A Security Defect Diagnosis Method of Wireless Network based on Modal Symmetry Algorithm

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Abstract. In order to enhance the security of wireless networks and enhance the ability of data acquisition, processing and transmission, the security defects of wireless networks are diagnosed based on the modal symmetry algorithm. According to the amplitude of the defective signals collected by wireless network sensors, the average value of the signals collected by the centro symmetric sensors is linearly subtracted, and the asymmetric modal information and the asymmetric modal amplitude of the axial position of wireless networks are obtained. On the basis of the original defect vibration signal graded by variational mode, several eigenmode components are obtained, and then the ranking entropy of each modal component is calculated. The ranking entropy is input as eigenvector to support vector machine classifier to complete the classification and recognition of wireless network security defects. The experimental results show that this method can accurately diagnose the security defects of wireless networks in different locations. The more complex the wireless network is, the higher the accuracy of the diagnosis results is and the shorter the time consuming results are. After the defect diagnosis, the wireless network data acquisition, data processing and transmission capabilities have been enhanced.

Keywords: Modal Symmetry, Wireless Network, Security Defects, Diagnosis, Signal Amplitude

1. Introduction
The status quo of wireless network security is as follows: NIST’s Handbook classifies general security threats into nine categories. More worrying about wireless communication are service rejection, device theft, malicious hackers, service theft, malicious code and industrial or foreign espionage activities. Because of the portability of wireless devices, they seem to be easily stolen, and both authorized and unauthorized system users may cheat and steal. However, authorized users are more aware of what resources the system has and the security flaws of the system, so they are more likely to cheat and steal.

Because of the openness of wireless networks and flexible networking methods, data tampering in wireless networks is technically easier to achieve. Experts and scholars at home and abroad have done a lot of researches on the security defect diagnosis of wireless network. Yang Yang et al. have studied
the relevant content of WSN fault management in view of the characteristics of wireless network constrained by limited resources, and described the advantages and disadvantages of centralized fault diagnosis method in detail [1-3]. Beatrys et al. put forward the management system structure MANNA. In order to realize the real-time monitoring of the network, the management center is created and the global information of the whole network is known through the management center. PD2 is a data-centric approach based on certain inference rules. It identifies the source of specific application performance problems by observing the data flow generated by the specific application and correlating the deterioration of the specific application performance with the packet loss and data flow delay detected by the node and the network software unit. Miintroute generates a visual network topology map by collecting neighbor lists of wireless network nodes, and uses this to judge the reliability of network connections. The main idea of Dustmineral is to find out the sequence of events that can represent the network error behavior, so as to discover the errors caused by the interaction between network nodes and the security defects in wireless networks [4-5]. In order to improve the security of wireless networks, it is necessary to accurately diagnose the security defects of wireless networks, and improve the quality of wireless network information collection and transmission.

2. Definition of the Algorithm

2.1. Modal Symmetry Algorithm

When the wireless network is safe and flawless, the displacement distribution of the wireless network sensor is circular symmetry. By linear subtraction of the signal amplitude collected by any two diagonal sensors, the asymmetric mode guided wave of the wireless network can be obtained [6]. It can be seen that when the asymmetric mode amplitude of the wireless network is low, there is a wireless network security flawless graph as shown in Figure 1.

![Fig. 1 Circumferential displacement diagram without security defects in wireless networks](image)

When the wireless network has security defects, the symmetrical circumferential displacement state of the echo signal of the wireless network is broken, and the circumferential displacement distribution diagram [7-8] as shown in Figure 2 is still processed by the above method. At this time, the amplitude of the signal collected by the wireless network sensor E is higher, and the position of the defect on the circumference is the bus position of the wireless network where the sensor E is located. By linearly subtracting the signals collected by two centrosymmetrical sensors and taking their average values, the asymmetrical modal information of the axial position of the whole wireless network can be obtained, thus the asymmetrical modal can be extracted from the symmetrical modal. Because the asymmetric mode amplitude of defect location is high, it can accurately judge whether the location of wireless network is defective by observing whether the asymmetric mode amplitude of defect echo changes abruptly.
Fig 2. Circumferential displacement diagram of wireless network with security defects

By designing the above method into a corresponding algorithm and drawing the corresponding curve in the environment of MATLAB, since the method is based on the principle of modal symmetry of guided waves, the curve drawn by this method is called modal symmetry curve, and the designed algorithm is called modal symmetry algorithm [9], as shown in formula (1):

\[ Y = \frac{1}{N} \left( |F_s| + |F_{s_1}| + |F_{s_2}| - |F_{s_{N-1}}| - |F_{s_N}| \right) \]

Where, \( Y \) is the amplitude of the modal symmetry curve, \( |F_s| \) is the amplitude of the signal on the corresponding bus of each sensor in the wireless network, and \( N \) is the number of sensors.

2.2. Security Defect Diagnosis of Wireless Network

In this paper, combined with the modal symmetry algorithm, the advantages of amplitude estimation of sensor acquisition signal, and the characteristics of that VMD (variable modal grading) entropy energy can detect time series randomness and dynamic mutation, a wireless network security defect diagnosis method based on modal symmetric algorithm is proposed [10]. Firstly, the original vibration signal is decomposed into VMD, and several eigenmode components are obtained. Then the permutation entropy of each modal component is calculated. Finally, the permutation entropy is input as eigenvector to support vector machine classifier for classification and recognition of safety defects. The specific steps are as follows [11-12]:

Step (1): When the wireless network is in normal operation state and there are security defects, the vibration data samples in each state are obtained by resampling according to a certain sampling frequency.

Step (2): Vibration signal data in different states of wireless network are decomposed by VMD, and modal components of different scales in different states are obtained.

Step (3): The permutation entropy measure \( PE_i (i = 1, 2, ..., K) \) of modal separation complexity at each scale is computed, and high-dimensional feature vectors are constructed:

\[ PE = [PE_1, PE_2, ..., PE_K] \]

Step (4): The obtained high-dimensional eigenvectors are input into the SVM for training, and the SVM prediction model for each type of fault is obtained.

Step (5): Acquisition of test signals. According to step (1), step (2), step (3), the prediction model for test sample is built. Through the output of SVM classifier, the type of wireless network security defects and wireless network working status are determined.

3. Results
3.1. Comparison of Diagnostic Accuracy of Safety Defects

In order to verify the validity of the method for wireless network security defect diagnosis based on modal symmetry algorithm in this paper, the application effect of this method is simulated and analyzed. In order to highlight the validity of this method, the method of wireless network security defect diagnosis based on WEP protocol and the method of wireless network security defect diagnosis based on Internet of Things are used as experimental reference. Experiments are made to compare the application effects of three methods in the actual wireless network security defect diagnosis. The wireless network in a certain area is used as the experimental research network. The practical application effects of the three methods are simulated and analyzed. Whether the three methods can accurately complete the wireless network security defect diagnosis and diagnose the fault location is taken as the evaluation index in the experiment.

From the data results, we can see that all three methods can diagnose the security defects of wireless network to a certain extent. By analyzing the data results, we can see that when the proposed method is used to diagnose wireless network security, it can diagnose the most security defects of wireless networks. Only the security defects of Node 12 and Node 13, and the security defects of Node 15 and Node 16 cannot be diagnosed. In this method, the error rate of wireless network security defects is 2/23=8.7%; while when the method based on WEP protocol is used to diagnose wireless network security defects, only 6 security defects can be correctly diagnosed in 23 wireless networks, and the error rate of security defects diagnosis is 17/23=73.9%. The results show that the method has a high error rate when it is used to diagnose the security defects of wireless networks, which is not conducive to the maintenance personnel to find the location of security defects in time, and has a great impact on the timely recovery of wireless networks.

3.2. Comprehensive Evaluation of Wireless Network Security Defect Diagnosis

Table 1. Evaluation results of the application value of this method in wireless network security defect diagnosis (points)

| Expert Number | Economic efficiency | Data acquisition capability | Data Processing Ability | Data transmission capability |
|---------------|---------------------|-----------------------------|-------------------------|-----------------------------|
| 1             | 9.56                | 9.02                        | 9.26                    | 9.15                        |
| 2             | 9.45                | 9.35                        | 9.35                    | 9.26                        |
| 3             | 9.25                | 9.41                        | 9.42                    | 9.35                        |
| 4             | 9.36                | 9.35                        | 9.47                    | 9.15                        |
| 5             | 9.52                | 9.26                        | 9.55                    | 9.36                        |
| 6             | 9.47                | 9.24                        | 9.56                    | 9.24                        |
| 7             | 9.52                | 9.37                        | 9.51                    | 9.51                        |
| 8             | 9.55                | 9.26                        | 9.52                    | 9.47                        |
| 9             | 9.56                | 9.14                        | 9.53                    | 9.56                        |
| 10            | 9.45                | 9.11                        | 9.54                    | 9.54                        |
| 11            | 9.34                | 9.23                        | 9.56                    | 9.62                        |
| 12            | 9.25                | 9.84                        | 9.54                    | 9.66                        |
| 13            | 9.47                | 9.62                        | 9.47                    | 9.67                        |
| 14            | 9.41                | 9.14                        | 9.56                    | 9.58                        |
| 15            | 9.36                | 9.24                        | 9.22                    | 9.52                        |
| Average       | 9.43                | 9.31                        | 9.47                    | 9.44                        |
On the basis of the above experimental results, this paper evaluates the application value of the proposed method in wireless network security defect diagnosis, and verifies the value of this method in wireless network security defect diagnosis. The experiment comprehensively evaluates the selected wireless network from four aspects: economy, wireless network data acquisition, data processing and transmission. The evaluation is based on a 10-point system. The higher the score is, the better the economy of the method is, and the stronger the ability of data acquisition, processing and transmission is after completing the wireless network security defect diagnosis. Fifteen evaluation experts gave the evaluation results of the application value of three methods for wireless network security defect diagnosis as shown in Table 1.

From the data in Table 1, we can see that when the proposed method is applied to wireless network security defect diagnosis, each expert has a higher economic evaluation result of this method, with an average evaluation score of 9.43 points. The result shows that the proposed method has low cost and strong economy when it is used to diagnose wireless network security defects. From the evaluation results of wireless network data acquisition of three methods, it can be seen that after using the proposed method to diagnose wireless network security defects, the evaluation results of wireless network data acquisition of wireless network change from 9.02 to 9.84 points, while the other two methods of wireless network data acquisition change from 6.58 to 7.35 and from 5.26 to 6.45, respectively. The results show that the application of wireless network security defect diagnosis by using the proposed method is helpful to improve network data acquisition. By comparing the scores of network data processing and transmission of three methods applied to security defect diagnosis by experts, it can be seen that the evaluation score of the proposed method is much higher than that of the other two methods. So, it shows that the method in this paper is of high value in practical application to the diagnosis of wireless network security defects.

Table 2. Time-consuming of three methods for diagnosing security defects in different complex wireless networks (s)

| Number of wireless network nodes (n) | 30-Jun-18 | WEP Protocol Law Method (s) | Internet of Things Method (s) | 30-Jun-18 | WEP Protocol Law Method (s) | Internet of Things Method (s) | 30-Jun-18 | WEP Protocol Law Method (s) | Internet of Things Method (s) |
|-------------------------------------|-----------|-----------------------------|------------------------------|-----------|-----------------------------|------------------------------|-----------|-----------------------------|------------------------------|
| 50                                  | 2.36      | 3.25                        | 5.21                         | 2.25      | 5.52                        | 10.26                       | 2.36      | 5.62                        | 4.14                        |
| 100                                 | 2.21      | 4.25                        | 5.36                         | 2.31      | 5.81                        | 14.25                       | 2.14      | 8.65                        | 4.65                        |
| 150                                 | 2.45      | 4.65                        | 8.65                         | 2.14      | 6.95                        | 15.36                       | 2.54      | 11.02                       | 8.24                        |
| 200                                 | 2.48      | 5.21                        | 11.26                        | 2.35      | 7.52                        | 17.24                       | 2.54      | 14.81                       | 10.65                       |
| 250                                 | 2.31      | 6.24                        | 14.54                        | 2.15      | 8.52                        | 19.21                       | 2.84      | 16.24                       | 14.23                       |
| 300                                 | 2.32      | 7.51                        | 16.34                        | 2.36      | 14.26                       | 22.36                       | 2.36      | 18.24                       | 15.63                       |
| 350                                 | 2.36      | 10.26                       | 22.51                        | 2.24      | 18.26                       | 25.14                       | 2.24      | 21.54                       | 19.54                       |
| 400                                 | 2.24      | 14.35                       | 26.54                        | 2.35      | 21.65                       | 26.87                       | 2.33      | 24.56                       | 22.54                       |
| 450                                 | 2.36      | 18.62                       | 28.41                        | 2.38      | 24.35                       | 31.25                       | 2.61      | 27.51                       | 26.34                       |
| 500                                 | 2.14      | 24.61                       | 29.35                        | 2.21      | 26.25                       | 33.26                       | 2.54      | 32.21                       | 28.14                       |
| 550                                 | 2.26      | 28.54                       | 31.24                        | 2.25      | 32.25                       | 34.25                       | 2.57      | 35.32                       | 31.36                       |
| 600                                 | 2.25      | 35.24                       | 33.25                        | 2.26      | 34.58                       | 38.47                       | 2.65      | 38.47                       | 35.14                       |

From the data in Table 2, it can be seen that the security defects of wireless networks diagnosed by the proposed method almost do not change with the increase of the number of wireless network nodes, and always keep below 3s. The diagnosis time of the other two methods increases with the increase of the number of nodes. When the number of wireless network nodes is 600, the diagnostic time of the
other two methods exceeds 30s. The results show that the proposed method not only has high accuracy in wireless network security defect diagnosis, but also takes short time to diagnose. It is a widely used security defect diagnosis method.

When the number of wireless network nodes is 400, the number of wireless network security defects diagnosed by the proposed method is close to the actual value. Detailed analysis of Table 2 and shows that when the diagnosis date is June 30, the number of security defects diagnosed by the proposed method is 400, which is 14 different from the actual value of 414; while the diagnosis results of WEP protocol method and Internet of Things method are 150 and 274, respectively, which are 264 and 140 different from the actual values, respectively. This shows that the method in this paper has high accuracy in the diagnosis of wireless network security defects on June 30, and can almost diagnose all the security defects of wireless network. By analyzing the results of the three methods for security defects diagnosis on July 30 and August 30, we can see that the method in this paper has high accuracy in the diagnosis of security defects. It has strong application value in wireless networks with more complex nodes, and can accurately diagnose security defects and provide strong guarantee for the normal operation of wireless networks.

Similarly, when the number of nodes in the wireless network is 600, the number of security defects diagnosed by the proposed method is consistent with the actual number of security defects on June 30. In addition, analysis of the diagnostic results of the three methods on July 30 and August 30 shows that the diagnostic accuracy of this method is high. Therefore, synthesizing the above experimental results, we can see that the method in this paper has high diagnostic accuracy and strong wireless network economy, data acquisition, data processing and transmission ability after diagnosis.

4. Discussions
At present, wireless network has been widely used in many fields, such as environmental monitoring, medical monitoring, power monitoring and so on. Taking power monitoring as an example, wired communication is widely used for data transmission in traditional power system monitoring. This communication mode requires a large number of communication cables, which is difficult to install and costly. Because of this, people gradually turn their focus to the wireless communication mode with simple installation and low cost in power monitoring. The emergence of wireless network provides a new prospect for fault monitoring and diagnosis of power system. At present, the application of wireless network in power monitoring mainly includes the monitoring of the operation status of power equipment, the monitoring of power quality, the monitoring of icing status of power facilities and the monitoring of the external working environment of power equipment. It is the application of wireless network in environmental monitoring, power monitoring and other fields that has solved some problems that have puzzled these fields for a long time to provide a very good development direction for these fields. However, the wireless network is not perfect. Since the deployment of the network node, the network has been in the state of no one to monitor and check. We cannot know the status of the node itself. Because of the bad working environment and other factors, the node is very prone to failure. Once a node fails in the network, it may not be able to ensure that the monitoring system completes the scheduled monitoring tasks.

5. Conclusions
Wireless network security defect diagnosis is helpful to the normal and stable operation of wireless network. Timely and accurate diagnosis of wireless network security defect can improve the data transmission capability of wireless network. After the application of modal symmetry algorithm in security defect diagnosis, wireless network security has been greatly improved. It is helpful for wireless network maintenance personnel to timely and accurately find and solve the problem of failure, and lays a solid foundation for long-term use of wireless network. And the data acquisition and transmission capability of wireless network after defect diagnosis has been greatly improved, which is a high-quality security defect diagnosis method of wireless network.
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