Retraction

Retracted: Mechanical Vibration Test Based on the Wireless Vibration Monitoring System

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

1. Discrepancies in scope
2. Discrepancies in the description of the research reported
3. Discrepancies between the availability of data and the research described
4. Inappropriate citations
5. Incoherent, meaningless and/or irrelevant content included in the article
6. Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article’s content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

References

Mechanical Vibration Test Based on the Wireless Vibration Monitoring System

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In order to apply wireless sensor networks to mechanical vibration monitoring, the author proposes a wireless network topology with multiple data collection points for mechanical vibration monitoring. This structure reduces the transmission load of the data collection point, increases the data transmission rate of the network, balances the energy dissipation in the network, and utilizes the general wireless sensor network hardware platform. The network transmission protocol and related auxiliary mechanisms are designed and implemented, and a wireless vibration monitoring test platform is constructed. The transmission performance of the network structure with multiple data collection points is evaluated through the actual test. The experimental results show that by using the wireless sensor network topology with multiple data collection points, it can meet the requirements of continuous transmission of vibration data obtained by 1 kHz sampling.

Conclusion: The system performance of the wireless sensor network based on this network structure has been improved under the condition of general hardware, and the network structure of multiple data collection points shows good performance in the process of high-speed data transmission.

1. Introduction

The reliability, availability, safety, and maintainability of mechanical equipment, especially large-scale key equipment, are related to the production efficiency of enterprises and the safety of people’s lives and properties. In order to prevent mechanical equipment failures, more and more industrial enterprises use mechanical vibration monitoring systems to monitor key equipment. A variety of mechanical vibration monitoring systems have been launched at home and abroad, which to a certain extent ensure the safe and stable operation of key mechanical equipment, as shown in Figure 1 [1]. Most of the existing mature mechanical vibration monitoring systems use wired connections to connect sensors, signal conditioning equipment, and data acquisition equipment. This data acquisition method has many connections, complicated wiring, easy cable damage, high cost, poor maintainability, and disadvantages such as lack of flexibility. For a large number of moving and rotating equipment or components, a wired connection is difficult to effectively complete the monitoring task [1]. Using the emerging wireless sensor network (wireless sensor networks, WSNs) monitoring mode to build a wireless, distributed mechanical vibration monitoring system, it can make up for the shortcomings of traditional wired monitoring systems [2]. A wireless sensor network has the characteristics of easy deployment, flexible expansion, and easy maintenance. Using wireless sensor network nodes, the mechanical vibration signal measuring points can be networked so that the mechanical equipment and the monitoring system can be combined into a whole, constituting the intelligent equipment Internet of Things system.

2. Literature Review

Priyanka et al. designed a wireless vibration monitoring (WiVib) vibration wireless sensor network monitoring system and verified it in the research base [3]. For system verification, place an accelerometer on the housing at a motor bearing. The sensor node collects data every 10 minutes and transmits it to the routing node and then to the server, where the data are analyzed and processed.
experiment uses only 3 sensor network nodes: the terminal node, the routing node, and the management node. The terminal node is only responsible for data collection, and the server is responsible for data processing. Pavlack et al. use the Jennic JN5139 wireless sensor network module to target specific objects (single-phase induction motor). A new industrial wireless sensor network (IWSN) for mechanical condition monitoring and fault diagnosis is proposed, by collecting the current signal and acceleration signal output by the rotor, then the signal feature extraction and neural network are used for fault classification, and finally, the fault fusion is performed at the routing node to obtain the operating state of the mechanical equipment [4].

Na et al. developed an aircraft condition monitoring system based on the ZigBee wireless sensor network, designed a monitoring node composed of a CC2431 wireless SOC chip and a convergence node composed of CC2431 and C8051F340 as the core, and selected a 2 GB TF card as the data storage system. The sensor selected is the ADXL321 MEMS acceleration sensor. However, due to the limitations of the experimental conditions and the completion of the project, the actual aircraft condition monitoring experiment has not been carried out at present [5].

Hu et al. adopted the wireless sensor network mechanical equipment monitoring system designed by themselves and applied it to 4 QUY50C crawler cranes. The performance of their equipment was tested, and the stress values of various places when the equipment was loaded were obtained, as well as the safety and life of the machine were successfully evaluated [6]. The development of wireless sensor network technology is still immature, and various software and hardware conditions limit the application range of wireless sensors. In vibration signal monitoring, it can only meet the test requirements of low vibration frequency (0 ~ 200 Hz) [7]. For relatively high-frequency mechanical vibration monitoring (sampling frequency is usually 1 kHz to 10 kHz), there are still many key technologies to be solved, and the first problem to be solved is how to ensure the continuous and reliable transmission of a large amount of monitoring data [8,9]. The author optimizes the wireless sensor network structure and transmission mechanism according to the characteristics of the mechanical vibration monitoring application. Taking the wireless sensor network structure as a breakthrough point, mechanical vibration monitoring is realized on the current general wireless sensor network hardware platform.

3. Research Methods

3.1. Network Structure Design of Multiple Data Collection Points. The wireless sensor network is a typical multihop network; its topology is flexible and dynamic, and the network structure can directly affect the efficiency of data transmission [10]. Therefore, the core task of designing a network structure is to control its topology, which is of great importance for prolonging the network lifetime, reducing communication interference, and improving the efficiency of media access control (MAC) and routing protocol significance. In view of the high-performance requirements of network scale and vibration acquisition in mechanical vibration monitoring systems, the networking method adopted is usually simple in structure and strong in robustness and is mainly based on a tree-like directional network structure. The data collection point (base station node) of the network has a limited rate of receiving data, which affects the network transmission rate and the number of networking nodes to a certain extent. At the same time, the energy consumption of the network is not balanced, which affects the network’s survival time. Therefore, the author proposes a network structure of multiple data collection points to solve the above problems.

3.1.1. Network Topology Optimization Design. In the mechanical vibration monitoring system based on the wireless sensor network, the required number of networking nodes is small, and the coverage area is small. In most applications, the wireless transmission distance is short (within tens of meters), and the single-hop networking mode can be used to complete the data acquisition task [11]. Figure 2 shows the single-hop star topology. Its network structure is simple, and it is easier to perform ad hoc networks because there is no multihop in the network. Although the communication distance from the node to the base station varies, the wireless transmission power of each node will vary differently, however, relatively speaking, the node energy consumption is relatively average, and the network delay of the data packet
is small. According to the test needs of different objects, the distribution of points in the network is not uniform, and the RF conditions of the test environment are complex, so it is difficult to ensure that all nodes are in a good wireless transceiver environment. At the same time, the acceptance rate of the base station is limited. During the vibration data collection process with high sampling frequency, the number of nodes $N$ is limited by the data packet sending frequency of the node and the data packet receiving frequency of the base station node. Furthermore, the value of $N$ is directly related to the performance of the hardware. For the MICAz platform, $N$ is usually around a dozen of nodes to ensure the requirements of low-speed data transmission.

In order to solve the harsh RF conditions in the field test environment and increase the reliability of data transmission and the flexibility of the layout, the network structure mainly used in the mechanical vibration test is a multihop tree directional networking mode. As shown in Figure 3, when the network is initialized, the network structure is established through self-topology, and each node is based on the strength of the radio frequency signal, selecting the single-hop or multihop method to transmit data to the base station node. This method avoids the need for the node to transmit signals with high power. It will not cause excessive energy dissipation due to excessive distance or strong radio frequency interference, and at the same time, it increases the reliability of data transmission and the flexibility of measuring point layout [12]. However, due to multihop, the node closer to the base station will have heavier forwarding tasks, the MAC layer will have a larger channel conflict burden, and the energy consumption of the network will be unbalanced. Nodes 6, 7, and 10 in Figure 3 all need to forward the data sent by more nodes. Like the single-hop network structure, its data transmission rate is also affected by the acceptance rate of the base station node.

The main problem faced by the single-hop star network structure is that the network range is small, and the installation of sensor nodes is subject to certain constraints. However, the energy consumption of the nodes in the tree-oriented network structure is not balanced, and the sensor nodes close to the base station node often have the heavy task of forwarding data packets, which affects the transmission rate of the network to a certain extent. The wireless transceiver performance of the base station node and the sensor node is the same, but the data to be received by the base station node come from all nodes in the network, so the following results can be obtained: The base station node is the data collection point of the network, and the rate of receiving data packets plays a decisive role in the speed of network data transmission; the multihop network increases the flexibility when deploying sensor nodes, and it can avoid nodes due to distance or radio frequency interference. This results in reduced transmission reliability and excessive energy consumption. Reducing the number of hops from sensor nodes to base stations can improve network transmission performance [13].

According to the above analysis, the author designs a multidata collection point network structure with multiple base station nodes, as shown in Figure 4. By increasing the number of base station nodes, the data throughput of each base station can be reduced, the data transmission rate of the network can be increased, the sampling frequency of each node is increased, and the grouping around the base station node is realized based on the principle of proximity, which significantly reduces the number of multihop data transmissions at the edge node, reduces the probability of packet loss and transmission delay, and improves the reliability of data transmission. It also reduces the transmission load of the transit node, increases the balance of energy dissipation in the network, and at the same time, inherits the flexibility of measuring point deployment of the tree-like directional network structure.

3.1.2. Network Self-Organization Method. In the multidata collection point network structure, the process of network self-organization is somewhat similar to the tree-like directional network. There are many self-organization methods in the multihop tree network structure. Blast is a more mature method, it has strong data transmission reliability. However, due to the addition of base station nodes, the data diffusion directions in the network have changed from one to multiple, which makes the networking process more difficult. The networking method of the multidata collection point network is improved on the basis of the blast prototype, and blast is mainly composed of two components: one for selecting the parent node component network and the other for reliable transmission of data. The author uses only its reliable data transfer component.

In the process of network self-organization, the self-topology control of the network is accomplished through the following principles: The base station node broadcasts the initialization node in the network to the network, and each node selects the base station node group according to the received signal strength indication (referred to as RSSI) value. The RSSI threshold determines whether the node performs single-hop communication. The RSSI threshold is set based on experience, the single-hop nodes in different groups broadcast, respectively, and the non-single-hop nodes that receive the broadcast signal select the group number and parent node according to the RSSI, and so on, in order to complete the self-organization of the network [14]. Since multiple base station nodes in the network are affected by the
location and radio frequency environment, it is likely to cause unbalanced grouping in the network, resulting in great differences in the communication load of base station nodes, which puts forward higher requirements for the deployment of base station nodes.

3.2. Multidata Collection Point Network Transmission Implementation. In order to realize the transmission mechanism of the multidata collection point network structure, a mechanical vibration monitoring test platform based on a wireless sensor network has to be built first. The wireless sensor network part adopts the MICAz wireless sensor node and base station node Mib520 of the Crossbow company. The MICAz node works in the 2.4 GHz frequency band, can generate RSSI signals, and uses the TinyOS operating system as the software platform, which is supported by more component interface programs and which makes the development process flexible and efficient. Lance LC0401 acceleration sensor and signal conditioning box are used to acquire vibration signals, and the built-in A/D of the MICAz node is used to acquire vibration signals. In the specific construction process of the test platform, the main work is software design and network transmission implementation.

The reference voltage provided by the AD converter is 2.5 V, and the AD conversion result is recorded as RESULT, then the corresponding voltage value can be calculated by the formula.

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\text{sink node}
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\text{PC}
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Figure 3: Multihop tree-oriented topology.

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\text{sink node}
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\text{PC}
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Figure 4: Multidata sink network topology.
3.2.1. Software Implementation. In the process of software development, the existing protocol stack components of TinyOS are directly used to avoid the repetitive development of the physical layer and the MAC layer. The developed node software mainly includes the following modules: a. Networking components based on the network structure proposed in this paper; b. Components for collecting vibration signals and data storage; c. Time synchronization components; d. Data packet retransmission components for reliable transmission; e. Control the data transfer component for packet sending [15]. The structure of the node software is shown in Figure 5, which is mainly composed of two parts: one completes the data acquisition of the vibration signal with the data acquisition and related processing modules, and the other transmits the collected data to the base station through the selected network path.

3.2.2. Realization of Network Transmission Technology. Since the transmission protocol stack of the multidata collection point network structure mainly uses the underlying protocol for the MICAz platform in the TinyOS operating system as its basis, and based on the network self-organization strategy of multidata collection points, the construction of routing layer and application layer protocol has been completed so as to form a relatively complete network protocol.

The standard TinyOS physical layer provides comprehensive interface support for MICAz’s CC2420 chip and uses the interface provided by TinyOS to operate components, shielding the complex and cumbersome underlying coding process and making it easy to use. The TinyOS MAC protocol is a MAC protocol B-MAC based on collision detection and low-energy monitoring. It is relatively energy-saving, and the protocol is simple, occupying fewer hardware resources, and is more suitable for the wireless sensor network vibration signal acquisition system. The main task of the routing protocol design is to form a routing table in node data packets according to the network self-organization method proposed by the multidata collection point network structure. In the process of network self-organization, the base station initializes the number of each node, and each node forms its own routing table by selecting the base station group and the parent node number, thereby determining the sending path of the data packet. In order to realize the network transmission application, the following technical issues need to be considered: the length of the data packet, which directly affects the data transmission rate, the determination of the transmission frequency of the data packet, and the realization of the reliable transmission mechanism of the data packet.

(1) Packet parameters. The bandwidth supported by the wireless sensor network node hardware is not equal to the actual data transmission rate. The data packet contains not only the acquired vibration data but also the data header related to the network transmission [16]. Generally, the length of the header of the data packet is determined. Obviously, the longer the length of the data packet, the higher the transmission efficiency of its effective data. However, if the length of the data packet is too long, the probability of packet loss during transmission will be high. At the same time, because the data packet is too long, under the condition of certain hardware performance, the transmission frequency of the data packet will be reduced. This also results in a reduction in the speed at which the valid data are sent.

The data transmission rate of the multidata rendezvous network structure is determined by the receiving rate of the base station node. Under the condition that a single node sends a data packet to the base station, the relationship between the length of the data packet and the transmission frequency of the data packet is obtained through experiments, as shown in Figure 6(a). As the packet capacity increases, the speed at which nodes process and send packets decreases. Since the product of the content length of each packet and the transmission frequency of the packet is the effective transmission rate of the data, Figure 6(b) intuitively reflects the relationship between the length of the packet and the effective transmission rate. In order to obtain the highest effective data transmission rate, it is found that the length of the data packet is about 65 byte, and the transmission rate of effective data is the highest, which can reach about 6.5 kbps, which is also the maximum value of the base station’s ability to accept data.

(2) Reliable transmission mechanism. The reliable transmission mechanism of wireless sensor networks is a research hotspot of wireless sensor networks, and some typical reliable transmission mechanisms have been formed, such as multisegment reliability transmission (reliable multisegment transport, referred to as RMST) and rate-controlled reliable transmission (rate-controlled reliable transport, referred to as RCRT), but these methods are not suitable for use in mechanical vibration monitoring systems [17]. After comparing several commonly used reliable transmission mechanisms, the mechanical vibration monitoring system has the characteristics of small network scale, high-speed transmission, and high energy consumption. Based on the end-to-end reliable transmission mechanism, a mechanism for data packet recovery based on transmission path priority has been added. When data packet loss is detected for data recovery, considering that the transmission path of some nodes is multihop, it is no longer necessary for the source node to resend the lost data packet. Instead, this data are retransmitted from the forwarding node, and this recovery mechanism is relatively efficient and more energy-efficient.

(3) Node deployment. For networking with a multidata collection point network structure, the deployment of base station nodes needs to be considered. Usually, in the collection of vibration signals, the sensor nodes are relatively fixed during installation and deployment. According to the vibration test requirements of the structure, the installation points are relatively uniform. The number of base station...
nodes is proportional to the sampling frequency of the sensor, according to the test experience in this paper, and when each node acquires data at a sampling frequency of 1 kHz, it is necessary to ensure that there are no more than 4 nodes in each base station group in the network. The deployment of base station nodes needs to be evenly distributed in the network or at the edge of the network, ensuring that there is no unbalanced grouping during networking.

4. Analysis of Results

In order to test the transmission performance of the multidata collection point network structure in the wireless sensor network mechanical vibration monitoring system, 15 measurement points were deployed, and 4 base station nodes were used to test the vibration signal of a motorcycle frame. In order to evaluate the transmission performance of the multidata sink network structure, the sampling frequency of sensor nodes is set to 1 kHz. Figure 7 shows the ad hoc network topology of the nodes under test [18, 19].

When the data reliability transmission mechanism is not used, from the statistical data of the success rate of data packet transmission in wireless sensor networks, it can be obtained that the one-time success rate of data packet transmission is higher than that of conventional network structures, which is above 90%. After adopting the reliable data packet transmission mechanism, no data packet loss was found during the entire data collection process. This
indicates the network transmission mechanism implemented for the multidata sink network structure can meet the data transmission requirements of vibration signals obtained by sampling at 1 kHz.

From the statistical analysis of the time delay probability of data packets, it can be found that the time delay of data packets is low. The maximum time delay of data packets is 10.13 ms, and the average time delay is 6.35 ms, showing good real-time performance. Due to the complex radio frequency environment of the mechanical equipment site, the MICAz node used by the author works in the 2.4 GHz wireless transmission frequency band. Compared with the Mica2 node (operating in the 868 MHz frequency band), it is found that the wireless signal transmission and reception quality of the MICAz node in the same environment is higher, and the wireless signal quality of other frequency bands needs further research. At the same time, the node energy limitation factor has a great influence on the field application. The wireless sensor node is powered by two ordinary AA batteries, and when the power supply voltage of the node is less than 2.7 V, the sampling error will be too large. Therefore, during the test process, the node is under the working condition of continuous sampling, and the average time is 10–15 h. After that, the supply voltage will drop below 2.7 V. In the future system development, the monitoring time can be extended by some technical means such as data compression.

5. Conclusion

The author proposes a wireless sensor network networking method characterized by multiple data collection points and builds a test platform to test the vibration signal of a motorcycle frame. Experiments show that the system performance of the wireless sensor network based on this network structure has been improved under the condition of general hardware, and the network structure of multiple data collection points shows good performance in the process of high-speed data transmission. However, the system can only meet the basic requirements of mechanical vibration testing at relatively low frequencies, and the network has a short survival time.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest.

References

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