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Patient Health Monitoring in ICU using Internet of Things

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Abstract—In the modern era, IoT has massive application domains in civil and military environments. IoT shelters critical infrastructures such as, defense, healthcare, energy, transportation, and manufacturing under its umbrella. With the advancement of technology and the convergence of multiple technologies, the conception of the Internet of Things (IoT) has evolved. IoT enables various systems to communicate with each other without human involvement. Intensive Care Units (ICU) are a critical domain of medical wards in hospitals, where patients suffering from drastic and fatal injuries and illnesses are treated. Once the patients are in the out-of-danger state, they are either discharged or admitted to a normal ward for further treatment. ICU is divergent in its explicit environment as compared to other healthcare bailiwicks because it includes extraordinary dependency and provisions, relentless care, close observation to rescue a life from an existential threat. This paper is comprised of a comprehensive study and analysis of modern IoT based patient monitoring techniques with their design and security issues in ICU. In the light of analysis, particular challenges in this domain are discovered, and some disadvantages and shortcomings of topical technologies are identified. In the consideration of those findings, several suggestions are proposed to improve system efficiency and response.

Index Terms—Monitoring, ICU, Internet of Things, IoT, Real-time, health, Restful.

1 INTRODUCTION

Internet of things (IoT) is the comparatively modern realm of sensor networks having surprisingly enormous application domain by encompassing almost every domain of life. The organizational structure of IoT consists of interrelated computing devices or objects destined to sense, connect, correlate, collaborate, and exchange information. The idea behind IoT envisions connectivity to anything or everything which can be connected to the Internet and annihilation of Human-Human and Machine-Human interaction. The objects or things in terms of IoT can be any type such as animals, ovens, refrigerators, organs. IoT plays a great role in all types of application domains such as commercial, industry, and modern infrastructure and considered an enormous economic wave in upcoming years. A study

[1] forecasts that IoT devices will reach 20.8 billion by the year 2020. In commercial services, health care is the most critical for the sustainability of an exemplary community. A responsive, efficient, fast, and effective healthcare system is essential for a country, so IoT has a great appeal for healthcare systems [2].

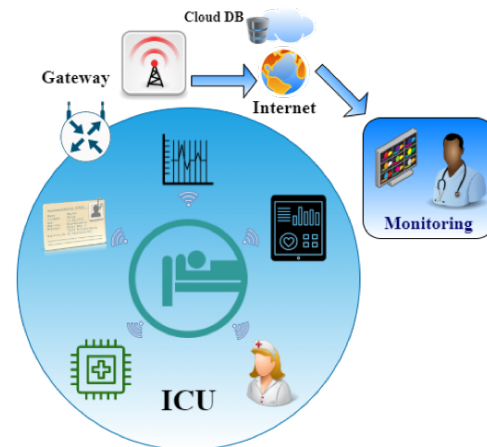


Fig. 1: Smart IoT Based Intensive Care Unit

In modern-day society, one of the most challenging tasks is to improve the effectiveness of underlying healthcare infrastructure and biomedical systems. The exponential growth in the human population and the increasing cost of medical expenses, human health has become one of the most vital issues for an individual's health. Traditional health care systems are manual and human dependent, so it is quite problematic to cope with increasing challenges and requirements of healthcare systems. IoT based health care systems are automating solutions that reduce human labor toward resource management and patient monitoring in an efficient and cost-effective manner [3], [4].

This paper is comprised of the study of various IoT based architectures and methodologies suggested for the healthcare domain in CCU, ICU and emergency situations.

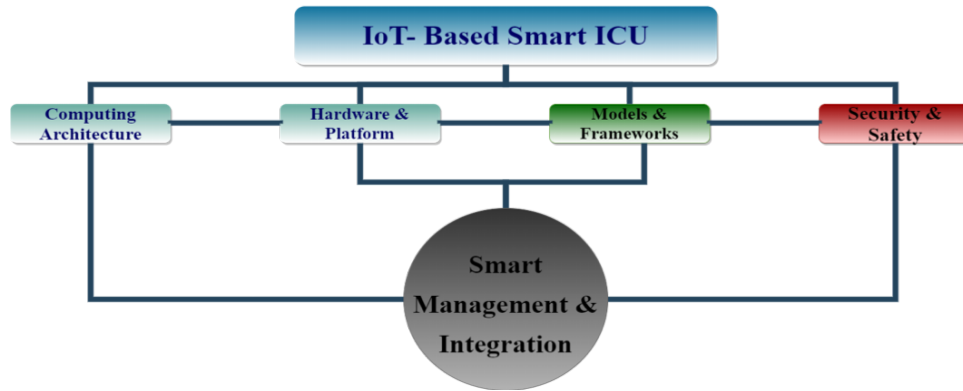


Fig. 2: Design Diagram For Smart IoT based ICU.

To provide effective and real-time monitoring in ICU, on wheels or CCU is an essential need in the health domain as the life of the patient depends on it. The precise information of the patient under the treatment with a minimum possible delay is always the preference of the physician. This is also very important for the life of a patient in a critical situation. Currently, nurses and other relevant medical staff continuously monitor these critical care units, but lack of high qualified and properly trained medical staff is a key issue for under developing countries like Pakistan and India.

One advantage of the smart healthcare system is the help to reduce the likelihood of human judgment error by a substantial margin. Specifically, the instantaneous IoT based system to monitor the patients in ICU will avoid human error and enable to monitor the patient with reduced staff size and effectively communicate the needed information [4], [5]. The monitors connected by the side of the hospital cot/bed of the patient will collect data about the patient's health in real-time. The data is uploaded to the cloud for additional processing using the intercommunication network system. This data is processed by an intelligent software agent procedure and alert is triggered out to a monitoring cell, that will deliver it to the concerned physician or medical staff. Figure-1 illustrates the general IoT-based health care ICU systems and Figure-2 depicts the general taxonomy of smart IoT based healthcare systems.

The structural representation of the paper is ordered as The recent concerned literature is briefly discussed in upcoming Section number II, and the next section consists of comparative analysis of the techniques and methodologies discussed in section II. Section IV of the paper focuses on the conclusion and future work.

2 LITERATURE REVIEW

In this section, various cutting-edge research efforts exerted in the IoT based healthcare technologies for public hospitals and medical institutions are discussed briefly. Remarkable research efforts have been dedicated since the last decade in this domain. Since health-care monitoring systems are a critical and significant issue for humans, notable research efforts considering different aspects of the system dedicated across the globe to proposing smart health solutions using multiple hardware and software techniques. Below are a few of the recent researches in the relevant field.

2.1 Adaptive Automotive Technique

An adaptive automated technique [1] based on running applications in physicians' tablets was suggested. In which physicians directly connect with the ICU server to check the patients' records. The proposed system provides seamless flow and immediate access to information across the hospital. For catering security issues, authors have proposed protected access through the physician's device's Mac IDs. Next research papers based on IoT technologies, where we will discuss enhanced and improved IoT based solutions. A brief study on the IoT based healthcare system also evaluated the suggested methodologies and concluded that web-based and cloud-based technologies are the best solutions for these systems [2].

2.2 Embedded Based Smart ICU-For Intelligent Patient Monitoring

Embedded Based Smart ICU-For Intelligent Patient Monitoring was suggested [3] for the improvement of critical care service standards in ICUs. They termed critical care staff as 'intensivists' and their office as 'War Room' and suggested facilitations such as remote access to those intensivists to communicate and guide staff. All the communication is made possible by video, continuous sound, and electronic reports in a persistent way. The patient information is also transferred in this way and this information includes the physiological status of the body for example blood pressure, ECG, Haemoglobin, and past records.

2.3 UPHM using Raspberry Pi 3B

A universal patient health monitoring infrastructure for smart healthcare was suggested [4] for remote monitoring and surveillance of patients in medical wards. IoT and Integrated cloud computing are the basis of this Universal Patient Health Monitoring (UPHM) system. In intensive cases, continuous monitoring, especially until the patient, is rescued from critical conditions. In a continuous state of monitoring, the sensor constantly gathers important data and submits it to the server. This System also integrated with on-demand monitoring, which is done after an authorized request generation from medical staff, physicians, or patients. This system also integrated with emergency alarming, and all the generated data is protected and maintained in the database. The data is retrieved when require

2.4 Patient Monitoring System Using Raspberry PI

Patient Monitoring System Using a Raspberry PI was introduced [5] to overcome less efficiency and real-time parameters in manual systems. The constant and continuous monitoring is essential for a modern healthcare system. This system helps to measure and monitor various health parameters continuously and calculated results are represented using Raspberry Pi. The sensed parameters are set to a threshold if this threshold crossed, an alarm is triggered and an emergency alert is sent to physicians.

In a combined sense we may state that Smart ICU [3], [4], [5] suggested a system where patient's health statistics such as body temperature, pulse rate, blood pressure, and HRV can be monitored remotely by the medical specialist. Medical Specialist can not only instruct the patient care staff remotely to take necessary measures, but also can communicate with the patient directly. Smart ICU's proposed solution is composed of Raspberry Pi 3 chip that comes with a more powerful Processor along with LAN, Bluetooth, and improved Power Supply. An LM35 Temperature Sensor is added to sense the temperature accurately. The pulse and heart rate of the patient is measured by MAX30100. A Raspberry Pi Camera is also attached to live telecast the video stream. The data acquired from the sensors devoted to the patient can be uploaded to a central server that can be accessed and retrieved by the Physician or medical staff anywhere in the world. The IoT Based Advanced Universal Patient Health Observation System Using Raspberry Pi 3B [4] also supports on-demand monitoring where patients' records are maintained in the database and system generates a trigger in case of emergency. Additionally, the methodology added a mobile App for regular monitoring patients records in [5].

2.5 Chronic Health Monitoring System Using IoT

A smart Chronic Health Patient Monitoring System Using IoT was proposed, in which the prototype of a system is presented to monitor the long-time illness and suffering of patients using pulse, flux and temperature sensors [6]. The collected readings from these sensors are sent to a remote server with the help of raspberry pi connected to each sensor. A web portal has also developed for medical staff to monitor the health of patients remotely in a graphical format, where a physician can prescribe to a patient based on his health. In an emergency situation, an alert is triggered to the blood bank which in return can make arrangements for blood to save the patient timely.

2.6 Remote Heart Rate Monitoring System Using IoT

Similarly, a remote heart monitoring system was proposed [7], in which Arduino UNO gathers the readings from the heart rate sensor which in turn is connected to Raspberry Pi which directs the readings to the cloud. ThingsSpeak is used for cloud services where patient heart rate can be visualized by a practitioner or physician which can prescribe to the patient based on heart rate readings.

2.7 Fog Computing-Based Health System

A stimulating approach [8] for storing and processing sensor data was proposed which is based on a fog computing-based health system. In which, an MF-R (Meta-Fog Redirect) architecture is divided into three modules i.e. data collection and storage in big data format. The patient's health is monitored continuously with the help of sensors. The fog computing nodes act as a gateway to send readings to the Amazon cloud. The data received at the cloud is refined and processed into a big data format using Apache Pig. The GC (Group Categorization) architecture is proposed for analyzing the data. The analyzed data is categorized based on normal, critical and sensitive patient information. The results of this analysis are accessed by physicians with the application, so further action can be taken upon it.



Fig. 3: Advantages of Smart IoT-Based Healthcare [9]

2.8 Cloud-assisted Industrial Internet of Things (IIoT)

An interesting framework named "Health IoT-enabled monitoring" was proposed for healthcare, where ECG readings and further health care sensors readings are sent over the cloud where physicians can access the data remotely [10]. To reduce errors in clinical readings or avoid hacked identity, techniques like signal enhancing, adding watermarks and analytical tasks have been used. Multiple experiments and simulations have been performed from the data collected by the sensors to evaluate the results.

2.9 Advanced IoT based Combined Remote Health Monitoring

A health monitoring system with domestic automation and alarm was developed [11], which collects various readings such as the respiration rate, heartbeat rate, body temperature, blood pressure, body movement, and several levels of saline readings from all the sensors. The collected data from those sensors is then transferred to the cloud. An integrated web portal is designed to provide visualization of the patients' health data to medical staff. The main advantage of this system is the enhancement to trigger an alert to send a prescription to the patient in an efficient and fast way. Another important feature of this technique is the amendment of an information system which automatically updates patients' family in particular conditions, such as if any of the health reading parameters approaches a threshold. In this case, the necessary quick actions are taken down to tackle a patient's health and recovery.

2.10 Fog Assisted-IoT Enabled Patient Health Monitoring in Smart Homes

Another Fog assisted-IoT [12] enabled patient health monitoring system model was proposed. The model was based on layered architecture for smart monitoring of patient health, which is based on fog nodes at the edge of the network. The role of the first layer is to collect data from all the sensors, and the role of the second layer is to check if the patient is new and to register it to the system by getting information about the patient's personal health. Then the system creates a unique ID for the patient at the cloud. The patient's data is deposited to the fog nodes in the second layer. The Bayesian belief network model is trained to classify the patient's health status. The sensor readings data is compared by the ones provided by physicians and the output of the Bayesian belief network is passed onto the next layer to extract unique features that are used to classify the degree of impact score. The next Information mining layer is used to extract real-time important data from fog data services. The time-dependent patterns are extracted using temporal mining. The data is stored at the cloud layer and processing of large datasets is done using the Map-Reduce technique. Events are triggered based on abnormal health after analysis of the data and notification are sent to the relevant physicians. The system is validated based on data of around 67 patients for a period of 30 days. Patients monitoring in ICU requires high availability of real-time patients' data. The network availability is a critical factor to transmit this data to the key stakeholders (Physicians, Medical Staff, and family members, etc.). Because in the absence of network availability, the patients' data fails to transmit and may result in a health disaster of the patient.

2.11 Smart Internet of Things Device

A Continuous Smart Monitoring System [13] using MPM and URT sensor to transmit the Patient's various readings ECG, Blood Pressure, Heart Rate and Pulse Rate to the Android device of the physician if the device is available in the local network. In the case of the physician's device is out of bounds of the local network, the data is transmitted to the device via the cloud to ensure the high availability of the patient's data. A typical to identify an abnormality in the data by declaring a threshold value and comparing the real-time data to that value.

2.12 Real-Time Patient Monitoring System based on Internet of Things

Real-Time Patient Monitoring System based on the IoT [14] was suggested as a way to predict an abnormality by defining a mathematical relationship among various bio-parameters.

2.13 A Study of Developing Security Requirements for the IoT

The mathematical equations for computing weight of bio-parameters should be precise and clear because Security is an important aspect to consider while interacting with IoT devices. A Study to Develop Security Requirements for the IoT [15] found that more than 90% of devices are a

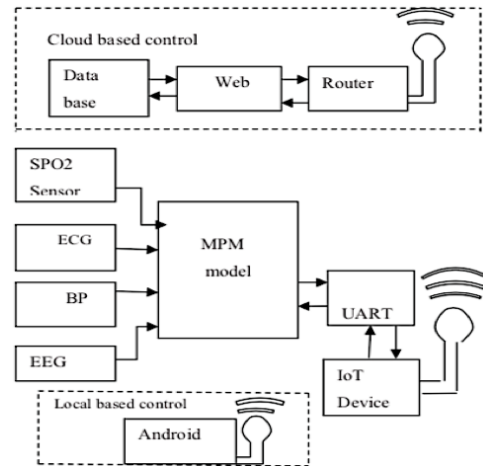


Fig. 4: Local and Cloud-based Module Architecture for Continuous Monitoring System using MPM and UART [13]

security risk in the IoT environment, it is more critical in the health care department where network security is equally important to data security, inaccurate data may cause death.

2.14 IoT Based Body Sensor Networks

Body Sensor Networks (BSN) based smart IoT Systems [16], [17] suggested to efficiently monitor patients. In BSN architecture local processing unit (LPU) is responsible for data collection from Bio-sensors. LPU is a portable device that may interact with physicians, family members or emergency healthcare centers in case of any abnormality. Abnormality is detected by comparing the value from the sensor with the threshold value defined for each sensor. When the value from the sensor exceeds or recedes the threshold value, an abnormality warning is raised. The Authentication protocols for network security and offset codebook (OCB-AES) encryption scheme used to secure data [16]. Extremely Secured IoT Based Healthcare System for Aged Persons using BSN suggested an Ethernet-based system where Bio-sensor monitors through a mobile application [17]. An alert message is generated in the form of a buzzer or LED.

2.15 Physiological Sensor Measurements in Wearable Medical Systems

Physiological Sensor Measurements in Wearable Medical Systems [18] identified the methods to perform data manipulation attacks on IoT bio-sensors and also suggest ways to countermeasure those attacks. The claim is verified by introducing noise in the network that was connected to the ECG sensor. This resulted in ECG data being manipulated and altered before reaching its destination. They then proposed to use the Principal Component Analysis (PCA) to identify the alterations in data. And their proposed system was able to identify the falsifications in ECG data with an accuracy of 98% in just 3 seconds.

2.16 Risks of Adding the Internet of Things to Healthcare Networks

Ransom ware is an emerging security threat that is responsible for affecting and stealing personal data from millions of

TABLE 1: Comparative Analysis of Smart Healthcare systems

IOT Systems	SC ¹	SE ²	TP ³	CS ⁴	I ⁵	E ⁶	SA ⁷	WP ⁸	SP ⁹	RA ¹⁰	RT ¹¹	DA ¹²	BD ¹³	VF ¹⁴	BP ¹⁵	ECG ¹⁶	A ¹⁷	R ¹⁸	D ¹⁹
ESIFIPM [3]	Y	L	Y	N	Y	N	N	Y	H	Y	Y	Y	N	Y	Y	Y	Y	Y	N
UPH [4]	Y	L	N	Y	Y	N	N	Y	H	Y	Y	Y	N	N	Y	Y	Y	Y	Y
APHMRP [5]	Y	L	Y	N	Y	N	Y	N	M	Y	Y	Y	N	N	Y	Y	Y	Y	Y
CHPMS [6]	Y	L	N	Y	Y	N	N	Y	H	Y	Y	Y	N	N	N	N	Y	Y	Y
ReHRMS [7]	Y	L	Y	N	Y	N	N	N	M	Y	Y	Y	N	N	N	N	Y	Y	N
MFR&GC [8]	Y	H	N	Y	Y	Y	N	Y	H	Y	Y	Y	Y	N	Y	N	Y	Y	Y
CAIIoT [10]	Y	H	N	Y	Y	N	N	N	H	Y	Y	Y	Y	N	N	Y	Y	Y	Y
CRHM&AS [11]	Y	M	N	Y	Y	N	N	Y	H	Y	Y	Y	N	N	Y	Y	Y	Y	Y
FSRPM [12]	Y	M	N	Y	Y	Y	N	N	H	Y	Y	Y	N	N	Y	Y	Y	Y	Y
CMSA [13]	Y	M	N	Y	Y	N	Y	Y	H	Y	Y	Y	N	N	Y	Y	Y	Y	Y
RPTM [14]	Y	M	N	Y	Y	N	Y	Y	H	Y	Y	Y	N	Y	Y	Y	Y	Y	Y
BSN-Care [17]	Y	H	N	Y	Y	N	Y	Y	H	Y	Y	Y	N	N	Y	N	Y	Y	Y
DDM-Attacks [18]	Y	H	N	N	Y	N	N	Y	M	Y	Y	N	N	N	N	Y	Y	Y	Y
FMRA [19]	N	L	N	Y	Y	N	N	N	H	Y	Y	Y	Y	N	N	N	Y	Y	Y
IOTBHMS [20]	Y	M	Y	Y	N	N	N	Y	M	Y	Y	Y	N	N	Y	Y	Y	Y	Y
SPICU [21]	Y	L	Y	N	N	N	N	N	M	Y	Y	Y	N	Y	Y	Y	Y	Y	Y
RTMLM [22]	Y	L	Y	Y	N	Y	N	Y	M	Y	Y	Y	N	N	Y	Y	Y	Y	Y
RPMS [23]	Y	L	Y	Y	N	N	N	Y	H	Y	Y	Y	N	N	N	N	Y	Y	Y

SC- Scalability
E- Edge Computing
RA- Restful Architecture
BP- Blood Pressure

SE- Security
SA- Smartphone APP
RT- Real Time
ECG- Electrocardiography

TP- Third Party Server
WP- Web Portal
DA- Data Analytics
A- Availability

CS- Cloud Server
SP- System Performance
BD- Big Data
R- Remote

I- Interoperable
RA- Restful
VF- Video Feed
D- Database

devices across the globe. Lately, Health Data has become a key target of cybercriminals due to its private and sensitive nature. IoT devices in Healthcare systems have some security risks [24]. It suggests that IoT devices are potentially vulnerable to various cybersecurity attacks such as Ransomware, Malware, and White Hat Devices Hacks. Therefore, it is advised to apply proper security measures to protect the system and the network from such kinds of threats that may result in a security breach or a disaster. A unified modelling-based approach for body sensing health monitoring IoT system [19] proposed, which is consisted of six domains integrating to function the entire system. The research included a case study of sleep quality monitoring service to prove the information fusion reference architecture under IoT monitoring.

2.17 Personal Healthcare IoT System model using Raspberry Pi 3

Cloud Computing with the internet of things boosted up the capabilities, efficiencies, and performance of resources. Another scheme proposed [25] a cloud community where interested members can join the community. Multiple members wearing sensor devices share their environment data i.e

noise, weather. Then they update it on the cloud. Whenever another member wants to visit that place he can make his decision regarding his health condition and its effect on his health. A heart patient might not want to visit a noisy place or a patient with pollen allergy might not want to visit green areas. The system also informs the patient about the nearest medical facilities. The system uses Euclidean metrics for location and the raspberry Pi 3 platform is used.

2.18 IoT Based Health Monitoring System Using Raspberry PI-Review

The elderly people require constant care and continuous monitoring especially in case of disease while they are at home or somewhere else. The effective especially response system in case of unfortunate mishaps is especially required for them. The IoT Based Health Monitoring System [20], where a device is attached to the patient's body which gathers the readings and send these after processing by Raspberry Pi to an online server, where readings are analyzed and presented to physician with help of a web application, which physician can review and prescribe accordingly to patient to take precautionary measure and raise alarm if the

health of patient is critical and patient can be shifted to the hospital for further treatment.

2.19 Smart and Pervasive ICU based-IoT

A smart and pervasive ICU based-IoT health care system [21] was suggested to improve and enhance efficiency and performance. It is a noteworthy methodology considering the hybrid architecture on a single platform to detect the risk situations and Alert (ADSA). Numerous multi-camera systems and a cooperative network consisted of multiple medical sensors are used for thoroughly visual monitoring in an automated manner. The smart function of this wireless-based IoT network optimized the patient monitoring system in CCU and improved intensive care quality in a cost-effective way. Smart and pervasive ICU based-IoT for improving intensive health care [3] was suggested to improve and enhance healthcare system efficiency and performance. It is a remarkable methodology considering the hybrid architecture on a single platform for the detection of risk situations and Alert (ADSA). Numerous multi camera systems and a cooperative network consisted of multiple medical sensors are used for thoroughly visual monitoring in an automated manner. The smart function of this wireless based IoT network optimized the patient monitoring system in CCU, and improved intensive care quality in cost effective way.

2.20 Multilayered IoT Based Body Area Networks

Another multilayered IoT-based smart healthcare monitoring framework for instantaneous patient supervision by calculating biomedical signals was proposed which enhances the precision of bio-sensor data collection, aggregation, and analysis to support decision making bodies in an intensive care environment or situation. This framework ensures better control. The framework focused on four-layered IoT architecture involving Sensor Network Layer, Gateway Layer, Cloud Datacenter layer resulting in improving the computational capabilities of biosensors by embedding few components of body area network (BAN) [22].

2.21 INTER-Health: An Interoperable IoT Solution

A research study presents the initial outcomes of the current INTER-Health pilot coming out from the application of the scheme projected and established within the framework of the INTER-IoT, a state of the art European venture aka Horizon 2020. The modern IoT powered healthcare platform backing up distributed architecture and mobile observation of modern lifestyle in extreme heterogeneous environments, has been acquired by incorporating supplementary existing diverse, non-interoperable IoT platforms following the INTER-IoT methodology to provide value-added supported existing mobile healthcare services. This system surpasses the performance as compared to the traditional and manual standard monitoring performed by conventional healthcare centers. The precise and speed detection and correction of wrong lifestyles or the risk factored critical situations will be the result of the good interoperability of IoT environments [26].

2.22 IoT-Based Remote Pain Monitoring

A scheme proposed a scalable IoT-based system which includes a comfortable and easy low-energy wearable band incorporated with a bio-sensing mask to read facial expressions to automatically measure agony or pain intensity of a patient by applying facial surface electromyogram (sEMG) [23]. The wearable device is mechanized as a wireless sensor node fused into IoT to monitor remote pain. Eight channels of sEMG are used in the scheme and every channel is sampled at 1000 Hz, to encompass full frequency range. The real-time transmission is performed via a gateway to the cloud server and a web application is also introduced for real-time streaming of sEMG data, visuals, interpretation, and signal processing.

3 COMPARATIVE ANALYSIS

This section performs the comparative analysis of smart healthcare systems using IoT. In order to develop an efficient, smart, capable and cost-effective solution for continuous monitoring of the healthcare system especially in ICUs, there is always a need to observe how different methodologies evolve and work? We have studied and analyzed several recently suggested systems and methodologies and found that each system has its advantages and disadvantages. Those pros and cons are briefly analyzed and represented in Table-1.

Such as Adaptive automated technique [1] was a good effort into proposing a hospital management system, but the technique lacks response efficiency. In the ICU environment, the triggers and alarm approach will be more effective rather than wasting time to check patients' report online. IoT makes it possible to build smarter ICUs with more capability and efficiency. Embedded Based Smart ICU-For Intelligent Patient Monitoring [3] has a lack of an alert system, good efficiency, and security. Health Monitoring Systems Using a Raspberry PI [3], [4], [5], [6], [7], [20] have good efficiency, performance, and speed. On the other hand, Raspberry PI platforms are not sufficient for bigger organizations that already have good servers and have compatibility issues with other platforms. They already perform things that Raspberry PI has to do. There are various security issues related to PI. Chronic Health Patient Monitoring System has a security issue and an overhead issue. Remote heart monitoring system [7] has implementation limitations to only heart patients and it includes an unnecessary function of SMS response from the doctor but it is efficient and easy to use. This system needs evaluation and needs to be experienced for other patients. Most of the techniques use cloud domain for critical objectives which are not good because of security issues. The WSN environments can be easily manipulated by adversaries. Fog computing is an emerging concept that is being adapted in IoT based system including smart health applications [8], [12], [24]. In fog computing, edge devices are responsible for some computation over the internet backbone. The approaches using fog-computing are surely secure and good to use but very expensive. Health IoT-enabled monitoring using IIoT [10] is used to reduce errors in clinical readings. The Security [15] and effectiveness are of key importance in health monitoring systems due to the critical implications of

TABLE 2: – Explanation of IoT based Systems acronyms with taxonomy

Systems Acronym	IoT System / Framework Name	Taxonomy			
		Computing	Architec- ture	Platform	
ESIFIPM [3]	Embedded based Smart ICU for Intelligent Patient Monitoring	Cloud Computing		Raspberry Pi	
UPH [4]	Universal Patient Health framework				
APHMRP [5]	Android-based Patient Health Monitoring System using Raspberry Pi				
CHPMS [6]	Chronic Health Patient Monitoring System using IoT				
CRHM&AS [11]	Combined Remote Health Monitoring & Alarm System				
DDM-Attacks [18]	Detecting Data Manipulation Attacks on Physiological Sensor				
IOTBHMS [20]	IoT Based Health Monitoring System Using Raspberry PI-Review				
CAIIoT [10]	Cloud Assisted Industrial Internet of Things enabled framework				Simulation
CMSA [13]	Continuous Monitoring System Architecture in ICU				MPN-URT sensors
ReHRMS [7]	Remote Health Rate Monitoring System using IoT				Arduino
SPICU [21]	Smart and pervasive ICU based-IoT for Healthcare			Any	
BSN-Care [17]	Highly Secure Body Sensor Network				
RMPS [23]	Remote Pain Monitoring IoT-based			sEMG ¹ , Any hardware sensor platform	
MFR&GC [8]	Meta Fog Redirection and Grouping & Choosing architecture	Fog computing	MF-R ² , BD, Apache Pig		
FSRPM [12]	Fog-based Smart Remote Patient Monitoring		BBN Model ³		
RTPM [14]	Real-Time Patient Monitoring	Local Servers and Internet	LPU ⁴		
FMRA [19]	Fusion Model Reference Architecture of Sensed Information	Referenced Architecture for sensed data			
RTML [22]	A real-time multi-layered approach for IoT Based Healthcare	INTER-Health Interoperability research study			

MF-R- Meta Fog Regenerator
sEMG- surface Electromyogram

LPU- Local Processor Units (combination of diverse sensors)

BBN Model- Bayesian Belief Network Model

this domain. The Combined Remote Health Monitoring & Alarm System [11] has an interesting initiative by including the family or friends of the patients in a smart monitoring system but this seems unnecessary because it is not always good for the family of the patient to know about the critical situations.

While assessing the performance of a system, multiple factors are involved including scalability, interoperability, response time which depends on communication technology used, security, which cloud service is being used, availability and others. An efficient IoT based patient health monitoring system needs to be responsive along with scalability, availability, security. The system should not depend on the third party. When we look into the Horizon 2020 [26], a state of the art research venture establishing the interoperability between diverse IoT based framework, this is the best thing happening in healthcare systems. The interoperability has been tested by the inter-IoT scheme. The

interoperability results have shown enhancements and good outcomes because we observed one of the main loopholes in the currently existing smart healthcare system is the problem of increasing patients affecting the performance of the systems. The system should be more responsive and effective even in unusual situations.

4 CONCLUSION & FUTURE WORK

The increasing population has aggravated the situation in every domain of life. Now diseases are more likely to occur due to pollution. It is crucial to integrate most emerging technologies like the IoT, Wireless sensors network, Vehicle to vehicle communication in order to provide timely treatment to every deserved individual. In this paper, we presented a detailed survey and analysis of existing smart IoT-based healthcare applications and infrastructures with related issues. If smart IoT-based health systems are implemented across the globe, there will be a significant reduction

in professional overhead, managerial pressure, and ultimately mortality ratio by keeping healthcare management and the general public at ease.

While inspecting through the IoT based smart healthcare systems, we have observed that despite of the state of the art technologies there is a gap in emergency response systems. In existing systems, the patient or end-user has to call for healthcare help. Like, if an elderly person or any person home alone feels some health-related abnormality then he can call the hospital for ambulance and treatment. Let's suppose if they face sudden unconsciousness by felling down the stare or other medical issues such as low blood pressure, low sugar level, syncope (low blood flow to the brain), and neurologic syncope. The results may get worst in case of sudden cardiac arrest. If the person is home alone, and he does not have a chance to call the SOS call or able to do that by himself and neither is anyone there to do that. There must be a solution to cope with it. So we propose an IoT-based BAN device, not only capable of identifying an anomaly in a person's state (falling unconscious etc.), but also capable to trigger an emergency alarm to nearby medical facilities. In the future, we'll pursue our research in creating such a smart device and try to evaluate the results of our proposed solution.

After thoroughly analyzing the IoT based system and identification of their drawbacks, we come to the conclusion that a single system cannot be a complete or authentic solution due to the drastic nature of the problem domain. We suggest using the most efficient, cost-effective, and state of the art technologies like Artificial Intelligence, Machine learning, deep learning and blockchain and so on. In fact, artificial intelligence (AI) and IoT both are modern generation technologies. The use of AI technology powered with deep learning reduces the chances of human errors [27]. As we know, AI or its child domain Machine Learning work on the principle of developing software programs that intelligently perform their specific operations like humans. The major essence of IoT devices is to gather data for further functionalities of the system. AI and ML boost up the processes to sense data and operations based upon that data collected from different IoT devices. We can call it the Internet of intelligent things. In the IoT systems based upon AI and ML, it is quite easy and fast to reach or process valuable information, detailed insight, and full potential performance in cost-effective ways. IoT with AI will improve operational satisfaction and efficiency, accuracy rate, maintenance, and predictive analysis. In critical installments and environments such as ICUs based upon IoT, it will be beneficial to develop systems with a combination of IoT and AI.

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