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Investigation of failed node method to support healthy communication for linear wireless sensor networks

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Abstract

Wireless Sensor Networks (WSNs) are used extensively in many natural environment research and observation applications in the world, and their popularity is increasing day by day. In parallel with these studies, Linear Wireless Sensor Network (LWSN), which is a type of WSNs application, is frequently encountered for reasons such as meeting the security requirements of highways, bridges, pipelines, and border lengths, determining the needs, and observing. In the network structure of LWSNs, the nodes are lined up sequentially and the communication environment is created in a linear order. In this type of wireless networks, communication is carried out with Media Access Control (MAC) protocols, and it is important to design these protocols in accordance with linear array characteristics. Because, as the number of nodes in the network increases, the end-to-end delay of the packets increases and the data traffic of the nodes close to the coordinator node reaches very high levels. Although the increasing number of nodes in linear topology increases the possibility of collision and congestion, it is also important that the network connections of the nodes are not broken and the communication continues in a healthy way. Therefore, protocols developed for linear topologies are expected to have characteristics that can be connected seamlessly and transmit data to the center without error. For this purpose, within the scope of a project, a new MAC protocol has been designed by us, which is effective in minimizing LWSN problems and can ensure the continuity of the network connection in difficult physical conditions. With the failed node method, which is the main subject of our article and introduced in the protocol in question, an important study has been put forward to avoid situations that will disrupt the data transmission of the network.

1. Introduction

Nowadays, developments in electronic technologies make it possible to produce low-cost, high-processing, and small-sized sensor nodes (LN). As a result of these important developments, possibilities have emerged that allow the implementation of Linear Wireless Sensor Network (LWSN) applications, which can consist of many sensor nodes and are used along linear lines, easily. LWSN is a specialized type for WSN applications that require linear topology characteristic as seen in Figure 1. Thanks to its linear array feature, operations such as installation, maintenance, and routing are very easy. However, there are difficulties to be solved in such networks, such as end-to-end latency, excessive data traffic at end nodes, network reliability, node failure, and link failure [1]. The linear nature of such networks can be an important motivation for designing custom protocols to increase reliability, efficiency, energy savings and network lifetime [2,3].

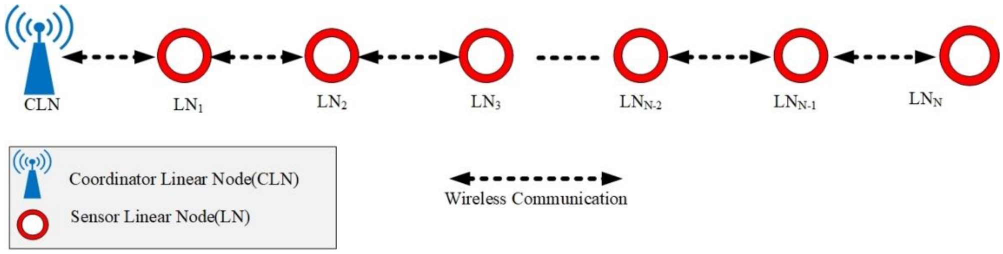

Figure 1. An example LWSN scheme structure

A MAC protocol that can be used in LWSNs and provides effective, healthy, and lossless communication has been put forward by us. A new method has been proposed, aiming to prevent the interruption of the communication of the nodes in the network with each other, which will be activated in case the nodes in the network fall from the network and contribute to the continuity of the network, even though the node named as the Failed Node is disconnected from the network. The success of the proposed method was demonstrated by the simulation and network model application. The performance analysis of the proposed MAC protocol was performed. The results show that the method that is activated in the node failure scenario in the proposed MAC protocol is a very effective method that can eliminate the disconnection in the network and continue the communication without any problems.

When all these developments are evaluated, it is thought that the method in the proposed MAC protocol will have an important place in the literature.

Karveli et al. [4] proposed a protocol that guarantees collision-free communication between sensor nodes distributed on a linear line and running synchronized with each other, which they called Directional Scheduled MAC (DiS-MAC). Thanks to the use of directional antennas; higher gains were obtained, signal transmission was provided to longer distances between nodes, and noise and collisions were eliminated as a result of the transmission of radio waves in a certain direction. In DiS-MAC, a single channel is used for data transmission and other operations.

In the LC-MAC [5] protocol, Fang et al. proposed a mechanism that pre-books relay nodes and transmits it in a burst to reduce end-to-end delivery delay in a long-chain sensor network without sacrificing energy efficiency.

The study named WiWi [6] can be said to be an advanced version of DiS-MAC. In particular, both protocols avoid interference between simultaneous transmissions by using alternate transmission based on sequencing between neighboring nodes.

LWSN networks continue to increase in popularity day by day. Well-designed MAC protocols, and the methods and methods used in these protocols have an important place among the most important factors affecting the efficient use of resources by sensor nodes with limited resources with low features. MAC layer in a layered WSN architecture; It is the layer where delays are tried to be reduced, possible collisions are prevented to reduce packet losses, and energy efficiency is tried to be increased with minimum packet traffic.

The MAC protocol developed within the scope of this study; has been designed by taking into account the control and energy saving issues, especially in roadside lighting in urban and intercity highways. In addition, different operating modes (ToSlave, ToMaster, and 2Way) have been introduced in order to overcome energy efficiency and worst-case scenarios in the network. An uncontested approach has been established in the proposed MAC protocol.

LWSN is formed by arranging sensor nodes one after another along a line. In fact, as the number of nodes increases, many network parameters such as end-to-end latency, network connection success, energy saving, and network lifetime are adversely affected. In this respect, many researchers have focused their attention on topology optimization, and many studies have been and continue to be made on this subject [7–11]. Considering all these, topology optimization is among the attractive research topics in the LWSN literature.

Energy-efficient node placement research is among the main design considerations for all WSNs, and especially for large-area LWSNs [3]. Li and Shunjie [11] investigated two different node placement strategies to maximize network lifetime and optimize network load balance in LWSNs.

In our study, it is thought that the proposed method to optimize the topology and feel the network disconnection as little as possible will take its place by supporting the topology optimization approach.

With these aspects, it is thought that the method in the proposed protocol will make an effective contribution to the literature.

2. Material and Method

The Failed Node method, which is included in the developed MAC protocol and maintains the communication in the network even if the nodes are disconnected from the network by ensuring the continuity of the network, and which significantly affects the protocol performance in this respect, has the mechanism whose diagram is given in Figure 2.

Thanks to this structure defined in the MAC protocol, the node, which decides that its neighbor has dropped from the network, increases its coverage area, scans the distance of two hops instead of one hop, and communicates with its neighbor at two hops distance and can ensure the continuation of the network over themselves. Thus, this mechanism ensures continuity of the communication line. In the example simulation scenarios, in the first case, neighboring nodes communicate in the area with a radius of 125m. In case of a node failure, that is, if the node drops from the network for any reason, if the node that will transmit the packet cannot receive the negative-addressed reflection packet for a certain period of time, it concludes that there is no node within the scope of the packet in the relevant forward direction. In this case, it expands its coverage area, in other words, it increases the signal strength to cover the area with a radius of 225m. Thus, it switches to a 2-hop communication mode and reaches the two next nodes, and the communication of the network continues without interruption. Within the scope of this study, only one node disconnected from the network was studied, and the behavior in case of disconnection in more than one consecutive node was not discussed.

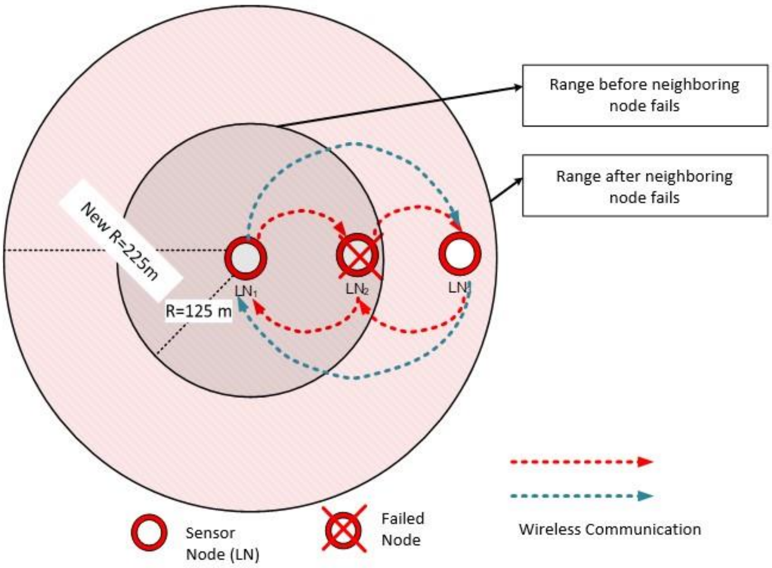

Figure 2. Behavior Mechanism of Failed Nodes

The Riverbed Modeler program was preferred for the performance evaluation of the MAC protocol proposed within the scope of this project. There are three types of nodes in the prepared Network Project environment. There are 10 standard nodes (LN, Sensor Node), 2 CLN (Coordinator Node) and 1 SINK node. The radio propagation range is 125m - 225m. The simulation parameters are given in Table 1.

Table 1. Simulation Parameters

Items	Value(s)
Radio propagation delay model	dra_propdel
Modulation	bpsk
Radio propagation Range	125m & 225m
Transmit Power	SR_tx = 0.027w
Receive Power	Sr_rx = 0.0366w
LN Count	10, 20, 30, 40, 50
CLN Count	2
Sink Count	1
Node Layout	Linear
Used Channel Count	1
Distance Between Nodes	100m
Simulation time	25s

Connection Continuity Analysis of the Nodes has been done under the above-mentioned network environment conditions, and the success status has been obtained.

3. Results

It is of great importance in terms of network performance that LWSN nodes connect to the network and perform their duties without disconnecting from the network. In fact, the failure of a node can affect the entire network from the linear topology feature. Under this title, the reactivity and behavior of the protocol, due to the relevant method, in case if a node drops (breaks off) from the network for any reason, has been examined. Within the scope of the project, single node falls on the line are considered. A consecutive large number of node failure (error burst) cases are left as a subject for further studies and are not covered in this study. The example scenario applied to show the response of the nodes and the continuation status of the network in case of node failure is shown in Figure 3.

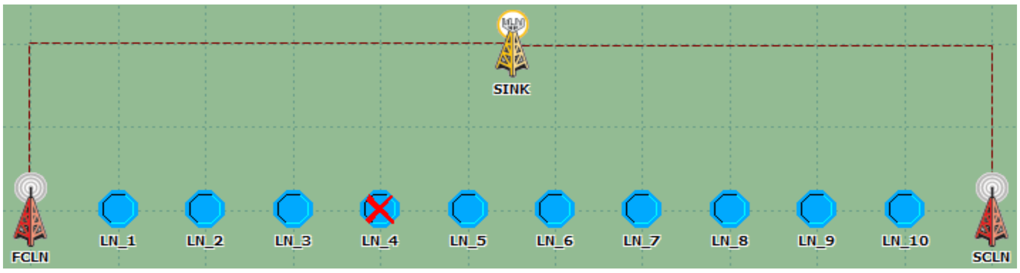

Figure 3. Failed node example scenario

As can be seen in the figure, a node (LN4) in the network was disconnected from the network in a certain time period and after a while, the disconnected node was allowed to join the network again. Against this situation, the total number of active nodes in the network is shown in the graph in Figure 4.

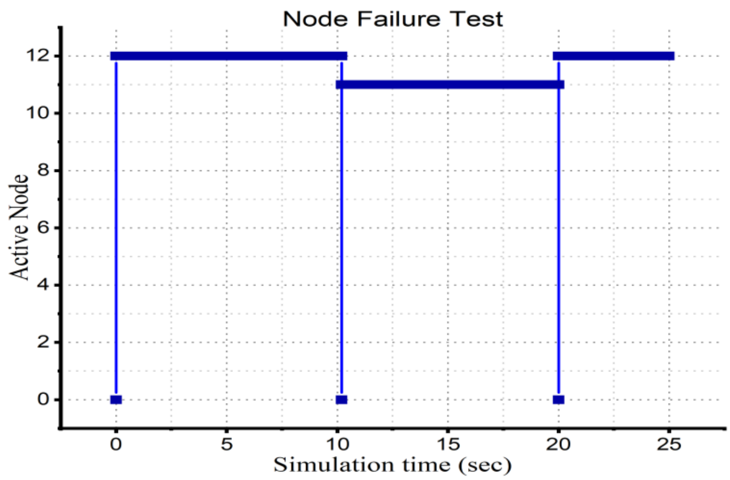

Figure 4. Failed node graphic

In Figure 4, it can be seen that the number of nodes decreases by 1 when one of the nodes is dropped from the network. If packet mobility continues in the network, it can be said that the broken node does not affect the network communication. When Figure 5 is examined, the packet mobility situation is observed in the above graph, although the number of nodes is missing 1 for a while and after a certain period of time, it rejoins the network and completes the number of nodes.

4. Discussion

When Figure 5 is examined, it is seen that although a node is disconnected from the network, data packet communication continues in that process. In this case, with the node falling from the network, neighboring nodes doubled their coverage area, and continued communication and connection continuity was ensured in the network. It is seen that the same number of packets reached the destination in all three data transmission models. The results show that the failed node method in the proposed protocol works, and the transmission continues without packet loss in the network, proving the success of the method.

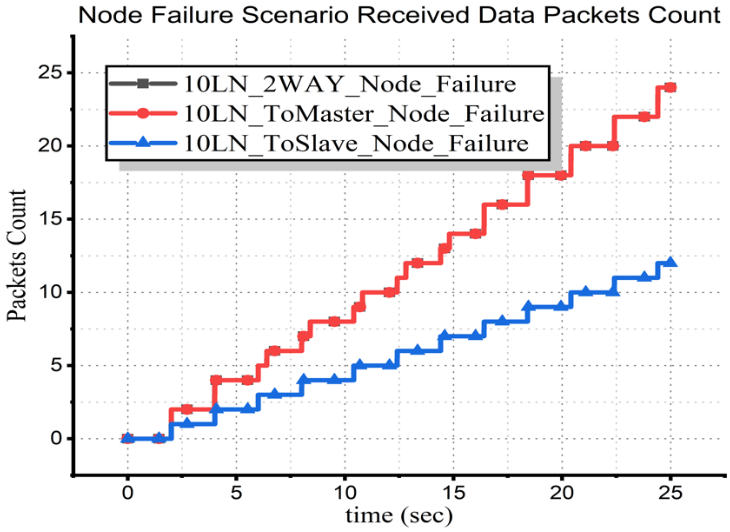

Figure 5. Number of data packets transmitted in case of failed node

5. Conclusion

LWSN application simulation shows that the proposed protocol in the simulation environment and the node failure method in the protocol work successfully, and this success also shows that our proposed method has an important place among the precautions to be taken against breaks in the network.

In the node failure method, the node that has fallen from the network performs its task by expanding the coverage area of the neighboring node, and the continuity of data communication is ensured without disrupting the communication of the network.

Within the scope of this study, only one node disconnected from the network is studied, and the behavior in case of disconnection in more than one consecutive node is left for later studies.

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Author contributions

Musa Çibuk and **Davut Ari:** Conceptualization, Methodology, Software. **Fikri Ağgun:** Data accuration, Writing-Original draft preparation, Software, Validation. **Ümit Budak:** Visualization, Investigation, Writing-Reviewing and Editing.

Conflicts of interest

There is no conflict of interest between the authors.

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