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Application of Artificial Intelligence Technology in the Optimal Deployment of Wireless Sensor Network Nodes

Yichen Lei

Xi'an University of Technology, Xi'an, China

Abstract: WSN (Wireless Sensor Network) is a network composed of a large number of sensor nodes self-organizing through wireless communication technology. Nodes are prone to failures due to environmental impact and energy depletion, and environmental interference and node failures can easily cause changes in the network topology. This article conducts research on the application of AI (Artificial Intelligence) technology in the optimal deployment of WSN nodes. Using AI technology to optimize the deployment of hybrid WSN mobile nodes, ensuring that the node density of each sub target area reaches its expected node density to ensure effective coverage of the entire target monitoring area. Given the target area range, the number and position of sensor nodes are determined through AI technology, which is the network layout for a given target area. Effectively reducing the data flow of the entire network. Due to the limited energy of sensor nodes, minimizing energy consumption and maximizing network lifespan are the main goals of designing WSN. Deployment strategies must optimize the deployment strategies of sensor nodes, intermediate nodes, and base stations to ensure coverage, connectivity, and robustness.

Keywords: Artificial Intelligence Technology; Wireless Sensor Network Nodes; Optimal Deployment.

1. Introduction

WSN is a highly flexible, low-energy-consuming and complex sensing detection system which is composed of a large number of nodes that can perceive the surrounding environment, perform simple calculations and have certain wireless communication capabilities, and integrates data acquisition, data processing and data transmission [1]. Large-scale WSN consists of thousands of micro-sensors, and these sensor nodes monitor the target. Nodes in the network can perceive the surrounding environment, perform simple calculations on the perceived information, and communicate with their neighboring nodes within the communication radius [2-3]. Wireless sensor nodes form a highly flexible and low-energy network through self-organization. In the case of random deployment of nodes, although the fixed WSN composed of fixed nodes can adopt high-density node deployment strategy to improve the service quality of the network and extend the life cycle of the network by controlling the working state of nodes, the fixed WSN still can't overcome the problems of poor adaptability to the environment and self-repair due to the fixed position of nodes after initial deployment [4-5]. The hybrid WSN, which consists of a large number of fixed nodes and a small number of mobile nodes, can improve the distribution of nodes in the target area by optimizing the deployment position of mobile nodes, so it has good economy and good environmental adaptability and self-repair ability [6]. In order to enable energy constrained sensor networks to monitor as large an area as possible for a longer period of time, it is necessary to save network energy consumption and optimize existing network resources through appropriate communication protocols and effective deployment algorithms, in order to achieve maximum utilization or minimum energy consumption for a single task in future applications. As a complete set, the target area is divided into two parts: coverage area and blind area based on whether it can be covered by the mixed WSN. The coverage area is the target area where any point is within the perception radius rs of at least one node; The blind spot is the complement of the coverage area. Because in many cases, WSN works in the unknown target area, it is often necessary to use random deployment strategy to complete the initial deployment of nodes, so this paper studies the application of AI technology in the optimal deployment of WSN nodes.

2. Description and Definition of Node Deployment Problems in Wireless Sensor Networks

WSN is a network composed of numerous micro nodes. The energy reserves and computing capabilities of nodes themselves are limited. Recently, many research works have proposed cross layer design to address the resource constraints, where each layer of software opens internal protocol interfaces, allowing upper and lower layers of software to traverse inter layer shielding and dynamically adjust the internal implementation of the software to optimize the operational efficiency of sensor nodes in real time [7]. The hardware and software of WSN are combined to provide users with various data collection and processing services, forming an architecture. By summarizing various existing sensor network applications and research work, the network architecture can be roughly divided into several parts: network communication protocols, network management technologies, application support technologies, and WSN architecture, as shown in Figure 1.

WSN is randomly deployed in a two-dimensional target monitoring area, which can be a subset of the whole target area or the whole target area. Both fixed nodes and mobile nodes are uniformly and independently randomly distributed in the target monitoring area, and multiple nodes cannot be deployed at any position at the same time, so the probability of nodes falling into any position in the target monitoring area is the same [8]. After WSN nodes are deployed in the monitoring area, need to be able to quickly complete self-positioning, time calibration, self-adjustment of node position, etc., and the coverage algorithm needs to be fast, easy to operate and low in execution complexity to meet the real-time requirements of applications [9]. Change in the network application environment. When the coverage requirements of the monitored area need to be adjusted, the implementation complexity of the algorithm is low to quickly adapt to the needs of the network and ensure the network security.

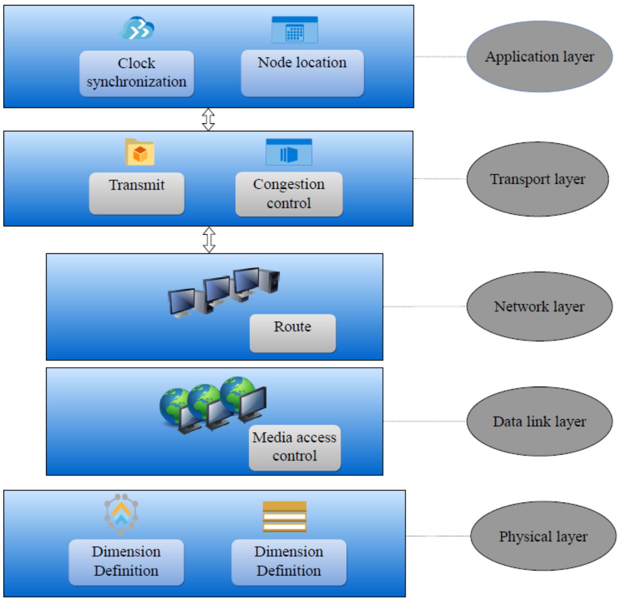

Figure 1. WSN Architecture

Because the computing power, storage capacity, communication capacity and node energy of sensor network nodes are limited, a single node can only obtain the topology information of the local network, and the network protocols running in the network should not be too complicated. At the same time, in addition to the dynamic changes in the structure of sensor networks, the network resources are constantly changing, which all put forward higher requirements for network protocols [10]. It is impossible for network users to accept and deploy a sensor network that has not solved the security and privacy problems. Therefore, when designing the protocol and software of the sensor network, we must fully consider the security problems that the sensor network may face and integrate the security mechanism into the system design. Only in this way can we promote the wide application of sensor networks, otherwise sensor networks can only be deployed in a limited and controlled environment, which is contrary to the ultimate goal of sensor networks-to realize universal computing and become an important way in people's lives.

3. Research on Artificial Intelligence Technology in Optimal Deployment of Wireless Sensor Network Nodes

3.1. Wireless Sensor Network Coverage

WSN often undertakes the task of monitoring and detecting certain areas, and coverage is a measure of the detectability of the target monitoring area. Coverage is a key issue in WSN, which affects the monitoring of a region by sensor networks. Network coverage can be seen as an overall measure of the quality of detection service provided by sensor nodes with different geographical locations. The sensor coverage model is the foundation of this metric, which is closely related to factors such as the sensing function of different types of sensor nodes and different application requirements. Any point in the target monitoring area is covered by a mixed WSN, if and only if it is within the perception radius rs of at least one node. As a complete set, the target area is divided into two parts: coverage area and blind area based on whether it can be covered by the mixed WSN. The coverage area is the target area where any point is within the perception radius rs of at least one node; The blind spot is the complement of the coverage area. If the target monitoring area is divided into adjacent but non overlapping sub areas, the coverage of the entire target area by the hybrid WSN can only achieve the expected goal if and only if the network coverage quality of each sub target area reaches the expected coverage quality.

Since its inception, AI has become increasingly mature in theory and technology, and its application fields have also expanded. It can be imagined that the technological products brought by AI in the future will be the "container" of human intelligence. Large-scale WSN consists of thousands of micro-sensors, and these sensor nodes monitor the target. Nodes in the network can perceive the surrounding environment, perform simple calculations on the perceived information, and communicate with their neighboring nodes within the communication radius. Or more strictly speaking, it is difficult for computers to learn "qualitative change that does not rely on quantitative change" in the process of human practice includes both experience and creation. This article will use AI technology to optimize the deployment of hybrid WSN mobile nodes, so that the node density of each sub target area reaches its expected node density, in order to ensure effective coverage of the entire target monitoring area by the network. After the target area range is given, the number and location of sensor nodes are determined through AI technology, which is the network layout for the given target area. At this point, network deployment is divided into deterministic deployment and stochastic deployment. In deterministic deployment, the most interesting aspect is how to fully cover the target area with the minimum number of sensor nodes. There are always some sensors that are not activated and areas that are covered within the target area, namely coverage vulnerabilities. This situation occurs when the energy consumption of sensor nodes is exhausted or when the number of randomly deployed sensor nodes is less than the required number of sensor nodes. For mobile targets, coverage refers to the degree to which active nodes in a sensor network monitor the moving target.

3.2. Node Deployment Analysis

The research of existing deployment algorithms can be divided into two parts from the time period of network application: initial static deployment and dynamic adjustment in application. The deployment has developed from the initial gallery problem and circular coverage problem to the deployment problem of adhoe network, and now the deployment problem of WSN considering energy consumption, and even the mobile site-assisted deployment scheme has appeared. In this paper, WSN nodes are optimized by AI technology. By analyzing the experimental data in Table 3, it is not difficult to find that the coverage quality of hybrid WSN to the target monitoring area has improved after the optimal deployment of mobile nodes, which shows that the optimization method of mobile node deployment proposed in this paper can reasonably adjust the deployment position of mobile nodes, thus making the distribution of hybrid WSN nodes more reasonable and improving the service quality of the network.

Table 1. Network coverage quality of WSN mobile nodes

	Experiment condition	1	2	3	4
1	Initial coverage quality	0.6234	0.6112	0.6895	0.7036
	Optimized coverage quality	0.5865	0.6587	0.7014	0.7325
2	Initial coverage quality	0.6625	0.6851	0.7102	0.7256
	Optimized coverage quality	0.7136	0.6901	0.7526	0.7623
3	Initial coverage quality	0.6852	0.7032	0.7016	0.6857
	Optimized coverage quality	0.7446	0.7134	0.7111	0.7623

From the perspective of the application of the entire network, balancing the energy consumption of each node under AI technology can lead to the premature depletion of energy in certain nodes, resulting in the loss of information in certain areas or network paralysis. In order to enable energy constrained sensor networks to monitor as large an area as possible for a longer period of time, it is necessary to save network energy consumption and optimize existing network resources through appropriate communication protocols and effective deployment algorithms, in order to achieve maximum utilization or minimum energy consumption for a single task in future applications. After WSN nodes are deployed in the monitoring area, need to be able to quickly complete self-positioning, time calibration, self-adjustment of node position, etc., and the coverage algorithm needs to be fast, easy to operate and low in execution complexity to meet the real-time requirements of applications. Due to the limited energy of sensor nodes, minimizing energy consumption and maximizing network lifespan are the main goals of designing WSN, the deployment strategy must optimize the deployment strategy of sensor nodes, intermediate nodes, and base stations to ensure coverage, connectivity, and robustness. The key challenge is how to determine a perception domain framework system that can minimize overhead, improve the coverage time of AI technology in WSN nodes, respond to node failure energy, and appropriately calculate and communicate trade-offs.

4. Conclusion

As a new technology that will change the interaction between human beings and the real physical world, plays an active and important role in military, industrial, medical, transportation and environmental protection, with broad application prospects and great commercial value. In this paper, the application of AI technology in the optimal deployment of WSN nodes is studied. Due to the large number of sensor nodes, they can only be randomly placed, and the positions of sensor nodes cannot be determined in advance. At any time, nodes are connected through wireless channels to self-organize the network topology. Sensor nodes have strong cooperation ability, and complete the global task through local data acquisition, preprocessing and data interaction between nodes. After the WSN node is deployed in the monitoring area, it needs to be able to quickly complete self-positioning, time calibration, self-adjustment of node position and so on. By adjusting the deployment position of mobile nodes, the node density in each sub-target area is optimized, so as to improve the service quality of hybrid WSN to the target area. Because this method does not need to calculate the mutual position relationship between nodes, it requires less node position information and has high computational efficiency.

References

[1] Sundar R, Ahamed J A S, Suganya. V.INGREDIENTS OF WIRELESS SENSOR NETWORK TECHNIQUE USING ARTIFICIAL INTELLIGENCE AND VIRTUALIZATION[J]. TecnoLógicas, 2019, 11(2):8-12.

[2] Celis J M, Escobar C, Sepulveda S,et al. Design of a Wireless Sensor Network for Optimal Deployment of Sensor Nodes in a Cocoa Crop[J].TecnoLógicas, 2020, 10(9):31-38.

[3] Zolotukhin M, Sayenko A, Hamalainen T. on Optimal Deployment of Low Power Nodes for High Frequency Next Generation Wireless Systems[J].Computer Networks, 2018, 144 (OCT.24):120-140.

[4] Zhang J. Real-time detection of energy consumption of IoT network nodes based on artificial intelligence[J].Computer Communications, 2020, 153(7):20-26.

[5] Mohar S S, Goyal S, Kaur R. Optimized Sensor Nodes Deployment in Wireless Sensor Network Using Bat Algorithm[J].Wireless Personal Communications, 2020, 22(2):1-19.

[6] Elmosilhy N, Haleem A A E, Elmesalawy M. Optimal Deployment of Heterogeneous Wireless Nodes in Integrated LTElWi-Fi Networks[J]. 2019, 19(4):26-31.

[7] Li S S Y. Near-Optimal Co-Deployment of Chargers and Sink Stations in Rechargeable Sensor Networks[J].ACM Transactions on Embedded Computing Systems, 2018, 17(1): 10-14.

[8] Yu X. Construction of an Innovative Development Model of Intelligent Media under the Coverage of a Wireless Sensor Network[J].Mathematical Problems in Engineering, 2022, 20(7):15-20.

[9] Perumal S, Tabassum M, Narayana G, et al. ANN Based Novel Approach to Detect Node Failure in Wireless Sensor Network [J]. Computers, Materials, and Continuum (in English), 2021, 12(011):14-19.

[10] Vishal P, Babu A R. Firefly Algorithm for Intelligent Context-Aware Sensor Deployment Problem in Wireless Sensor Network [J]. Journal of Circuits, Systems and Computers, 2022, 28(1):1-4.