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IoT based Sensor Fusion Algorithm for Online Smart Health Monitoring

A Vijayalakshmi, Ebenezer Abishek B, C Arul Stephen

Abstract*: Emerging Internet of Things technology plays the major role in modern healthcare not only for sensing but also in recording, communication and display results. The major role of an intensive care unit (ICU) is to improve patient health such as bringing about a change in the treatment or move the patient to a step-down unit etc. Monitoring also shows the extent of observance with a formulated standard of care. In ICU, care should be taken to monitor medical parameters, such as EEG, EMG, BP etc , continuously. In recent health care applications such as real time human health condition monitoring, patient information management etc, IoT technology brings convenience of general practitioner and human, since it is applied in various medical areas, the Body Sensor Network (BSN) is one of the main technology of IoT based medical applications, where a tiny smart and lightweight wireless sensor nodes are used for monitoring patient's health condition. Hence, this paper proposes BSN integrated with IoT based sensor fusion algorithm to save human life those who are in critical condition. Sensor fusion algorithm is used to detect the criticality of the patient's health condition and IoT technology is used for communicating information. The testbed has been developed using Rasberry Pi controller, EMG sensor,, BP sensor etc and tested. The tested results also analyzed.

Keywords*: Body Sensor Networks, Healthcare Monitoring, Rasperrypi Processor, Sensors.

I. INTRODUCTION

Nowadays, in emerging field of modern medical environment [2] such as real-time health monitoring of the patient, maintenance of health condition information as data base, and data base of patient's information etc., the IoT technologies bring convenience for Medical practitioners' and patients. The body area sensor network (BASN) technology integrated with IoT help medical field in various applications. In IoT based BSN, human body is monitored by deploying collection of small battery-powered and lightweight wireless sensor nodes. The wireless technology gives a splendid support to the various real time applications like industrial monitoring, structural monitoring, environment monitoring, patient health monitoring etc.

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***** Correspondence Author
A Vijayalakshmi*, Associate Professor in the department of Electronics and Communication Engineering, Vels Institute of Science, Technology and Advanced Studies, Chennai. India.
Ebenezer Abishek B, Assistant Professor in the department of Electronics and Communication Engineering, Vels Institute of Science, Technology & Advanced Studies, Chennai
C Arul Stephen, Assistant Professor in the department of Electronics and Communication Engineering, Vels Institute of Science, Technology & Advanced Studies, Chennai

These have been done by enabling instant remote based control and monitoring environment. Sensors are tiny devices that can give the status of the monitored device to the outside world.

Nowadays, wireless sensor networks integrated with internet is used in real time applications which will give fast and reliable communication. In medical application, it will play a promising role. The body area network field with internet could allow less expensive real-time updates of continuous health monitoring. Computer-assisted rehabilitation or early detection of medical conditions could be possible with wearable wireless body area network [15] which includes integration of different intelligent physiological sensors.

Fig. 1 shows that, the human body is deployed with different sensors which sense the health information and issues of the human and the sensed information is communicated to the different recipients such as physicians, relatives', central monitoring station etc., through internet. The wireless technology gives a splendid support to the various real time applications like industrial monitoring, structural monitoring, environment monitoring, patient health monitoring etc. These have been done by enabling instant remote based control and monitoring environment [21]. Sensors are tiny devices that can give the status of the monitored device to the outside world. Nowadays, wireless sensor networks integrated with internet is used in real time applications which will give fast and reliable communication. In medical application, IoT is playing a promising role In recent healthcare applications [21], IoT-based body sensor network (BSN) technology [11] is used for monitoring health condition of the human being. Health condition of human body and surrounding environment is monitored and sensed using a group of light weight, less powered wireless sensor nodes and communicated through internet. These can also be used in hostile environment, gathering of life critical information etc. Integration of IoT and WSN provides accurate reliable and timely information to avoid unexpected problems in health care system. In this article, several wireless health- monitoring system using BSN is discussed first and then introduction about monitoring of human body is explained in section I. The rest of the article is discussed as follows. The use of IoT in medical applications is presented in Section II and different type of sensors used in medical field is presented in Section III. Literature survey is discussed in Section IV. Integration of Body Sensor Network with IoT is explained in V. Prototype model and relevant discussions on outcomes are presented in Section VI and VII. Finally, Section VIII concluded the work.

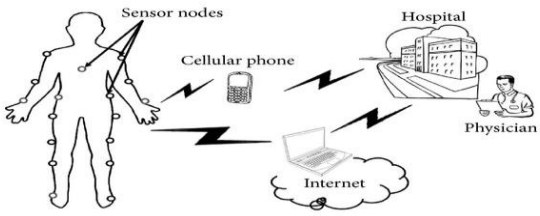

Fig. 1.Body Area Sensor Networks with IoT

II. INTERNET OF THINGS

The internet of things, or IoT [1]–[5], is a communication technology which is used to transfer information or data over a communication network. It is an organized system of computing devices, mechanical and digital devices, objects, living or non-living things that are capable of transferring information without involving human-to-human or human-to-machine interaction. This means that it always gives the connection with anyone, anything, anytime, anyplace, any service, and any network. It also utilizes the extended returns of today's internet infrastructure for various smart applications like such as smart traffic congestion control, smart city, waste management, industrial systems control, smart security, structural health and smart health care applications. Smart medical human physical condition care is one of the most significant and attractive application areas for the IoT [10].

Internet of Things or IoT [14] is the promising technology which integrates human, method and technique with computational and connectable devices and sensors. This integrated technology enables online and remote monitoring, status information, information handling and valuation. The Internet of Things (IoT) is a system of interrelated computing devices, mechanical and electronic/digital machines etc., that are provided with selected identifiers and ability to communicates data over a network without interfering of human-to-human or human-to-computer interaction. IoT technologies are implemented in various fields like industries, precision agriculture, structural management, healthcare, power and transportation, etc.

III. SENSORS

A sensor is a device whose purpose is to sensor detect events or changes in the environment and transmits the information to the collective node or sink node which then activate the actuators (output devices) to provide the corresponding output. The sensed physical data sensed by the sensor is converted into digital data that a computer can understand using Analog to Digital converter.Fig. 2 shows Electromyography (EMG) is a diagnostic process that analyzes human health condition based muscles and nerve cells monitoring. The nerve cells transmit electrical signals whenever muscles contact or relax. These muscles are activated electrically and electrical potential generated by these muscles are recorded and analyzed. EMG is used for recording and analyzing these electrical signals which in turn used to detect the abnormal condition of the human.

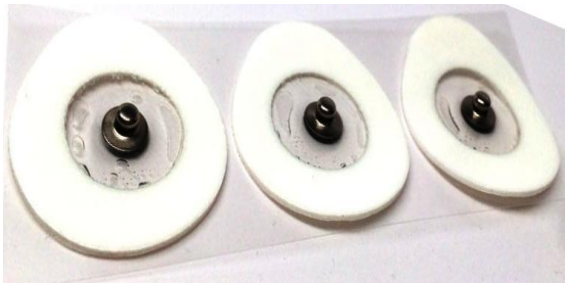

Fig. 2.EMG Sensor

Fig. 3.BP Sensor

Blood pressure (BP) is one of the important measuring constraints of human health condition monitoring. It indicates pressure of the circulating blood on the walls of blood vessels of human being. The arterial pressure in the blood circulation is measured using blood pressure sensor. This is expressed in terms of the systolic or diastolic. Systolic means maximum or high during one heart beat pressure and diastolic means minimum or low in between two heart beats pressure. Blood pressure is measured in terms of millimetres of mercury -mmHg. Normal blood pressure in an adult is approximately 120 mmHg /80 mmHg.

IV. LITERATURE SURVEY

The recent advancement of embedded technologies nowadays called as Internet of Things (IoT) [6]. IoT allows human and machines in the real world as well as virtual environments to interact with each other than to create smart environments, such as real smart transport systems, smart cities, smart health and so on. The distributed IoT system architecture [6] and authentication scheme provides secured data transmission.

The main issues in modern medical applications discussed in [8]. Wireless Sensor Networks are used in modern and smart medical applications which deals with person health monitoring issues and implementation of smart system that includes smart medical sensors, low-power integrated circuits etc. Wireless medical Communications using IEEE 802.15.4 have been used to enable low-cost medical sensors, small, lightweight, and intelligent physiological sensor nodes. In recent development, healthcare medical applications are considered as an important field in for wireless sensor networks. The patient's health condition monitoring using wireless network is expressed as wireless medical sensor networks (WMSNs) [7].

Some medical applications require secured transmission of the patient's health condition. Security and privacy [7] issues are major challenges in wireless medical healthcare application.

Transmission of medical information with confidentiality in wireless sensor network was discussed by [9]. In a sensor network scenario, performance metric such as packet rate, packet size, packet routing can interpret information about the sensors deployed, nature of event, severity of the event and frequency of events monitored [16], network topology and location identification etc. Constant and continuous monitoring of the patient's health condition parameters in health care medical system discussed in [12]. The deployed sensors on patient's body form a wireless body sensor network (WBSN) and they can able to sense various parameter like ECG rate, BP value and so on and the abnormality is communicated through router node.

The survey of Body Sensor Network (BSN) is addressed in [13]. Body Sensor Network plays promising role in medical environment, social welfare and sports etc. Recent wireless healthcare research development has aimed to monitor the patient's health at various levels such as Continuous patient's health monitoring, In-ambulatory, In-clinical monitoring and Athletic health monitoring in open environment

CodeBlue project developed by [16] was the integration of a number of bio-sensors which are deployed on the human body. The human body conditions are sensed from these sensors and transmitted to the corresponding authorized devices. Any expert who needs this medical information could possible to get from anyplace and anytime using their own handheld device. These sensors data are wirelessly communicated to the destination device such as PDAs, laptops, personal computer etc., for further analysis. CodeBlue is simple and easy project in which a doctor or medical professionalist can make query about patient's health and can access the details thru Personal devices.

Alarm-Net is heterogeneous network architecture [18]. It was developed with body sensor networks and environmental sensor networks for human being who requires assistant for living in home or hospice environment. Alarm-Net is also used to sense the health condition of the human and communicate the sensed data using single hop or multi-hop communication. In Alarm-Net, stationary nodes were used for single-hop communication and Gateway node for multi-hop communication.

Median-Patient monitoring during disaster events, comprises of multiple physiological monitors to collect health information (blood oxygenation, pulse rate etc). The author acknowledged the need for encryption but did not specify the scheme to ensure confidentiality. The industrial health monitoring of the equipment using code algorithm was discussed in [20]. Automatic patient Healthcare monitoring was discussed in [17]. It enables wireless medical sensor network for automation of human health monitoring without disturbing patient comfort. In addition to wireless communication of health condition, security is the major issues [19].

V.BODY SENSOR NETWORK WITH IOT

The proposed work developed online and remote patient's health monitoring using body sensor network. The prototype model has been developed using Raspberry pi microcontroller. The Raspberry Pi is a series of small single-board computers which is embedded with Broadcom BCM2837 SoC chip, 1.2 GHZ quad-core ARM Cortex, 1 GB SDRAM, IEEE 802.11n Wireless LAN and Bluetooth Version 4.0. The patient's body is deployed with Body Area Sensor Network (BASN) which comprises of Blood pressure sensor, EMG sensor and Temperature sensor. Human body is deployed with various health condition sensors to monitor the health condition of the human without disturbing the daily routine of the patient. The sensed health related physiological parameters are communicated to medical practitioner, patient's family member etc through server using Internet of Things.

Fig.4 illustrates the proposed work using Body sensor network with Internet of Things. Blood pressure of human body is measured using blood pressure sensor and Electrical activity of muscles at rest and during contraction is measured using EMG sensor. Criticality of the human health is detected using Threshold level of each sensor. All the patients database is stored in the cloud using Raspberry Pi3 and 'ThingSpeak'. ThingSpeak is used for various applications such as sensor data logging applications, moving vehicles location tracking applications etc. This work has developed for patient health condition monitoring using EMG and Pressure sensor. Health monitoring sensors are deployed on the body of patient. These sensor senses the corresponding body condition. The sensed physical data of EMG and pressure are analyzed using Raspberry pi processor. The flow diagram of the health monitoring process is shown in Fig. 5. The patient body condition is monitored using various sensor nodes which are deployed on the patient's body. These sensors continuously monitor the health condition, and check with the maximum tolerable limit. Whenever sensed value of EMG and BP sensor exceeds the maximum tolerable limit, the abnormality is detected. Once the abnormality is detected, information is sent to the patient's family or patient's physicians or Emergency care. The recipients are selected based on the criticality of the patient's health condition. The communication has been established using Raspberry Pi3 processor and Wi-Fi module. The health condition is communicated to the corresponding responder through way2sms web link. This web link connection is established using Wi-Fi module through internet and the information reaches the responder as early as possible. Otherwise the process of monitoring of the patient's health continues.

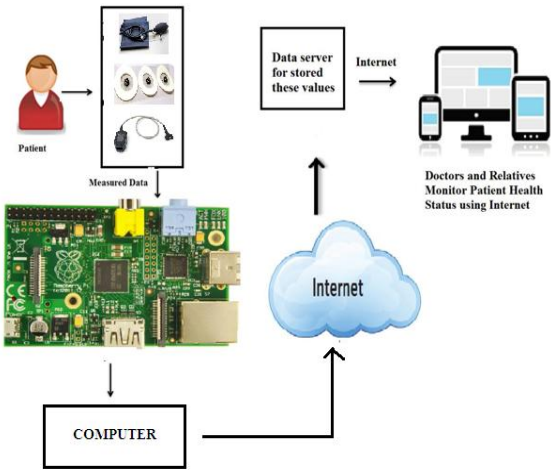

Fig. 4.Body Sensor Network with IoT

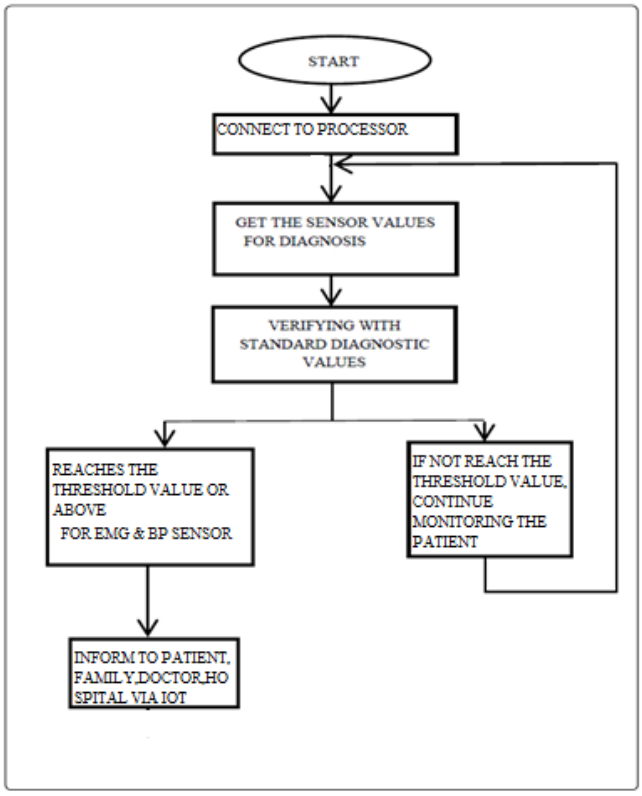

Fig. 5.Flow Diagram Of The Process

Fig. 6 shows the algorithm for the health monitoring of the patient. It explains that N number of sensors could be used but for the prototype this work uses two sensors such as EMG and BP sensor. These sensors monitor the human health condition continuously. Then the degree of criticality (DOC) has been identified. If there is any abnormal condition rise through these sensors, the sensed values are compared with the DOC. Depending on the condition of the sensed values, the criticality condition of the patient has identified. Based on the nature of the health condition the information is communicated to the care provider. At the same time the data base of the patient health condition is maintained in the cloud.

Algorithm 1 : Sensor Fusion Algorithm to detect criticality

Input: N number of health sensors, predefined threshold value for each sensor.

Output: health condition of the patient.

Step 1: BP and EEG Sensors sense blood pressure and muscles condition of the patient

Step 2: Read sensed physical data using Raspberry Pi processor

Step 3: Calculate Degree of criticality (DOC) using threshold value

Step 4: If (DOC value exceeds Thershold Range)
then
Patient_Condition = unsafe
Goto Step 7

Step 5: Else
Paitent_Condition = Safe

Step 6: Return Paitent_Condition

Step 7: Activate the Event criticality
Health_Condition = Critical

Step 8: Generate information signal to Responder

Step 9: Send Physical data to cloud for database management and analysis

Step 10: Exit

Fig. 6.Algorithm for Health Monitoring

Table 1 Sensor Fusion

EMG Sensor	BP Sensor	Output
Normal	Low	Informed to Doctor, Family Member
High	Normal	Informed to Doctor
Low	High	Informed to Family Member, Doctor
Low	Low	Informed to Patient, Doctor

VI. PROTOTYPE MODEL

B The hardware implementation of the proposed work has been done using Raspberry Pi processor. It is a small size ARM based Single Board Computer (SBC). Blood pressure sensor and EEG sensors are used to detect the sensed values. Python programming that supports multiple programming pattern including object-oriented programming, imperative and functional programming etc and ThingSpeak is used to store the information on cloud.

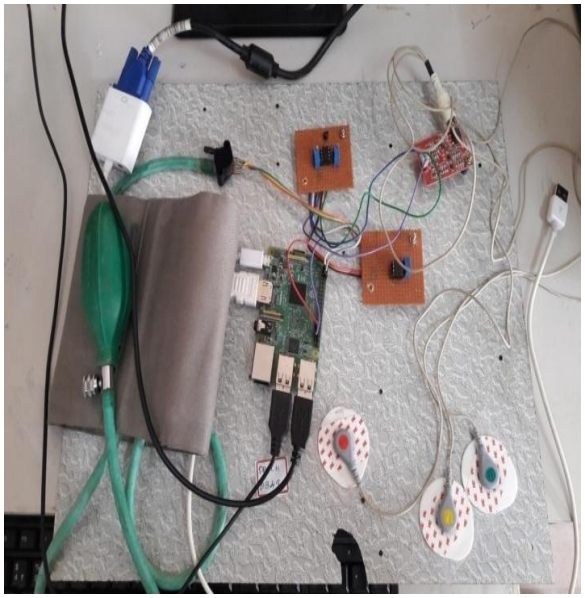

Fig. 7.Prototype Setup for Human Health Monitoring

The main features of Raspberry Pi 3 include:

- A 1.2GHz 64-bit quad-core ARMv8 CPU
- IEEE 802.11n Wireless LAN
- Bluetooth 4.1
- Bluetooth Low Energy (BLE)

Hardware implementations using Body Sensor Network with IoT proposed in this work is shown Fig. 7. It consists of Raspberry Pi Processor, an EMG sensor, a BP sensor and ADC which are connected to personal computer. The sensors are connected to the Raspberry Pi which has inbuilt Wi-Fi. These sensors are connected to the human body which senses the human condition, and then these sensed values are processed by Python software to detect the condition. Once any abnormality is detected then the information is communicated to the responsible person or takecarer depending on the criticality of the human body condition. The communication has done by using inbuilt Wi-Fi module of Raspberry Pi.

VII. PROTOTYPE OUTCOME

BFig. 8 shows the outcome of the EMG and BP sensors. This outcome shows High blood Pressure detection and EMG measure of the human body. The detected High BP is communicated to the concern responsible person such as family members, through Way2SMS using Wi-Fi module which is shown in Fig 9a. Similarly, the detect fall is identified and information is communication is shown in Fig 9b. More critical condition is detected using BP and EMG sensors, then the alert message is sent to the Doctor is shown in Fig. 10.

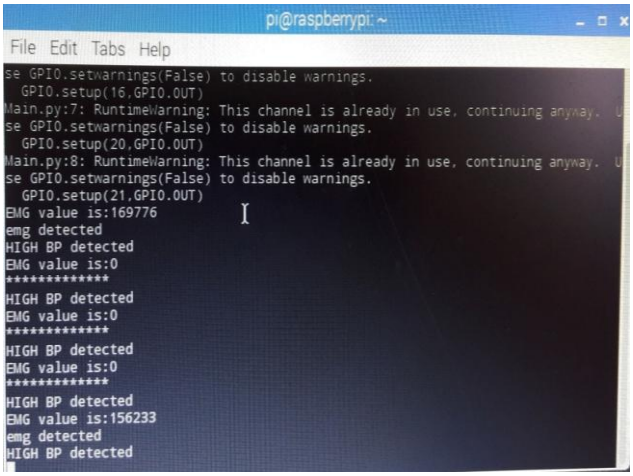

Fig. 8.Outcome of the EMG and BP Sensors

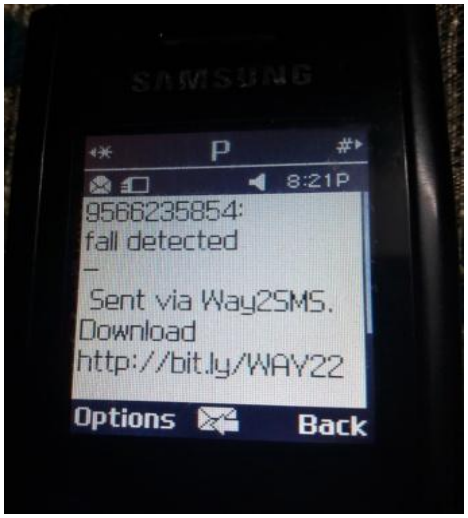

Fig. 9a. Fall Detected

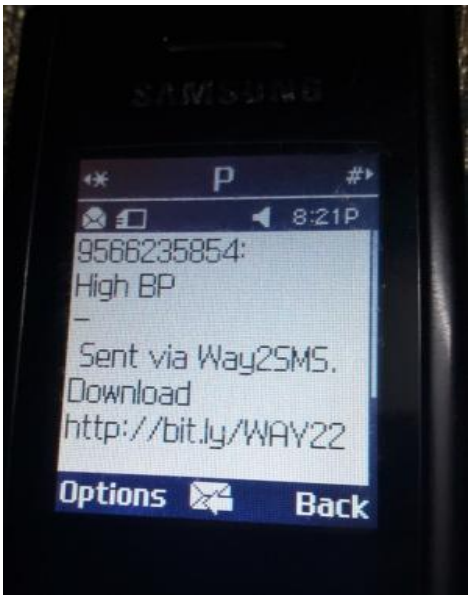

Fig 9b. High BP detected

Fig. 9.Alert message send via Way2SMS

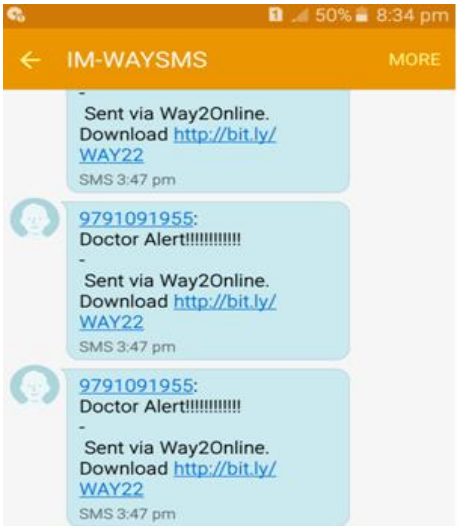

Fig. 10. Alert message send to Physician via Way2SMS

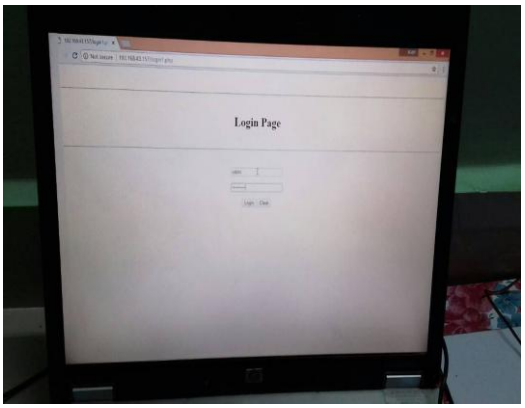

Fig. 11. Login page for Patient Health Monitoring

In this work IoT plays a major role. The communication messages are sent only after accessing the internet. Way2SMS web page is accessed through Wi-Fi module in Raspberry Pi. Fig. 11 and Fig. 12 show the Login page for the patient details and database for the patient health. The complete outcomeshow that the proposed work uses IoT for patient health monitoring system.

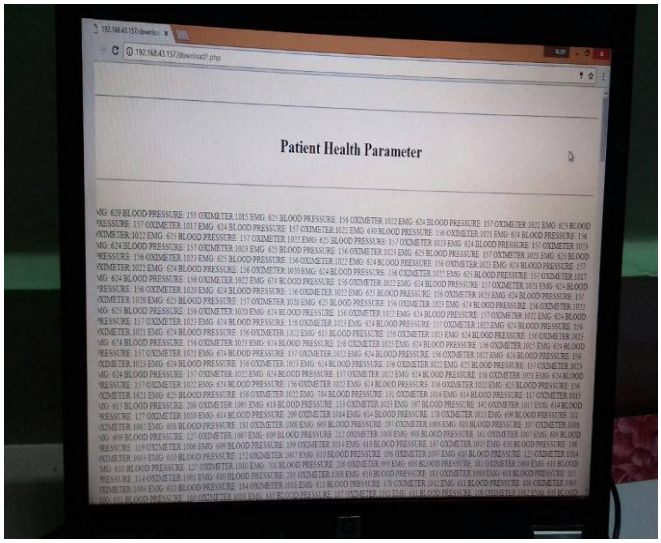

Fig. 12. Patient Health Monitoring Database

VIII. CONCLUSION AND FUTURE WORK

The sensor fusion algorithm based Remote health monitoring of intensive care patient monitoring has been developed using Internet of Things. The sensed health condition of the patient is detected using multisensory fusion algorithm and sensed values from different sensors are fused. This fused value is used to detect the criticality of the patient's health condition. The prototype model has been developed using Raspberry Pi, EMG, BP sensor with IoT. The proposed sensor fusion algorithm for healthcare monitoring reduces the transmission energy because instead of sending all the sensed values only critical health condition is communicated to the recipients. The speed of the information communication is also high because of IoT. The outcome of this work saves the ICU patient's survival. This work has been verified using prototype model which includes Raspberry Pi processor, Wi-Fi modules, blood pressure sensor and EMG sensor. In future, this proposed work is to be designed using cloud based system with high security algorithm.

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AUTHORS PROFILE

Vijayalakshmi Alagarsamy received her M.E. degree in Embedded System Technologies and Ph.D. degree from the Anna University, Chennai, India. She is currently working as an Associate Professor in the department of Electronics and Communication Engineering, Vels Institute of Science, Technology and Advanced Studies, Chennai. India. She has rich teaching and research experience of 19years. Five Ph.D. scholars are currently working under her guidance. Her areas of research interest include Wireless AdHoc and Sensor Network, Internet of Things, Data Science and embedded system design. She has published many journal and conference publications and acted as a reviewer for reputed journals such as IEEE Sensor journal, IJNS, IJCNC etc. She is a Life Member of MISTE.

Ebenezer Abishek. B received his B.E in Electronics and Communication Engineering from Anna University, M.E VLSI Design from Anna University, Chennai, in 2010 & 2012 respectively and currently pursuing his PhD in Vels Institute of Science, Technology & Advanced Studies. He is currently working as Assistant Professor in the department of Electronics and Communication Engineering, Vels Institute of Science, Technology & Advanced Studies, Chennai with experience of 6 years. He was a student member of IEEE Antennas & Propagation Society. He authored papers in reputed journals and international/national conferences. His area of interest includes Antennas, Wireless Communications, Internet of Things and VLSI Design. His ORCiD is 0000-0003-2908-7069.rofile which contains their education details, their publications, research work, membership, achievements, with photo that will be maximum 200-400 words.

Arul Stephen. C received his B.E in Electronics and Communication Engineering from Anna University, M.E Communication systems from Anna University, Chennai, in 2006 & 2010 respectively and currently pursuing his PhD in Vels Institute of Science, Technology & Advanced Studies. He is currently, working as an Assistant Professor in the department of Electronics and Communication Engineering, Vels Institute of Science, Technology & Advanced Studies, Chennai with experience of 9 years He authored papers in reputed journals and international/national conferences. His area of interest includes Wireless Communication and body sensor network. His ORCiD is 0000-0003-4950-9310rofile which contains their education details, their publications, research work, membership, achievements, with photo that will be maximum 200-400 words.