Wavelet Sampling Algorithm for Environmental Monitoring and Management Based on the Internet of Things

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Abstract. Aiming at the problem of ecological environment monitoring, the paper proposes an IoT technology for ecological environment monitoring based on wavelet sampling algorithm and multi-sensor network platform. This technology divides the monitoring area into several different clusters, each cluster collects and collects various types of environmental monitoring data, and different types of sensors such as temperature, humidity, noise sensors, etc. can be set according to the monitoring needs; Set up mobile Agent nodes in the monitoring area, establish a real-time two-dimensional positioning table based on network energy consumption, use wavelet sampling algorithm projection method to select the optimal path, construct a mobile plan, collect the collected data and forward it to the control centre. Simulation experiments and mathematical analysis show that the technology has real-time and reliability for remote data collection and transmission for environmental monitoring, and the overall network energy consumption is low.

Keywords: Internet of Things, environmental monitoring, wavelet sampling algorithm, ecological environment.

1. Introduction
Economic and social development has brought about serious environmental pollution problems, affecting the long-term development of society, and affecting human health. At present, my country has been committed to the cause of environmental protection, emphasizing the economic development viewpoint of not only gold and silver mountains, but also green mountains and green mountains. The relevant departments have also formulated a series of laws and regulations to effectively control environmental pollution. However, due to the low degree of informatization in the field of environmental monitoring, it is difficult to effectively control environmental pollution. The application of the Internet of Things technology in the field of environmental monitoring has improved the degree of informatization in the field of environmental monitoring, can provide timely dynamic information, discover environmental pollutants in time, and effectively control environmental pollution problems in a timely manner [1]. Therefore, this article proposes an ecological environment adaptive real-time monitoring system based on the Internet of Things technology. The system adopts a self-organizing method to form a multi-sensor network composed of several clusters. It gathers data based on mobile Agent nodes, and according to a two-dimensional positioning table, the current optimal route is
calculated by wavelet sampling and projection method, which improves the efficiency of data aggregation while reducing Data transmission energy consumption enhances the robustness of the monitoring system.

2. Theoretical overview

2.1. Overview of the ecological environment
Ecological environment refers to the whole composed of biological and non-biological communities and some non-biological natural factors, which directly or indirectly touch people's survival. People survive in the ecological environment, and in the process of using and changing the natural environment, people need to be aware of the consequences of the destruction or pollution of the natural environment in time and take preventive work. The ecological environment and people's living environment have always been interdependent. With the continuous improvement of society, the ecological environment plays an increasingly important role in people's society. Therefore, real-time monitoring of various ecological environments and real-time detection of environmental indicators such as air quality, water quality, and temperature are beneficial to promote the improvement of people's society.

2.2. Overview of IoT technology
The Internet of Things is an emerging data technology, and it is an important stage in the data age. The focus and foundation of the Internet of Things is still the Internet, but it has evolved from the virtual to the connection of things. It is the data exchange and communication between things, that is, the relationship between things. The Internet of Things technology refers to the use of related data sensing equipment, such as infrared sensors, global positioning systems, etc., to connect goods to the Internet in accordance with the corresponding agreed rules, so as to achieve the purpose of data exchange. It is a kind of network technology that can realize the intelligent identification, positioning and tracking of goods. The ecological environment detection based on the Internet of Things technology realizes real-time detection and monitoring of the ecological environment through the relevant Internet of Things technology. Using this technology, the ecological environment detection area can be divided into multiple clusters, and the corresponding data can be sampled and collected for different clusters. Different sensors can also be used to meet the detection needs. The use of this technology can effectively realize remote sampling and data collection, and has real-time and reliability, and consumes less overall network.

3. Ecological monitoring model and principle based on the Internet of Things
The ecological monitoring model based on the Internet of Things is mainly composed of four parts: data collection sensor node, cluster head node, mobile agent centre node, and control centre. In the self-organizing multi-sensor network of the clustered area of the Internet of Things, the sensor nodes used include various hydrological sensors, air quality sensors, light intensity sensors, temperature sensors, humidity sensors, etc. In addition, a wireless short-distance communication data transmission function module is installed on all sensors. After the multi-sensor in the clustering area collects various types of environmental monitoring data, it sends the data to the cluster head node of the cluster, or the mobile agent node that can be detected, which will be collected by the cluster head node or mobile agent node. After the data is gathered, it is forwarded to the control centre.

The sensor node data acquisition module sends data to the cluster head node after a hop, and the node is equipped with a real-time monitoring function module for pollution sources, which can monitor whether there is pollution in the circular monitoring area of the node, and send the monitoring data in time, and this operation The priority is higher than the sending of general environmental monitoring data, and the cluster head node is required to forward it first, so that it can fully meet the actual needs of monitoring data collection and environmental pollution source monitoring. The monitoring sensor node is designed with embedded technology. The function modules of the node
include: data collection type module, data wireless transmission module, high-efficiency power supply module, real-time pollution source monitoring module, and mobile Agent monitoring module, as shown in Figure 1.

The ecological environment monitoring sensor node adaptively activates the corresponding type of data monitoring module according to the monitoring demand, and adopts the centralized data collection method. Its workflow is as follows: 1) According to the monitoring demand from the control centre, the corresponding data type module is activated. The monitoring data types are: Hydrological data acquisition module, air quality data acquisition module, light intensity data acquisition module, temperature data acquisition module, humidity data acquisition module, etc.; 2) Periodically start the mobile agent discovery module, and if found, send the data to be sent to Mobile Agent node; 3) Periodically start the data wireless transmission module, and send the collected data to the cluster head node; 4) Periodically start the pollution source real-time monitoring module according to the control information feedback from the control centre, if a pollution phenomenon is found, then go to (3); 5) If the cluster head node in the cluster where the node is located fails, go to (2).

Figure 2 shows the deployment of the ecological monitoring network based on the Internet of Things. It can be seen from Figure 2 that in the monitoring of the Internet of Things, the monitoring area is divided into several clustered areas, and each cluster has a cluster head node. In addition, several mobile Agent nodes are set up in the entire network, which collects in real time. The data gathered by the cluster head nodes of each cluster, on the other hand, avoids the failure of a cluster head node of a cluster, causing blind spots in the monitoring area, causing the network to be paralyzed and unable to monitor in real time.
4. Optimal path based on wavelet sampling projection method

The output of each spatial grid point in the ecological environment sampling area is a fuzzy signal, and a unidirectional coupling mapping grid point loop L-OCRML with a length of 10 is selected to generate a path used as environmental information. The description equation of the system is:

\[
\begin{align*}
    x_i(n+1) &= (1 - \varepsilon_i) f(x_i(n)) + \varepsilon_i f(x_{i-1}(n)) \\
    x_i(n+1) &= (1 - \varepsilon_i) f(x_i(n)) + \varepsilon_i f(x_{10}(n))
\end{align*}
\]  

Among them, \( n \) represents discrete time, \( i \) represents the position of the spatial grid point, and \( \varepsilon_i \) is the coupling parameter of the \( i \)-th spatial grid point, with a value range of \((0.75, 1)\); the length of the OCRML system is 10. The definition of function \( f(x) \) is: \( f(x) = 4x(1-x) \). The output of any grid point in the system is a fuzzy signal, which is a real-valued path between \((0, 1)\). Based on this path, \{0,1\} two value path. Let the output of the \( k \) spatial grid point evolve with time \( n \) to obtain the \((0, 1)\) real-valued fuzzy path \( \{x_{n,i} \} \), and the real number \( x_{n,i} \) is expressed in binary as:

\[
x_{n,i} = b_1(x_{n,i})b_2(x_{n,i})b_3(x_{n,i})...b_i(x_{n,i})...b_{10}(x_{n,i})
\]

Among them, \( b_i(x_{n,i}) \) represents the \( i \)-th decimal place in a binary number, calculated with the following formula:

\[
b_i(x_{n,i}) = \text{sign} \left( 2^{i-1} \left| x_{n,i} \right| - \left\lfloor 2^{i-1} \left| x_{n,i} \right| \right\rfloor \right)
\]

For each real value in the fuzzy path \( \{x_{n,i} \} \), take its \( i \)-th bit as the encoding bit, so that the \{0, 1\} binary path is obtained

\[
\{b_1(x_{n,1}), b_2(x_{n,2}), b_3(x_{n,3})...\}
\]

The balance of the binary path generated in the ecological environment sampling area, sensitivity to the initial value, and related characteristics all have good properties.
Wavelet analysis is widely used in image processing. The image is decomposed into 3 layers using wavelet transform, and after decomposition, a low-frequency approximate image and 8 high-frequency detail images in different directions are obtained [5]. The following uses the representation decomposition layer to represent 1 low-frequency approximation image and 3 high-frequency detail images after the first-level wavelet decomposition, and $\theta = 0, 1, 2, 3$ respectively represent the low frequency approximation (LL) and the horizontal high frequency detail (HL), vertical high-frequency detail (LH), diagonal high-frequency detail (HH). Use two tuples $\{,\}$ to represent each subband of the multilevel wavelet decomposition. The sub-bands of the three-level wavelet decomposition of the image are represented as the following tower structure as shown in Table 1:

|                | {3,0} | {3,1} | {2,1} |
|----------------|-------|-------|-------|
|                | {3,2} | {3,3} |       |
|                | {2,2} |       | {2,3} |
|                |       |       | {1,1} |
|                |       |       | {1,2} |
|                |       |       | {1,3} |

4.1. Extraction of environmental information
The paper uses the original image $I$ to find all the wavelet coefficients that can be added to the environmental information and extract them, and arrange them according to the original arrangement. At the same time, arrange the coefficients at the corresponding positions in the image $I_{w}$ to be tested in the same arrangement to obtain $x_{j}$, then According to formula (5), the environmental information $w_{j}^{*}$ to be tested can be extracted.

$$w_{j}^{*} = \frac{x_{j} - x_{j}}{\alpha_{j}}, j = 1, 2, ... J$$

4.2. Detection of environmental information
After extracting the environmental information $w_{j}^{*}$ to be tested, the similarity between $w_{j}^{*}$ and $w_{j}$ is calculated to detect whether the environmental information $w_{j}$ is implicit in the image to be tested. The similarity function $sim$ is as follows:

$$sim(W, W^{*}) = \frac{C(W, W^{*})}{C(W, W)}$$

Among them, $C(W, W^{*}) = \frac{1}{J} \sum_{j=1}^{J} [w_{j} - W][w_{j}^{*} - W^{*}]$; $C(W, W) = \frac{1}{J} \sum_{j=1}^{J} [w_{j} - W]^{2}$ ; Ideally, the detection value $=1, sim(W, W^{*})$. Actually, when the environmental information image is attacked by different, the detection value will be reduced, but compared with the environmental information that is not added, the detection value is still relatively large, so take An appropriate comparison threshold $\rho$, when the environmental information detection value is greater than the set threshold $\rho$, the image to be tested contains environmental information $w$. In the experiment, $\rho = 0.25$, that is, $sim(W, W^{*}) > \rho$ detects environmental information $W$, $sim(W, W^{*}) \leq \rho$ but does not detect environmental information $W$.

5. Simulation experiment and evaluation
The ecological environment monitoring area is set to 1 200 m × 800 m, the simulation time is 1 500 s, and 50 sensor nodes are randomly deployed. Every 10 sensor nodes form a cluster, so 5 cluster head nodes and 1 control node are required in the centre, 5 mobile Agent nodes are also set as standby. In the experiment, it is assumed that the ecological environment monitoring sensor nodes, cluster head
nodes, and mobile Agent nodes have the same transmission power and communication distance. Because 10 sensor nodes in a cluster collect different types of data to form a multi-sensor network, in the experiment, it is assumed that their energy and the power of the transmitted data are different.

Figure 3 shows the comparison between the simulation experiment during the 1500 s monitoring process and the overall energy consumption change of the network after the EM_IOT technology is adopted when the system is applied to the above-mentioned monitoring area. The statistical analysis results of the simulation experiment show that the energy consumption of the network is gradually increasing and decreases at 700 s. This is because the failure of some cluster head nodes causes the network to be paralyzed and blind spots appear [6]. At this time, EM_IOT adopts the mobile agent mechanism. When the cluster head node is found to be invalid, it can move to the clustering area to maintain normal data transmission.

![Figure 3. Monitoring the overall throughput of the network](image)

Use the message samples collected above as the test set to simulate the routing link sending and receiving of the IoT sensor network, and use the method in this paper to extract the link information cluster head node and locate the information source, and obtain the link information cluster head node extraction result as shown in the figure. It can be seen from the figure that the improved design of sensor network routing using the algorithm in this paper can effectively extract the characteristic information of the link information cluster head node and realize the accurate positioning of the routing link information.

![Figure 4. Link information cluster head node extraction results](image)
6. Conclusion
The thesis first builds the networking and routing detection model of the environmental monitoring sensor network under the Internet of Things. Based on this, the link node energy and wavelet sampling distance hierarchical method are used to achieve routing optimization design. Simulation experiments are performed to perform performance tests and show this the algorithm has superiority in realizing route optimization design and improving the reliability of data transmission.

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