

Wireless Body Sensor Network Applied to Blood Pressure Monitoring System

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Abstract

Continuous and accurate blood pressure monitoring is crucial for the early detection and management of cardiovascular diseases. Wireless Body Sensor Networks (WBSNs) have emerged as a promising technology for non-invasive and continuous blood pressure monitoring, offering numerous advantages over traditional cuff-based methods. This abstract presents a comprehensive overview of the application of WBSNs in blood pressure monitoring systems, focusing on sensor technology, data transmission, signal processing, power management, security, and clinical applications. Sensor technology in WBSNs encompasses various techniques, such as photoplethysmography (PPG) and oscillometric methods, enabling the measurement of blood pressure with acceptable accuracy. The collected physiological data are wirelessly transmitted to a central processing unit, which employs advanced signal processing algorithms to filter noise and motion artifacts, ensuring reliable blood pressure readings. Efficient power management techniques play a vital role in extending the battery life of wearable devices, enabling continuous monitoring without frequent recharging. Low-power communication protocols like Bluetooth Low Energy (BLE) and Zigbee facilitate seamless data transmission while minimizing energy consumption. Data security and privacy are paramount in healthcare applications. Encryption, secure communication, and user authentication measures are employed to protect sensitive patient data from unauthorized access. Validation studies and clinical trials have demonstrated the reliability and accuracy of WBSNs for blood pressure monitoring. The continuous and non-invasive nature of WBSNs allows for remote monitoring and telemedicine applications, empowering healthcare providers to remotely monitor patients and intervene promptly when necessary. Moreover, the integration of WBSNs with electronic health records (EHRs) and telehealth platforms streamlines data sharing and enables personalized healthcare interventions. In conclusion, the application of Wireless Body Sensor Networks to blood pressure monitoring holds significant promise in revolutionizing healthcare practices. With ongoing advancements in sensor technology, data analysis, power efficiency, and security measures, WBSNs offer the potential to improve patient outcomes and enhance cardiovascular health management.

Keywords: Wireless, Body Sensor, Network, Blood Pressure, Monitoring System.

Introduction

Wireless Body Sensor Networks (WBSNs) use miniaturised, low-power sensor nodes to monitor the human body. These sensor nodes monitor physiological parameters and collect

health data for medicinal applications (Geng & Li, 2015). These sensors wirelessly communicate data to a central processing unit for analysis, storage, and therapeutic use. Humanity's health is crucial. Healthy people lessen the demand on overworked hospitals, clinics, medical personnel, public safety networks, charity groups, and governmental (or non-governmental) organisations. Modern healthcare must be effective and accessible to maintain health. A modernised healthcare system should provide improved services at any time, from any location, and at an affordable, patient-friendly price. Darwish and Hassanien (2012) said the healthcare system is changing from traditional to patient-centered. Traditional healthcare practitioners lead. They must see patients to diagnose and counsel. This strategy has two key issues. Additionally, biomedical equipment must be attached to the patient's bedside. The patient needs a doctor nearby. The patient-oriented strategy addresses these two issues. This approach equips patients with the knowledge and tools to actively diagnose and prevent their illnesses (Amna & Asma, 2015). This second technique relies on an easy-to-use Patient Monitoring System (PMS).

Existing mobile phone networks can be of use in this area due of their broad nature. It has been suggested by Boyeon, *et al.*, (2015) that mobile networks are essential to the process of resolving future issues pertaining to the state of global health. The mobile healthcare system is a developed concept at this point thanks to the widespread adoption of mobile phones across the world's markets. People who live in rural locations with limited access to other modes of communication may be able to use their mobile phones to participate in the healthcare system. This is made possible by employing mobile phone technology. Even something as basic as a cell phone can today serve as an effective instrument in medical care (Liang, *et al.*, (2019). It is possible to swiftly transmit time-sensitive and real-time information about a patient to a distant location via phone calls and text messages. Patients who live in rural places might avoid making pointless trips back and forth to healthcare facilities that are located further away as a result.

The collection of continuous blood pressure (BP) information is currently recognised as one of the most difficult difficulties faced by pervasive health systems. Monitoring spikes in blood pressure levels among the huge patient population that suffers from chronic high blood pressure can lead to the right customization of medicine in some cases (He *et al.*, 2017). In addition, the classification of patients with 'white coat' hypertension, which refers to persons whose blood pressure skyrockets as a direct result of the stress of going to the doctor, may be carried out precisely. Thirdly, according to Ahmed, *et al.*, (2013), continuous blood pressure monitoring can provide users with the opportunity to change their behaviour through the use of biofeedback. For instance, if a person is driving and their blood pressure starts to rise, receiving a warning that their blood pressure is rising while they are driving can help people relax and enhance their health. Professional medical personnel carefully keep an eye on an important sign known as blood pressure. It is normally measured manually or digitally with an inflatable arm cuff, which mechanically inflates and deflates to estimate blood pressure. This process is known as a sphygmomanometer. Variations in

blood pressure readings can be caused by a variety of factors, such as the time of day or even one's position, when using this technique for measurement (Park *et al.*, 2016). The inflation of the arm cuff, along with the disturbance and discomfort that it causes, has hindered widespread continuous monitoring of blood pressure in mobile settings.

There has been a large amount of motivation surrounding the human body to improve the quality of life, which has been made practicable by the development of miniaturised, intelligent, low-power, and autonomous sensor nodes. This has been brought about by the growing and ageing population as well as the increasing expenditures of healthcare systems. A body sensor network (BSN) is a wireless technology that is based on radio frequency (RF), and it connects nodes in a human body that have sensing or actuation capabilities (Tison *et al.*, 2020). A sensor node is responsible for data collection, processing, and wireless transmission afterward. A sensor is made up of several different parts, including a power device, a CPU, a memory unit, and either a receiver or a transmitter (Chen *et al.*, 2016). The electrocardiogram (ECG), electroencephalograph (EEG), artificial knee, blood pressure monitor, hearing monitor, breathing monitor, positioning monitor, motion monitor, and temperature monitor are some examples of the types of equipment that fall under this category.

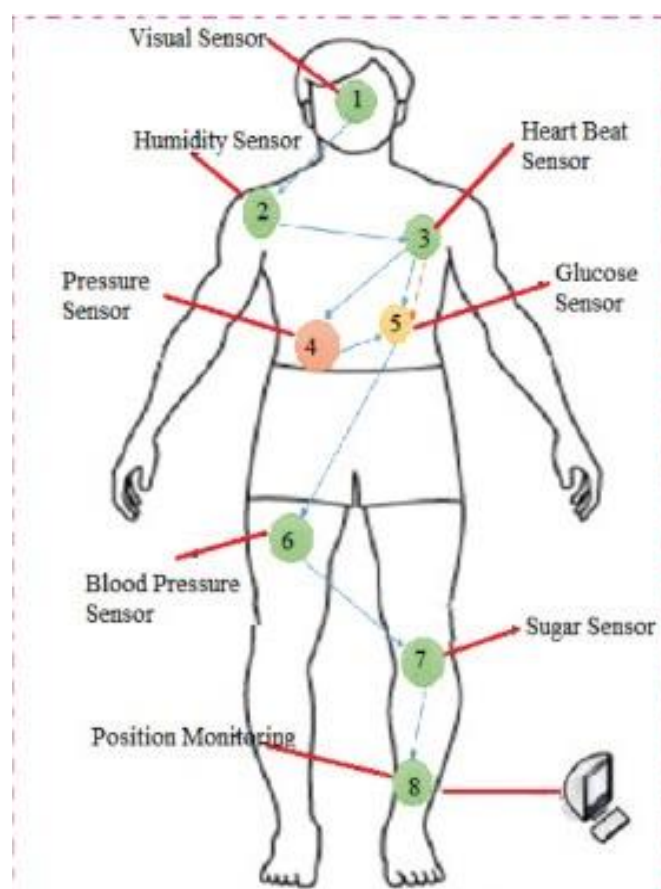


Fig. 1: Wireless Body Sensor Networks (WBSNs)

Source: Kalaivaani & Krishnamoorthi (2020)

Wireless body sensor networks are designed for use in applications that involve the monitoring and processing of human vital signs for the sake of health and well-being, entertainment, and tracking (Boulis *et al.*, 2012). The fundamental purpose of WBSNs is to provide continuous and real-time health monitoring, as well as to enhance the quality of medical services by making it easier to recognise potential health problems at an earlier stage. Another objective of WBSNs is to improve the overall health of the population. WBSNs can be used for a wide variety of purposes, one of which is to monitor the patient's blood pressure. This is a significant application that holds a tremendous amount of promise for enhancing the treatment of hypertension and other cardiovascular problems.

Problem Statement

Since these networks primarily deal with human vital signs, one of the most crucial requirements for a WBSN is to establish and maintain dependable and timely data transfer between the sensor nodes and the coordinator node. It could mean the difference between life and death if important human vital signs cannot be sent or received, or if they are received with significant delays. For an aged or a person with a chronic illness, it might be important to give ongoing patient care and monitoring. WBSNs offer a reasonably safe, affordable, and low-maintenance solution for people to keep their independence without the need for constant supervision or the presence of carers. In these situations, the patients are free to carry out their everyday activities, and as many people live in highly crowded metropolitan settings, such as marketplaces, hospitals, offices, and residential communities, WBSNs are continually confronted with a constantly shifting interference background.

Interference brought on by overlapping networks and/or technologies using the same radio spectrum is one of the main problems with wireless networks, especially WBSNs. Such issues become apparent in two situations: When two separate networks utilising the same protocol interact with one another. When other networks using various modulations and protocols conflict with one another.

Both of these scenarios presuppose that all involved networks are using overlapping or similar frequency bands, and that the distance between nodes of the two distinct networks is less than the range of their radio transceivers. The second case—external interference—is the sole focus of this theory. On IEEE 802.15.4 WBSN, the interference brought on by stationary Wireless Fidelity (Wi Fi) access points based on IEEE 802.11b is taken into consideration (Baozhi, & Pompili, 2012). Data transmission failure due to external interference is one of the effects of using the same spectrum as other technologies, and this gradually lowers network performance overall.

Objectives

The objectives of this study include the following;

- To provide efficient, timely, and emergency medical care

- To reduce the amount of power consumption in the network
- To ensure data integrity is maintained within the network
- To enable the WBSN operate across different networks without any interference from the other networks in the vicinity.

Literature Review

An important indication known as blood pressure measures the power that the heart uses to push blood through the circulatory system against the artery walls (He *et al.*, 2017). For the detection and treatment of disorders like hypertension (high blood pressure) and hypotension (low blood pressure), regular blood pressure monitoring is essential. These conditions can lead to severe health complications, including heart disease, stroke, and organ damage.

Traditional blood pressure monitoring methods involve using inflatable cuffs and auscultation (listening to Korotkoff sounds) or digital devices placed on the arm (He *et al.*, 2017). However, these methods often provide intermittent readings and may not capture fluctuations in blood pressure over time, especially during daily activities or sleep. This limitation highlights the significance of continuous, non-invasive blood pressure monitoring using innovative technologies such as WBSNs.

Components of a Wireless Body Sensor Network for Blood Pressure Monitoring

A typical Wireless Body Sensor Network for blood pressure monitoring comprises several key components according to Park *et al.*, (2016):

1. **Sensor Nodes:** These are small, wearable devices equipped with specialized sensors to measure physiological signals such as arterial pressure, heart rate, and other relevant biometric data. For blood pressure monitoring, the sensors typically measure the oscillometric method, photoplethysmography (PPG), or other optical-based techniques.
2. **Data Processing Unit:** The collected data from the sensor nodes are sent to a central data processing unit, which can be a smartphone, wearable device, or a dedicated gateway. This unit processes the raw data and converts it into meaningful blood pressure measurements.
3. **Communication Module:** The communication module allows the sensor nodes to wirelessly transmit data to the data processing unit. Common communication protocols used in WBSNs include Bluetooth, Zigbee, Wi-Fi, or cellular networks.
4. **Power Management:** Since WBSNs involve wearable devices, power management is crucial to ensure the longevity of the sensor nodes' operation. Low-power design techniques and energy-efficient algorithms are employed to extend the battery life of these devices.
5. **Data Storage and Analysis:** The collected blood pressure data is stored in the data processing unit and can be analyzed in real-time or periodically. Data analysis may

involve detecting abnormalities, trends, and patterns, which can be used to generate actionable insights for healthcare professionals and patients.

Advantages of Wireless Body Sensor Network Blood Pressure Monitoring

The implementation of WBSNs in blood pressure monitoring systems offers several advantages (Tison *et al.*, 2020):

1. **Continuous Monitoring:** WBSNs enable continuous and real-time monitoring of blood pressure throughout the day, providing a more comprehensive understanding of a patient's cardiovascular health. This continuous data can reveal patterns and trends that may be missed by intermittent measurements.
2. **Mobility and Convenience:** WBSNs are wearable and non-invasive, allowing patients to carry out their regular activities without restriction while being monitored. The convenience of wearable sensors encourages better patient compliance with monitoring regimens.
3. **Early Detection and Intervention:** Continuous blood pressure monitoring facilitates the early detection of abnormal fluctuations, enabling healthcare providers to intervene promptly and prevent severe complications.
4. **Remote Monitoring:** WBSNs facilitate remote monitoring, allowing healthcare professionals to access patient data from a distance. This feature is particularly valuable for home-based care and telemedicine applications, especially in rural or remote areas.

Challenges and Considerations

While WBSNs for blood pressure monitoring present significant benefits, they also come with challenges and considerations that need to be addressed:

1. **Accuracy and Reliability:** Ensuring the accuracy and reliability of blood pressure measurements from wearable devices is crucial. Factors such as motion artifacts, sensor calibration, and patient-specific variations can affect the accuracy of readings.
2. **Security and Privacy:** WBSNs handle sensitive health data, and maintaining the security and privacy of this information is paramount. Encryption, secure communication protocols, and access controls must be implemented to safeguard patient data.
3. **Power Efficiency:** Maximizing the battery life of wearable sensor nodes is essential to ensure uninterrupted monitoring. Advanced power management techniques and energy-efficient sensor designs are vital to achieve this goal.
4. **Standardization:** The lack of standardized protocols and data formats in WBSNs can hinder interoperability between different devices and systems. Establishing industry-wide standards can promote seamless integration and data exchange.

Methodology

Small heterogeneous sensor nodes form a WBSN. Figure 2 shows multiple sensor nodes on the body for various tasks. One for blood pressure, one for ECG, EEG, etc. BSUs are these nodes. BSUs communicate intra-WBSN/tier-1. The body control unit receives sensor node data. Inter WBSN/tier-2 connection sends data to laptops, phones, etc. These devices send data to an access point utilising Bluetooth, ZigBee, etc. The gateway connects to several networks using this data. Hospital, telephone, and medical centre networks are examples. Bangash, Abdullah, Anisi, and Khan (2014) state that internet data is available worldwide. These places can store data in database servers for doctors, researchers, patient history, and other uses. To prevent misuse, security features can restrict access to authenticated users. Our iPod or phone can save and transfer the data to a computer. Doctors can diagnose and give patients medications from afar. Beyond WBSN/tier-3 communication (Ronnie & Sungwon, 2014). 3G/4G networks allow internet data transfer.

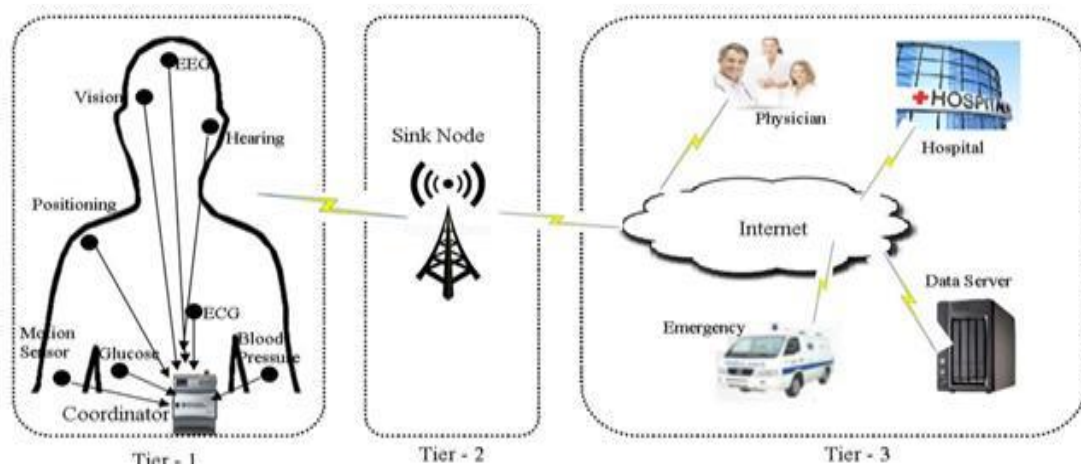


Fig. 2: The three tiers of WBSN

Source: Goyal *et al.*, (2023)

Sensor Nodes

Signal detection, signal digitization/coding/control for communication including multiple access, and lastly wireless data transmission via a transceiver are the three main tasks performed by a sensor node (Aarti & Partha, 2015). The signals that are picked up from the human body are noise-filled and feeble. Signal amplification, which improves the signal's power, is followed by signal filtration, which removes the noise from the signal. The analogue to digital converter converts analogue signals into digital signals, which are subsequently stored in the microcontroller.

The microcontroller then uses the transceiver to send these data packets to the internet. The energy distribution from the battery is optimally managed by the microcontroller. This is accomplished by the power management technique of turning off the devices that are in sleep mode.

Technology

IEEE 802.15.4 and ZigBee provide wireless sensor network infrastructure. ZigBee defines network and application layers, while 802.15.4 defines physical and MAC layers (Ekta & Mahesh, 2014). They can create WSNs with low data rates, complexity, power, and cost. The MAC layer controls radio channel access using Carrier Sense Multiple Access with Collision Avoidance. Direct sequence spread spectrum coding reduces interference and noise-induced packet loss in the IEEE 802.15.4 PHY. It offers two PHY layer modulations. The 868/915 MHz PHY uses binary phase shift keying, while the 2.4 GHz PHY uses offset quadrature.

MAC Reduced Function Devices (RFDs) include end devices, coordinators, and routers. FFDs might be network coordinators or regular devices. It can talk to anything. Light switches and simple sensors use RFDs. It only talks to FFD. ZigBee Coordinator base stations construct and administer the network quickly. It needs lots of memory and processing power. ZigBee routers join groups and send packets multi-hop. It links routers and endpoints. ZigBee devices can only communicate via FFDs. (Fen & Xiuli, 2012). ZigBee theoretically supports 65,536 nodes. Authentication and 128-bit AES encryption secure it. The gearbox range is 10–75m, depending on power output and climate. ZigBee devices should last several months to years.

Case Studies and Applications

Several research studies and commercial applications have explored the implementation of WBSNs in blood pressure monitoring systems:

1. **Research Studies:** Various academic and clinical research studies have assessed the accuracy and usability of WBSNs for blood pressure monitoring. These studies have demonstrated promising results, highlighting the potential of continuous blood pressure monitoring in managing hypertension.
2. **Commercial Applications:** Several companies have developed wearable devices and smartphone applications that incorporate WBSNs for blood pressure monitoring. These products aim to provide users with convenient and continuous blood pressure measurements.

Conclusion

Wireless Body Sensor Networks applied to blood pressure monitoring systems offer a revolutionary approach to healthcare by providing continuous, real-time data for managing hypertension and related cardiovascular conditions. With advancements in sensor technology, communication protocols, and data analysis techniques, WBSNs have the potential to transform healthcare, enabling early detection of health issues and improving patient outcomes.

Recommendations and Suggestions

Based on the literature review, the following recommendations and suggestions are proposed to improve the application of Wireless Body Sensor Networks to blood pressure monitoring:

- **Long-Term Monitoring Studies:** Conduct long-term monitoring studies to assess the performance and reliability of WBSNs in real-world scenarios. These studies should involve diverse patient populations to validate the technology's applicability in different healthcare settings.
- **User Education and Training:** Educate patients and healthcare providers about the benefits, usage, and interpretation of blood pressure data from WBSNs. Proper training will help users maximize the potential of WBSNs and make informed healthcare decisions.
- **Integration with Electronic Health Records (EHRs):** Integrate WBSNs with existing electronic health record systems to streamline data sharing and ensure seamless access to patient information by healthcare professionals.
- Conduct cost-effectiveness assessments to assess the financial effects of installing WBSNs for blood pressure monitoring.

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