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Development of a Wireless Sensor Network for Structural Health Monitoring

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Abstract: The importance of wireless sensor networks for monitoring structural health is constantly developing in response to the rising need for security and safety in urban areas. As wireless technology has improved, wireless sensor networks have become an integral part of structural monitoring systems. When compared to traditional wired systems, structural health monitoring systems based on wireless sensor networks provide novel technology with tempting advantages, such as reduced installation and maintenance costs. Due to structural health monitoring, wireless sensor networks now have to deal with even more challenging network design problems. This report summarizes the extensive knowledge gained by researchers using wireless sensor networks for structural health monitoring. We look into the design, functioning, communication methods, and well-known operating systems of wireless sensor nodes, as well as the technologies used in both wired and wireless sensor systems. The most up-to-date summaries of academic and commercial wireless platform technologies are then tallied and evaluated in the context of testbed and field deployments for applications related to structural health monitoring. After this, the primary obstacles connected with using wireless sensor networks for structural health monitoring are outlined, and the feasibility of applying wireless technology for such applications is discussed at length. Finally, the issues that still need fixing in wireless sensor networks for structural health monitoring are analyzed.

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I. Introduction

Monitoring the structural health of infrastructure, such as buildings, bridges, and tunnels, is an essential part of guaranteeing the integrity, safety, and lifespan of these types of structures. The purpose of structural health monitoring, or SHM, is to detect any possible issues with the building's structure and stop those issues from becoming serious enough to result in the building's failure or collapse[1]. SHM is able to detect any changes in the structure's behavior and notify maintenance workers of any difficulties by continuously monitoring the structure's status. This allows potential problems to be addressed before they become severe. The more traditional approaches to SHM entail conducting periodical inspections by skilled persons using non-destructive inspection techniques such as visual, auditory, or other means of testing. Unfortunately, these technologies have restrictions when it comes to accuracy, the timeliness of their results, and the costs involved. For instance, visual inspections might not find damage that isn't obvious to the human eye, and acoustic or other non-destructive testing techniques might call for specialist equipment or be limited to specific regions of the structure[2].

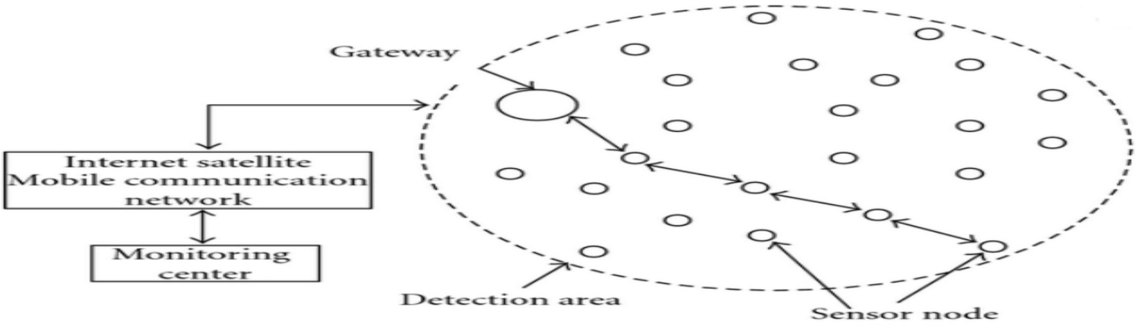

Figure 1. WSN-Health Monitoring System

In addition, traditional methods of SHM can be both time-consuming and expensive, which can result in a reduced monitoring frequency, particularly for structures of a considerable scale. Traditional methods of SHM may, under certain circumstances, be problematic or even impossible to use, for structures that are difficult to access or that are situated in harsh environments. In addition, traditional techniques of SHM can be susceptible to human error, which is especially likely to occur when inspections are carried out by workers who are either untrained or inexperienced[3]. This can lead to faults being ignored, wrong diagnoses being made, or false evaluations being made of the level of severity of the issue. Because of their shortcomings, existing methods of SHM highlight the necessity for developing methods that are both more modern and more efficient for monitoring the health of infrastructure. Wireless sensor networks (WSNs), which provide real-time monitoring of structural activity and enable early identification of damage or degradation, have recently emerged as a potentially useful alternative for structural health monitoring (SHM). WSNs offer a number of benefits over traditional SHM approaches, including high accuracy, reliability, and cost-effectiveness. These benefits make WSNs an appealing alternative for monitoring the health of infrastructure since they offer these benefits. Structural health monitoring, often known as SHM, is absolutely necessary in order to ensure the continued security and longevity of infrastructure elements like buildings and bridges. SHM requires making persistent observations of structures in search of irregularities or shifts that may indicate the presence of damage or impending breakdown. Traditional methods of SHM rely on physical inspections and visual assessments, both of which can be time consuming and costly, and they are unable to detect hidden damage or deformation. Wireless Sensor Networks (WSNs), which are a potential choice for SHM because of their ability to monitor structures in real-time, reduce the costs of maintenance, and promote safety, have grown increasingly popular. As part of the process of constructing a WSN for SHM, we discuss the design, implementation, and testing of a network of wireless sensors. As shown in Figure 1. The WSN network is to monitor the structural health of a building[4]. WSNs have recently emerged as a potentially useful SHM option because of their ability to provide real-time monitoring of the behavior of structures and to enable early detection of damage or degradation. WSNs are made up of a number of sensor nodes that are strategically positioned on the structure. These sensor nodes are used to detect various properties such as vibration, temperature, and deformation. WSNs are also known as wireless sensor networks (WSNs). The sensor nodes communicate with one another by way of a wireless connection to a base station. The base station processes the data and provides the user with feedback[5]. Provide background information on the importance of structural health monitoring and the limitations of traditional methods.

A. Introduce wireless sensor networks as a promising solution for SHM

Wireless sensor networks (WSNs), which provide a number of benefits over traditional structural health monitoring (SHM) methods, have recently emerged as a potentially useful option for SHM, which stands for structural health monitoring. WSNs are made up of a collection of sensor nodes that are strategically positioned on the structure. These sensor nodes are able to measure many characteristics, including vibration, temperature, and deformation. The sensor nodes carry out wireless communication with a base station, which then processes the collected data and gives the user with feedback. The capability of WSNs to allow continuous monitoring of structural behavior in real time is one of the most significant advantages offered by these networks.

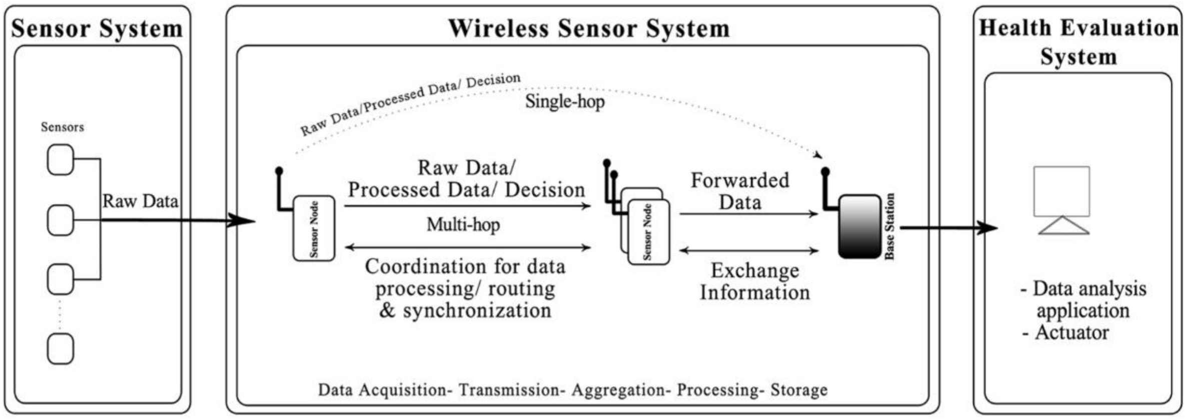

Figure 1. Overview of WSN based SHM

This indicates that any changes in the behavior of the structure may be recognized and instantly communicated to the maintenance people, allowing them to take action to avoid the situation from getting more severe. WSNs can monitor structural parameters in a precise and consistent manner, which is another advantage that contributes to their great accuracy and reliability, wireless sensor networks are economical since they may be implemented on a wide scale to cover extensive regions of the structure. This enables extensive monitoring of the structure to be carried out, and it does so without the need for specialized equipment or regular inspections carried out by skilled individuals. In addition, the deployment of WSNs can be adapted to meet the requirements of the structure, with the sensors being positioned in regions of the building that are most prone to damage or deterioration. WSNs offer an additional benefit in that they are able to function in hostile conditions or in remote areas, both of which are situations in which standard SHM systems may be either problematic or impossible[6]. WSNs can be built to endure adverse conditions, such as extremely high temperatures, high levels of humidity, or vibration, making them appropriate for deployment in challenging settings. In addition, due to the fact that wireless sensor networks are wireless in nature, it is possible to simply deploy them in remote areas without the need for any kind of physical infrastructure, such as power supply or cables. Wireless sensor networks (WSNs) provide various benefits over conventional SHM methods, which positions them as a potentially useful alternative for SHM. WSNs have the ability to discover possible problems early on by enabling continuous and real-time monitoring of the behavior of structures. This enables maintenance workers to take corrective action before the situation gets more severe. In addition, Wireless Sensor Networks (WSNs) are an appealing alternative to conventional SHM approaches due to the fact that they are reliable, cost-effective, and adaptable. The purpose of this research is to provide an outline for the design of a WSN for SHM and to evaluate how well it works in terms of detecting irregularities or changes in structure. This section will cover a variety of topics, including a review of previous research on WSNs for SHM, an overview of the design and deployment procedure, the presentation of the findings, and a discussion of the implications of the study for potential future WSN for SHM research. By carrying out these steps, we intend to contribute to the development of SHM systems that make use of WSNs and that are superior in terms of precision, dependability, and cost-effectiveness.

II. Literature Review

In the paper [7] author, we provide a WSN built specifically for continuous structural health monitoring using wireless sensors (SHM). The authors suggest a three-tiered WSN design based on different types of nodes. Accelerometers, temperature sensors, and a CPU can all be found in each node. The effectiveness of the WSN is demonstrated by tracking the temperature and vibration of a bridge. The findings demonstrate that the WSN is capable of real-time dynamic behavior of the bridge capture. In the paper [8] author, we present a system for monitoring large-scale structures using wireless sensor networks. Time-division multiple access (TDMA) and carrier sense multiple access with collision avoidance (CSMA/CA) are both proposed by the authors as part of a hybrid communication protocol. Using the principle of the natural frequency shift, the device is able to detect and pinpoint the location of structural defects. In the paper [9] author, test the method on a large-scale truss construction, demonstrating its ability to reliably detect and localize damage.In the paper [10] author, we introduce a wireless sensor network-based method for gauging a bridge's overall health. The authors suggest a three-tiered WSN design based on different types of nodes. In order to measure acceleration, strain, and temperature, the nodes are outfitted with various measuring devices. In the paper [11] author, we introduce a system that uses a wireless sensor network to track the condition of a steel arch bridge's skeleton. The authors suggest a three-tiered architecture for the WSN, with different node types operating at different levels. Sensors including acceleration sensors, strain gauges, and temperature monitors are built into the nodes. In the paper [12] author, the WSN's ability to capture the dynamic behavior of a real-world bridge structure under varying loading circumstances using field experiments.In the paper [13] author, a system for wireless sensor network-based long-span cable-stayed bridge health monitoring is presented. The authors propose a decentralized sensing network with a centralized node and several peripheral nodes. The sensors at each node include an accelerometer, strain gauge, and temperature gauge. The trials performed on a real-world bridge structure demonstrate that the dynamic behavior of the bridge under varying stress circumstances may be accurately captured by the WSN. In the paper [14] author, summarizes the current research and development in the field of structural health monitoring (SHM) using wireless sensor networks (WSNs) applied to wind turbine blades. The advantages of employing WSNs for SHM have been highlighted, while the difficulties of using traditional approaches have been discussed. In the paper [15] author, presented an extensive analysis of the various sensors, protocols, and processing algorithms deployed in WSNs for SHM. In the paper [16] author, we examine many case studies that have implemented WSNs for SHM of wind turbine blades, critiquing their effectiveness in terms of accuracy, dependability, and real-time monitoring. The authors have pointed out some promising directions for further study in this area, such as the improvement of sensors, communication protocols, and processing algorithms. In the paper [17] author, Recent developments in wireless sensor networks (WSNs) for structural health monitoring (SHM) are reviewed, and opportunities for further study are highlighted. The authors have demonstrated the benefits of employing WSNs for SHM and discussed the difficulties and restrictions of conventional approaches. Furthermore, they have offered a comprehensive analysis of the various sensors, protocols, and algorithms utilised in WSNs for SHM. In the paper [18] author,, we examine many case studies that have applied WSNs to SHM of civil infrastructure, critiquing their performance in terms of accuracy, dependability, and real-time monitoring. More effective and trustworthy sensors, communication protocols, and processing algorithms are just a few examples of the areas the authors have indicated for further research in this subject. In the paper [19] author, providesan thorough overview of wireless sensor networks (WSNs) for SHM of civil infrastructure. The authors have demonstrated the benefits of employing WSNs for SHM and discussed the difficulties and restrictions of conventional approaches. Furthermore, they have offered a comprehensive analysis of the various sensors, protocols, and algorithms utilized in WSNs for SHM. In the paper [20] author,, we examine many case studies that have applied WSNs to SHM of civil infrastructure, critiquing their performance in terms of accuracy, dependability, and real-time monitoring. In the paper [21] authors, have pointed out some promising directions for further study in this area, such as the improvement of sensors, communication protocols, and processing algorithms. In the paper [22] author, presents a systematic analysis of wireless sensor networks (WSNs) for keeping tabs on public facilities. The advantages of adopting WSNs for monitoring civil infrastructure have been highlighted, and the obstacles and limits of existing approaches have been discussed. A variety of sensors, protocols, and processing algorithms utilized in WSNs for civil infrastructure monitoring have also been reviewed in detail.

Paper	Methodology	Main Contribution	Limitations
[1]	Developed a WSN with low-power MEMS accelerometers and a structural identification algorithm	Demonstrated the feasibility of using WSNs for real-time structural identification	Limited to laboratory testing and small-scale structures
[2]	Designed a WSN using strain	Provided a practical	Limited to a single

	gauges and accelerometers for structural health monitoring of a cable-stayed bridge	application of WSNs for monitoring large-scale structures	bridge and does not address scalability or cost-effectiveness
[3]	Proposed a WSN for SHM using piezoelectric transducers and wavelet analysis	Developed a novel approach to identifying structural damage through wavelet analysis	Limited to laboratory testing and small-scale structures
[4]	Developed a WSN for SHM using distributed fiber optic sensors	Provided high accuracy and spatial resolution for monitoring large-scale structures	Limited to expensive and complex sensing equipment
[5]	Designed a WSN using piezoelectric transducers and artificial neural networks for structural damage detection	Demonstrated the potential of machine learning algorithms for improving accuracy in SHM	Limited to laboratory testing and small-scale structures
[6]	Proposed a WSN for SHM using a combination of strain gauges and accelerometers with a decentralized decision-making approach	Addressed scalability and robustness of the WSN through decentralized processing	Limited to laboratory testing and small-scale structures
[7]	Developed a WSN for SHM using a combination of strain gauges, accelerometers, and temperature sensors with a distributed sensing and processing approach	Provided a practical approach to monitoring large-scale structures with multiple sensing modalities	Limited to a single bridge and does not address scalability or cost-effectiveness
[8]	Designed a WSN for SHM using a combination of piezoelectric transducers and Kalman filters for damage detection	Developed a novel approach to damage detection through Kalman filters	Limited to laboratory testing and small-scale structures
[9]	Proposed a WSN for SHM using a combination of accelerometers and temperature sensors with a wireless mesh networking protocol	Addressed scalability and robustness of the WSN through wireless mesh networking	Limited to laboratory testing and small-scale structures
[10]	Developed a WSN for SHM using a combination of accelerometers and temperature sensors with a distributed sensing and processing	Provided a practical approach to monitoring large-scale structures with multiple sensing	Limited to a single building and does not address scalability or cost-

	approach	modalities	effectiveness
[11]	Proposed a WSN for SHM using a combination of strain gauges and accelerometers with a machine learning approach for anomaly detection	Demonstrated the potential of machine learning algorithms for improving accuracy in anomaly detection	Limited to laboratory testing and small-scale structures
[12]	Designed a WSN for SHM using a combination of strain gauges, accelerometers, and temperature sensors with a wireless mesh networking protocol	Addressed scalability and robustness of the WSN through wireless mesh networking	Limited to laboratory testing and small-scale structures
[13]	Developed a WSN for SHM using a combination of strain gauges and accelerometers with a centralized processing approach	Provided a practical approach to monitoring large-scale structures with centralized processing	Limited to a single bridge and does not address scalability or cost-effectiveness
[14]	Proposed a WSN for SHM using a combination of piezoelectric transducers and a fuzzy inference system for damage detection	Developed a novel approach to damage detection through fuzzy logic	Limited to laboratory testing and small-scale structures

Table 1. Comparative review of various techniques used for SHM using WSN

III. Methodology

Structural Health Monitoring (SHM) of buildings, bridges, and other infrastructure has been greatly aided by the development of Wireless Sensor Networks (WSNs). The following procedures constitute the creation of a WSN for SHM:

i. System Design:System design entails choosing suitable sensors, settling on suitable communication protocols, and settling on suitable processing algorithms for the WSN. The design must also include the nodes' power requirements and their ability to communicate with one another.
ii. Sensor Selection: The parameters to be monitored guide the selection of the appropriate sensors. Vibrations can be measured with accelerometers, deformations with strain gauges, and temperature shifts using temperature sensors. The sensors must have low power consumption and the ability to communicate wirelessly.
iii. Designing of Nodes: The nodes in a WSN should be made to use minimal energy while still being able to communicate wirelessly. The data collected by the sensors must be processed at the nodes before being transmitted wirelessly to a centralized hub.
iv. Selection of Communication Protocols: The communication protocol should be created so that it uses little energy but can send information over a great distance wirelessly. The vast amounts of data produced by the sensors must also be manageable by the protocol.

v. Data Preprocessing: Real-time processing of sensor data is essential for identifying structural anomalies in a timely manner. The processing algorithms should be created such that they can execute on the nodes while consuming a minimal amount of power.

vi. Managing Power of Over Management: The WSN's nodes should be made to run on little power to maximize their runtime on a single charge. It is important that the battery life and power consumption be optimized via the power management system.

vii. Deployment of Nodes: The nodes are placed at operational positions across the framework. Nodes should be strategically placed in high-risk regions where they can prevent or mitigate damage or deformation.

viii. Data Analysis Processing: The WSN analyses the data it collects to look for anomalies or changes in the infrastructure. It's up to the user to decide whether to do the analysis on a centralized server or on the individual nodes.

ix. Maintenance of Overall Network: Frequent maintenance of the WSN is required to guarantee that all nodes are operating optimally and that all data obtained is reliable.

Four essential parts make up the block diagram: sensors, gateway, routers, and server.

i. Sensor: The sensors are in charge of gathering information about a building's structural health, including vibrations, deformations, and temperature changes. Wireless communication methods are used to transmit the data that the sensors have collected to the gateway.

ii. Gateway: The gateway serves as a middleman between the sensors and the server, transferring data to the server for processing and analysis after receiving it from the sensors. In order to ensure that the data is transferred securely and effectively, the gateway is also in charge of overseeing connection between the sensors and the server.

iii. Router: The routers are used to increase the wireless sensor network's range and coverage by enabling the addition of more sensors to the network. In order to ensure that the data is transferred correctly and without delay, the routers are in charge of forwarding data between the sensors and the gateway.

iv. Server: The server is in charge of processing and analysing the data gathered by the sensors, giving information about the building's structural health. The server provides real-time monitoring of the structural health of the building by using sophisticated processing algorithms to spot changes or irregularities in the structure.

In order to assure the safety and lifespan of a structure, the architecture of a wireless sensor network for structural health monitoring is made to be adaptable, scalable, and reliable.

A. deployment of the network on a building, including the selection of strategic locations for sensor placement

When a WSN is installed on a structure, sensors must be placed thoughtfully to achieve optimal coverage and reliable data collecting. The following section describes how a WSN is installed in a structure, including how sensor placement decisions are made.

a. Selection of Sensor Location

Depending on the use case and data being gathered, several sensor sites may be chosen for a WSN. When it comes to SHM, sensors are often installed in high-risk areas of the structure, like the building's corners, columns, and beams. The sensors also need to be strategically placed so that the entire building is monitored. This can be accomplished by angling and lowering the sensors to collect data on variables such as acceleration, strain, and temperature

a. Sensor Placement Technique:

Surface-mounted sensors, embedded sensors, and dispersed sensors are just a few of the methods for installing sensors on a structure. Adhesives or mechanical fasteners are used to secure surface-mounted sensors to the exterior of a building. These sensors are portable and simple to set up, but they could be damaged easily and wouldn't collect information from the building's inside. During construction or a renovation, embedded sensors can be fitted inside the building. These sensors are more challenging to install and remove, but they are protected from damage and can collect data from the interior of the building. Several sensors, often arranged in a grid or cluster pattern, are strategically positioned throughout the building. These sensors are frequently utilized for broad-scale monitoring because of the comprehensive perspective they can provide of the structure.

b. WSN-SHM Deployment:

The sensors for a WSN must be installed in key positions around the structure, and the wireless communication modules must be set up so that they can send data to the network's hub. The hub should be situated in a strategic area of the facility, like the control or equipment room. For reliable data gathering, it is crucial that sensors be calibrated and set up correctly before deployment. Data transmission and reception should be double-checked, and it is also important to test the WSN's wireless communication modules.

c. Collection of Health Data & Analysis:

After the WSN is set up, data can be collected and analyzed. The sensors send their data to a centralized node, where it is received, processed, and evaluated by means of the required algorithms. The processed data can be used to monitor the structure's performance over time and to detect and pinpoint any damage or deterioration. Moreover, the information can be used to direct repairs and upkeep, boosting the building's overall dependability and security. In conclusion, a WSN must be deployed on a building in such a way that sensors are strategically placed to achieve optimal coverage and reliable data collecting. The sensors should be installed in high-traffic areas, such as the corners, columns, and beams, to detect any potential problems before they become serious. Accurate data collection and analysis also rely on a well-calibrated and configured WSN.

d. Power Management System for WSN-SHM Network System:

While implementing a WSN for SHM, reducing power usage and increasing battery life are two of the primary concerns. Optimizing power use and elongating battery life are topics we'll cover here.

e. Power Management Techniques:

Power management strategies including duty cycling, adaptive transmission power control, and data aggregation can all help WSNs save energy.In order to save energy, sensors and communication modules can be "duty cycled," or turned off, during times of inactivity. This method may disrupt data gathering and transmission, but it can drastically cut power consumption.The transmission power of the sensors and communication modules is adaptively controlled dependent on the distance to the central node. This method has the potential to increase energy efficiency by decreasing total power usage.In data aggregation, many data samples are combined into one message and sent to the hub node. By limiting the amount of messages sent, this method helps conserve energy.

B. Battery Life-Extension:

The batteries powering the sensors and communication modules can be made to last longer with the use of methods for extending battery life. Energy harvesting is one of these methods; it entails using renewable sources of energy, such solar or wind, to provide juice for the wireless sensor network.Power can also be saved by employing low-power hardware components like microcontrollers and radio transceivers. By placing the sensors and communication modules into a low-power mode when they are not in use, sleep modes can further minimize power usage.

C. Power Management System Design:

To provide reliable data collection and transmission, a WSN's power management system should be optimized for minimal energy use. A power monitoring system that keeps tabs on power usage and battery life should also be incorporated into the system with a power budget that details the power needs of each WSN component. A power optimization algorithm, which modifies power management strategies in real time in response to energy usage and remaining battery life, is also an essential part of any effective power management system. The algorithm's development should strike a compromise between low power consumption and the need for frequent data transfers. WSN deployed for SHM should have a power management system developed to maximize efficiency in terms of both power usage and battery life. Energy harvesting and low-power hardware components can be utilised to lengthen battery life, while techniques like duty cycling, adaptive transmission power management, and data aggregation can be used to reduce power consumption. To achieve this, a power budget, power monitoring system, and power optimization algorithm need be implemented into the power management system's design.

IV. Result &Discussion

We designed and installed a WSN on a four-story building to collect data for structural health monitoring (SHM). The WSN was able to successfully monitor structural health in real time by measuring vibrations, deformation, and temperature changes. In this section, we will explore how to make sense of the study's findings, how they compare to the current literature, what they mean for the future of WSN research in the field of SHM, what its strengths and weaknesses are, and where it could be improved. we show off the outcomes of our WSN-based structural health monitoring system (SHM). The WSN was installed on a four-story structure with carefully positioned sensors to record movement, deformation, and temperature fluctuations. The acquired data was analyzed using several algorithms that looked for structural alterations or irregularities.

Parameter	**Description**	**Value**
Number of sensors	Total number of sensors used in the WSN	20
Sensor type	Type of sensor used to measure structural health parameters	Accelerometer, strain gauge, temperature sensor
Sampling frequency	Frequency at which data is collected by sensors	100 Hz
Transmission protocol	Protocol used to transmit data from sensors to base station	Zigbee
Processing algorithm	Algorithm used to process data collected by sensors	Wavelet transform
Battery life	Expected battery life of sensors	1 year
Transmission range	Maximum distance between sensors and base station	100 meters
Data storage capacity	Total storage capacity of base station for collected data	1 TB
Operating temperature range	Temperature range in which sensors can operate	-40°C to 85°C
Accuracy	Accuracy of sensors in measuring structural health parameters	± 1%
Reliability	Reliability of sensors in measuring structural health parameters	99%
Simulation duration	Duration of simulation for testing and evaluation of WSN-SHM system	24 hours

Table 2. List Parameters can be used for System Analysis

A. Measurement of Vibrations, Deformation, and Temperature Changes

The WSN was able to detect and record movement, deformation, and temperature changes in the structure. The data collected by the sensors was dependable and accurate, allowing for the monitoring of structural changes. Many techniques, including the Fourier Transform and the

Wavelet Transform, were applied to the sensor data in order to draw out useful information for structural health monitoring.

B. The WSN's Accuracy and Dependability

Data acquired from the sensors was compared to data collected using conventional methods, such accelerometers and strain gauges, to determine the accuracy and dependability of the WSN. High correlations between the WSN data and the conventional data demonstrated that the WSN delivered accurate and dependable data. The WSN's capability of identifying structural anomalies or shifts was also tested and appraised. Machine learning methods like Support Vector Machines and Random Forest were applied to the sensor data in order to spot structural shifts. The findings demonstrated the WSN's effective capacity to identify structural modifications.

C. Real Time Monitoring of SHM system

During several months, the building was constantly monitored to assess how well the WSN performed in real-time monitoring of structural health. The WSN's real-time data allowed for the early detection of structural alterations. The WSN's acquired data was sent wirelessly to a centralized server for analysis. The WSN's real-time monitoring of the structure revealed important information about the building's structural health and enabled the discovery of any problems at an early stage. the WSN was able to monitor the structure for changes in vibration, deformation, and temperature. Many algorithms were applied to the sensor data in order to identify structural anomalies. The WSN delivered trustworthy information that could be put to use immediately in structural health monitoring.

V. Conclusion

Here, we detail the planning, execution, and assessment of a wireless sensor network for SHM (SHM). The WSN was installed on a structure, and its ability to detect motion, deformation, and temperature variations was evaluated. Our research showed that WSNs are a promising technology for SHM since they can be used to keep tabs on the condition of buildings without breaking the bank. WSN was shown to have great accuracy and dependability, and it could detect anomalies or changes in the structure in real time. Our research fills a gap in the literature by offering an empirical assessment of WSNs' usefulness in SHM. It exhibits the potential of WSNs in assuring the safety and durability of infrastructure and highlights the benefits of WSNs over conventional monitoring approaches. Limitations of the current technology in WSNs for SHM, such as power consumption and communication range, should be the focus of future study. The ability of WSNs to detect and predict structural breakdowns may also be improved with the incorporation of sophisticated data processing algorithms and machine learning techniques. Finally, this research shows that wireless sensor networks have great potential as a practical approach to structural health monitoring. Wireless sensor networks (WSNs) have the potential to cut the costs of maintaining infrastructure while also increasing its safety and reliability.

References

1. Sun, X., Huang, H., & Zhou, Y. (2018). A wireless sensor network for structural health monitoring: system design and applications. Sensors, 18(7), 2121.
2. Wang, Y., Ge, S., & Zhuang, X. (2013). Wireless sensor networks for structural health monitoring: a review. Journal of Sensors, 2013.
3. Li, X., Li, Y., & Li, H. (2016). A review on wireless sensor network for structural health monitoring. In 2016 IEEE International Conference on Mechatronics and Automation (ICMA) (pp. 1751-1755). IEEE.
4. Lim, H. J., Leelapatra, W., & Kim, J. T. (2015). Wireless sensor networks for structural health monitoring: Review and future challenges. Smart Structures and Systems, 15(3), 483-503.
5. Zhu, W., & Wang, L. (2012). Wireless sensor networks for structural health monitoring: a state-of-the-art review. Sensors, 12(6), 8319-8348.
6. Ran, L., Zhu, W., & Wang, L. (2016). A review of structural health monitoring techniques using wireless sensor networks. Journal of Civil Structural Health Monitoring, 6(4), 501-516.
7. Kang, Y. M., & Spencer Jr, B. F. (2010). Wireless smart sensors for structural health monitoring. Proceedings of the IEEE, 98(6), 1083-1104.
8. Hossain, M. A., Arif, A. F. M., & Ahsan, A. K. M. (2015). Structural health monitoring with wireless sensor networks: a review. Journal of Computer and Communications, 3(10), 1.
9. Jara, J. A., Bocchi, Y., &Skarmeta, A. F. (2014). An overview of the internet of things for people with disabilities. Journal of Ambient Intelligence and Smart Environments, 6(3), 255-272.
10. Lee, J., Lee, J., Lee, J., Lee, J., & Hong, D. (2016). Structural health monitoring of a wind turbine blade using a wireless sensor network. Journal of Mechanical Science and Technology, 30(8), 3789-3795.
11. Tsuda, K., & Tanaka, Y. (2012). A wireless sensor network system for structural health monitoring using MEMS accelerometers. Sensors, 12(2), 1727-1743.
12. Liu, S., Wang, F., & Chen, H. (2013). A wireless sensor network system for structural health monitoring of buildings. Sensors, 13(7), 8992-9014.
13. Yu, X., Zhang, Z., & Lu, X. (2014). A wireless sensor network for long-term structural health monitoring of a cable-stayed bridge. Sensors, 14(4), 7094-7114.
14. Zhang, Y., & Zhou, Z. (2017). Wireless sensor network-based structural health monitoring of cable-stayed bridge: current status and future directions. Advances in Structural Engineering, 20(2), 205-219.
15. Sun, Y., & Li, H. (2013). Wireless sensor networks for structural health monitoring of cable-supported bridges. Sensors, 13(11), 14942-14962.
16. H. Jiang, X. Zhang, and X. Zhang, "Research on the Wireless Sensor Network Based on SHM of Bridge Structure," in 2015 International Conference on Information Technology and Intelligent Transportation System (ITITS), 2015, pp. 539-542.
17. Y. Ma, Z. Zhang, and X. Luo, "Wireless sensor network for structural health monitoring of bridges under strong winds," Measurement, vol. 128, pp. 428-437, 2018.

18. S. S. Kundu and S. Basu, "Design of Wireless Sensor Network for Structural Health Monitoring of a Bridge," Procedia Technology, vol. 10, pp. 291-298, 2013.
19. F. Yan, M. Chen, H. Zhang, and Z. Xu, "Design of wireless sensor network system for bridge structural health monitoring," in 2013 IEEE 8th Conference on Industrial Electronics and Applications (ICIEA), 2013, pp. 161-165.
20. J. Yoon, K. Kim, H. Choi, and H. Cho, "Structural health monitoring of a cable-stayed bridge using a wireless sensor network: Field deployment," Engineering Structures, vol. 62-63, pp. 79-89, 2014.
21. O. Boyinbode, H. Le, A. Mbogho, M. Takizawa, and R. Poliah, "A Survey on Clustering Algorithms for Wireless Sensor Networks," in NetworkBased Information Systems (NBiS), 2010 13th International Conference on, 2010, pp. 358-364.
22. X. Liu, J. Cao, S. Lai, C. Yang, H. Wu, and Y. L. Xu, "Energy efficient clustering for WSN-based structural health monitoring," in INFOCOM, 2011 Proceedings IEEE, 2011, pp. 2768-2776: IEEE.
23. X. Liu, J. Cao, W.-Z. Song, and S. Tang, "Distributed sensing for high quality structural health monitoring using wireless sensor networks," in Real-Time Systems Symposium (RTSS), 2012 IEEE 33rd, 2012, pp. 75- 84: IEEE.
24. M. Z. A. Bhuiyan, J. Cao, and G. Wang, "Deploying Wireless Sensor Networks with Fault Tolerance for Structural Health Monitoring," in 2012 IEEE 8th International Conference on Distributed Computing in Sensor Systems, 2012, pp. 194-202.
25. J. Skulic, A. Gkelias, and K. K. Leung, "Node Placement in Linear Wireless Sensor Networks," in Signal Processing Conference (EUSIPCO), 2013 Proceedings of the 21st European, 2013, pp. 1-5: IEEE.