International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 11
November 2017

Wireless Protocols for Healthcare Applications

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Abstract- *Due to growing population, specifically taking into consideration the population that is suffering from various diseases, particularly heart diseases; the demand for smart and better health facilities is also increasing. As a much known fact, heart diseases like stroke, heart attack, etc.can occur anytime and anywhere, because of its unpredictable nature, it becomes mandatory to monitor the patient in a real-time scenario, continuously and remotely. A few decades ago it was not feasible to achieve the parameters discussed, but now due to enormous advancements in the sphere of ICT (Information and Communications Technology), like sensing technologies and;wireless technologies as a union,have served us greatly in acquiring, transmitting and receiving data (heart signals). The objective of such a system is to provide in home smart health monitoring, so that the person is not required to visit the doctor time and again especially for routine checkups and in case of plight, a quick response by the doctor/expert can save the life of the patient. The above stated objectives come to life due to various wireless communication protocolssuch as Bluetooth, Zigbee, 3G/4G, NFC etc., employed for transmission and reception of heart signals, as a consequence to rescue various lives. Therefore, communication plays a remarkable part in the whole process.This paper reviews various protocols required for the cycle of transmitting and receiving heart signals (ECG signals).*

Keywords: Cardiovascular Diseases (CVDs), ECG, ICT, Wireless Technologies

1. INTRODUCTION

Now-a-days, Cardiovascular Diseases (CVDs) have become a major cause of concern, threat and most significantly, the reason for increasing mortality rate worldwide. Talking about the figures, it was reported of deaths caused due to CVDs, the figures are defined as 422.7 million,CVDs cases were observed in 2015. It was approximated that 17.7 million died due to various types of CVDs in 2015. Out of this number 7.4 million lost their lives to coronary heart disease, and 6.7 million due to stroke [1]. It is also predicted by World Health Organization (WHO) that by 2030, about 24.6 million people will lose their lives because of CVDs.The figures discussed are huge and needs to be restrained. The solution to this is a system that has the ability to monitor and record (home location or remote location)the heart signals, consequently transmit the heart signals to the doctor/expert and then after analyzing the waveform if any sort discrepancies (deviation from the normal heart signal) are observed then a proper suggestion/remedy by the expert can reach the caregiver or the patient hence providing a solution to guard the life of the patient. This system also holds advantages such as reduction in time and effort, supportive during financial crunch, long-term, real-time and continuous monitoring of ECG signals, so that deaths due to various types of CVDs can be controlled hence reducing the figure as well. Following this,the next section throws some light on the cardiovascular diseases.

A. Cardio Vascular Diseases (CVDs)

Cardiovascular diseases are caused due to malfunctioning in the blood vessels (arteries, capillaries, veins and venules)or heart or a combination of both, thus affecting the brain, kidneys, lungs and other parts of the body as well. The heart diseases may include coronary heart disease, ischaemic heart disease, rheumatic heart disease cerebrovascular disease, strokes, heart valve issues etc. The most typical causes for a person to suffer from one of the CVDs are excessive intake of tobacco and alcohol, taking a lot of stress, no involvement in any kind of physical activities and moreover having a baleful diet. The most common symptoms of heart diseases include shortness of breath, fatigue, chest pain,pounding heart beat [2]. As reported by MaltiBansal et al in [3], that CVDs are most leading and globally published reason for deaths especially in low and middle income

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IJETSR
www.ijetsr.com
ISSN 2394 – 3386
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countries, approximately 37% deaths are caused in these areas.Also, in 2012 it was reported that CVDs approximate for 31% deaths worldwide. Below are two tables depicting the death toll due to various types of CVDs and the other table showing the percentage of death toll for males and femalesrespectively.

TABLE 1 : DEATHS DUE VARIOUS CVDS [4]

S.No	Type	Death Toll
1.	Coronary heart disease	7.2 million
2.	Rheumatic heart disease	0.3 million
3.	Congenital heart disease	8 to 12 per 1,000 live births
4	Stroke	5.5 million
5.	Aortic aneurysm and dissection	30 cases per million individuals per year
6.	Other cardiovascular diseases	2.4 million

TABLE 2 :DEATHS DUE TO VARIOUS CVDS IN MALES AND FEMALES [5]

S.No	Type	Percentage of deaths (%)	
		Males	Females
1.	Rheumatic heart disease	1	1
2.	Inflammatory heart disease	2	2
3.	Cerebrovascular disease	34	37
4.	Ischemic heart disease	46	38
5.	Hypertensive heart disease	6	7
6.	Other cardiovascular diseases	11	14

Huge numbers of deaths are specified in the tables above, this can be reduced when sensing and wireless technologies walk hand in hand. So, basically shifting the approach from hospital-oriented to in-home monitoringapproach [6,7] so that patients don't have to rush to the hospitals frequently for minor issues, also they able to connect to the expert if they are at a remote location in case of crises. The communication between the devices and people (patient and doctor) is possible due to developments in the sphereof ICT (communication protocols). The next section elaborates on the concept of ICT and it's applications in the healthcare domain.

B. INFORMATION AND COMMUNICATIONS TECHNOLOGY (ICT)

As a much known fact and also witnessing a huge transformation and progressin the field of electronics (devices)and communication, does not provide any latency in dispatching any kind of information to a person located locally or remotely. Specifically, considering the case of ECG systems, the process starts from sensing the heart signals, then the information is sent to a smart device like phone or computer (sensor-to-machine communication), then through gateways [8, 9,10,11,12], the signals are sent to the doctor's/expert'ssmart device (machine to machine communication)for analysis, so that any feedback for relief can be provided to the care-giver/patient in case the of an emergency situation [13].Theentireapproach requiresvarious communication protocols for transmitting and receiving the information either wireless or wired fashion from patient to doctor and vice versa. All accolades to the advancements in ICT due to the fact that portable devices using wireless technologiesas tool for communication has a brilliant futureand need of the hour in today's lifestyle [14]. This has given birth to expectations to people worldwide, also the idea of such a health-care monitoring system has gained attention of many researchers, people from industry and medical experts to focus theirinterest in this field [15]. Therefore, the next section elaborates ICT applications in healthcare services.

C. ICT AND IT'S APPLICATIONS IN HEALTHCARE SERVICES

ICT is a user-centeredoutlookand it's intention is clearly visible in the field of healthcare.The world is witnessing the way ICT has changed the perspective of people how they now look at healthcare services, basically it has led to creation of such systems that are based on IoT (Internet of Things) in which people are able to self-monitor and self-manage their health [16]. ICT basically facilitates various devices (ECG device in this case) to monitor,

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www.ijetsr.com
ISSN 2394 – 3386
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capture and record data then further send it other devices or can be stored in the cloud. If we consider the ECG monitoring scenario, then first the patient's heart signals will be sensed and sent to the smart device, then further the information is sent to the other (doctor) smart device, and the feedback from the doctor is received by the patient, so to achieve this cycle different protocols such as Bluetooth, NFC, Zigbee, 3G/4G, LAN, WAN so on and so forth. The objectives of ICT for healthcare services (ECG) are discussed as follows:

- Real-time and continuous ECG signals monitoring.
- Long-term ECG monitoring.
- Remote monitoring
- Better communication between the patient, care-giver and doctor.
- Reduced cost and effort.
- Communication is possible in rural areas.
- Internet is available at a low price so it is accessible by everyone, also the interface it quite simple to operate.
- It is capable of providing ambient intelligence.
- To provide interconnection between sensors, devices, intelligent or non-intelligent devices [17].

The objectives discussed above can only be achieved with the help of different kinds of wireless technologies, that allow communication between the devices, between human beings and devices too. Therefore, the next section depicts the various wireless technologies used for sending and receiving information (ECG signals).

2. WIRELESS TECHNOLOGIES

Numerouswireless technologies that are employedfor communication i.e., sensor-to-machine communication and machine-to-machine communication to be specific with respect to ECG monitoring systems are presentedand an evaluationis done on the basis of frequency, bandwidth, range etc., in the table below:

TABLE 3 :VARIOUS WIRELESS PROTOCOLS

S.No	Protocol Name	Frequency	Range/ Speed	Data Rate	Power Consu-mption	Band-width
1.	Blue-tooth	2.4 GHz	Class1 Range-20-30m Class1 Range-5-10 m	1 Mbps	1–35 mA [18]	1 MHz
2.	UWB (Ultra Wide Band)	3.1-10.6 GHz	10 m [19]	50 Mbps [19]	-41.3 dBm/ MHz [18]	500 MHz - 7.5 GHz
3.	ZigBee	2.4 GHz	10m- 100 m	250 Kbps	0.035706 W (trans-ferring 24 bytes of data)	0.3/0.6 MHz; 2 MHz
4.	NFC	13.56 MHz [20]	<20 cm	106, 212, and 424 Kbps [18]	2.5 mA [20]	±7 kHz-1.8 MHz
5.	6LoWPAN	2400MHz [21]	10m-30m [22]	250 Kbps	3dbm	250/40/ 20 Kbps
6.	Ethernet	125 MHz	100 m	10 Mbps	50 W to 80 W	10 Mbps
7.	WLAN	2.4 GHz	32 m	11-54 Mbps	25.5 W	2.4 GHz
8.	WIFI	2.4 GHz, (5 GHz)	100 m	54 Mbps	100–350 mA [18]	22 MHz

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S.No	Protocol Name	Frequency	Range	Data Rate	Power Consu-mption	Band-width
9.	GPRS	850, 900, 1800, 1900 MHz	15 - 40 Kbps	56–114 Kbps	100-200 mA	296 Kbps
10.	GSM	900, 1800, 1900 MHz	35 km	9.6 Kbps	1.5 mA	200 KHz
11.	2G (SMS, MMS)	900, 1800, 1900 MHz (CDMA)	Covers a wide distanc-e	50 Kbps	400 mW	25Hz
12.	3G	2100 MHz	Covers a wide distanc-e	3.1 Mbps	0.5W	25Hz
13.	4G	850 MHz, 1800 MHz	Covers a wide distanc-e	100-300 Mbps	0.5W	100 Hz
14.	LTE	700 MHz, 1700-2100 MHz, 1900MHz and 2500-2700 MHz (on WiMax)	350 to 500 km/hr	100 Mbps	0.5 W	1.4 MHz
15.	5G	3-300 GHz	Covers a wide distanc-e	<1 Gbps	800 W (128 antennas)	1000x BW per unit area

Various types of protocols are presented, in the next segment we present how these protocols are employed into the system and how they help the system to operate and communicate to provide better health opportunities.

4. Basic System Model for ECG Monitoring System

In the following model, the architecture of the smart ECG monitoring system required for long-term, continuous, real-time and remote monitoring required for transmitting (ECG sensor to device)and receiving (device to device) ECG signals. The ECG sensors could be either electrodes (wet [23, 24] or dry [25]) or smart wearables [26] like vest [27], t-shirt [28], belt [28], wrist band etc. So, the first and foremost thing to do is acquire the signals from these sensors. Once the signals are ready, they should be sent to the smart devices (phone, laptop, computer) so that it can be viewed and interpreted, these can be sent via Bluetooth, Zigbee, NFC, 6LoWPAN, etc. Then futher the signals are sent to the doctor (his/her smart device) for analysis and

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www.ijetsr.com
ISSN 2394 – 3386
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further the doctor can send the feedback (remedy) to the patient or the care-giver so that necessary actions can be taken to pacify the patient.

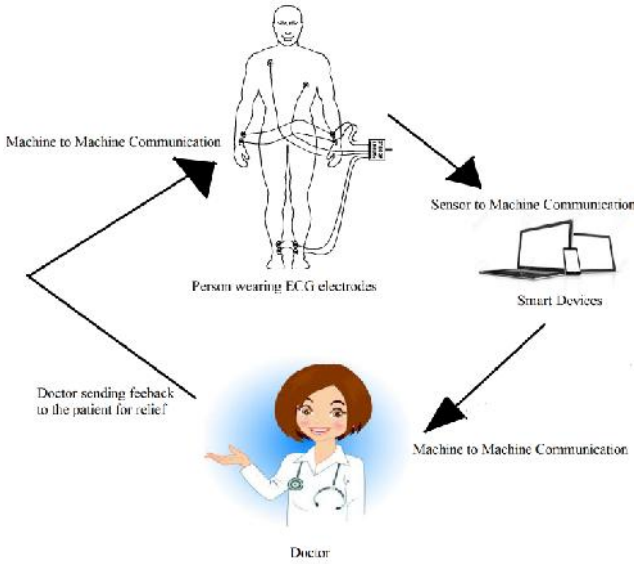

Figure 1 Basic system model for ECG monitoring system

The next segment of the paper illustrates and compares the various ECG monitoring systems based on various wireless protocols.

A. Related Works

TABLE 3 COMPARISION OF WORKS BASED ON ECG MONITORING SYSTEMS

S.No	References	Wireless Technologies Used For		Target Application
		Sensor to machine communication	**Machine to machine communication**	
1.	[29]	NFC, RFID	Internet Web Services	Telemedicine
2.	[30]	ZigBee	Wifi or GPRS	Telemedicine (residential gateway)
3.	[31]	ZigBee, Bluetooth	Ethernet	Tele-monitoring, In-home monitoring
4.	[32]	6LowPAN	3G/4G or Wi-fi	U-healthcare for indoor and outdoor monitoring
5.	[33]	Bluetooth	Wi-fi/3G/4G	Remote Monitoring
6.	[34]	Zigbee	WLAN	Ubiquitous healthcare system
7.	[35]	ZigBee	GPRS	Smart home monitoring

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ISSN 2394 – 3386
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S.No	References	Wireless Technologies used for		Target Application
		Sensor to machine communic-ation	**Machine to machine commu-nication**	
8.	[36]	Bluetooth	Wi-fi	Wheel chair users
9.	[37]	ZigBee	WLAN	U-Health telemedicine
10.	[38]	Bluetooth	GSM/ GPRS	In-home health monitoring
11.	[39]	Bluetooth	Internet (HL7 aECG Gateway)	Remote monitoring
12.	[40]	Zigbee	Wireless Local-Area networks (WLANs)	E-Health applications (specialized physiological rehabilitation centers, or individuals.)
13.	[41]	Bluetooth	GPRS	Remote ECG continuous monitoring of patients with diverse cardiac diseases
14.	[42]	Bluetooth	UDP or TCP	Gait Analysis Platform, Alertness Training Platform,
15.	[43]	Zigbee	Internet (The server is built as a Microsof-t WCF service hosted inside a Window-s service)	In-home monitoring (Elderly people)
16.	[44]	ZigBee	Through Internet Cloud	Telemedicine (Tele-monitoring)
17.	[45]	NFC	Internet	Telemedicine (IoT)
18.	[46]	6LoWPAN	TX4140 Wi-Fi module	Telemedicine (IoT)
19.	[47]	6LoWPAN	Wifi, Ethernet	Remote Monitoring and feedback

CONCLUSION

In today's lifestyle, it becomes necessary to have platform where people old or young are able to self-monitor and self manage their health. It is beneficial for those people who are seriously ill and cannot visit the doctor or hospital each time.The smart healthcare platform should be such that the interface should be user friendly, and should be efficient in terms of finances and performance and should be able to operate even at a remote location. The notion of remote monitoring has been only possible due to utilization of the wireless protocols. As a result people don't have to visit the hospitals frequently, in critical situations doctor can provide the feedback over the phone, cost and efforts have definitely reduced, so monitoring is possible from anywhere and everywhere and everytime. The review in this paper is only limited one kind of monitoring i.e., ECG, further it can span to monitoring of various bio-signals such as EEG, EMG, EOG, Glucose etc. It would be really great if all these systems can be brought to one platform, so that a device is able to monitor all the parameters in go and if any irregularities are observed in any of the signals then an immediate action can be taken to save the life of the patient.

ACKNOWLEDGMENT

One of the authors (Bani Gandhi) acknowledges the fellowship support she is receiving from Delhi Technological University (DTU), for carrying out this work, as a part of her PhD thesis work in the domain of Nano-Electronics. She also acknowledges the guidance support from her thesis supervisor, Dr. MaltiBansal, Assistant Professor, Department of Electronics and Communication Engineering, DTU, for carrying out this research work.

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