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Review Article

A Review of Application of Wireless Sensor Networks in Healthcare

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Abstract

Recent developments in electronics and wireless networks have paved the path for the emergence of emergency wireless sensor networks and their subsequent widespread deployment (WSNs). WSNs have emerged as indispensable tools in a wide variety of fields, including industrial automation, infrastructure, healthcare, agriculture, environmental control, and military leadership, to name a few. Recent progress in wireless sensor networks has made it possible for a wide variety of applications to be implemented in the healthcare industry. Because of the vast potential it holds, it has recently become a focus of intensive investigation. The application areas of wireless sensor networks, specifically as they pertain to the medical industry, are the primary emphasis of this research. In this work, we have attempted to explain the fundamentals of wireless sensor networks as well as the various difficulties that WSNs must overcome in order to put their plans into action. The various benefits and drawbacks of using WSNs in the healthcare sector are also covered in this article. This paper also presents a number of essential metrics, each one of which may be utilized for the purpose of doing performance evaluations of wireless sensor networks. Because of the critical nature of the problems facing healthcare today, wireless sensor networks have a tremendously bright future, and it is imperative that they be implemented as soon as possible.

Keywords *- Wireless sensor Networks (WSNs); Healthcare Sector; Performance Evaluation,*

1. Introduction

We have seen in recent years the growth of wireless sensor networks (WSNs) in healthcare, which is driven by technological advancements in low-power networked systems and medical sensors. Early system prototypes, for instance, have shown the potential of WSNs to enable early clinical deterioration detection through real-time patient monitoring in hospitals [1-2], improve first responders' ability to provide emergency care in major disasters through automatic electronic triage [3-4], enhance the quality of life for the elderly through smart environments, and enable large-scale field studies of human behavior and chronic diseases [5–6].

Wireless local area networks (WLAN), mobile ad hoc networks (MANET), and cellular networks are examples of classic wireless networks. Wireless sensor networks are very distinct from these networks. Organization, routing, and mobility management functions are utilized in these networks to enhance bandwidth efficiency and improve quality of service (QoS) [7]. Although energy consumption is of minor concern, these wireless networks strive to offer great throughput and latency characteristics under highly mobile settings. On the other hand, a wireless sensor network is made for unattended operation, and energy conservation is a crucial factor in extending lifetime. Most nodes instead interact with their local peers rather than the closest base station. Wireless sensor networks represent a novel class of wireless networks with unique properties and difficulties [8]. With the deployment of wireless sensor networks, it is now possible for a patient to go about his regular business at home or at work while being watched for any health anomalies [9–15] in a more efficient and cost-effective manner. Greater mobility, less patient restraint, and an essentially imperceptible method of patient monitoring are all made possible by the wireless capability and node size [16]. As an illustration of the significance of wireless sensor networks, Intel® Proactive Health asserts that they may be "critical to solve the pending

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global age wave and public health problem" [17]. In order to improve both the patient experience and the standard of treatment, wireless sensor networks can be deployed successfully in the healthcare industry [18]. For instance, patients who have a body sensor network (BSN) may receive their diagnosis without physically being present at the doctor's office. A body sensor network demonstrates its suitability for emergency situations, as it communicates patient health data on its own so the doctor can get ready to treat the patient right away [19–21].

Although the usage of AAL systems and wireless communications in the health sector is expanding, there is still a dearth of research literature examining trials of these technologies. The application of WSN in the health domain is systematically reviewed in this paper, and unresolved challenges are identified for future research.

2.Basics of WSN

A Figure 1 illustrates how wireless sensor networks, also known as smart sensor nodes, are made up of numerous geographically dispersed autonomous devices that work together to jointly monitor environmental or physical variables at various locations [22]. A wireless sensor network is made up of numerous sensor devices that can communicate wirelessly and work together to accomplish a single goal. Data from all sensor devices is collected by one or more sinks (or base stations) in a WSN. The WSN's interaction with the outside world is represented by these sinks [23]. The fundamental idea behind a WSN is to accomplish networked sensing utilizing a large number of relatively simple sensors rather than the more traditional method of creating a few expensive and sophisticated sensing units [24]. Greater coverage, accuracy, and reliability at a potentially reduced cost are the main benefits of networked sensing over the traditional approach [23].

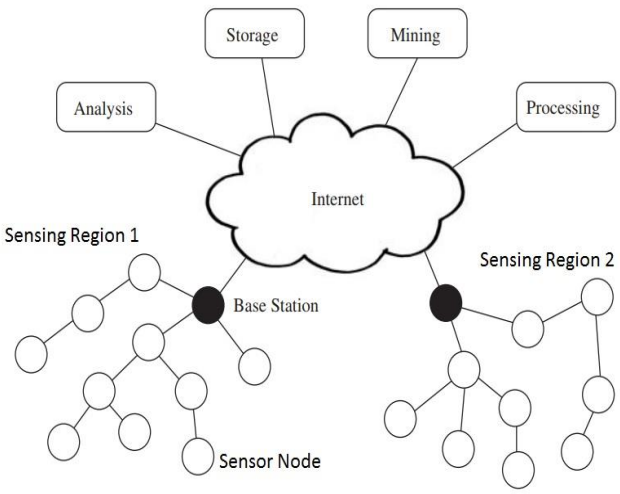

Fig. 1 Basics of Wireless Sensor Networks (WSN)

Initially created for military use, wireless sensor networks have since been applied to a variety of civil applications, including traffic management, home automation, environmental monitoring, and monitoring of animal habitats [25]. The use of wireless sensor networks in games is advantageous [26]. Additionally, commercial applications are starting to emerge [27].

Wireless sensor networks have become a viable technology for a wide range of uses, including numerous applications in the field of health care. Health Care WSNs (HCWSNs) that fulfill the essential system architecture needs of reliable communication, node mobility support, multicast technology, energy efficiency, and timely data transmission can be designed using WSN technology.

3.Application Area of WSN in Healthcare Sector

Healthcare is a constant source of worry since it affects the kind of life a particular person can lead. Since it is usually preferable to avoid illness than to treat it, regular individual monitoring is necessary. The aging population of wealthy nations places increasing financial strain on the government and creates new problems for healthcare systems, particularly when it comes to the number of elderly individuals residing in independent senior housing [28].

Since it affects how people live, healthcare is a constant, crucial topic. It has always been of utmost importance in every field. WSN has numerous applications in the healthcare industry. We have made an effort to condense all WSN application areas in this work. The applications of WSN in the healthcare industry have been divided into various areas.

Despite the fact that biomedical smart sensor technology is still in its infancy, some applications already exist. Wireless sensor networks are currently being used in healthcare applications that target heart disorders, such as continuous ECG monitoring to identify potential issues beforehand [29–30], asthma [31], emergency response [32], and stress monitoring [33]. The post-operative phase is a major source of worry for doctors [34] because patients are at danger because of post-operative pain. In the near future, it will be possible to combine current specialist medical technology with pervasive wireless networks [34]. Wireless sensor networks are advantageous for medical applications in several ways. The latest improvements in the downsizing of smart biosensors will create new possibilities for ongoing patient monitoring. Small, discrete wearable sensors will make it possible to collect enormous volumes of data automatically, cutting down on the expense and inconvenience of frequent doctor visits. Thus, many more researchers may sign up, which would be advantageous to all research peers [35]. In [36], the authors describe a method for enabling wireless medical body sensors (WMBSs) to be as simple to use as plug-and-play devices by allowing body-worn

sensors to identify the body they are being used on. No interference is created between WMBSs since the smart sensor connection is restricted to on-body sensors. In-person communication is referred to by these authors as "body-coupled communication" (BCC).

3.1 Home monitoring

Future medical systems can use wireless sensor networks to their greatest advantage in areas including in-home help, smart nursing homes, clinical trials, and research augmentation. The capacity to provide services at home supports and enhances patient benefits such as privacy, dignity, and convenience. The healthcare team includes both the family and the smart homecare network. Memory aids and other patient assistance services can help patients maintain their safety while regaining some lost freedom.

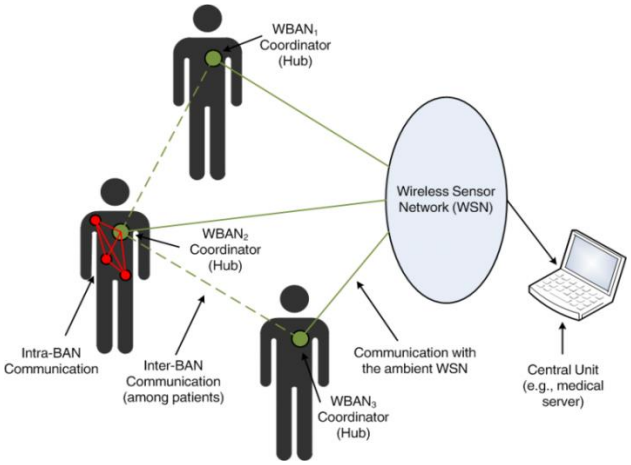

Fig. 2 Multi-patient scenario

Multiple patients are being watched in a small area in the multi-patient situation shown in Figure 2. (e.g., a clinic room, a hospital wing, etc.). Each patient has a single coordinating node that forms a WBAN from the sensors they are carrying. The coordinator is in charge of gathering all the data and sending it, through an ambient WSN, to the central unit. If every patient wears the same kind of sensor, the overall network traffic may be homogeneous; otherwise, it may be heterogeneous.

3.2 Preventing medical accidents

The prevention of medical accidents brought on by human mistake is currently one of the most crucial topics in the medical field. Approximately 98'000 persons every year pass away as a result of such mistakes. Hospitals have a high number of fatal medical errors and mishaps. Wearable environmental sensors are used as part of a sensor network in the "E-nightingale project" to decrease medical errors by observing nurses' actions [37]. By keeping track of previous medical mishaps, the sensor network can alert the nurses in the event of a recurrence, reducing the number of mishaps and perhaps saving many lives.

3.3 Cardiovascular diseases

Cause a lot of deaths in industrialized nations. If the doctor had been aware of the patient's existing health situation earlier, many lives could have been prevented. Smart sensor nodes that can be discretely implanted on the patient are used in several ideas [38–40]. The appropriate medical staff is informed of the patient's vital signs, including heart rate and abnormalities, in order to prepare for therapy and monitor the patient's health.

3.4 Alzheimer, depression, and elderly people monitoring.

The number of elderly individuals is rising as the global population becomes older. Alzheimer's disease affects many elderly people, many of whom experience loneliness and depression and have little to no interest in social interaction or physical activity. Wireless sensor networks provide a way to prevent this result by integrating home automation, detecting anomalous circumstances (like a fall), or even notifying friends, family, or the closest hospital. [41] describes an accelerometer-based method for detecting irregular movement that can be used to non-intrusively and non-invasively identify seizures. The scientists created an algorithm that recognizes brush, wash, and shave activity using ZigBee protocol devices. [42] presents a different idea. To assist those who are confined to their homes, the authors deploy a mobile phone and a wireless sensor network-based strategy. The system offers real-time warnings and notifications and can employ a ZigBee or Bluetooth enabled wireless sensor network.

3.5 Cancer Detection

Reflects one of the key healthcare issues. Cancer is one of the most common treatments for human existence today. Currently, 9 million people have received a cancer diagnosis, and 1,221,800 new cases were reported in 1999, making cancer the second highest cause of death in the United States [43]. However, there is currently no proven method for preventing cancer, and early identification is essential. Nitric oxide, which has an impact on the circulation in the region around tumors, is expelled by cancer cells, according to studies. In questionable areas, a sensor that can identify these alterations in the blood can be positioned. Additionally, research is being done on the use of sensors on a needle to help doctors diagnose malignancies without doing a biopsy. This device's sensors are able to distinguish between various cell types, recognizing malignant ones [44].

3.6 Asthma

Sudden allergic morbidity poses a serious threat to the lives of the millions of asthmatics around the world. Rapid-onset asthma attacks must be treated with terbutaline quickly to alleviate symptoms; otherwise, the attacks could be fatal [45–46]. They can benefit from a wireless sensor network since it has sensor nodes that can detect allergens in the air and communicate the situation continually to a doctor or the patient. A portable GPS-based gadget that constantly checks in with a remote server and reports was created by Hsueh-Ting Chu et al. (47).

3.7 Monitoring in Mass-Casualty Disasters

Emergency medical services already have triage procedures in place, but as more victims are treated, their efficiency can soon deteriorate. Additionally, during such mass-casualty crises, there is a need to enhance the evaluation of the health state of the first responders. Wireless sensing devices' improved portability, scalability, and ability to be quickly deployed can be utilized to more efficiently track the health of first responders at disaster scenes and automatically report the triage levels of numerous victims [48–49].

3.8 Vital Sign Monitoring in Hospitals

In order to monitor patients in hospitals and emergency rooms, wired sensors frequently have limitations that wireless sensing technology helps to overcome [2]. In addition to making patients less mobile and more anxious, the all-too-common tangle of wires tied to a patient is difficult for the personnel to handle. When patients are transported throughout a hospital and handed off to different units, purposeful sensor disconnections by worn-out patients and improper sensor reattachments are quite prevalent. Unobtrusive wireless sensing technology with constant network connectivity to back-end medical record systems helps lessen patient anxiety and wire tangles while also lowering error rates.

3.9 At-home and Mobile Aging

A number of cognitive, physical, and social changes that occur as we age pose a threat to our health, independence, and quality of life [50]. Monitoring and treating conditions like diabetes, asthma, chronic obstructive pulmonary disease, congestive heart failure, and memory loss can be difficult. Patients participating actively in the monitoring procedure can help these disorders. Wirelessly networked sensors can gather data about a person's physical, physiological, and behavioral states and patterns in real-time and everywhere. These sensors can be carried by a person or integrated in their living spaces. These data can also be connected to environmental and social context. Such "living records" allow for the deduction of beneficial health and wellness information. This can be shared with caregivers for early identification and intervention as well as for self-awareness and individual analysis to help with behavior adjustments. These procedures are also efficient and affordable ways to keep an eye on ailments associated with aging.

3.10 Large-scale In-field Medical and Behavioral Studies

Body-worn sensors and sensor-equipped Internet-connected smart phones have started to transform medical and public health research studies by making it possible to continuously collect behavioral and physiological data from a large number of dispersed individuals as they go about their daily lives. Such sensing systems are becoming essential to medical, psychological, and behavioral research due to their capacity to provide insight into subject states that cannot be replicated in controlled clinical and laboratory settings and that cannot be measured from computer-assisted retrospective self-report methods. Indeed, the development of such field deployable sensing tools to quantify environmental exposures (such as psychosocial stress, addiction, toxicants, diet, and physical activity) objectively, automatically, and for days at a time in the participants' natural environments is a key objective of the Exposure Biology program under the NIH's Genes and Environment Initiative (GEI). Researchers have acknowledged the value of such sensing in making measurements for longitudinal research spanning from the scale of people to huge populations, both inside the GEI program [51-52] and elsewhere [53-55].

3.11 Assistance with Motor and Sensory Decline

To actively support and direct patients dealing with deteriorating sensory and motor capacities is another use for wireless networked sensing. We are witnessing the introduction of new categories of intelligent assistive devices that use sensors placed in the environment, worn or even implanted on the user, to collect data about the user's physiological and physical status. In addition to adapting their responses to specific users and their current circumstances, these intelligent assistive gadgets can also give users and their carers important feedback for longer-term training. Traditional assistive tools like canes, crutches, walkers, and wheelchairs can combine data from internal and external sensors to give users ongoing, individualized feedback and pointers on how to utilize the tools properly. The physical properties of such devices can also be modified in accordance with the environment and a recommended training or rehabilitation program [56]. Furthermore, wireless networked sensing offers brand-new categories of assistive technologies for the blind, like walking navigation [58] and way-finding [57].

3.12 Performance Parameters of WSN

As shown in Figure 3, there are various criteria by which we can assess the effectiveness of wireless sensor networks. Evaluation of the WSN's performance in terms of frequency, precision, and duration. For WSN nodes, the sensors' data precision, response time, battery life, and packet loss rate are crucial considerations [59–61].

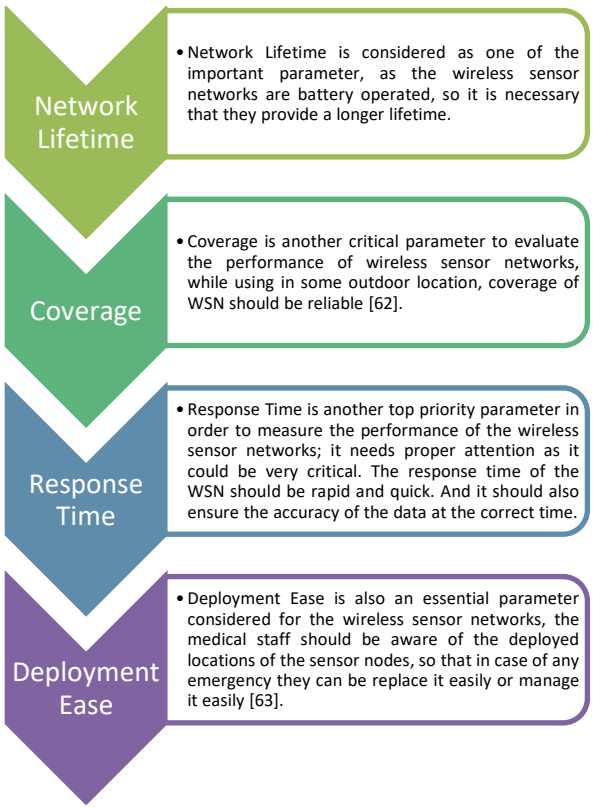

Fig. 3 Performance Parameters of Wireless sensor Networks

4. Challenges

Although there are many advantages to using WSN in the healthcare industry, there are also some drawbacks, including low power, restricted computation, low bandwidth, reliable data transmission, continuous operation, interference, node mobility support, vulnerability, security, timely data delivery, security, privacy, congestion, and regulatory constraints. WSN devices often have limited power, processing, and communication capabilities. The lack of power severely restricts computing. WSNs are susceptible to a number of sensor flaws, which makes it difficult for healthcare applications to respond quickly and effectively. Any system needs to be secure, but healthcare WSNs are particularly vulnerable because we are dealing with patients' private medical information. A key problem is security breaches in WSN applications used in healthcare [64]. Patients' concerns about privacy are among the biggest obstacles to the adoption of electronic healthcare. End-to-end reliability, which assesses how effectively a system functions in the presence of disturbances, is constrained by healthcare applications. Since it interferes with data flow and causes delivery delays, congestion must be reduced. Interoperability issues are brought on by the integration of many sensing devices that operate at various frequencies.

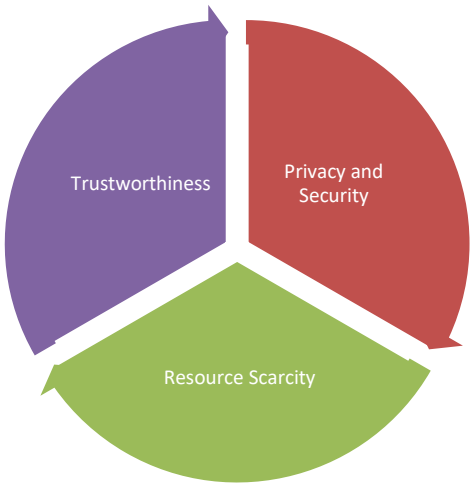

Fig. 4 Major Challenges for WNS in Healthcare Sector

Security Due to their wireless nature, wireless sensor networks have always faced a particularly difficult security issue. There are grave threats that could trigger major security problems. For instance, in some situations, employing a wireless sensor network to track a location can have detrimental effects. It can result in inappropriate use of the WSN. A WSN should be intelligent enough to protect the patient's data. The patient is given the reassurance that the system is dependable and trustworthy and would protect their data [32].

Regarding healthcare concerns, privacy has always been the main consideration in wireless sensor networks. Patients are extremely concerned about their privacy and personal information. It may pose a serious threat to a patient's right to privacy. People are extremely cautious about their data, including where it is held, how it is used, and who has access to it. The sensor nodes that are implanted inside of human bodies raise yet another significant privacy issue. Patients are under psychological pressure and can believe that their privacy has been taken away from them [65].

Nowadays, power is seen as the greatest difficulty, as WSN require constant power even though they require less power overall. One of the biggest problems that WSN apps confront is continuous performance; if it doesn't function properly on a regular basis, it might be quite harmful and, given how sensitive healthcare-related concerns are, have serious repercussions [66].Wireless sensor networks' robustness is another key issue. Regardless of the surroundings and circumstances they are in, sensor nodes should guarantee their extended lifespan and function.

Another significant difficulty that the WSN apps must overcome is data synchronization. The integrity

of the patient's data must be guaranteed by WSN in order to provide the right data at the right time [66].

Conclusion

This study demonstrates the broad applicability of wireless sensor networks in healthcare and the high level of engagement in this field of study. It examined a wide range of healthcare systems and applications, discussed the principal difficulties, and provided metrics for assessing wireless sensor networks. Smaller and more feature-rich sensor nodes from the industry could lead to further development of these new small body networks and make their use seem as natural as donning clothing. A long-standing objective made possible by the development of mobile technologies is remote patient monitoring. Wireless sensor networks, on the other hand, offer an inexpensive way to monitor a specific area, and because they are wireless, they work well for inconspicuous deployment on patients. Even while some sensor networks have been put into use for medical purposes, the majority are still in the prototyping stage. The cost of the currently employed smart biosensors is still high, and we are still a long way from having sensors that can be thrown away. Smart biosensors require a lot of power, but batteries are not developing at the necessary rates.

Wireless body sensor networks are the future, yet there are several issues with wireless communication, from the usable spectrum to the consequences on the human body. Robustness, security, and interference-free communication are important considerations when it comes to protocols. We think that wireless sensor networks can play a bigger part in medicine. Wireless sensor networks will soon allow smart spaces to assess environmental conditions and take preventive measures based on the presence of people in those places. Therefore, the system can become ubiquitous, where each person would have a computing module capable of interacting with the smart space's system and avoiding health issues. It appears promising that IP will be used as a protocol to link the body sensor network to the rest of the world [69]. When compared to the current proprietary technique, the integration of IP into the smart sensor nodes may offer advantages in self-configuration and data collection, but it also introduces communication overhead and may impair the real-time behavior that we anticipate such systems to display. We are presently working on this line of inquiry.

Future Directions

In the future, the healthcare industry will likely be significantly impacted by wireless sensor networks, in our opinion. Wireless sensor network usage is rapidly expanding, and because it already has a significant impact on human life, it has been projected that these smart sensors would become an integral part of our daily lives. WSNs that self-organize have a promising future in the healthcare industry. Wireless sensor networks can enhance systems like smart nursing and in-home support. The patient can maintain their privacy while at home, and healthcare services will be delivered right at their front door.

The first generation of wireless sensor networks for healthcare has demonstrated its ability to change the practice of medicine, driven by user demand and supported by recent advancements in hardware and software. The extent to which wireless sensor networks will be successfully incorporated in healthcare practice and research will depend on the struggle between trustworthiness and privacy, as well as the capacity to deploy large-scale systems that meet the applications' requirements even when deployed and operated in unsupervised environments.

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