A Systematic Review of Wireless Body Area Network

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Abstract—**Combining tiny sensors and wireless communication technology, wireless body area network (WBAN) is one of the most promising fields. In other words, the development of wireless body area network has accelerated due to the rapid development of wireless technology. This article presents a detailed survey as well as a comparative study on wireless body area networks (WBANs). Basically, the paper aims to study the significant characteristics, issues and challenges with WBAN in various fields majorly, in medical application. Moreover, recurrent technologies used in WBANs are the ones most focussed upon during the findings. Also, the recent trends and future research scope have been addressed in this article.**

Keywords— Sensor Networks; Wireless Body Area Network; Security and Privacy Issues

I. INTRODUCTION

Recently, there is an emerging interest in wireless body area networks (WBAN) since it enables real-time and continuous monitoring in various fields including telemedicine, entertainment, sports, and military training. Specifically, it is one of the most convenient, cost-effective and accurate technology for health monitoring.

Since people nowadays are more health conscious, there is an immense pressure on quality and quantity of healthcare. Therefore a need of technology arises that can continuously monitor the health and share information with remote care providers or hospitals. As a result, WBAN as a technology helps in providing this kind of information [29].This technology is a subfield of existing research in the field of Wireless Sensor Networks (WSNs)[30] and offers the potential of great improvement in the delivery and monitoring of healthcare. Not only limited to medical field but WBAN has its application in different sectors as well such as entertainment, sports, military and many more. A WBAN can also be used to monitor athletes' performance and assist them in training activities [37].

WBANs are small wireless networks that incorporate quite a number of wide-ranging biological sensors. With an ability to be positioned in various parts of body, these sensors could be wearable or implantable. These comprise of certain pre-requisites, mainly used for respective missions. These devices accumulate changes in a patient related to signs, emotions or status of a being, say anxiety, fear, happiness. Special coordinator node is used for the purpose of communication having lesser energy constrained and more processing capacities. For real time medical diagnosis, this is responsible for putting across biological signals of the patient, for the medical doctor to examine [39].

[28] defined the network architecture of medical BAN mainly into two main parts. The first part includes the Multiple Body Sensor Units and the second part comprises of a Body Central Unit. The vital operations such as medical data acquisition, data (pre) processing, actuator control and data transmission are performed by Body Sensor Units with some basic user feedback. On the other hand, the Body Central Unit links multiple sensor units, performs data collection, data processing/compression, event detection or management. Furthermore, provides external access, together with a personalized user interface [35].

II. EVIDENCE ACQUISITION

A search was carried out while creating a boolean using keywords such as Wireless sensor network, wireless body area network, medical body sensor network. Articles were then selected from year 2005 through 2018 using Clarivate Analytics from Web of Science indexed SCI, SCIE and ESCI. After initial screening on the basis of title and abstract of almost 512 articles, 434 were excluded. Furthermore, 52 articles were again rejected from the remaining 78 as they were not fulfilling the desired objective. A detailed description of the search strategy is given in Figure 1.
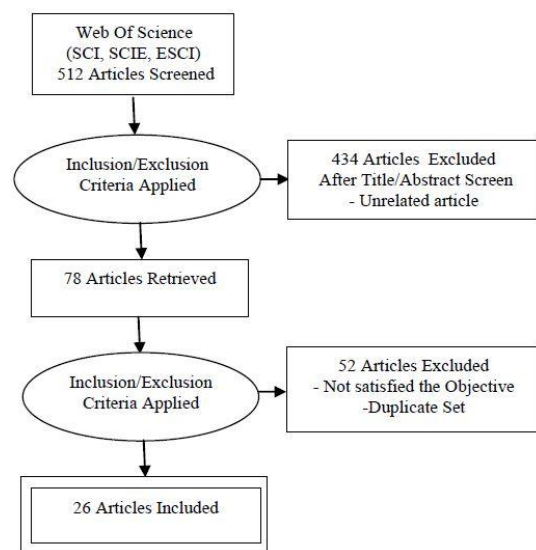

Fig. 1. Flow Diagram of Evidence Acquisition

TABLE I. Overview of Articles related WBAN

Reference	Year	Study Description	Sensor Type	Issues	Tools	Applications	Findings
Maali Said Mohammed et al.[1]	2018	Comprehensive Study	Wearable	Obesity Control	Real time solution	Medical	Analyzed and discussed the current health oriented WBANs
Fengye Hu et al.[2]	2017	Comprehensive Study		Energy Limitation	Model Building	Medical, Sports, Entertainment	Importance and technologies of WEIT
Salayma, M et al.[3]	2017	Survey	Wearable & Implantable	Fault tolerance	Real time solution	Medical & Entertainment	Fault tolerance in WBAN cannot be considered complete if it only allows fault detection, ignoring real-time fault recovery.
Monton, E et al.[4]	2008	Experimentation	Wearable	Data Monitoring	Simulation	Health Monitoring	Designing of Wireless BAN
Wu, Dapeng et al.[5]	2016	Experimentation	Both	Energy efficient	Simulation	Medical	High energy-efficiency and reliability of WBAN data transmission can be achieved by EDFS
Kim, Yena et al.[6]	2013	Experimentation	Wearable & Implantable	Interference problem in presence of WiFi network	Simulation	Medical & monitoring	Designed algorithm that controls WiFi traffic and guarantees delay requirements of ZigBee sensors
Tmar-Ben Hamida, S et al.[7]	2015	Case study	Wearable	Monitor sleep disorder	Real time solution	Medical	Reviewed efficient mHealth applications for the remote assessment and monitoring of patients' sleep disorders
Touati, F et al.[8]	2015	Comparative Study	Wearable & Implantable	QoS	Real time solution	Medical	BLE showed good potential in terms of throughput, end to end delay and packet error rate
Hayajneh, T et al.[9]	2014	Comprehensive study and in-depth analysis	Wearable & Implantable	Coexistence of an interfering network.	Simulation	Health Monitoring	Using LP-WiFi for WBANs is a feasible and promising option when compared to Zigbee and IEEE 802.15.6 standards.
Almashaqbeh, Ghada et al.[10]	2014	Experimentation	Wearable & Implantable	QoS	Simulation and Model Building	Health monitoring	CHMS proved to be efficient in supporting larger no. of users while maintaining a high-performance level.
Chakraborty, C et al.[11]	2013	Survey	Wearable & Implantable	Bandwidth Limitation, Power Consumption, Skin Protection, Fine tuning quality of data	Real time solution	Tele medicine	Designed the framework for integrating BANs on telemedicine systems.
Samanta, A et al.[12]	2017	Comprehensive study	Wearable & Implantable	QoS	Simulation	Medical	Attempts to minimize the dynamic connectivity,interference management, and data dissemination costs for WBAN.
Wei, FS et al.[13]	2018	Comprehensive study	Wearable & Implantable	User privacy and Data confidentiality	Simulation	Medical	Proposes efficient computation scheme that ensures formal security and strong anonymity.
He, Debiao et al.[14]	2016	Comparative study	Wearable & Implantable	Privacy and Security	Analysis	Medical	Provably secure AA scheme is created satisfying security requirements
Yazdi, FR et al.[15]	2017	Literature Review	Wearable & Implantable	Challenges in development of WBAN	Real time solution	All	Researchers focused on issues related to improve communication and review challenges and numerous WBANs applications.
Ghare, PH et al.[16]	2017	Comprehensive study	Wearable & Implantable	Interference	Simulation	Healthcare	Quanititative analysis shows that number of BANs, transmission power of sensors as well as path loss exponent have a great impact on level of interference.
Al-Janabi, S et al.[17]	2017	Literature review	Wearable	Security and Privacy	Real time solution	healthcare	Reviewed the deployment of WBANs and the threats to the integration of sensors and actuators as well as attacks to WBANs.
Zou, SH et al.[18]	2017	Comprehensive Study	Wearable & Implantable	Security	Simulation	Healthcare	Provided solutions for securing internal communication, and securing communication between WBAN and external users

Masdari, M et al.[19]	2016	Comparative Study	Wearable & Implantable	Data Authenticity & Security	Analysis	Healthcare	One-way authentication,mutual authentication, and anonymous authentication services have been analysed. Also, comparison of the properties of the authentication schemes were presented.
Aguirre, E et al.[20]	2016	Comprehensive Study	Wearable	Performance of wireless network	Simulation	Indoor Health Monitoring	WBAN system with 3D RL method was studied to see the behavior of electromagnetic waves generated by the system.
Ghamari, M et al.[21]	2016	Survey	Wearable & Implantable	QoS	Real time solution	Residential environment health Monitoring	Abnormal conditions can be detected early by enabling healthcare professionals to continuously monitor patients and elderly people in their own residential environments.
Xu, HS et al.[22]	2016	Experimentation	Others	Information Security	Simulation	Medical	Cooperative relays applied during data transmission helps in the improvement of transmission rate and signal power capacity.
Al Rasyid, MUH et al.[23]	2015	Experimentation	Body temperature and blood oxygen sensor	Data storage	Real time solution	E-health monitoring	Application can be used to store the data in a database and display it via a website which can further be accessed remotely.
Ha, I et al.[24]	2015	Literature Review	Others	WSN vs WBAN	Survey	Medical	Study examined the characteristics of WBANs that are different from that of existing WSNs and classified WBAN-related technologies that have been studied recently.
Cavallari, R et al.[25]	2014	Survey	Others	WBAN Designing	Simulation	All	Described main standards that can be used as a reference in a RF-based WBAN design paying more attention to the IEEE 802.15.6.
Li, Ming et al.[26]	2010	Survey	Wearable	Data Security and Privacy	Real time solution	Healthcare	ABE-based access control method is more capable than other techniques of achieving all the security requirements. It is fine-grained, context-aware, revocable, and efficient to implement on local servers.

III. EVIDENCE SYNTHESIS

A. Search Results

This paper identified 512 publications in the initial search, of which 78 met inclusion criteria for full text review. Of these, data on the outcomes of interest for 26 publications was obtained. Characteristics of the studies which were included can be found in Table 1(listed about here)

B. Years

Transpiring as a prominent one, Wireless Body Area Network (WBAN) has gained enormous interest and proved one of the most explored technologies in the field of health care facilities. Therefore, the study has reviewed the papers covering the time span of 10 years i.e. from 2008 to 2018. Mostly, the advancement of work has been carried out in the year 2016-2017.

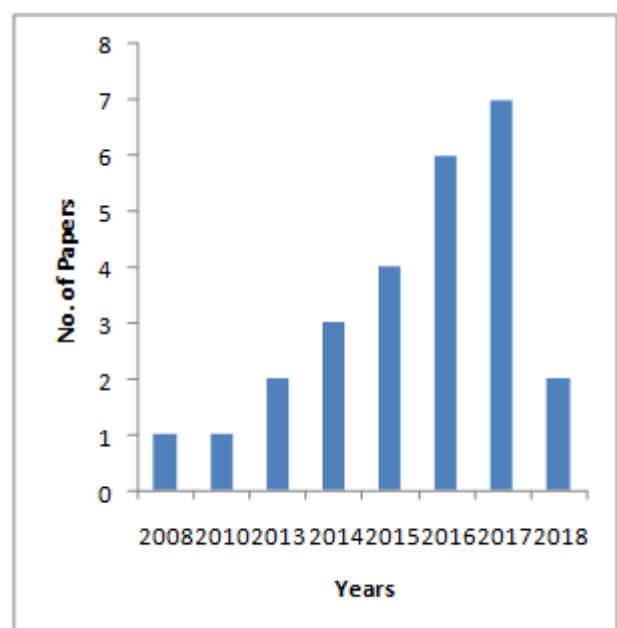Figure 2 shows the bar chart of the papers selected from respective years.

Fig. 2. Papers selected in previous years

C. Sensors

Sensors in Wireless Body Area Network are the tiny devices with communication capabilities, located inside or outside of a human body. Classifying on the basis of its functions.

Wearable Sensors: To observe and check the progress of patient's health, necessary data is required. This data can be obtained by some objects known as wearable objects integrated with small sensors. When this wearable object comes in direct contact with the patient they are termed to be as Wearable Sensors. The main function of wearable sensor is to convert physical statistics into electrical signals. For eg. Pedometers worn by a walker or a runner records the number of steps taken, is a type of wearable sensor.

Parameters like blood pressure, ECG can be easily monitored with the help of wearable sensors.

Implantable Sensor: Commonly known as in-body sensors, these devices are implanted in the body. Any movement in the organ whether affected or transplanted can be detect by using implantable sensors [36]. For example, Cranial sensors are used to monitor patients after brain surgery. Other applications for implantable sensors can be found in [3].

D. Challenging Issues

Having certain restrictions and constraints, WBAN can be categorized as one of the most critical real time networks. The factors that contribute to such critical aspects include environmental constraints, device hindrances and architectural constraints; raising device issues related to network life, reliability, fault tolerance and security [31]. Also, WBAN is still facing several important challenging issues related to user requirements [32-33], most of which arising from inefficiency and impracticality such as privacy [17], safety, ease of use, security [38] and compatibility. Hindering the solution space, these challenges need to be scrutinized carefully while designing mechanism [40].

E. Tools

Researchers are actively involved in developing new techniques and improving the existing ones, for making life easier. Each of these developed and/or improved techniques need to be extensively tested and verified before it can be used in the actual production.

The real-world implementation and test-beds come to rescue for being most accurate and reliable. But these are sometimes not possible or even harder. Alternate methods are of Modeling and Simulation.

The review of the research papers shows that experiments were performed on the simulated environment based on mathematical models and the strategies were tested on a real-world system. [27] presented a partial list of available models and simulation/emulation tools for the wireless sensor networks.

F. Innovating and Interesting Applications of WBAN

WBAN Application are broadly classified into medical and non medical application[34]. Medical application include early detection and prevention of any chronic disease, monitoring patient's routine activities, obtaining information of patient at remote location.

Treatment of elderly people at their homes can be easily carried out with the help of WBAN sensors. Non medical application spans its usage in the field of sports(analyze soldier energy level), entertainment and military . Table II gives an overview of the same.

TABLE II. WBAN APPLICATION WITH EXAMPLES

Application	Examples
Telemedicine	Remote Health monitoring
	Emergency rescue
	Prevention and detection of diseases
	Daily-life activity monitoring
	Post-surgery in-home recovery monitoring
Military and Defence	Asses solider fatigue,
	Detect life threatening situations
Sports	Monitors heartbeat, blood pressure
Entertainment	Gaming purposes
	personal item tracking and social networking
Assisted Living	Assisted living for elders
	Treatments of peoples at home

IV. CONCLUSION

The systematic review suggests that wireless BAN is a key point for Research & Development projects. As the advancement in wireless sensor networks revolutionize healthcare domain, WBAN systems will help in facilitating a better communication with patients to acquire services in the optimal time before the serious danger of diseases threatens their lives. With a potential to offer a wide range of benefits to patients, medical personnel and society through continuous monitoring and early detection of possible problems, it is expected to be extremely useful technology.

This paper gives a glimpse of different issues and deficiencies of Body Area Network. The review serves as a call to action for better design in terms of security, privacy, data authenticity, etc. Schemes like AA scheme for WBAN was proved to be secured enough while satisfying security requirements. Whereas a way forward is to design more flexible, cryptographic enforced, and attribute-based access control schemes for WBANs. Finally, further it can be concluded that WBAN will remain in the process of experimentation for a good number of years as it does not require much modifications and expensive redesigning.

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