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Research on Optimization of Node Deployment in Wireless Sensor Networks Driven by Artificial Intelligence

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Abstract. The security deployment of WSN (Wireless Sensor Network) nodes also needs to ensure the performance of node coverage, which affects the accuracy and integrity of information detected by the network and the quality of service of the network. It is not enough to improve the network coverage and network performance of nodes only by adjusting the network topology of WSN, so there will be a problem of excessive node density in the network deployment area, which will lead to node redundancy and coverage hole, which will eventually affect the accuracy and integrity of monitoring information. In this paper, the deployment of WSN nodes driven by AI(Artificial Intelligence) is optimized. The data fusion theory is introduced, and the data fusion model is used to integrate node synchronization task scheduling, dynamic node deployment and dynamic network topology recovery.

Keywords: Artificial Intelligence; Wireless Sensor Network; Node Deployment Optimization.

1. Introduction

In WSN, the multi-objective combinatorial optimization problem can be regarded as a mapping process from one set of parameter decision variables to another set of objectives [1-2]. For the security optimization deployment of multi-target nodes, the improvement of network security is a problem worthy of in-depth consideration, while ensuring the improvement of network coverage [3]. Because there are many external interferences and uncontrollable factors in the communication link, the quality of WSN communication link is usually unstable. Especially when data needs multi-hop transmission to reach the target node, each hop in the transmission process will lead to the decrease of data transmission rate, the increase of transmission delay and the increase of node energy consumption. The basic idea of applying AI to solve WSN coverage optimization problem is to abstract each node into a virtual charge, and each node is acted on by other nodes around it as a force. The data fusion theory is introduced, and the data fusion model is used to synthesize various strategies such as node synchronization task scheduling, dynamic node deployment, dynamic network topology recovery, etc., which ultimately determines the ability to effectively obtain physical information and comprehensive service quality in the target environment [4]. This paper only considers the security connection with Shared secret from the perspective of security connectivity and network coverage, so as to reduce the damage to the network security connection when improving network coverage, without selecting other objectives. Multi-objective security optimization deploys WSN nodes, considers the security connectivity of nodes to ensure the security of the network, and improves the coverage of nodes through node movement. Optimize the deployment of multi-target WSN nodes based on secure connection, reduce the secure connection between nodes to ensure the existence of shared keys, and improve the coverage of WSN [5].

2. Basic Research on Node Security Deployment in Wireless Sensor Networks

2.1. Characteristics of Wireless Sensor Networks

WSN is a multi-hop self-organizing network, where large-scale nodes are deployed in monitoring areas, and data transmission between nodes is mainly through wireless communication. Collaborate between nodes to perceive, collect, and process monitoring target information within the monitoring area, and send it to users. Sensor nodes are not only able to generate data, but also transmit data [6-7]. Moreover, nodes can spontaneously establish communication links with nearby nodes without the need for other network devices. The coordinated perception monitoring behavior of nodes is achieved through layered protocols and distributed algorithms, and self-organized communication networks are formed through wireless communication [8]. The networking process of WSN does not rely on any fixed network infrastructure. Wireless sensor nodes form self-organizing networks through distributed network protocols, which can automatically adjust to adapt to the movement, joining, and exiting of wireless sensor nodes. Multiple activated wireless sensor nodes in WSN can quickly and automatically form an independent WSN [9]. Wireless sensor nodes in WSN may exit WSN due to energy depletion or failure, or they may exit WSN operation according to a predetermined program. Wireless sensor nodes outside of WSN can join WSN at any time, and wireless sensor nodes can move [10]. Because the communication radius of nodes is generally within a certain range, WSN nodes need to run routing protocols to communicate with nodes beyond the communication radius. Each node in WSN can not only serve as a sender of data, but also as a relay for data transmission.

2.2. Security Threats and Requirements for Wireless Sensor Networks

The security issue of WSN is the primary task of researching its related technologies, and the primary task of researching the secure deployment of nodes is to ensure the establishment of secure communication links between nodes during deployment. Therefore, WSN technology includes the coverage issue of wireless sensor networks. The most challenging issue for WSN is network security. The specific security service requirements of WSN are shown in Table 1.

Table 1. WSN Security Service Requirements

Security Service Requirements	Specific description
Authenticity	After receiving the information, it is necessary to verify whether it comes from authorized nodes to prevent attackers from impersonating normal nodes and injecting false information.
Freshness	Freshness ensures that information is instant and effective to prevent duplicate messages from being sent.
Confidentiality	It can only be transmitted in this network, and nodes in other networks and other unauthorized nodes cannot obtain this information.
Integrity	If information is obtained by unauthorized nodes and tampered with, it will affect the integrity of the information.

By reasonably allocating various software, hardware, and network resources in WSN, the service quality of WSN can be improved. Therefore, by optimizing the location of wireless sensor nodes deployed in WSN through effective WSN coverage strategies, the software, hardware, and network resources in WSN can be reasonably allocated to reduce energy consumption of WSN nodes and improve WSN usage time.

3. Optimization of Node Deployment in Wireless Sensor Networks Driven by Artificial Intelligence

3.1. Coverage Perception Model for Wireless Sensor Networks

In order to improve the unreasonable distribution of wireless sensor nodes during random deployment and increase the coverage of monitoring areas. Design a node mobility scheme that divides the mobility process into multiple parts with conflicting optimization objectives in the network, this paper only considers the security connection with Shared secret from the perspective of security connectivity and network coverage, so as to reduce the damage to the network security connection when improving network coverage, without selecting other objectives. However, improving the coverage quality of the initial deployment of WSN nodes often requires node movement. This article attempts to optimize the deployment of WSN nodes driven by AI. Due to the limitations of sensor nodes' own resources and functions, in the data transmission process of homogeneous sensor network architecture, sensor nodes need to cooperate with each other to complete the collection and acquisition of monitoring data, and transmit the acquired perception information to the higher-level aggregation node through AI multi hop routing transmission. The perception model assumes that the perception probability of wireless sensor nodes towards targets in the monitored area is determined, but in practical application environments, the monitoring ability of wireless sensor nodes is actually uncertain, and the probability perception model reflects the uncertainty of this perception ability. The deployment area T is discretized into $m \times n$ target point sets $T = \{T_1, T_2, T_3, \cdots, T_m\}$, where the position coordinates of the target point T_l are expressed as (x_{T_l}, y_{T_l}), and the Euclidean distance between the target point T_l and the node S_i is:

$$d(S_i, T_l) = \sqrt{(x_{S_i} - x_{T_l})^2} \tag{1}$$

The perception probability $P(S_i, T_l)$ of the node S_i to the target point T_l can be calculated by using the Boolean perception model:

$$P(S_i, T_l) = \begin{cases} 1, & d(S_i, T_l) \leq R_s \\ 0 & \end{cases} \tag{2}$$

If the distance from the target point T_l to the node S_i is less than or equal to the perception radius R_s of the node, the perception probability of the node S_i to the target point T_l is 1, that is, the target point is covered by the node.

Because the wireless sensor nodes may move out of the monitored area during the moving process, AI has a negative impact on the monitoring effect. In the deployment of WSN nodes, if we only pursue the improvement of coverage quality unilaterally, it will lead to the decline of indicators such as secure connection. Collaborate between nodes to perceive, collect, and process monitoring target information within the monitoring area, and send it to users. Sensor nodes are not only able to generate data, but also transmit data. Moreover, nodes can spontaneously establish communication links with nearby nodes without the need for other network devices. The coordinated perception monitoring behavior of nodes is achieved through layered protocols and distributed algorithms, and self-organized communication networks are formed through wireless communication. Therefore, in the traditional node deployment optimization, the goal is only to improve the network coverage, and at the same time, the security connectivity of nodes should be taken as the optimization goal, and the full coverage of the network and the energy consumption of node movement should be taken as the constraint functions to achieve the goal of maximum network coverage and maximum-security connectivity of nodes.

3.2. Centroid Oriented Virtual Force Coverage Scheme for Secure Connections

If there is virtual gravity between nodes, they move towards positions close to each other. If it is virtual repulsion, nodes repel each other without any force, and nodes do not move. Each wireless sensor node follows the same method to move to the appropriate location, ensuring uniform distribution of nodes in the entire WSN area, and achieving coverage that meets deployment requirements through AI driving. Due to the presence of numerous external interference and uncontrollable factors in the communication link, the quality of WSN communication links is usually unstable. Especially when data needs multi hop transmission to reach the target node, each hop in the transmission process will lead to a decrease in data transmission rate, an increase in Transmission delay and energy consumption of the node. The basic idea of applying AI to solve the WSN coverage optimization problem is to abstract each node into a virtual charge, and each node is subjected to the force of other surrounding nodes as a force. The virtual force analysis of nodes is shown in Figure 1, taking node S1 as an example to analyze its virtual force. Node S1 outside the communication radius of node S1 has no virtual force on node S2, otherwise there is a virtual force. If node S3 is outside the communication radius, the virtual force on node S4 is zero. For the virtual force between node S2 and node S3 within the communication radius of node S1, the communication radius R1 is the critical point where the virtual force is gravitational and repulsive: nodes with a distance less than the distance threshold act as repulsive forces on them.

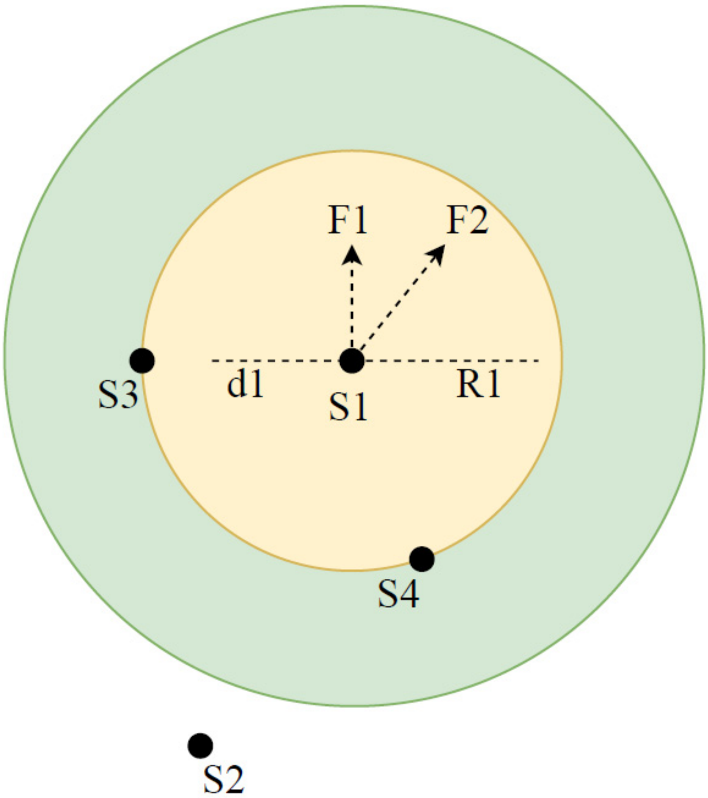

Figure 1. Virtual force analysis of nodes

Wireless sensor nodes in WSN may exit WSN due to energy depletion or failure, or they may exit WSN operation according to a predetermined program. Wireless sensor nodes outside of WSN can join WSN at any time, and wireless sensor nodes can move. Because the communication radius of nodes is generally within a certain range, WSN nodes need to run routing protocols to communicate with nodes beyond the communication radius. Each node in WSN can not only serve as a sender of data, but also as a relay for data transmission. AI aims to improve WSN coverage and reduce the movement distance of wireless sensor nodes. The virtual force algorithm is modified and a node deployment algorithm based on AI evidence theory is designed.

4. Conclusion

This paper optimizes the deployment of WSN nodes driven by artificial intelligence. A node movement scheme is designed, which divides the movement process into several parts with conflicting optimization objectives in the network. This paper only considers the secure connection sharing secret from the perspective of secure connection and network coverage, so as to improve the network coverage and reduce the damage to the secure connection of the network, and does not choose other objectives. However, improving the coverage quality of initial deployment of WSN nodes usually requires node movement. Due to the limitation of sensor nodes' own resources and functions, in the data transmission process of homogeneous sensor network architecture, sensor nodes need to cooperate with each other to complete the collection and acquisition of monitoring data, and transmit the obtained sensing information to higher-level sink nodes through AI multi-hop routing. The data fusion theory is introduced, and the data fusion model is used to synthesize various strategies such as node synchronization task scheduling, dynamic node deployment and dynamic network topology recovery. This paper studies the optimal deployment of WSN nodes from the aspects of WSN key management scheme, optimal deployment strategy of WSN nodes based on secure connection and multi-objective optimal deployment of WSN nodes. Because there are a large number of wireless sensor nodes in WSN, and most of the wireless sensor nodes can only be randomly deployed, it is impossible to determine the location of wireless sensor nodes in advance. In the future research, the energy consumption caused by node movement can also be considered as the optimization goal, and the establishment of each objective function should be optimized.

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