Forward Privacy Preservation Strategies for IoT-Based Healthcare Environments

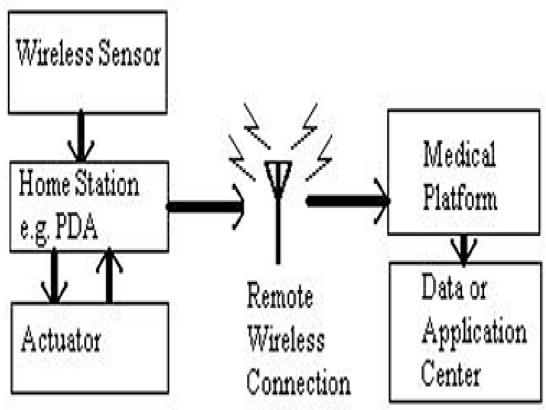
Mr.E.Srinivasa Rao[1]., Sandi Neelima[2]
1 Assistant Professor, Department of CSE, Malla Reddy College of Engineering for Women., Maisammaguda., Medchal., TS, India
2, B.Tech CSE (20RG1A05G9),
Malla Reddy College of Engineering for Women., Maisammaguda., Medchal., TS, India

Abstract

The proliferation of wireless networks and the shrinking size of electronic devices have made possible the development of BSNs. (WBANs). It isaninnovative tool for managing and diagnosing medical conditions. Smart biosensors are either externally attached or surgically implanted as part of WBAN. Potential uses for these sensors exist in fields including consumer electronics, interactive games, and real-time health monitoring. Since WBAN does not need a patient to remain hospitalized, it allows for more freedom of movement. In this study, we will examine the many facets of WBAN.

Introduction

Major difficulties have arisen for policymakers, providers, and businesses in the healthcare sector because of the rising expense of healthcare and the aging population in industrialized nations. To provide patients with individualized and long-term care, there is a strong push to use new wireless technologies for remote patient monitoring. One such developing technology that has the potential to enhance medical operations, diagnostic monitoring, and illness tracking is wireless body area networks (WBANs). WBANs' capacity to provide extremely dependable communications for medical devices, particularly those implanted in the human body, is vital. The sensors that make up a WBAN are small, lightweight, and cheap; they may be worn as tiny intelligent patches, sewn into clothes, implanted under the skin, or buried deep inside the body's tissues. Their primary function is to ensure the health and well-being of patients while medical professionals are doing their duties. With the use of WBAN technology, consumers have access to high-quality healthcare that does not break the bank. BANs may be used for a wide variety of purposes, including but not limited to health and home care, sports, ambient systems, and ubiquitous computing. Vital indicators including electrocardiogram (ECG), electroencephalogram (EEG), and blood pressure, as well as essential environmental elements like temperature and humidity, are continuously monitored by strategically placed wearable or implanted wireless sensor nodes. It is possible that all WBANs' patient data (collected data) will be sent to a single healthcare repository in the future. Doctors may use this information to determine the patient's health from afar. SMS, alarm, and reminder messages may also be sent to the patient. This article provides a comprehensive review of recent developments in the field of wireless body area networks. The purpose is to shed light on the pressing problems facing this new area of study. This paper's remaining sections are structured as follows. Section 2 focuses on the WBAN Channel Characteristics. The third part explains the common methods of WBAN communication. In Section 4, we discuss why privacy and security are so important in WBAN. The Physical Layer and Current MAC Layer Protocols are discussed in Section 5. The WBAN-specific routing protocols and associated protocols are covered in Section 6. In Chapter Seven, we discuss how all of this relates to wireless sensor networks. Section 8 provides a summary of ongoing initiatives. Section 9 is where the paper comes to a close.



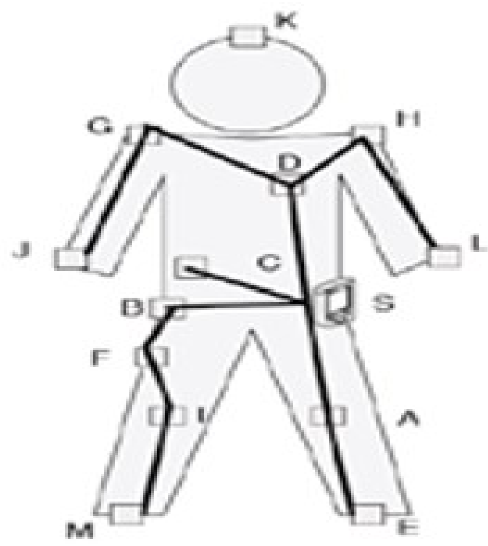


Fig. 1. (a) Data flow in a typical medical BAN; (b) Schematic representation of an example of WBAN on the human body. Sensor D measures the heart rate.

WBAN Channel Characteristics

The WBAN's resulting network will be situated either directly on or extremely near the human body. Typically, sensors will be positioned on a wrist band or affixed through a patch. The ramifications of this for channel quality are substantial. The quality of the channel is strongly affected by the nodes' locations on the body and the paths between them. Because the channel is also affected by the structure of the body, the quality of the channel will vary from person to person. Tissues in the body will attenuate the signal and cause more path loss if there is a straight line of sight between two nodes. As a result of poor channel quality, networking for WBANs presents a significant problem. Due to the small size of the sensors, strict limits will need to be placed on the amount of power they require. The radio is the biggest energy drain, so keep it muted whenever possible. WBAN protocols need to be resilient in the face of subpar channel conditions. After the computing process, nodes in a WBAN may enter a sleep state like hibernation to save energy.

Access method

Common medium access strategies in WBAN include Carrier Sense Multiple Access (CSMA) and Time Division Multiple Access (TDMA). The initial step for a node using a CSMA-based protocol is to detect the carrier, or medium. If the node detects no activity, it will begin broadcasting. Otherwise, it will begin a hold off operation where it will wait for a certain amount of time based on probabilities. The key concept underlying time division multiple access (TDMA) is the use of time slots to manage use of a shared media. These slots are allotted to nodes requesting access to the medium. Slot reservation for nodes in TDMA makes it more reliable than CDMA, which makes it the favoured accessing strategy in WBAN. Not only that, but CDMA has more stringent delay assurances than TDMA. In a WBAN, all connections terminate at a central hub, making it a kind of many-to-one communication. While sink-to-node traffic is not to be ignored in WBAN, it is often assumed that most of the traffic will go in the other direction, from the nodes to the sink. The quantity of data traffic from the nodes to the sink is far larger than the amount of control traffic flowing in the other direction. Since it is believed that WBAN is a linked network, nodes have the option of establishing a direct connection to the sink or relying on other nodes to establish contact on its behalf. Most studies on WBAN assume symmetric networks and multi-hop topologies to make analysis easier and to offer great energy efficiency, however this may not be the case in practice.

Bluetooth

Because of the wide variety of hardware implementations, Bluetooth has become more popular for modern medical care solutions. However, Bluetooth and other WPAN protocols were developed with low latency and high throughput in mind, neither of which are necessary for WBAN. The protocol overhead will rise much more if the data speeds are reduced.

Security and Privacy

Protecting the WBAN system from potential security risks requires the creation of a comprehensive and robust security strategy. Prevent data from being leaked, data confidentiality is necessary. Data pertaining to patients might be severely compromised by eavesdropping. Therefore, the need for secrecy, trustworthiness, authenticity, timeliness, accuracy, completeness, availability, and safe administration is paramount. While WBAN prototypes do exist, there has been surprisingly little research into data security and privacy concerns, and current solutions are far from ideal. Conflicts between, say, security, safety, and usability, are a practical problem that must be optimized for.

Physical and MAC layer

A great deal of study has focused on the physical layer. Several early WBAN researchers advocated for using Ultra Wide Band (UWB) as the network's physical Leeuw's range is broad enough to accommodate the whole body, it uses little power, and it works well with other wireless networks. UWB does not advance well because of standardization challenges and difficulty supplying the extremely high speeds. Other researchers have recommended using the narrower Industrial, Scientific, and Medical (ISM) frequencies of the IEEE 802.15.4 and IEEE 802.15.6 instead of the wider bands proposed by UWB. Most existing WBAN prototypes rely on ISM bands now. Various MAC protocols designed for WBANs already exist. Both single-hop and multi-hop protocols exist for this purpose. The latter are protocols designed specifically for networks with several hops. Initially, protocols were developed with a one-hop topology in mind. A MAC protocol that uses the heartbeat to synchronize its nodes is called Heartbeat driven MAC (H-MAC). Although the protocol was developed with WBANs in mind, it cannot accommodate for variations in traffic. Given their adaptability, ad hoc networking protocols might be thought of as WBAN protocols as well. Since ad hoc network protocols rely on always-on radios, it is impractical to apply them to WBAN.

WBAN specific routing protocols

The absorption of radiation and the heating effects of wireless transmission around and on the human body are crucial considerations. Five thermal-aware routing techniques were developed to mitigate the problem. Tissue heating may be reduced by using traffic control algorithms or decreasing the radio's broadcast power. Radiofrequency radiation has been shown to have biological impacts, and these effects have been shown to be strongly correlated with incoming power density, network traffic, and tissue properties. Algorithms for power scheduling and traffic management demonstrate that the bioeffects may bemitigated with little effort. Hotspots are regions where data transmissions are concentrated, and the Thermal Aware Routing Algorithm (TARA) directs traffic away from these nodes.

Relation to wireless sensor networks

Several articles treat WBANs as though they were their own subset of WSNs or WSANs, Wireless Sensor and Actuator Networks. However, the unique difficulties of human body monitoring are not addressed by conventional sensor networks. In contrast to nodes in a WSN, which may be considered redundant, nodes in a WBAN must be able to communicate with one another reliably. This is in line with how WBANs are often utilized in healthcare, when just a single sensor is used for each essential parameter. In addition, as compared to widespread WSN deployments, WBANs are modest in size. While WSN protocols are typically developed for hundreds of nodes deployed in regions with diameters of hundreds of meters, WBANs anticipate deploying up to twenty nodes on a single individual. Energy-efficient routing is a hot topic of study for both ad hoc and WSNs. For WBANs, however, the offered solutions fall short.

Here are some examples that highlight the key distinctions between WBANs and WSNs: Unlike with WSNs, WBANs do not use any device redundancy strategies. The network's nodes must be rock-solid, trustworthy, and precise. If a node fails, its data is usually irretrievable by other nodes in the network. The data loss is worse in the WBAN because of the unique characteristics of its operating environment (the human body). The signals from the sensors, especially the implanted ones, areseverely weakened since the waves must travel through or over an extremely lossy medium. Quality-of-Service (QoS) and real-time data interrogation capabilities may need the use of proprietary techniques. The absence of data may be compensated for by additional sensors in WSNs. Allow for discrete monitoring of patients, sensors implanted into tissue or connected to the skin must be very tiny in size. Although smaller sensors are preferable, their size is not the primary consideration in WSNs. WBAN sensors' compact form factor has a major impact on their devices' ability to store and use energy. Devices cannot because to a lack of available power. This necessitates sensors with a very extended lifespan. The sensors of a WBAN are embedded in or worn by a mobile human subject. WBAN faces this difficulty, which is seldom met by WSNs. Thus, the WBAN must be adaptable to the highly likely network topology changes. In addition, the richness and variety of life creates a more disorganized framework.

Application	Data rate
ECG (12 leads)	288kbps
ECG (6 leads)	71bps
EMG	320kbps
EEG (12 leads)	43.2kbps
Blood saturation	16bps
Temperature	120bps
Motion sensor	35kbps
Cochlear implant	100kbps
Artificial retina	50-700kbps
Audio	1Mbps
Voice	50-100kbps

Challenges	WBAN
Scale	As large as human body parts (millimeters/centimeters)
Node number	Fewer, more accurate sensor node required
Node size	Pervasive monitoring and the need for miniaturization
Event detection	Early adverse events detection vital; human tissue failure irreversible
Data protection	High level wireless data transfer security required to protect patient's information
Access	Implantable sensor replacement difficult and requires biodegradability
Bio Compatibility	A must for implantable and some external sensors. Likely to increase cost
Context Awareness	Very important because body physiology is very sensitive to context change
Wireless Technology	Low power wireless required, with signal detection more challenging
Data Transfer	Loss of data more significant, and may require additional measures to ensure QoS and real-time data interrogation capabilities

Existing WBAN projects

A great deal of research on WBANs has been published in recent years. The efforts are primarily concerned with offering remedies for the problems facing WBANs. The structure of WBANs and the protocols and processes of the physical layer and MAC sub layer of WBANs have been one of the most critical topics that have caught the attention of many studies prior to the introduction of the IEEE 802.15.6 standard by the IEEE 802.15 Working Group. Several international research teams are now engaged in developing and deploying a WBAN. Projects involving wireless short-range communication have made use of a variety of wireless technologies, including those from the IEEE 802 family of WPANs, wireless local area networks (WLANs), Bluetooth, and Zigbee. Before the IEEE 802.15.6 standard is developed, the IEEE 802.15.4/ Zigbee system has been the most preferred technique in current projects due to substantial shortcomings of alternative WPAN and WLAN solutions. A method for real-time monitoring of complicated circumstances using data streams from several body sensors connected to a wireless body area network is proposed in [4]. (WBAN). Using this setup, a Wide-Area-Network (WBAN) of interconnected sensors may be used to create custom medical applications for individual users. Although Nano power Wake up Radio was created by Stevan Marinkovic and Emanuel Popovici for use in Wireless Body Area Networks (WBANs), it is applicable to other forms of low power wireless networks as well. The radio's power requirements and resistance to communication interference from a wireless device were evaluated to ensure they would be sufficient for a WBAN user. A WSN-based framework work for human healthmonitoring was established by Janani, V.R., and Sarma Dhulipala [2] and R.M.Chandrasekaran et al., [3].The paper's suggested structure makes it easy to grasp how WSN is put to use in the context of remote patient monitoring. The study primarily focuses on the readability, scalability, power consumption, and network characteristics involved in hospital-based remote patient monitoring. An improved QAPM (Quadrature-Amplitude-PositionModulation) system was suggested by Jae-Hoon Choi and Heung-Goon Ryu in [8]. In this study, we compare the previously proposed QAPM system with the current PSSK. Extension methods like the PSSK and QAPM scheme are used to improve power efficiency. Moreover, the simulated BER performance of QAPM and PSSK is superior to that of QAM and PSSK in the AWGN channel. When the signal-to-noise ratio (SNR) is low, QAPM's throughput characteristics are superior to those of PSK, QAM, and PSK. An opportunistic method is provided in Opportunistic Routing for Body Area Network [9] that takes use of the body's natural motions while walking to prolong the network's useful life. In this study, the authors took use of the body's natural mobility to extend the network's durability. Energy consumption per bit in the network is evaluated across three different scenarios (a single hop, a multi-hop employing a relay node, and an opportunistic method) to gauge the effectiveness of the proposed strategy. The findings demonstrate that the suggested method may extend the network's lifetime by lowering the energy requirements of sensor and relay nodes while keeping the bit error rate (BER) constant with the other two approaches. Electrocardiogram (ECG), Photoplethysmography (PPG), Skin Temperature, Accelerometer, and other sensors were incorporated into a wearable, ubiquitous healthcare monitoring system as part of the Wearable ECG Monitor project [10]. This idea utilizes WBAN to provide nonintrusive healthcare over a large region while using just a little amount of battery life for RF transmission. Wearable physiological signal devices in this system interface with the custom mobile system through WBAN, namely Zigbee. We have created a number of gadgets, including ones that may be worn on the chest, the wrist, and the neck. The wireless sensor network for Mobile networks may send physiological data from a wearable ubiquitous healthcare monitoring device. An effective secure data transmission system in WBAN with data integrity is suggested by [11] Mrinmoy Barua and M.S. Allam [2] and Xiaohui Liang et al. The secure key is shared across all sensors in a WBAN, making the scheme user-centric and reducing the need for extra memory and processing resources. The technique has been shown via security analysis and numerical findings to reduce the average waiting time of real-time traffic in WBAN while maintaining privacy and confidentiality. Energy-efficient cooperative communications in wireless body area networks (WBANs) are studied by Xingang Huang and Hang guan Shan [2] and Xuemin (Sherman) Shen et al; [3]. In this article, we examined three different methods of transmission. Direct transmission, collaboration with a single relay, and cooperation with several relays. They examined the reliability of each one during blackouts and investigated the issue of optimum power distribution within the bounds of a desired outage frequency.

Conclusion

Channel characteristics, access approaches, routing protocols, WBAN problems, and ongoing WBAN initiatives are all detailed in this article. Energy needs, security/privacy concerns, and WBAN's many levels were all examined. In conclusion, several specific health related WBAN applications are provided. High-bandwidth, low-energy communication protocols, compatibility across BANs and other wireless technologies, and the development of effective applications are only some of the numerous issues that have yet to be resolved. The focus of future efforts will be on the development of a portable, adaptable, and context-aware mechanism that meticulously balances security, safety, and usability. Insights gained from this paper, we believe, will lead to the development of workable designs for cryptographically enforced, context-aware, reliable, and privacy-enhanced WBANs.

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