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Intensifying Remote Healthcare Monitoring System using Internet of Things: A Survey

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ABSTRACT

Internet of Things (IoT) is an indispensable paradigm to assimilate several computing and communication technologies. IoT network connects different smart objects together via Internet and providing more data exchange from anyplace, anytime, connectivity for anyone. The perpetual rise of chronic diseases leads to an expanding demand for constant monitoring and also created a major incentive to emerging accessible remote healthcare monitoring system. IoT based remote monitoring enables unified monitoring and control of all the actions taking place in healthcare supervisions. This system has potential to provide error free treatment by identifying the right medical data, tracking hos- pitalized patients, create alerting system in emergency situations, and deliver a convenient healthcare service to both caregivers and patients without visiting the hospital or clinic. This survey inspects the potential applications of the IoT based remote monitoring framework, integration of different technologies, and computing system that enables the remote healthcare monitoring in IoT conception are discussed. Finally, the open areas for future research challenges and deployment of secure remote monitoring system isexplored.

Keywords: Internet of Things, Wireless Body Area Network, Fog computing, Big data, Security, Cloud computing

I. INTRODUCTION

Nowadays healthcare industry is growing tremendously due to the surge in elderly populace and the prevalence of chronic diseases. Since, it has become a crucial issue due to lack of medical doctors [1]. The hasty developments in Information Communi- cation Technology (ICT) and Wireless Sensor Networks (WSN) offers an excellent quality and more expedient healthcare services [2]. IoT is a neoteric communication prototype that envisages a near future, in which every day smart objects are furnished with sensing, identifying, networking and computation capabilities that will permit them to communicate with one another, and provide services over the Internet [3]. By adopting this model in the activities of traditional healthcare organizations, medics would be able to access heterogeneous medical datasets online rapidly and simply, helping them to take suitable decisions while saving the overall costs. Similarly, patients can monitor their health without visiting the physicians, hospitals or clinical centers, and they can upload or access their individual health data from a cloud server. They can also get suggestions from a doctor or a specialist for further analysis [4]. The collection of patient's health

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related data and transferring it to the healthcare professionals via IoT in real time will not only reduce the cost of healthcare services, but will also enable early treatment of the health issues before they becomeperilous.

This type of monitoring system performs a vigorous role in healthcare delivery services, by assimilating set of decisive operations such as data collection, data aggregation, data transmission, data processing and analysis [5]. Subsequently, several devices and systems work together in the context of the IoT based remote monitoring application. WBAN [6] is another important IoT enabling technology in healthcare. There are several communication technologies such as Bluetooth, ZigBee, 6LoWPAN or Wi-Fi that can be used to implement WBANs. The IEEE 802 has instituted a new short-range communication standard termed IEEE 802.15.6 for WBAN, the purpose of such standardization is to optimize low power, supports short range, and higher data rate with lower bandwidth utilization [7]. In addition, the IoT based approach enables the Radio Frequency Identification (RFID) communication technology to recognize the patients, caregivers, medical peripherals, and inquiring vital signs from various existing healthcare devices, as well as screening substantial information to the authorized patients. Moreover, the application running on smartphone devices gives the information and capabilities wherever and whenever they required [8]. This technique advances the quality of life-care through consistent monitoring and lower cost of care by eradicating the need for physicians to actively involved in data collection and analysis. Remote cloud servers are usually used for storing and processing the huge volumes of medical data collected from multiple WBANs. This model not only offers reliable, inexpensive and carefree centralized data processing services, but it also offers enormous computing resources and storage capacities that can that can scale up or down on demand[9].

At present, the medical healthcare industry is confronting with the colossal volume of health-related data like structured, unstructured data and mounting at an exponential rate. The large volume of data transmission may also result in higher latency, and therefore must require an essential server to reduce the amount of data transmitted over the network. A possible solution to tackle this latency in WBAN based environment is to integrate them with fog computing [10] to regulate some data sources tasks to the edge centers. The patient's vital information in the health care sector is growing immeasurably from different sources such as smart phones, personal smart wearable sensors, health related electronic records, medical images, videos, clinical transcripts, social forums and blogs etc. New form of sources include images, audio, text and sensor reading is also stimulating to the inevitability of Big data to handle these immense and silos of data available in the healthcare [11]. Subsequently, the healthcare professionals must require to operate on prognosis, preclusion and personalization to expand the quality patient care. Therefore, a combination of WBANs system, Cloud computing, Fog computing and Big data can be a sustainable solution for challenges in the current IoT based remote healthcare monitoringsystems.

The rest of the paper is drafted as follows: Section II presents the framework of IoT based remote healthcare delivery system with its fundamental key components. The communication and computing technologies for IoT based healthcare system are presented in Section III and Section IV respectively. Section V gives the security and privacy requirements, and challenges of remote healthcare monitoring system. Then, the open research challenges with feasible solutions are analyzed in Section VI. This paper is finally concluded in section VII.

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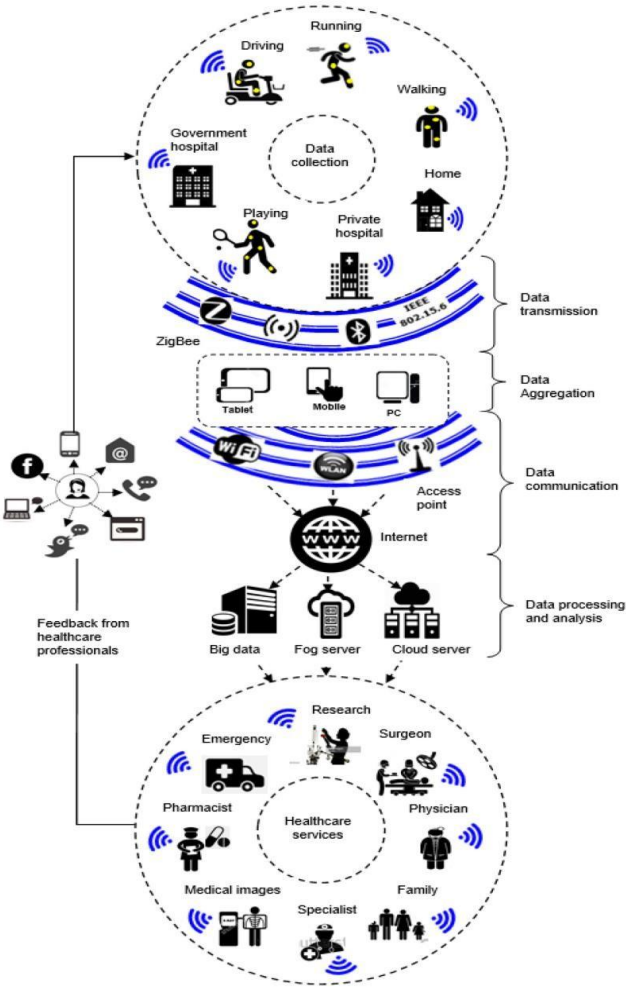

Fig.1 Overall design of IoT based Remote Healthcare Monitoring System.

II. IOT ENABLED HEALTHCARE DELIVERYSYSTEM

WBAN [12] plays a significant role in various areas of healthcare environments. In this, smart monitoring sensors are attached inside the body, outside the body or distributed around the human body to assess the status of patient's vital signs. The sensors which are located in smart homes or at hospital triage rooms might also supply extra information about the surroundings such as the temperature, humidity level, conditions of patient's sweat, and lighting which can be measured by innovative smart beds etc., all these are allowing the caregivers to provide faultless diagnosis and thus deliver more accurate medication [13]. The overall design of IoT based remote health monitoring system is depicted in Fig.1.

2.1 Fundamental KeyComponents

The overall IoT based remote healthcare framework is classified into four major key components [14] that enabled by various communication technologies.

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2.1.1Data Collection and Aggregation

The vital signs may be generated [15] using various implantable, wearable, IoT sensors and smart phone sensors. Then, all these het- erogenous vital signs are then transmitted from the human body to a network coordinator also called local server or aggregator. It is also responsible to aggregate, transmit the aggregated results to the base station and serve as a gateway between WBAN system and other medical data servers.

2.1.2Data Communication Networks

The IoT based remote health monitoring network consists of three types of communications: inter WBAN communications, from WBANs to IoT communications, and IoT to IoT communications. Several gateways or base stations with storage servers and data access networks that enabling medical practitioner to remotely access data, retrieve data from many servers like LTE-A, NFC, Wi-Fi, 4G and wireline networks[16].

2.1.3Data Storage and Processing

The collected vital signs are also typically stored and processed in remote fog or cloud data server, so it must ensure secure and privacy preserving data analysis and storage [17]. The inventive medical data analytics tools might be used to retrieve more accurate data from the actual data set. Furthermore, it can be examined for different treatment purposes.

2.1.4 Medical Data Services

The patient's vital signs can be remotely monitored in real time, even when the illness patient is on the ambulance, home or hospitals, allowing the medical practitioners to make proper diagnose at the right time, and the required medical instruments for the necessary treatment in advance [18]. Moreover, the phy- sicians can access the patient's vital data, display the results and update the stored data sets using smartphones, laptops, personal computers or even dedicated smart health monitoring devices. Since, the quality of remote healthcare service depends on the powerful incorporation of the above essential devices and innovative technologies, each of which is fascinating great efforts from both patient andcaregivers.

III. EMPOWERING TECHNOLOGIES FORHEALTHCARE

There are many auspicious technologies assisting the implementation of remote healthcare application. This section explores the substantial computing technologies that have the prospective to modernize remote healthcare delivery services. Table. 1 presents the major research issues present in recent technologies.

3.1 Cloud Computing

Cloud computing offers an effective and perfect solution with integration of IoT technologies [19]. These technologies will enhance the access to the shared resources, offer different services when required using the wireless medium and execute the necessary actions to meet individual needs of patients.

3.2 Fog Computing

Fog server acts as a passage between Public Communication Networks (PCNs) and the WBANs. It has an appropriate vital data decision system, lightweight storage, and the ability to send notifications or alert messages whenever emergency in patient's monitored data arises so that precise medical actions can be taken without any more delay. The foremost role of fogging is locating or fetching vital information near to the patients at the network edge. In [20], authors proposed a unique four-layer architecture to process the 10k, 100k and 1MB data file containing emergency heart rate data for sometimes in the fog nodes rather than cloud server. The performance results are evaluated with the cloud in order to minimize the delay. The notion of smart mobile fog

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will possibly a more challenging issue to handle set of functions, and event handlers for future internetapplications.

3.3 Grid Computing

Grid computing provides [21] ingenious solutions to the WBAN systems. In this, sensor nodes which involved in different grids are catered with colossal amount of computational medical data and resources. Then, it performs distributed computational operations in order to make use of idle health related data accessible on internet. Since it improves the resource utilization in the remote healthcare network.

TABLE 1. Major issues present in recent technologies

Technologies	Issues	Solutions	Operations
IoT	Security	Secure IoT based Health Monitoring System	Data Transmission or DataCommunication
Fog computing	Latency and Routing	Delay tolerate and Priority based Routing	Avoid the delay and Tunnel the Multiple Critical Information
Big data	Energy and Data Retrieval	Energy harvested	Data Storage and Data Management
Cloud Computing	Energy, Delay, Scheduling and Security	Energy Efficient Cloudlet based System	Data Storage and Data Analysis

3.4 Big Data

Big data is the prodigious volume of both structured and unstructured health related data that is very difficult to process using traditional software analytic tools [22]. The proficient big data analytical tools are necessary to upgrade the way of health analysis and monitoring trials.

3.5 CommunicationNetworks

Various types of network scenarios [23] for short range communications and long- range communications are part of the smart connected remote healthcare network. In addition, the coverage of Ultra-Wideband (UWB), Bluetooth Low Energy (BLE), Long-Term Evolution (LTE), Near Field Communication (NFC), and RFID technologies can support to construct low power body sensor devices and medium access protocols.

3.6 AmbientIntelligence

Ambient Intelligent (AmI) [24] is an intelligent computing paradigm that increases the capability of learning patient's reactions using smart connected sensor nodes and carried out needed actions stimulated by the life-critical events. The combination of both Autonomous Control Unit (ACU) and various learning techniques into AmI can enhance further the extent of IoT assisted remote healthcareservices.

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3.7 AugmentedReality

Augmented Reality (AR) can substantially increase the quality of treatment and prevention. Nowadays, healthcare provider uses the smart wearable glasses to assist the patients remotely during the complicated surgical operations. Consequently, it saves more time, overhead is minimized, and the complete treatment process is improved by reducing the chances of human mistakes. Hence, this technology [25] will also hugely promote their ability to analyze the present conditions by allowing medical professionals to access the patient's vital information in real-time, and they can take healthcare decisions faster than ever before, directing to a better healthcare and a better quality of life.

IV. VARIOUS REMOTE HEALTHCAREGATEWAYS

The gateways enable interconnection with other external devices and support various communication protocols in order to transmit patient's vital information. Also, it performs various operations such as local vital data processing, local storage and mining the vital data thus making a smart healthcare gateway terminal.

4.1 Local Data Processing

4.1.1. Data Compression

The huge volume of health-related data can be collected through smart healthcare IoT devices. Data compression [26] is the most substantial method for smart gateways due to various issues like limited bandwidth, susceptibility of life critical data and so on. The vital data is compressed at the gateway, since it reduces the bandwidth utilization, data overhead efficiently as well it increases the channel access capacity. Based on the healthcare applications, data compression may be performed in the WBANs, gateways or both.

4.1.2. Data Fusion

The data fusion is an effective process at the smart gateways because it has potential benefits such as extensive coverage, reliability, energy efficiency, and increased the quality of life critical data. In which, raw data is aggregated, only desire data are transmitted to the base station through transmission medium for further diagnosis. Since, it improves the bandwidth usage and energy efficiency.

4.1.3. Data Filtering

Data observed by each sensor node in the WBAN is required to undergo certain signal processing stage. The main purpose of signal processing techniques is used to minimize the complexity of raw data and extract valuable vital in- formation from the accumulated data sets. In [27], Authors considered a collaborative signal processing model to aggregate the physiological signals from the human by taking individual and internode data dependencies. By using this process, the patient can also get the local feedbacks even they are in offline mode. Since it increases the reliability of the overall healthcare system. The process of extracting useful information during the body movements is also very complex because movements aregenerally happened by concurrent displacement and rotation of multiple body segments.

4.2 Localstorage

The data availability is highly needed aspect in remote healthcare monitoring applications. Each and every gateway [28] needs an Operating System (OS) to accomplish a particular task such as data collecting and data forwarding from different WBAN systems to the remote medical servers. The local storage device is necessary to keep a copy of received vital data from WBAN, in addition with remote cloud server. Meanwhile, it gives more assurance to the patient in the presence of network unavailability. Furthermore, protecting the life critical

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data from the unauthorized access is very challenging task.

4.3 Embedded DataMining

The distribution of vital data is more essential. In general, the alerts will be generated in real time that based on the conditions and urgency of the patient. If there is any fault in the notification process, it can cause serious impacts and problems to the patient's medical process. The decisive results are finally reported to the patient either using the remote cloud servers or smart gateways. The vital information at the gate- ways are limited rather than remote cloud server. One important feature is that, patient can be received the notifications often from gateways whenever they required and also during the inaccessibility of remoteserver.Different learning and data mining techniques [29] can be applied on the local data storage in order to perform local computing for effectual comebacks and critical alarms based on the queries received locally and also from the remote cloud server. Therefore, it decreases the latency of emergency event notifications to the user or any healthcare professionals.

V. SECURITY AND PRIVACY REQUIREMENTS

The individual perceptions of the privacy and security of electronic medical records are major concern in the remote healthcare monitoring system. All smart healthcare devices may be connected to universal communication networks, or other WBAN systems for data access anytime, anywhere basis. There are so many possibilities to harm the patient's information. Thus, it is very difficult to identify and analyze the security requirements such as confidentiality, fault tolerance, integrity, authentication, availability, data freshness, resiliency and so on [30].

These security requirements are totally different when compared with existing security requirements. The novel solutions are necessary to address new challenges caused by the IoT aided remote healthcare. Moreover, the additional challenges [31] are also to be considered such as multiplicity of adding new devices, mobility of the patients, computational limitations, scalability, dynamic security updates etc.

VI. OPEN RESEARCH CHALLENGES ANDSOLUTIONS

Most of the existing surveys primarily focus on designing and considering architectural complications related to IoT based remote healthcare monitoring services. Many other open research issues are still needed to be addressed. This section inspects both explored and unexplored challenges present in IoT enabled remote healthcare delivery system.

6.1 Standardization

At present, the range of healthcare products and devices are getting increased drastically. In future, any new vendors may want to join with this auspicious technological contest. They might not be followed the communication standard rules and regulations for suitable interfaces and protocols with other devices, thus increasing interoperability issues. This issue can be avoided by introducing a new dedicated group to standardize IoT healthcare technologies. It should also support and more expedient with communications layers such as Physical (PHY) and Media Access Control (MAC) layers, data accumulation interface, and gateway terminals.

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6.2 HealthcarePlatforms

The hardware device is more sophisticated compared with usual IoT device operating system. There is an essential to design customized computing platform with proper requirements. A Service Oriented Approach (SOA) will be more suited for making different Application Package Interfaces (APIs). Moreover, the healthcare professionals should be used innovative platforms, library archives and charters. Since, they can make use of given health related documents, proceedings, text patterns, and other meaningful vital information.

6.3 App DevelopmentProcess

The contribution of an authorized team is mandatory in the healthcare app development process and also required to provide an apps for sufficient quality. Furthermore, systematic updates or dynamic updates on healthcare apps are very important so as to update the software based on the recent advances in healthcare applications.

6.4 TechnologyAdaptation

In future, the healthcare industry can revolutionize their traditional medical process by incorporating IoT paradigm. The continuous data transmission from personal de- vices to an IoT devices are always a challenging issue. Subsequently, there is a need to confirm the compatibility and flexibility with other existingdevices.

6.5 Low PowerProtocols

The sensor node in human body consumes more power for sensing, communicating and data processing. In such a case, sensor node performs distinct modes of operations: Transmit, Receive, Idle, and Sleep. Hence, the low power protocols will be considered to reduce the energy consumption problem in every mode of operations.

6.6 Scalability

This IoT enabled remote healthcare networks, services, and data storage servers should be scalable during the addition of several applications. Therefore, the relevant operations will become more difficult, demand from both patients and physicians also increased exponentially.

6.7 New Diseases andDisorders

Mobile smartphone plays a substantial role in IoT healthcare services. At present, there are so many personal health monitoring apps and also new apps are being added to the list. The usage of those apps has been restricted to classify the diseases. The innovative research should progress about the new types of chronic diseases and dis- orders. Since, it can help the early detection of erratic diseases.

6.8 Quality of Service(QoS)

The life critical data are highly delay sensitive and must require QoS guarantees in terms of substantial parameters such as Reliability, Energy efficiency, Delay, Priority based data transmission. Therefore, the quantitative analysis of each performance parameter within the IoT aided remote health monitoring framework will be more useful.

6.9 DataProtection

The protection of accumulated vital data from various WBANs is difficult. Therefore, strict privacy and security policy measures should be considered to share health related information with authorized patients, organizations, and hospitals for further treatment process.

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VII. CONCLUSION

The IoT based remote healthcare monitoring system provides an intelligent healthcare services by connecting smart bio sensors to the Internet for medical data gathering, data exchange and data computing. Based on the securely captured health data, the physicians can take proper decision to the right patient from anywhere. This paper reviewed the impendingscenario ofIoT basedremote monitoringarchitecture and their fundamental key components. Moreover, the communication technologies and IoT health gateway services are discussed in detail. The primary security and privacy measures and challenges for making such an efficient system are investigated. Then, the open research challenges of IoT healthcare services and with feasible solutions are addressed.

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