Enhancement of the Reliability of the Linear Wireless Sensor Networks

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Abstract. Wireless Sensor Network (WSN) is one of the trend technologies. It was aggregation, processing, and transferring a huge amount of data in different applications that deal with the surrounding environment. Using a huge number of sensors deployed or organized in a linear configuration between two parallel lines or carvings, a specific kind of WSN is constructed to monitor a particular type of infrastructure. This type of WSN is Known as Linear Wireless Sensor Network (LWSN). LWSNs are used in monitoring applications that are arranged in linear form like underground Pipelines, Bridges, Tunnels, Railway lines, Highways, and Borderlines. A transmission process must be reliable and efficient to ensure end-to-end packet delivery. The backbone or the shortest path approach is used to improve the network performance and prolong the network lifetime. In such networks, more packets are ultimately forwarded or relayed by the sensors closest to the sink than by other types of sensors. In this paper, a backbone approach has been implemented where data is sent from the backbone and the node outside the backbone. Any node outside the backbone selects the closest backbone and sends the sensing data to it.

1 Introduction

In many various applications, wireless sensor networks (WSNs) are utilized to collect and handle a wide variety of collected data. These tiny sensors are cheaper, use less energy, are easy to set up and self-organize. In several settings when the environment is difficult to access, sensors are easy to deploy and utilize. Applications for wireless sensor networks include environmental, wildlife, and nuclear reactor monitoring [1].

One of the WSN uses is linearly placing the nodes to monitor specific kinds of infrastructures. This is known as Linear Wireless Sensor Networks, a special instance of WSN networks. (LWSNs). Among these uses are the monitoring of roadways, gas, oil, and pipelines. These buildings can be anywhere between a few hundred meters and hundreds of kilometers long [1].

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By utilizing the network's linearity property, the performance, energy use, reliability, routing efficiency, and routing protocols of the network used to transport data in LWSNs can all be improved [2].

LWSNs are one-dimensional networks where sensors are placed between two parallel lines or in a small, rectangular area with a predetermined sensor number that is selected by a specified model based on the width and length of the distance to get the best coverage of the region. Sufficient sensors are deployed to take the shape of the area to complete that task. The deployment strategy, number of sensors, linear area (highways, bridges, borders, pipelines, etc.), and sinks must be carefully chosen.

This paper implements the network backbone approach. The backbone approach is represented by the selection a specific number of sensors known as a backbone. The neighboring sensors of the backbone are connected with it and send sensing data to the backbone to send it to the sink (the base station). Several presumptions are made to make all of the backbone nodes functionally and operationally identical to the standard sensor nodes. These sensor nodes are simpler and more inexpensive. To ensure the proposed backbone behaves well for routing reasons, it will be put to the test and reviewed. Improved communication efficiency, reliability, scalability, and fault tolerance are the main objectives of the suggested process.

In all previous works, the sink in a LWSN is typically located at the end of the network line. The WLSN receives its data from a linear network that may extend for a long distance. The sink is where the detected data is collected for additional analysis [3]. The dependability of LWSNs has been improved by a proposed topology in this study, which is indicated by the suggestion that there be two sinks at the linear area's ends. (terminated).

The remainder of this paper is arranged as follows. In section 2, we discuss the literature review, section 3 shows the proposed model for calculating the optimal sensor number. section 4 will present the backbone selection process, and section 5, will show how the nearest sink will be selected and sending messages. Different simulation cases and results are represented in section 6, while section 7 will present the conclusions.

2 Literature Review

Researchers in 2019 proposed a new approach, in the network where each virtual node is connected to a specific geographic region. The network traffic per virtual node is modeled analytically. Using a greedy method to determine how many sensors are needed. That ought to make up each virtual node shown. Performance Evaluation demonstrates that the avaricious placement can enhance the compared to the uniform network, network lifetime could increase by up to 40%. deployment. Additionally, the suggested strategy outperforms when used with a scheduling technique, related work it lessens the messages being heard twice. Also demonstrated is that if the network's lifespan is greatly increased, each sensor's battery capacity is measured while taking into consideration the data it transmits or relays [4].

The performance of an LWSN system with backbone nodes was presented and evaluated using an analytical method based on “multivalued decision diagrams”. They estimated and examined the likelihood of the hybrid LWSN performance level, which is determined by the number of sensors that can connect to the sink. This study used a case study to support the suggested approach for creating the best backbone node allocation plan to ensure the dependability requirement [5].

Two distributed topology discovery methods for thick LWSNs are "the linear backbone discovery algorithm (LBD)" and "the linear backbone discovery method with x backbone pathways." (LBDx). Both of them make an effort to create a linear backbone for efficient LWSN routing. The primary goal of the LBD method is to cut down on the number of messages sent during the basic method of discovery. Lowering the number of hops necessary to convey a message from a node to a sink is the main focus of the LBDx algorithm. LBD and LBDx exhibit positive characteristics, and comprehensive simulations show that they work effectively [6].

In this paper, the type of deployment sensors simple and economical sensors were approved without using a special type of sensors in the backbone as in most of the previous research. Also, the proposed two sinks were applied, unlike previous works, which used one terminated sink located at the end of the LWSN.

3 Number of deployed sensors

A novel model is suggested to determine the ideal number of sensors needed to cover a particular linear area. Based on the size of the target region and the communication range of the deployed sensors, an estimate of their number is made.

To optimize the distribution of sensors and ensure network connectivity, it is proposed to add a certain number (the tolerances fraction) to N by deployment randomness. This paper makes the addition of this number based on a given mathematical formula. The ideal tolerances fraction can be predicted using an equation for a uniform probability distribution (2). Equation (6) represented

Where:

L is the area length.

W is the area width.

R is the sensor communication range.

A mathematical formula is proposed in this paper to expect the number (N) of the required sensors to cover a certain area:

$$N = \frac{(L*W)}{R^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

It is used to suggest an additive number. The uniform probability distribution, represented by equation (2), can be used to forecast the ideal tolerances fraction.

(Y0) in figure 1 denotes the start coordinate value, which is represented by 0 in some cases. The coordinate value (Y1) indicates the end, or maximum length; X1 indicates the maximum width, or end; and X0, or 0 can be used to indicate the start.

$$P(i) = \frac{1}{(Y_1 - Y_0)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Equation 2 is valid for a line only, equation 3 will be valid for a rectangular area:

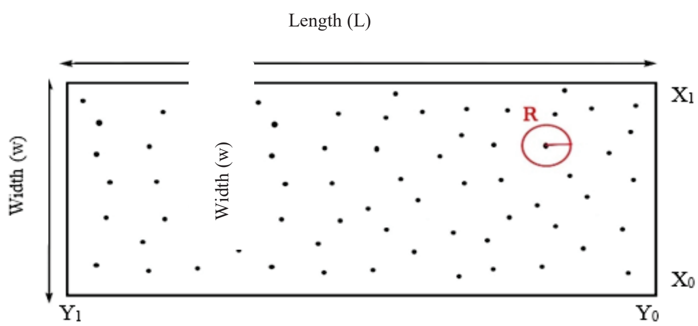

Fig. 1. The area of deployment

$$P(i) = \frac{1}{(Y_1 - Y_0)} * (X_1 - X_0) \quad (3)$$

$$P(i) = \frac{X_1}{Y_1}\ ; \quad Y_0 = 0; \quad X0 = 0 \quad (4)$$

$$N = \frac{L*W}{R^2} = \frac{Z}{R^2} \quad (5)$$

Equation 6 represents adding tolerances fraction to N:

$$N_r = \frac{Z}{R^2} + int \left| \frac{x*N}{Y} \right| \quad (6)$$

4 The backbone selection

In LWSN, the sensors are randomly deployed in a line to cover the linear area of the application (pipeline or real-time monitoring applications).
After sensor deployment, a number of them are selected to represent the Backbone of this network, through which all data sensitive by the network is sent to the sink located at its end. The shortest path is calculated using the Dijkstra algorithm, where the shortest path is determined between the proposed first sink and the last sink, and this path is considered the backbone.

5 Data Transmission

Following the backbone selection procedure, in the first instance where the node is situated on the backbone nodes, the sensing node—in this example, the backbone node—determines the separation between it and the first sink. Additionally, the distance is computed between the second sink and This backbone node will then select and indicate the closest sink. All communications sent to or through this backbone node will be sent to the nearest sink. Figure 2 depicts the suggested shortest path and its backbone nodes; Figure 3 illustrates an example of the data-sending process (transmission). Netlogo 6.1.1 is used for simulation.

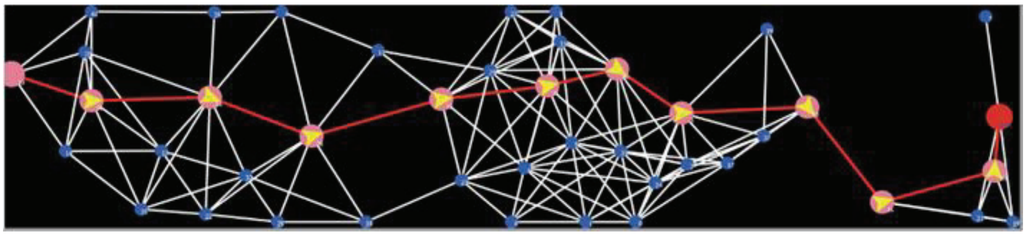

Fig. 2. LWSN with backbone

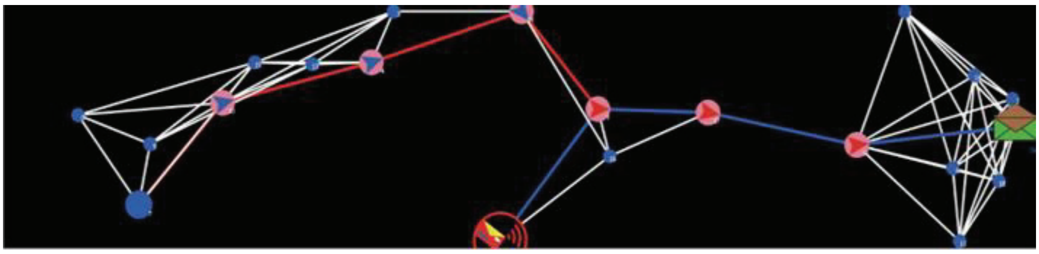

Fig. 3. Data Transmission process

6 Sensing Data by The Backbone Nodes

Once the backbone has been established, one of the backbone nodes can send specific packets in response to detecting specified information. At that time, the node will calculate the distances between the first and second sinks. The closest sink, selected by the server, is the recipient of all communications sent to or through it. As seen in Figures 4 and 5, the sending node will select the sink that is nearest to it (sink2).

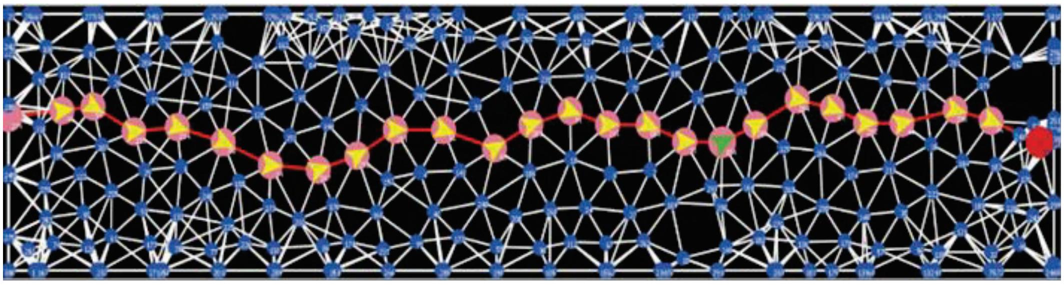

Fig. 4. Backbone node identification

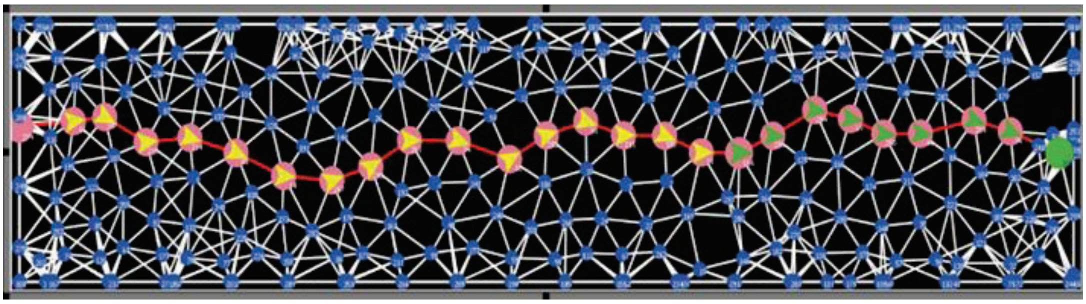

Fig. 5. Selecting the closest sink

7 Sensing Data by External Nodes

Any external node (one not located on the backbone) will be identified as a source node if it detects a specific action or event. The computed routes between this node and each backbone node are depicted in Figure 6. Calculated shortest paths between each node show which backbone node is closest. The data will be transmitted to this backbone node so that it can transfer the information to the closest sink through the intermediate backbone nodes. The message will be sent and the closest sink will be chosen. Figure 7 depicts the sending procedure. The following steps might be used to summarize this procedure:

• Picking a specific node from the list of backbone nodes and indicating the lengths of any potential routes connecting it to every other backbone node.

• Choose and highlight the one with the shortest backbone node.

• Measure the distance between this backbone node and the two base stations, then choose the closest one.

• Specify a transmission line from the source node to the chosen designated base station, and then carry it out.

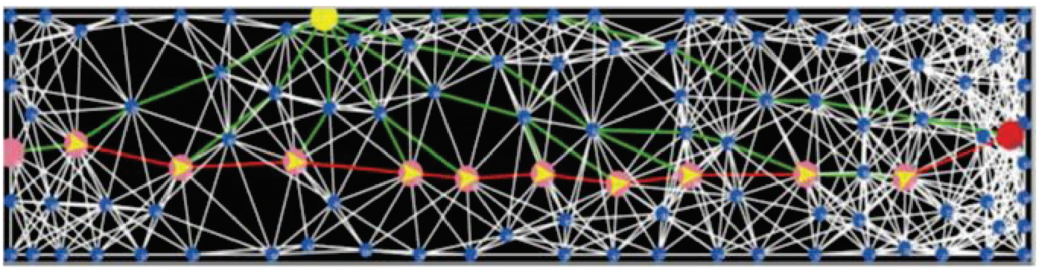

Fig. 6. Choosing the closest backbone node

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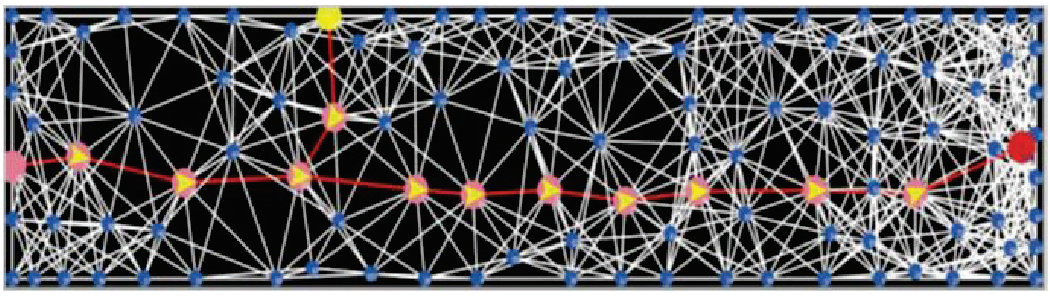

Fig. 7. Choosing the nearest path to the sink.

8 Results

Here, 525 nodes were randomly deployed. Equations (1-6) of the innovative mathematical model presented in this research were used to compute the appropriate number of deployed sensors:

Let L =1000m, W= 50m, R=10m

$N = \frac{1000*50}{10^2} = 500$

$N = 500 + int\,(\frac{50*500}{1000})$

$N = 500 + 25 = 525$ sensor nodes are needed.

Figure 8 The figure represents the right part of the LWSN topology represented by the first sink and the nodes located near it.

Figure 9, represents the second part of LWSN topology, which is the left part, which is screwed with the second sink and the nodes close to it.

In the figures, the yellow circle on the right and the left edge represents the sink, the red line represents the backbone and the green line represents the selected path to the nearest sink.

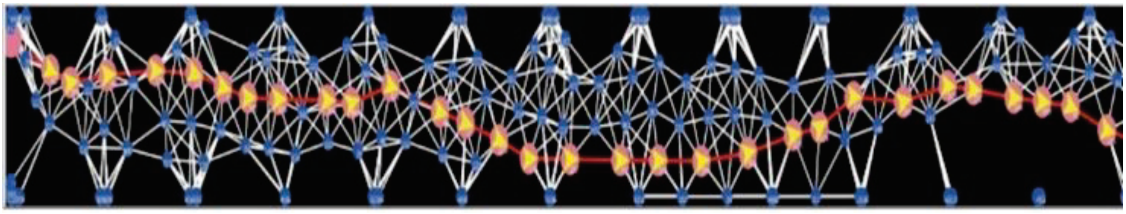

Fig. 8. The first part of WLSN

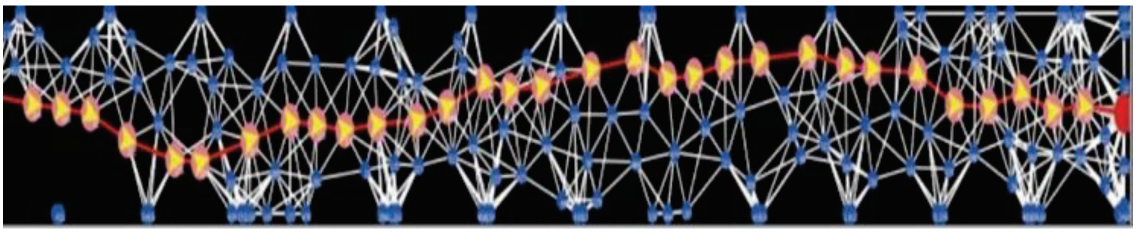

Fig. 9. The second part of WLSN

The following states are implemented by selecting various places for external nodes:

- State 1: If a node is on the area's left side, it will choose the sink. Figures 10 and 11 provide instances to highlight this state.

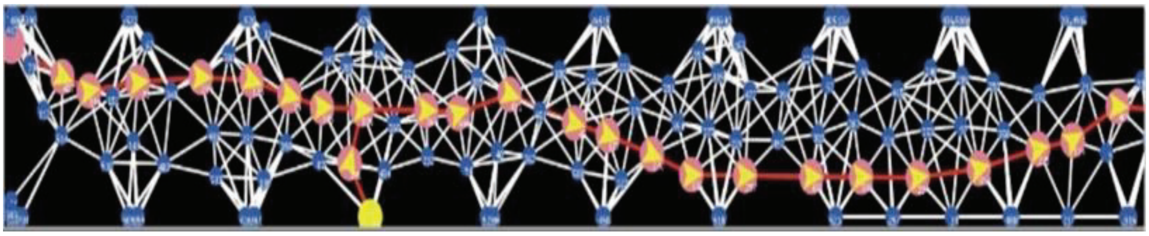

Fig. 10. External node selection

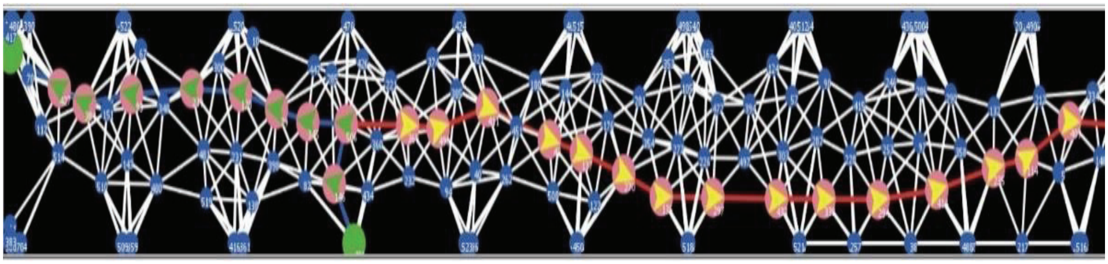

Fig. 11. The path to the nearest sink

- State (2): A node will choose the closest sink if it is situated in the area's center. 2. Figures 12 and 13 depict instances of states (2).

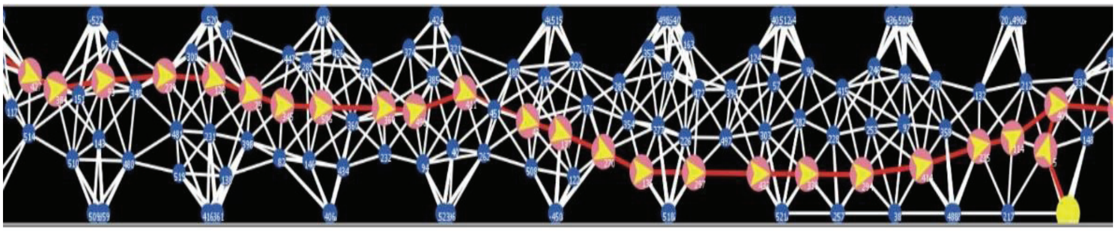

Fig. 12. External node selection

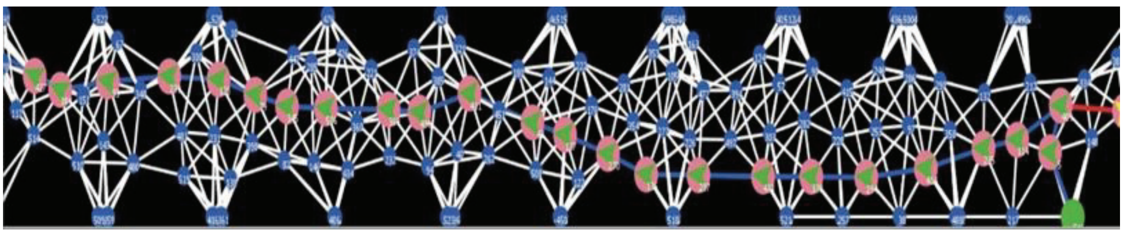

Fig. 13. The path to the nearest sink

- State (3) A node will choose the closest sink if it is situated in the appropriate location. 2. Figures 14 and 15 depict instances of states (3).

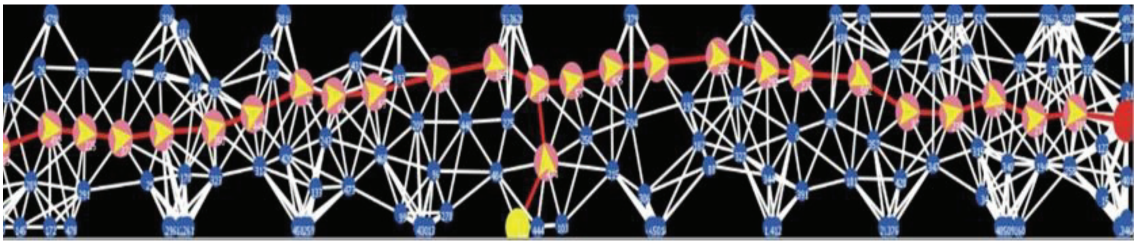

Fig. 14. External node selection

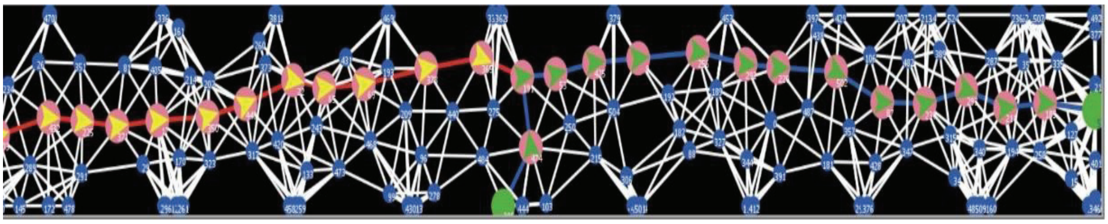

Fig. 15. The path to the nearest sink

9 Conclusions

To improve the behavior of LWSN, a simulation approach is used in this article. Numerous factors, including the number of nodes in the sensor's transmission range, the shortest path computation, the closest sink, and the backbone discovery strategy. In this instance. We suggest two terminated sinks. The performance of the network is enhanced by these sinks, which also cut the load on the sink in half. The outcome is less data loss and an extended network lifespan. Transmission will be accelerated and the amount of processing needed at each node will be reduced by keeping the shortest path between the outgoing node and the nearest sink and backbone node in the node's cache**.**

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