

# Application Research of Wireless Sensor Network in Building Structure Safety Monitoring

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**Abstract.** In order to ensure the safety of important buildings, the structural safety monitoring of buildings is indispensable. Compared with wired sensor network, wireless sensor network have the advantages of deployment flexibility, lower maintenance cost and higher monitoring accuracy. It has a better application prospect in the safety monitoring application of building structure. This paper studied the application of wireless sensor network in the safety monitoring of buildings by studying the application requirements in the safety monitoring of building structure in important buildings, proposed a routing algorithm to improve the network lifetime, and simulated the routing algorithm. The results show that the algorithm can effectively improve the network lifetime.

## 1. Introduction

The safety of buildings is related to people's life and property safety. During the service period of the building, due to the complex structure, corrosion, disasters and other reasons, it will cause potential safety hazard in the building structure. In order to ensure the safe service of the building, the safety monitoring of the structure of the building is very necessary.

The safety monitoring system of the building arranges the sensors in the key positions of the building to measure the real-time parameters of the building structure and the building environment. These parameters are transmitted to the data center through the communication technology, and the data center analyzes and stores the data. The data center observes changes in the structural system over time by analyzing dynamically collected dynamic response data and determines the health status of the building by analyzing the damage-sensitive eigenvalues extracted[1]. For long-term health monitoring of building structures, the effects of structural aging and poor service environment on the structure of the project are estimated mainly through periodic data updates and the ability of the building to continue its design capability. By monitoring the structural safety of the building, the problems existing in the building can be found in time to reduce the casualties and property losses[2].

In recent years, wireless sensor network technology has been developed rapidly, and its role in the bridge connecting the physical world and the computer world has been widely used. Wireless sensor networks not only have the advantages of low cabling cost, high monitoring accuracy and good fault tolerance, but also can be remotely monitored with outstanding advantages in fault diagnosis and safety monitoring[3]. At present, the main research directions of WSN are mainly in the field of military field,



field control of industrial automation and monitoring of the earth environment. There is not much research on the application of building safety monitoring, and there is a lack of practical wireless sensor network integrated system which accords with the characteristics of building safety monitoring[4].. With the continuous improvement of people's living standards, the modern intelligent building has made considerable progress. At the same time, the wireless sensor network system has gradually begun to infiltrate into the application of the modern intelligent building field because of its unique outstanding advantages. It has become a modern intelligent building Related areas of research focus.

## **2. Wireless Sensor Network Technology**

The architecture of wireless sensor network has many kinds of forms, it can be divided into the following three kinds mainly: the centralized structure, the distributed structure and the network structure. There are no central nodes in a typical wireless sensor network. All the nodes self-organize into a distributed network to send the monitoring data to the sink node. The sink node analyzes the data and converges the data to the data center[5]..

The structure of the wireless sensor node consists of four functional modules: (1) sensor module: composed of sensor and analog-digital conversion unit, mainly responsible for information acquisition and data conversion; (2) processor module: composed of processor and memory, and Generally built-in a small embedded operating system, its main work is to control the overall operation of sensor nodes, running high-level network protocol, data calculation and processing; (3) communication module: the antenna and wireless transceiver controller, the module's main responsibility is Communicate with other sensor nodes; (4) Energy supply module[6].: This module usually consists of a micro-battery or a button battery with limited energy and is mainly responsible for providing energy to the sensor node, which determines the life of the sensor node.

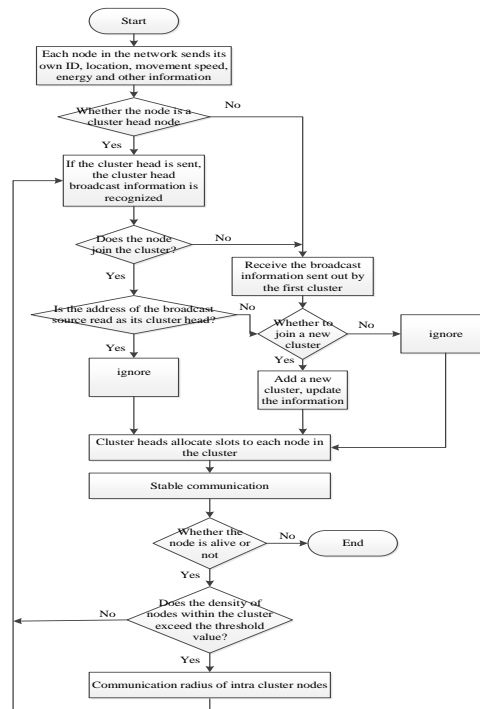
The protocol stack of the wireless sensor network consists of the physical layer, data link layer, network layer, transport layer and application layer. In addition, the protocol stack also includes the energy management platform, the mobile management platform and the task management platform.

Routing protocol is one of the key technologies in wireless sensor network. It logically divides the network topology and is responsible for establishing the data transmission path from sensor node to sink node. In order to extend the network life cycle, the routing protocol must be able to reduce the energy consumption of each node and the energy consumption of the entire network, and achieve the purpose of balancing the energy consumption load of the entire network. The routing protocols of wireless sensor networks can be divided into planar routing protocols and clustering routing protocols according to the network topology[7]..

The routing protocol in wireless sensor network not only need to select the energy consumption of small message transmission path, but also choose the route that consumes the entire network energy balance from the perspective of the entire network. The sensor nodes have limited resources. The routing mechanism of wireless sensor network should be able to transmit information easily and efficiently.

## **3. Design of Wireless Sensor Network Routing Algorithm**

LEACH is a classic routing protocol in wireless sensor network. In order to extend the lifetime of wireless sensor network, a new routing algorithm is proposed in this paper. The algorithm mainly includes five phases, which are clustering, node selection in a cluster Cluster head, node cluster, stable communication and communication radius adjustment. The specific process shown in Figure 1.



**Figure 1.** The wireless sensor network routing protocol flow chart based on node load balancing

### 3.1 Cluster head selection

In the same way as the LEACH protocol, in this algorithm, the nodes are self-organized into clusters, each cluster contains a cluster head node, which is responsible for converging and forwarding the data collected by nodes in the cluster to the Sink node. Due to the data fusion and forwarding, the cluster head consumes more energy than other nodes.

The node generates a random number between 0 and 1. For node  $n$ , if this random number is smaller than the threshold  $T(n)$ , the node broadcasts itself as a cluster head to the entire network[8].

$$T(n) = \begin{cases} \frac{P}{1 - P \times (r \bmod \frac{1}{P})} & n \in G \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

In the formula,  $P$  is the ratio of the preset cluster head node to all the nodes and the current round number,  $G$  is the set of candidate cluster head nodes, and also the set of nodes that have not elected cluster heads in the preceding consecutive  $P$  rounds, mod is modulo operation.

After the cluster head node is selected, the cluster head node will send the broadcast message. Once receiving the broadcast message sent by the first cluster head, the node joins the cluster. If the node can receive the broadcast message sent by other cluster heads, the node will be compared with the cluster head distance. If the new cluster head is closer to the node, the node will join the new cluster. Otherwise, the cluster head broadcast message will be ignored.

### 3.2 Energy level

The node neighborhood distance defined in this paper is for each node, which refers to the distance between the node in each node's neighbor node set and that node. The initial neighbor node set of each node is a set of nodes in the initially set transmission power range of the sensor nodes, that is the communication radius. During initialization, a test signal can be sent to the surrounding nodes through the node to record the number of neighboring nodes and the distance between each neighboring node and the node.

The radius of the power transmission range of each node at the initial time of the entire network is

$R_0$ , which is the broadcast domain or communication radius of node  $i$ . The set of neighboring nodes of node  $i$  is the set of neighbor nodes of the current node  $i$ , and the distance between each neighboring node through the test signal node  $i$  is the node's neighbor distance  $d_i$ :

$$d_i = \text{Dist}(\text{node } i, \text{node } i_{\text{neighbor } k}) \quad (2)$$

Where  $k$  represents the  $k$ th neighbor node.

Because the wireless sensor network is a self-organizing network, the remaining energy of each node in the network initialization is different. In order to save energy and increase the life cycle, load balancing is performed for each node, that is, the nodes with more residual energy can be more loaded, The remaining nodes with less energy load is relatively less, which can effectively extend the life cycle of the entire network to avoid excessive network load caused by local network collapse and consume more energy. In order to measure the residual energy difference between nodes, this paper introduces the node residual energy level REL, the introduction of the benefits of REL is equivalent to the normalization of energy to avoid tedious calculations for the sensor nodes to save storage space and Energy consumption, and use the number of loads corresponding to the discriminant energy level. Set an initial energy  $E_0$  for the entire network and  $m$  nodes for each energy level, then  $E_{\text{average}} = E_0/m$ , for each level. The energy level  $m$  can be calculated based on the density of communication nodes in the entire network. Suppose the current remaining energy of each node  $i$  is  $E_{i\_cur}$ , we can get the remaining energy level of a node  $i$  in the network at a certain moment as:

$$REL_{i\_cur} = [E_{i\_cur}/E_{\text{average}}] \quad (3)$$

$[E_{i\_cur}/E_{\text{average}}]$  represents the smallest integer greater than  $E_{i\_cur}/E_{\text{average}}$ . From (3), we can get the remaining energy level of each node in the range of  $[1, m]$  positive integer. The selection of the energy level  $m$  has an important influence on the performance of the entire optimization protocol and can be set according to the average node density of the entire network. The requirements for communication quality  $m$  can be flexibly set according to different networks. If  $m$  is smaller, the remaining energy difference of each node can not be reflected. The number of loads set according to the remaining energy level will not change significantly, and the effect of load balancing will be very insignificant.

### 3.3 stable communication

After the network completes the clustering and the nodes are clustered, the network conducts a stable communication process. The sensor node collects the monitoring data and sends the data to the cluster head. After the cluster head finishes data fusion on the received data, the data Send to Sink node.

## 4. Communication radius adjustment strategy

Due to the randomness of the monitoring nodes, some nodes in some clusters have more nodes and fewer nodes in some clusters. In order to prolong the lifetime of cluster head node, the communication radius of cluster head will be dynamically adjusted when the density of nodes in a cluster is larger, and when the density of cluster heads is larger, the communication radius will be reduced appropriately, Reduce energy consumption, achieve load balancing, extend network life. The relationship between the communication radius before and after adjustment is as follows:

$$R_c = (1 - Q_i) \times R \quad (4)$$

In (4),  $R_c$  is the adjusted communication radius,  $R$  is the communication radius before adjustment, and  $Q_i$  is the node density of nodes.

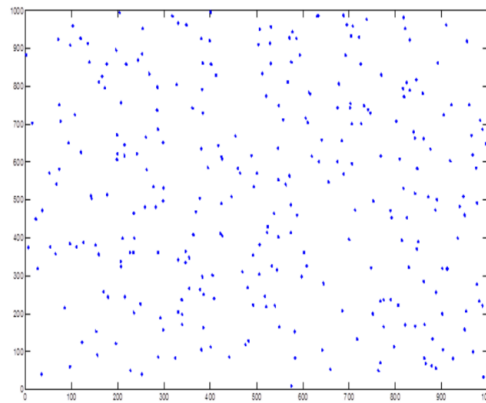
$$Q_i = \frac{N_{\text{neighbor}_i}}{N_{\text{wsn\_alive}}} \quad (5)$$

The expression of  $Q_i$  is as shown in formula (5),  $N_{\text{neighbor}_i}$  is the number of neighbor nodes of the

node  $i$ , and  $N_{wsn\_alive}$  is the number of nodes alive in WSN monitoring network.

## 5. Simulation analysis

In order to analyze and compare the performance of the routing algorithm, this paper carries on the data modeling of the LEACH algorithm and the proposed routing algorithm in the MATLAB environment. In the area of 1000m \* 1000m, 400 sensor nodes are randomly deployed, as shown in FIG. 2.



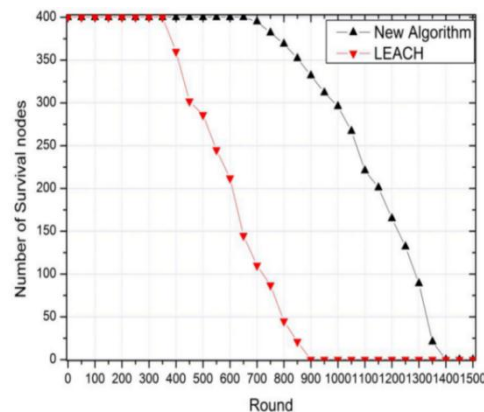
**Figure 2.** wireless sensor node distribution

Since the WSN is a self-organizing network, the initial energy of each node in the network initialization is different, and the sink node generally selected is a node with sufficient energy. Taking the above into account, the initial energy of the sink node is set as 1.00, In order to highlight differences in remaining energy levels, the initial energy of the remaining ordinary nodes is set to a random value between 0.50 and 1.00. Other simulation parameters can be set according to Table 1 below:

**Table 1.** simulation parameters

Parameter	Setting
Sensing area size	1000×1000
Number of sensing nodes	400
Sink node initial energy	1
Normal node initial energy	0.50~1.00
Broadcast energy consumption	0.0001
Send Message Energy Consumption	$\delta * \text{Dist}^3$

Send information energy consumption using the model of wireless communication distance and energy consumption  $E = \delta * d^3$ , and  $\delta = 0.0001 * (1/(25^3))$ . The choice of energy level  $m$  has an impact on the performance of the protocol, so the value of  $m$  is crucial. In this paper, the value of  $m$  is chosen according to the average density of nodes in the entire sensing region. In this paper,  $m$  values 9, then REL has 9 levels.



**Figure 3.** Comparison of the number of network survivors

Figure 3 shows the routing algorithm proposed in this paper and LEACH routing algorithm in the number of network nodes in the comparison. Network lifetime refers to the time when the first node in a network runs out of energy, expressed by the number of rounds. In order to fit an actual communication system, a node dies when the remaining energy is less than 5%. The number of surviving nodes in the network can also reflect the algorithm's lifespan of the entire network. It can be seen from the figure that LEACH algorithm will die at the first node in the 400th round, and the algorithm proposed in this paper will die at the 700th round. At the speed of node death, the proposed algorithm is also less effective than the LEACH algorithm. It can be seen from the figure that in the 900th round, all the nodes in the LEACH algorithm will die, and the algorithm proposed in this paper will die at 1400 rounds of all nodes. It proves that the proposed algorithm can indeed balance the load of the network and effectively extend the lifetime of the entire network.

## 6. Conclusion

Based on the analysis of the LEACH protocol, this paper proposes an improved routing algorithm for wireless sensor networks. In order to balance the load of each node, the energy steps are adopted in the algorithm. In order to reduce the node energy consumption, Used to adjust the communication radius of the method. The simulation results show that the algorithm can effectively improve the network lifetime.

## References

- [1] Yick J, Mukherjee B, Ghosal D. Wireless sensor network survey[J]. Computer Networks, 2008, 52(4): 2292-2330.
- [2] Chouhan S, Bose R, Balarishnank M. Integrated energy analysis of error correcting codes and modulation for energy efficient wireless sensor nodes[J]. IEEE Transactions on Wireless Communications, 2009, 8(10): 5348-5355.
- [3] Kalis A, Kanatas A G, Efthymoglou G P. A co-operative beamforming solution for eliminating multi-hop communications in wireless sensor networks[J]. IEEE Journal on Selected Areas in Communications, 2010, 28(7): 1055-1062.
- [4] Subramanian, A. P., Buddhikot, M. M., & Miller, S. (2006). Building structure condition monitoring system using wireless sensor network. Undergraduate Theses of Electrical Engineering Department, 55-63.
- [5] Morello, R., C. D. Capua, and A. Meduri. "Remote monitoring of building structural integrity by a smart wireless sensor network." Instrumentation and Measurement Technology Conference IEEE, 2010:1150-1154.
- [6] Dai, Zhicheng, S. Wang, and Z. Yan. "BSHM-WSN: A wireless sensor network for bridge structure health monitoring." Proceedings of International Conference on Modelling, Identification & Control IEEE, 2012:708-712.

- [7] Gao, Huiyan. "Application of Zigbee Wireless Sensor Network in Safety Monitoring System." *Computer Measurement & Control* 16.6(2008):766-768.
- [8] Gamwarige, S., and C. Kulasekera. "An energy efficient distributed clustering algorithm for ad hoc deployed wireless sensor networks in building monitoring applications." *Electronic Journal of Structural Engineering* 9(2009):11-27.