Studies in Big Data 30

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Internet of Things and Big Data Analytics Toward Next-Generation Intelligence

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Preface

Internet of Things and big data are two sides of the same coin. The advancement of Information Technology (IT) has increased daily leading to connecting the physical objects/devices to the Internet with the ability to identify themselves to other devices. This refers to the Internet of Things (IoT), which also may include other wireless technologies, sensor technologies, or QR codes resulting in massive datasets. This generated big data requires software computational intelligence techniques for data analysis and for keeping, retrieving, storing, and sending the information using a certain type of technology, such as computer, mobile phones, computer networks, and more. Thus, big data holds massive information generated by the IoT technology with the use of IT, which serves a wide range of applications in several domains. The use of big data analytics has grown tremendously in the past few years directing to next generation of intelligence for big data analytics and smart systems. At the same time, the Internet of Things (IoT) has entered the public consciousness, sparking people's imaginations on what a fully connected world can offer. Separately the IoT and big data trends give plenty of reasons for excitement, and combining the two only multiplies the anticipation. The world is running on data now, and pretty soon, the world will become fully immersed in the IoT.

This book involves 21 chapters, including an exhaustive introduction about the Internet-of-Things-based wireless body area network in health care with a brief overview of the IoT functionality and its connotation with the wireless and sensing techniques to implement the required healthcare applications. This is followed by another chapter that discussed the association between wireless sensor networks and the distributed robotics based on mobile sensor networks with reported applications of robotic sensor networks. Afterward, big data analytics was discussed in detail through four chapters. These chapters addressed an in-depth overview of the several commercial and open source tools being used for analyzing big data as well as the key roles of big data in a manufacturing industry, predominantly in the IoT environment. Furthermore, the big data Learning Management System (LMS) has been analyzed for student managing system, knowledge and information, documents, report, and administration purpose. Since business intelligence is considered one of the significant aspects, a chapter that examined open source applications, such as

Pentaho and Jaspersoft, processing big data over six databases of diverse sizes is introduced.

Internet-of-Things-based smart life is an innovative research direction that attracts several authors; thus, 10 chapters are included to develop Industrial Internet of Things (IIoT) model using the devices which are already defined in open standard UPoS (Unified Point of Sale) devices in which they included all physical devices, such as sensors printer and scanner leading to advanced IIoT system. In addition, smart manufacturing in the IoT era is introduced to visualize the impact of IoT methodologies, big data, and predictive analytics toward the ceramics production. Another chapter is presented to introduce the home automation system using BASCOM including the components, flow of communication, implementation, and limitations, followed by another chapter that provided a prototype of IoT-based real-time smart street parking system for smart cities. Afterward, three chapters are introduced related to smart irrigation and green cities, where data from the cloud is collected and irrigation-related graph report for future use for farmer can be made to take decision about which crop is to be sown. Smart irrigation analysis as an IoT application is carried out for irrigation remote analysis, while the other chapter presented an analysis of the greening technologies' processes in maintainable development, discovering the principles and roles of G-IoT in the progress of the society to improve the life quality, environment, and economic growth. Then, cloud-based green IoT architecture is designed for smart cities. This is followed by a survey chapter on the IoT toward smart cities and two chapters on big data analytics for smart cities and in Industrial IoT, respectively. Moreover, this book contains another set of 5 chapters that interested with IoT and other selected topics. A proposed system for very high capacity and for secure medical image information embedding scheme to hide Electronic Patient Record imperceptibly of colored medical images as an IoT-driven healthcare setup is introduced including detailed experimentation that proved the efficiency of the proposed system, which is tested by attacks. Thereafter, another practical technique for securing the IoT against side channel attacks is reported. Three selected topics are then introduced to discuss the framework of temporal data stream mining by using incrementally optimized very fast decision forest, to address the problem classifying sentiments and develop the opinion system by combining theories of supervised learning and to introduce a comparative survey of Long-Term Evolution (LTE) technology with Wi-Max and TD-LTE with Wi-Max in 4G using Network Simulator (NS-2) in order to simulate the proposed structure.

This editing book is intended to present the state of the art in research on big data and IoT in several related areas and applications toward smart life based on intelligence techniques. It introduces big data analysis approaches supported by the research efforts with highlighting the challenges as new opening for further research areas. The main objective of this book is to prove the significant valuable role of the big data along with the IoT based on intelligence for smart life in several domains. It embraces inclusive publications in the IoT and big data with security issues, challenges, and related selected topics. Furthermore, this book discovers the technologies impact on home, street, and cities automation toward smart life.

In essence, this outstanding volume cannot be without the innovative contributions of the promising authors to whom we estimate and appreciate their efforts. Furthermore, it is unbelievable to realize this quality without the impact of the respected referees who supported us during the revision and acceptance process of the submitted chapters. Our gratitude is extended to them for their diligence in chapters reviewing. Special estimation is directed to our publisher, Springer, for the infinite prompt support and guidance.

We hope this book introduces capable concepts and outstanding research results to support further development of IoT and big data for smart life toward next-generation intelligence.

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Part I
Internet of Things Based Sensor Networks

Internet of Things Based Wireless Body Area Network in Healthcare

G. Elhayatmy, Nilanjan Dey and Amira S. Ashour

Abstract Internet of things (IoT) based wireless body area network in healthcare moved out from traditional ways including visiting hospitals and consistent supervision. IoT allow some facilities including sensing, processing and communicating with physical and biomedical parameters. It connects the doctors, patients and nurses through smart devices and each entity can roam without any restrictions. Now research is going on to transform the healthcare industry by lowering the costs and increasing the efficiency for better patient care. With powerful algorithms and intelligent systems, it will be available to obtain an unprecedented real-time level, life-critical data that is captured and is analyzed to drive people in advance research, management and critical care. This chapter included in brief overview related to the IoT functionality and its association with the sensing and wireless techniques to implement the required healthcare applications.

Keywords Internet of things · Wireless body area network · Healthcare architecture · Sensing · Remote monitoring

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1 Introduction

Internet of things (IoT) represents the connection between any devices with Internet including cell phone, home automation system and wearable devices [1, 2]. This new technology can be considered the phase changer of the healthcare applications concerning the patient's health using low cost. Interrelated devices through the Internet connect the patients with the specialists all over the world. In healthcare, the IoT allows the monitoring of glucose level and the heart beats in addition to the body routine water level measurements. Generally, the IoT in healthcare is concerned with several issues including (i) the critical treatments situations, (ii) the patient's check-up and routine medicine, (iii) the critical treatments by connecting machines, sensors and medical devices to the patients and (iv) transfer the patient's data through the cloud.

The foremost clue of relating IoT to healthcare is to join the physicians and patients through smart devices while each individual is roaming deprived of any limitations. In order to upload the patient's data, cloud services can be employed using the big data technology and then, the transferred data can be analyzed. Generally, smart devices have a significant role in the individuals' life. One of the significant aspects for designing any device is the communication protocol, which is realized via ZigBee network that utilizes Reactive and Proactive routing protocols. Consequently, the IoT based healthcare is primarily depends on the connected devices network which can connect with each other to procedure the data via the secure service layer.

The forth coming IoT will depend on low-power microprocessor and effective wireless protocols. The wearable devices along with the physician and the associated systems facilitate the information, which requires high secured transmission systems [3]. Tele-monitoring systems are remotely monitoring the patients while they are at their home. Flexible patient monitoring can be allowed using the IoT, where the patients can select their comfort zone while performing treatment remotely without changing their place. Healthcare industry can accomplish some severe changes based on numerous inventions to transfer the Electronic health records (EHRs) [4]. Connected medical devices with the Internet become the main part of the healthcare system. Recently, the IoT in healthcare offers IoT healthcare market depth assessment including vendor analysis, growth drivers, value chain of the industry and quantitative assessment. In addition, the medical body area networks (MBANs) which are worn devices networks on the patient's body to interconnect with an unattached controller through wireless communication link. This MBAN is used to record and to measure the physiological parameters along with other information of the patient for diagnosis.

The 5G (fifth generation) of communication technologies supports the IoT technologies in several applications especially in healthcare. It allows 100 times higher wireless bandwidth with energy saving and maximum storage utilization by applying big data analytics. Generally, wireless communication dense deployments are connected over trillions wireless devices with advanced user controlled privacy.

Wired monitoring systems obstacle the patients' movement and increase the errors chances as well as the hospital-acquired infections. The MBAN's facilitates the monitoring systems to be wirelessly attached to the patients using wearable sensors of low-cost. The Federal Communications Commission (FCC) has permitted a wireless networks precise spectrum that can be employed for monitoring the patient's data using the healthcare capability of the MBAN devices in the 2360–2400 MHz band [5].

2 IoT Based WBAN for Healthcare Architecture

The IoT based wireless body area network (WBAN) system design includes three tiers as illustrated Fig. 1 [6].

Figure 1 demonstrates that multiple sensor nodes as very small patches positioned on the human body. Such sensors are wearable sensors, or as in-body sensors that implanted under the skin that operate within the wireless network. Continuously, such sensors capture and transmit vital signs including blood pressure, temperature, sugar level, humidity and heart activity. Nevertheless, data may entail preceding on-tag/low-level handling to communication based on the computation capabilities and functionalities of the nodes. Afterward, the collected data either primarily communicated to a central controller attached the body or directly communicated through Bluetooth or ZigBee to nearby personal server (PS), to be remotely streamed to the physician's site for real time diagnosis through a WLAN (wireless local area network) connection to the consistent equipment for emergency alert or to a medical database. The detailed WBAN system block diagram is revealed in Fig. 2. It consists of sink node sensor nodes and remote observing station.

The detailed description for the WBAN system is as follows.

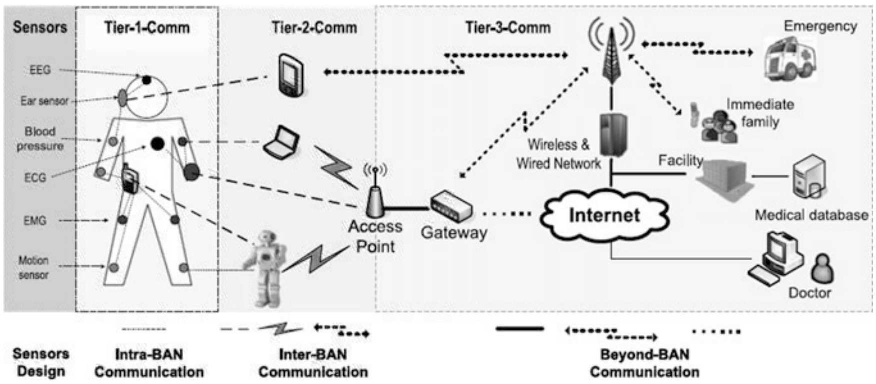


Fig. 1 IOT-based WBAN for healthcare architecture [6]

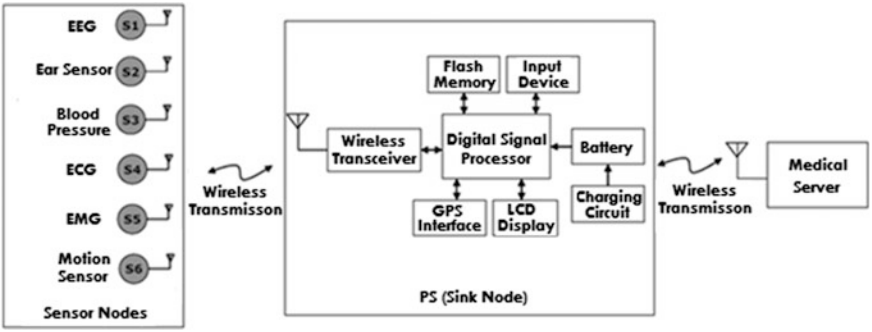
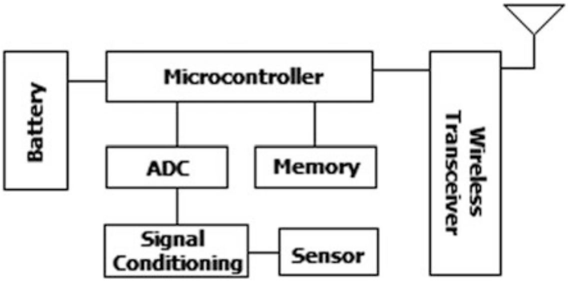


Fig. 2 WBAN system block diagram [7]

Fig. 3 Wireless sensor node block diagram [7]



2.1 Sensor Nodes

The sensor nodes have small size and a minute battery with limited power, communication and computing capabilities. The elementary smart sensor components are illustrated in Fig. 3.

The central components of the sensor nodes are:

1. **Sensor**: It encloses an embedded chip for sensing vital medical signs from the body of patient.
2. **Microcontroller**: It controls the function of the other components and accomplishes local data processing including data compression.
3. **Memory**: It is temporally stores the sensed data that obtained from the sensor nodes.
4. **Radio Transceiver**: It communicates the nodes and allows physiological data to be wirelessly send/received.
5. **Power supply**: It is used to supply the sensor nodes by the required powered through batteries.
6. **Signal conditioning**: It amplifies and filters the physiological sensed data to suitable levels for digitization.
7. **Analog to digital converter** (**ADC**): It produces digital signals from the analog ones to allow further required processes.

Furthermore, a sophisticated sensor that can be combined into the WBAN is the Medical Super Sensor (MSS), which has superior memory size, communication and processing abilities compared to the sensor nodes. The MSS utilized a RF to connect with other body sensors. In addition, Bluetooth or ZigBee can be utilized as a communication protocol to connect the obtained sensed data with the personal server. It gathers the multiple sensed vital signs by the body sensors and filters out all unnecessary data to reduce the data transmitted large volume (big data). Afterward, it stores the transmitted data temporarily, processes and transfers the significant data of patient to the PS over wireless personal realized by ZigBee/IEEE 802.15.4. This increases the inclusive bandwidth use and reduces the BSs power, where each node has to transmit the sensed data to collector which is MSS instead of the PS, where the MSS is closer to the BSs than the PS.

2.2 Personal Server (Sink Node)

The PS (body gateway) is running on a smart phone to connect the wireless nodes via a communication protocol by either ZigBee or Bluetooth. It is arranged to a medical server using the IP address server to interface the medical services. The personal servers is used also to process the generated dynamic signs from the sensor nodes and provides the transmission priority to the critical signs to be send through the medical server. It performs the analysis task of the vital signs and compares the patient's health status based on the received data by the medical server to provide a feedback through user-friendly graphical interface.

The PS hardware entails several modules including the input unit, antenna, digital signal processor, transceiver, GPS interface, flash memory, display, battery and charging circuit. The data received are supplementary processed for noise removal and factors measurements [7].

2.3 Medical Server

The medical server contains a database for the stored data, analyzing and processing software to deliver the system required service. It is also responsible about the user authentication. The measured data by the sensors are directed via the internet/intranet to medical personnel to examine it. The medical unit is notified for necessary actions, when there is deviation from the expected health records of the patient.

2.4 WBAN Communication Architecture

Typically, the WBAN communications design is divided into three components, namely the intra-BAN communications, inter-BAN and Beyond-BAN communications.

2.4.1 Intra-BAN Communications

The intra-BAN communications refers to about 2 m radio communications nearby the human body, which is sub-classified into connections among the body sensors or between portable PS and the body sensors. The intra-BAN communications design is grave due to the direct association with the BANs and the body sensors [6]. The essential operated battery and the low bit rate features of the prevailing body sensor devices lead to an interesting aspect to enterprise an energy effective MAC protocol with sufficient QoS. For wireless connection of sensors and PS challenges solving, several systems can be employed including the MITHril [8] and SMART [9]. These structures exploit cables to link multiple sensors with the PS. Instead, a codeblue [10] stipulates can be used to communicate the sensors directly with the access points (Aps) without a PS. In addition, a star topology can be used, where multiple sensors can forward the body signals to a PS to process the physiological data to an AP (e.g., WiMoCa [11]).

2.4.2 Inter-BAN Communication

The BAN is seldom works alone, dissimilar to the WSNs, which generally work as independent systems. The APs can be considered one of the main parts of the dynamic environment's infrastructure while managing emergency cases. The communication between the APs and PS is utilized in the inter-BAN communications. Correspondingly, the tier-2-network functionality is employed to communicate the BANs with various easy accessible networks, such as the cellular and Internet networks. The inter-BAN communication paradigms have the following categories: (i) infrastructure-based construction, which delivers large bandwidth with central control and suppleness and (ii) ad hoc-based construction that enables fast distribution in the dynamic environments including disaster site (e.g., AID-N [12]) and medical emergency response situations. Figure 4a, b illustrate the two structures respectively [6].

Infrastructure Based Architecture

Infrastructure-based and inter-BAN communications have a significant role in several BAN limited space applications, such as in office, in home and in hospital

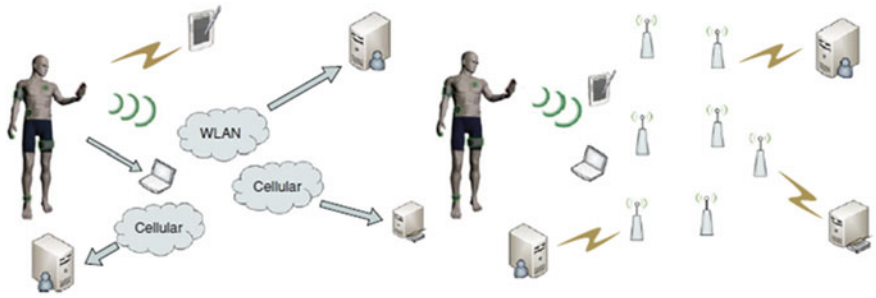


Fig. 4 Inter-BAN communication structure: **a** infrastructure-based structure; **b** ad hoc-based structure [6]

environments. The infrastructure-based networks allow security control and centralized management. Furthermore, the AP can act as database server in particular uses including SMART [9], CareNet [13].

Ad Hoc Based Architecture

Generally, multiple APs are organized to support the information transmission of the body sensors in the ad hoc-based construction. Consequently, the service coverage is in excess of the corresponding one in the infrastructure-based construction. These enable the users' movement around anywhere, emergency saving place and building, where the BAN coverage is limited to about 2 m. Thus, the ad hoc-based architecture of interconnection outspreads the system to about 100 m that allows a short-term/long-term setup. In this architecture setup, two classes of nodes can be used, namely router nodes around the BAN and sensor nodes in/around the human body.

Every node in the WSNs acts as a sensor/router node. The ad hoc-based architecture setup employs a gateway for outside world interface resembling the traditional WSN. Typically, all infrastructures share the same bandwidth, where there is only one radio. Consequently, the collisions possibility is definitely arise, where in some situations; the number of sensor/actuator nodes and the routers nodes is large in certain area. In order to handle such collision situations, an asynchronous MAC mechanism can be employed. A mesh structure is considered one form of the various APs of this system having the following characteristics:

A. Large radio coverage because of the multi-hop data distribution. Thus, superior support to the patient's mobility can be acquired, where during multi-hop data forwarding, the bandwidth is reduced.
B. Flexible and fast wireless arrangement is realized to speedily mount the emergency reply systems [10, 12].
C. Adaptation of the network can be simply extended without any effect on the whole network by adding new APs or any other requirements.

Inter-BAN Communication Technology

For inter-BAN communication, the wireless technologies are more established compared to the intra-BAN communications. It includes Bluetooth, WLAN and ZigBee. Since the BANs require provision low energy consumption protocols, the Bluetooth becomes a superior communications tool over a short range that is viable for BANs. The Bluetooth is considered a prevalent short range wireless communications protocol. ZigBee become popular due to its effective features, namely: (i) its low duty cycle, which allows offering extended battery life, (ii) its support to 128-bit security, (iii) it enables low-latency communications and (iv) for interconnection between nodes, it requires low energy consumption. Thus, several BAN applications deploy the ZigBee protocol due to its capability to support mesh networks.

2.4.3 Beyond-BAN Communication

A gateway device like the PDA is used to generate a wireless connection between the inter-BAN and beyond-BAN communications. The beyond-BAN tier communications can develop several applications and can be employed in different healthcare systems to enable authorized healthcare personnel for remote accessing to the patients' medical information through the Internet or any cellular network. One of the significant "beyond-BAN" tier components is the database, which retains the user's medical history. Thus, the doctor can admission the user's information as well as automatic notifications can be delivered to the patient's relatives based on through various telecommunications means.

The beyond-BAN communication design is adapted to the user-specific services' requirements as it is application-specific. Consequently, for example, an alarm can be alerted to the doctor via short message service (SMS) or email, if any irregularities are initiated based on the transmitted up-to-date body. Doctors can directly communicate their patients through video conference using the Internet. Afterward, remote diagnosis can occur through the video connection with the patient based on the transmitted patient's medical data information obtained from the BAN worn or stored in the database.

3 WBAN Topology

For frames exchanging through a relay node, the IEEE 802 Task Group 6 approved a network topology with one hub. This hub can be associated to all nodes via one-hop star topology or via two-hop extended star topology. Generally, the two-hop extended star topology is constrained in the medical implant communication service (MICS) band.

The beacon mode and non-beacon mode are the star topology communication methods that can be used. In the beacon mode, the network hub representing the star topology's center node switches the connection to describe the start and the end of a super-frame to empower the synchronization of the device and the network connotation control. The system's duty cycle known as the beacon period length can be identified by the user and founded on the WBAN's standard [14, 15]. The nodes required to be power up and elect the hub to obtain data. In the WBANs, cautious deliberations should be considered upon the one-hop or the two-hop topology choice.

4 Layers of WBAN

Generally, both the PHY (Physical) and MAC (Medium Access Control) layers are proposed by all permitted standards of 802.15.x. The IEEE 802.15.6 (WBAN) active collection has definite new MAC and PHY layers for the WBANs, which offer ultra-low power, high reliability, low cost, and low complexity. Typically, there may be a HME (hub management entity) or logical NME (node management entity) that connects the network management information with the PHY.

4.1 Physical Layer

The IEEE 802.15.6 PHY layer is responsible about the several tasks, namely the radio transceiver's deactivation/activation, transmission/reception of the data and Clear channel assessment (CCA) in the present channel. The physical layer selection is based on the application under concern including non-medical/medical and on-, in-and off-body. The PHY layer delivers a technique to transform the physical layer service data unit (PSDU) into a physical layer protocol data unit (PPDU). The NB PHY is accountable for the radio transceiver deactivation/activation, data transmission/reception, and CCA in the present channel. The PSDU should be pre-attached with a physical layer preamble (PLCP) and a physical layer header (PSDU) according to the NB specifications to create PPDU. After PCLP preamble, the PCLP header is directed through the data rates specified in its effective frequency band. The PSDU is considered the last PPDU module that comprises a MAC- header/frame body as well as a Frame Check Sequence (FCS) [16].

The HBC PHY offers the Electrostatic Field Communication (EFC) necessities, which cover preamble/Start Frame Delimiter (SFD), packet structure and modulation. For ensuring packet synchronization, the preamble sequence is sent four times, whereas the SFD sequence is only transmitted once [16]. The PHY header entails pilot information, data rate, synchronization, payload length, WBAN ID and a CRC designed over the PHY header.

The UWB physical layer is utilized to communicate the on-body and the off-body devices, in addition to communicating the on-body devices. Comparable signal power levels are generated in the transceivers in a UWB PHY. The UWB PPDU entails a PHY Header (PHR), a Synchronization Header (SHR) and PSDU. The SHR is made up of repetitions of 63 length Kasami intervals. It contains two subfields, namely (i) the preamble that is used for timing synchronization; frequency offset recovery and packet detection; and (ii) the SFD. The Ultra wideband frequencies provide higher throughput and higher data rates, whereas lower frequencies have less attenuation and shadowing from the body [17].

4.2 MAC Layer

On the PHY layer upper part, the MAC layer is defined based on the IEEE 802.15.6 working assembly to control the channel access. The hub splits the time axis or the entire channel into a super-frames chain for time reference resource allocation. It selects the equal length beacon periods to bound the super-frames [16]. For channel access coordination, the hub employed through one of the subsequent channel access modes:

(1) Beacon Mode with Beacon Period Super-frame Boundaries: In each beacon period, the hub directs beacons unless barred by inactive super-frames or limitations in the MICS band. The super-frame structure communication is managed by the hubs using beacon frames or Timed frames (T-poll).
(2) Non-beacon mode with superframe boundaries: It is incapable of beacons transmition. It is forced to employ the Timed frames of the superframe structure.
(3) Non-beacon mode without superframe boundaries: Only unscheduled Type II polled allocation in this mode is give by the hub. Thus, each node has to determine independently its own time schedule.

In each super-frame period, the following access mechanisms exist:

(a) Connection-oriented/contention-free access (scheduled access and variants): It schedules the slot allocation in one/multiple upcoming super-frames.
(b) Connectionless/contention-free access (unscheduled and improvised access): It uses the posting/polling for resource allocation.
(c) Random access mechanism: It uses either the CSMA/CA or the slotted Aloha approach for resource allocation.

5 WBAN Routing

For Ad Hoc networks [18] and WSNs [19], numerous routing protocols are designed. The WBANs is instead of node-based movement are analogous to MANETs with respect to the moving topology with group-based movement [20]. Furthermore, the WBAN has more recurrent changes in the topology and a higher moving speed, whereas a WSN has low mobility or static scenarios [20]. The routing protocols planned for WSNs and MANETs are unrelated to the WBANs due to the specific WBANs challenges [21].

5.1 Challenges of Routing in WBANs

There are several challenges of routing in WBANs including the following.

- Postural body movements, where the environmental obstacles, node mobility, energy management and the WBANs increased dynamism comprising frequent changes in the network components and topology that amplify the Quality of Service (QoS) complexity. Furthermore, due to numerous body movements, the link superiority between nodes in the WBANs varies with time [22]. Consequently, the routing procedure would be adapted to diverse topology changes.
- Temperature rise and interference at which the node's energy level should be considered in the routing protocol. Moreover, the nodes' transmission power required to be enormously low to minimize the interference and to avoid tissue heating [21].
- Local energy awareness is required, where the routing protocol has to distribute its communication data between nodes in the network to achieve balanced use of power and to minimize the battery supply failure.
- Global network lifetime at which the network lifetime in the WBANs definite as the time interval from the network starting till it is damaged. The network lifetime is significant in the WBANs associated to the WSNs and WPANs [23].
- Efficient transmission range is one of the significant challenges where in WBANs; the low RF transmission range indicates separating between the sensors in the WBANs [24].
- Limitation of packet hop count, where one-hop/two-hop communication is available in the WBANs in consistent with the IEEE802.15.6 standard draft for the WBANs. Multi-hop transmission offers stronger links that lead to increasing the overall system reliability. Large energy consumption can be achieved with the larger hops number [25].
- Resources limitations including energy, data capacity, and WBANs device lifetime, which is severely limited as they necessitate a small form factor.

6 Security in WBANs

Security is considered a critical aspect in all networks especially for the WBANs. The stringent resource restrictions with respect to the computational capabilities, communication rate, memory, and power along with the inherent security vulnerabilities lead to inapplicable certain security specifications to the WBANs. Consequently, the convenient security integration mechanisms entail security requirements' knowledge of WBANs that are delivered as follows [26]:

- Secure management at which the decryption/encryption processes involves secure management at the hub to deliver key distribution to the WBS networks.
- Accessibility of the patient's information to the physician should be guaranteed at all times.
- Data authentication at which the medical/non-medical applications necessitate data authentication. Verification becomes essential to both the WBAN nodes and the hub node.
- Data integrity at which the received data requirements should be guaranteed of not being changed by a challenger via appropriate data integrity using data authentication protocols.
- Data confidentiality at which data protection from revelation is realizable via data privacy.
- Data freshness which is essential to support both the data integrity and confidentiality.

A security paradigm for WBANs has been proposed by the IEEE 802.15.6 standard as illustrated in Fig. 5 comprising three security levels [27].

Figure 5 revealed that the main security levels are as follows:

(a) Level 0 refers to unsecured communication, which is considered the lowest security level, where the data is transmitted in unsecured frames and offers no measure for integrity, authenticity, validation and defense, replay privacy, protection and confidentiality.

(b) Level 1 is concerned with the authentication without encryption, where data is transmitted in unencrypted authenticated frames. It includes validation, authenticity, integrity and replay defense measurements. Nevertheless, it did not provide confidentiality or privacy protection.

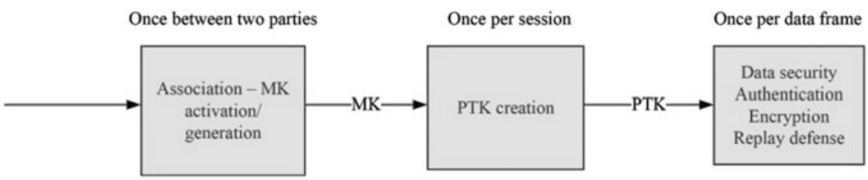


Fig. 5 IEEE.802.15.6 security framework

(c) Level 2 includes both encryption and authentication. Thus, it is considered as the highest security level at which messages are conveyed in encrypted and authenticated frames. The essential security level is chosen through the association process. In a WBAN, at the MAC layer prior to data exchange, all nodes and hubs have to go through definite stages.

Typically, the hub and node can exchange several frames, namely the connection task secure frames, connection request frame, security disassociation frame and the control unsecured frame.

7 WBAN Requirements in IEEE 802.15.6

The chief IEEE 802.15.6 standard requirements are as follows [21, 28–31]:

- The WBAN links have to support 10 Kb/s to 10 Mb/s bit rate ranges.
- The Packet Error Rate (PER) must be less than 10% for a 256 octet payload.
- In less than 3 s, the nodes must have the ability to being removed and to be added to the network.
- Each WBAN should has the ability to support 256 nodes.
- Reliable communication is required by the nodes even when the person is moving. In a WBAN, nodes may move individually relative each other.
- Latency, jitter and reliability have to be supported for WBAN applications. Latency should be <125 ms in the medical applications and <250 ms in the non-medical applications, while jitter should be <50 ms.
- In-body and on-body WBANs have to be able to coexist within range.
- Up to 10 co-located WBANs which are randomly distributed.
- In a heterogeneous environment, the WBANs must be able to operate as different standards networks collaborate among each other to receive the information.
- The WBANs have to incorporate the QoS management features.
- Power saving techniques must be incorporated to allow the WBANs from working under power constrained conditions.

8 Challenges and Open Issues of WBANs

The main challenges and open issues to realize the WBANs are:

- Environmental challenges:
  The WBANs suffer from high path loss due to body absorption. This should be reduced via multi-hop links and heterogeneous with different sensors at several positions. Due to the multi-path and mobility, the channel models become more

complex. In addition, antenna design leads to more challenging issues due to certain WBANs constraints related to the antenna shape antenna, size, material and malicious RF environment [32–36]. In fact, implant dictates the location of its antenna.

- Physical layer challenges:
  The PHY layer protocols have to be implemented for minimizing the power consumption without reliability. These protocols must be convenient for interference-agile places [37].
  Low power RF technology advancements can decease the peak power consumption leading to small production, low cost and disposable patches. The WBANs should be scalable and have about 0.001–0.1 mW peak power consumption instand-by mode and up to 30 mW in fully active mode [37].
  Interference is considered one of the significant WBAN systems drawbacks [38]. It occurs when peoples who wear WBAN devices and step into each other's range. The co-existence issues become more prominent with higher WBAN density. In addition, unpredictable postural body movements may facilitate the networks movement in and out of each other's range [17].
- MAC layer challenges:
  The IEEE 802.15.6 mechanisms do not build up the whole MAC protocol. Only the fundamental requirements to ensure the interoperability among the IEEE 802.15.6 devices [17].
  Furthermore, the MAC protocols must support the prolong sensor lifetime, WBAN applications energy efficiency requirement, save energy and allow flexible duty cycling. Generally, for WBANs, the proposed MAC protocols do not offer effective network throughput. Such protocols lead to delayed performance at varying traffic and challenging power requirements. The WBANs also have precise QoS necessities that required to be performed by the MAC proposal.
- Security challenges:
  Due to the resources limitation in terms of processing power, memory, and energy, the existing security techniques are incapable to WBANs.
- Transport (QoS) challenges:
  In WBANs applications, the QoS requirements must be achieved without performance degradation and complexity improvement. In WBANs, the limited memory requires efficient retransmission, error detection strategies and secure correction.

Currently, Smartphone devices are more user-accepted, inescapable and powerful. Correspondingly, mobile health (mHealth) technologies have qualified a minor change from implanting and/or wearing body sensors to carry a prevailing wireless device with multifunctional abilities [39]. In addition, Smart phones can be unconventionally used for sleep monitoring [40–43]. From the preceding discussion, the role of both IoT and big data is clarified. Both techniques has a role in different applications especially in healthcare [44–65].

9 Conclusion

In this chapter, an on-going research review of WBANs regarding the system architecture, PHY layer, routing, MAC layer, security are provided. Open issues in WBANs are also presented. In medical applications, the WBANs will permit incessant patients' monitoring that allows early abnormal conditions detection resulting in main developments in the life quality. Elementary vital signs monitoring can allow patients to perform normal activities. In instant, the technical research on this appreciated technology has noteworthy prominence in superior uses of accessible resources, which affect our future well-being.

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