. In this work a wheezing detection a common symptom in asthmatic patient is focused. But microphone is highly susceptible to any external noise and this limits its use in noisy environment and also not wearable for long time. A fiber optic sensor is an elastic substrate used in one study [6] was sensitive to measure vibration caused by respiration. In [7] a pressure type sensor was developed. Two parallel plate capacitors are used and during inhalation and exhalation, the plated moves apart and then closer allowing the measurement of respiratory rate. This method gives more accurate results as compared to nasal sensor and also comfortable to wear. Here, pressure sensor again highly sensitive to noise. Such as walking into wind.

A stretch sensor is commonly used for measuring respiratory rate was done in [8] a stretch sensor made from ferroelectric polymer transducer. When tensile force is applied it generated a charge. Thus, the measurement of changes in this charge enable us to find respiratory rate in [9] change in resistance was calculated to find respiratory rate. Resistance increases on applying the tensile force. This varying resistance causes the change in voltage, which can be further used to calculate a breathing rate. This sensor has also been limited by movement as it can cause sensor to sensitize with tensile force and in this way, sensor mistakes the movement of breathing. Hence, many different sensor types are there for measuring respiratory rate. However, in body area network the main factor to select the sensor type is wear ability. Therefore, stretch sensor is better choice.

C. Body Temperature Sensor

Body temperature is the third useful sign to measure the patient condition, it is mostly used to detect fevers, hypothermia, heatstroke and many more.

For measurement of body temperature generally thermistor- type sensors are mostly used a negative-temperature coefficient, which means resistance decreases on increasing the temperature of body, Positive-temperature-coefficient is may used in [10]. In all recent work thermistor is used measure a suitable range of temperature of human body, with acceptable amount of error.

TABLE 1. Different Sensor applications

Sensor Name	Technique used	Application
PPG Sensor	LED light intensities	Measure pulse rate and blood oxygen
Nasal Sensor EDR Sensor Fiber-optic Sensor Pressure-type Sensor Stretch Sensor	Thermistor ECG Signal Elastic Substrate Parallel plate capacitor Ferroelectric polymer transducer	Determing asthma attacks, apnea episodes, lung cancer hyperventilation, tuberculosis and more.
Body Temperature Sensor	Thermistor	Detect fever, hypothermia, heatstroke etc.

IV. Communication Standards for Sensors

In healthcare industry, short range communication is used in body area network to communicate sensors with the central node. To choose short-range communication standards in health care industry certain requirements are need to fulfill. The following , the effect on human health, security and latency. There should not be any adverse effect on human body as it may cause additional concern for patient health. Security of sensitive data of patient is equally important so that it could not be accessed by attacker. Finally, in healthcare applications low-latency is equally essential to maintain. So that system may call an ambulance on

emergencies. In such systems time delay cannot be compromised as it is a matter of life and death. There are many short-range communication standards, but commonly used in IoT are Bluetooth low energy (BLE) and ZigBee.

BLE is highly suitable for healthcare application. It is secure, covers high range, low latency rate and power consumption. BLE was developed by Bluetooth special interest group aimed to enable IoT, connecting devices to process such as smart phones [11]. BLE uses star topology which perfect for healthcare application. In body area network a central node act as a center of the star topology with all sensors linked with it. BLE communicate up to 150 m in an open area, sufficient for healthcare system WBAN [11]. It also has a low latency rate of 3ms and high data rate of 1Mbps [12]. For security features BLE uses 128-AES encryption to protect sensitive data from hackers.

Low-power Network (LPN) or a low-power wide-area network is a long-range communication standard suitable for IoT application. the range of LPN is longer than the traditional IoT communication types. LPN are designed to support short bust of data which has an advantage over 3G cellular network. As named low power network allows design for low-power devices, which ensures healthcare devices will operate for longer time. This reduces the risk of patient being offline. Therefore, LPN is highly suitable for healthcare applications, including monitoring of critical health of patient, receiving emergency calls and receiving updates continuously. based on mentioned advantages LPN is best for transmitting data from central node to the cloud for storage and processing.

The most useful standard for LPNs are Sigfox, LoRaWAN and NB-IoT. The new emerging standard Narrowband IoT influencing more to Health IoT over other two standards of LPN.NB-IoT can operate in LTE bands [13]. Due to high receiver sensitivity it covers the area up to 15 km with high speed [14]. 3GPP S3 security scheme is used by NB-IoT including other security features like authentication, securing user and device identity and data integrity [15]. Therefore NB- IoT is appropriate for healthcare purpose.

V. CLOUD FOR HEALTHCARE FOR SENSORS

Cloud technologies has achieving a greater benefit for maintaining, processing and analyzing of big data. In healthcare industry cloud technology basically provides three primary services software, Platform and Infrastructure Services. Software as a service enables healthcare providers to work with health data and perform another significant task. In healthcare, patient data and value of its vital sign need to be stored. Finally, Machine learning is applied to determine the patient's condition by applying machine learning algorithms.

VI. HEALTH IOT SYSTEM DESIGN SENSOR BASED

Communication System now, that we have studies most of the IoT technologies used in Health IoT, let us look at some of the design consideration for designing a seamless communication channel for Health IoT network.

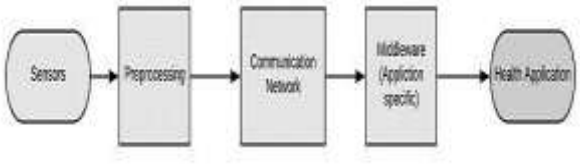

Fig. 4. Block Diagram of Health IoT [3]

The first considerations the design of sensors for BSN, which helps in interacting with physical environment, and they must have capability of storing and processing health monitoring data of patient intelligently at the edge of the network itself, called a preprocessing refer. Fig.ure4. The choice of PPG sensor is best for pulse sensing, stretch sensor for measuring respiratory rate and thermistor-based sensor for measuring body temperature for healthcare industry.

The next important design issue is choosing a right communication network in mainly, terms of Power requirement by IoT nodes. It has concluded that use of LPN is suitable choice for designing Health IoT communication network.it is therefore BLE for short range communication and NB-IOT is suitable to use for healthcare application

The cross layer communication on heterogeneous devices requires middleware platform

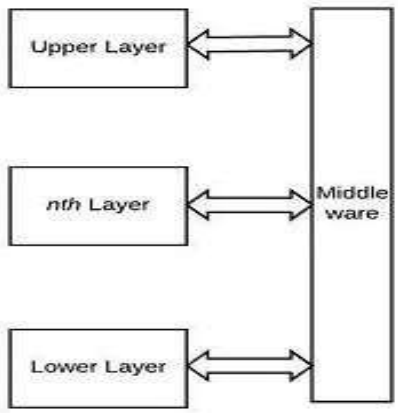

Fig. 5. Conceptual illustration of Centralized

Middleware Service oriented IoT middleware used for Health IoT are based on Service Oriented Architecture (SOA) which provides specific services like providing patient health data to the doctors for reference and recommendations as shown in figure 5. HYDRA is a one type of service oriented middleware.it consists of many software components for application of healthcare it is very useful to handle many task solution see figure. Ubiquitous computing is the necessary objective to connect healthcare system with Internet of things. Interoperability of such devices needs standardization of heterogeneous system. Middleware act as sandwich software between devices and applications to provide specific service to developers so that they focus more on quality of service.

Hence, Middleware provides an Application Programming Interface (API) for data communication and management, for machine learning, security and privacy.

Health IoT middleware faces many challenges like Interoperability, scalability, big data analytics, context detection, security and privacy.

In [10] Hydra middleware provides interoperable access to data information and knowledge across heterogeneous supported both new and existing wired or wireless network which operated with limited resources like computing power, energy and memory usage which would be beneficial for real-time usage in Health IoT. It is very effective for health application by providing secure, trust worthy and fault tolerance which all are the very key component of effective health monitoring and providing appropriate solution.

Finally, comes a health application layer, this includes creating an electronic health record (EHR) and transmit warning in case any abnormal ties are found. machine learning algorithms are may useful to fix minor problems and suggest a prescription to the patient.

VII. Conclusion and Future work

The IoT based seamless communication channel for healthcare system is designed in order to help general practitioner and doctors to monitor patient critical health conditions using the sensor nodes. The latest information about the condition of patient like blood pressure, pulse rate can be monitored continuously by health care team and relatives using the sensor network. It eliminates distance barrier by giving access to distant rural communities also .

Though 5G networks providing latest technologies and faster data access but the rapid consumption of wireless data pushes the health industry to meet demand .Hence 5 G network accommodate many more users and devices by delivering high data rate and new data collection algorithm based on sensor networks .

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