Modeling the Message Alternative Routes in a Large Scale Wireless Sensor Network

Sundos F. jabbar
Information Networks Department
College of Information Technology
University of Babylon
Babylon, Iraq
sundos.hadi@student.uobabylon.edu.iq

Saad T. Hasson
Information Networks Department.
College of Information Technology
University of Babylon
Babylon, Iraq
saad.aljebori@uobabylon.edu.iq

2021 1st Babylon International Conference on Information Technology and Science (BICITS) | 978-1-6654-1573-6/21/$31.00 ©2021 IEEE | DOI: 10.1109/BICITS51482.2021.9509885

Abstract*— One of the most common methods for relaying messages in a variety of networks is the shortest path. In terms of energy and time, it provides an effective message relaying to the destination through many nodes. The shortest hop or distance path can be constructed using a variety of algorithms. However, no algorithm for building a shortest hop multipath for wireless sensor networks (WSNs) has yet been proposed in the literature. This paper proposed a distributed shortest hop multipath algorithm for WSNs. An alternative approach is suggested as a path in the case of allocating certain node on another path at the same time to avoid the busy path. This case to solve the simultaneous data dissemination or routing messages from different nodes to a sink. This paper reduces the problem of losing the messages when there are common nodes on different paths at the same time. The proposed algorithm produces multi alternative paths with the fewest hops to ensure network load balancing.** ***Keywords—WSNs, Shortest path, multipath, data dissemination. **Introduction**

I. Introduction

Due to various technological developments and their military and commercial application potential, wireless sensor networks (WSNs) have gained worldwide attention in recent years. Individual nodes in these networks can communicate with their surroundings by sensing or monitoring physical parameters[1],[2],[3]. In comparison to conventional sensors, these sensor nodes are small, have limited processing and computing resources, and are inexpensive[4],[5]. These sensor nodes can sense, measure, and gather data from the environment, and then send that data to the user based on local decision processes. Since the sensors run on battery power [6], it's important to make the most of their resources to extend the network's lifespan [7]. The transmission of data packets produced by the sensor or relaying the packets of other sensors consumes the majority of the sensor's energy [8]. As a result, determining the best transmission paths from each sensor to the destination is a critical issue. WSNs are typically deployed in unattended scenarios and are characterized by energy sensitivity and low cost, making their output susceptible to external and internal energy influences [9]. Existing routing protocols sought to improve energy efficiency and routing reliability from the network's viewpoint [10], but failed to understand the environmental effect from the outside, resulting in their inability to respond quickly to complex changes in the setting.

II. Theoritical Background

One of the most common methods for relaying messages in all kinds of networks is the shortest hop or distance path [11]. In terms of energy and time [12], it provides an effective message relaying to destination. The Dijkstra and Bellman–Ford algorithms are two of the several algorithms for constructing shortest distance paths [13]. Many years ago, the distributed Bellman–Ford (DBF) and Chandy–Misra, a termination detection added variant of DBF [14], were proposed for distributed systems. Constructing the shortest distance path has a higher overhead than constructing the shortest hop path. The Periodic, Event-Driven and Query-Based Protocol (PEQ) and Interactive Connectivity Establishment (ICE) protocols, respectively, construct the shortest hop routes. The method for constructing the shortest hop path is also simple and straightforward; however, since the algorithm is asynchronous [15] so, the message complexity cannot be measured. Furthermore, the initiator node is unable to be determined if the algorithm terminates due to a lack of termination detection [16]. The construction of multipath between two nodes can be achieved in two ways. The classic node-disjoint multipath is one in which the alternative paths do not converge. Another method creates a large number of braided paths, with few fully disjoint paths and several partially disjoint alternative paths[17],[18],[19]. Fig.1. shows a sample for a WSN representation.

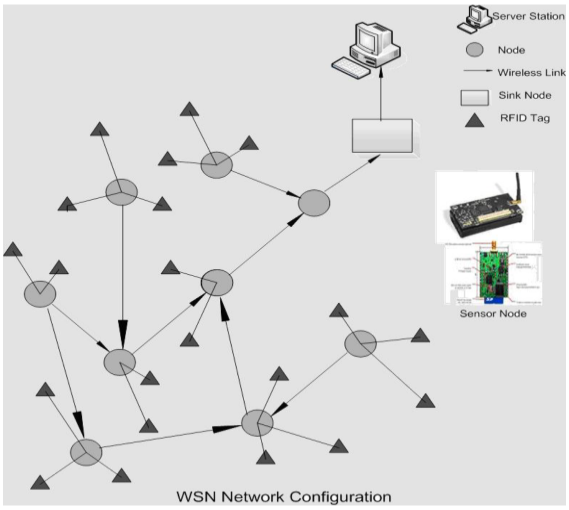

Fig.1. WSN Network [3]

III. LITERATURE REVIEW

Some researchers suggests a Data Traffic Trust Model for clustered Wireless Sensor Networks. A Cluster head collects data traffic from their presented sensor nodes and calculates trust values based on random traffic sampling. The data traffic sampling rate is used to identify the trust nodes. The number of sent and received data packets is used to determine the trust rate, while the un-matching packet rate is used to identify malicious packets. Cluster head is selected on basis of high potential energy that is left in the nodes. Finally Cluster head delivers the trusted information to the Base station[20].

Other researchers for sensor to edge server communication, the emphasis was on developing an energy-efficient hierarchical data dissemination protocol. Along with energy optimization, the proposed protocol aims to maintain network coverage and enable complex changes in network topology caused by harsh environmental interfaces such as node failure, node addition, and so on. As the sensor nodes are expected to work autonomously, the proposed protocols are built by considering only the local information of a sensor node[21].

IV. PROPOSED WORK

The following steps shown in fig.2. are suggested to represent the process of sending messages in WSN using shortest path algorithm. The suggested approach composed from the following steps:

1. The setup step, is to build the WSN system in its initial state by creating the required sensor nodes and a sink node. Net Logo commands were used to create and distribute them randomly in the simulated area.
2. determines the implement area and its coordinates.
3. Create number of nodes randomly. This number is chosen by the user.
4. The sink node and its location are controlled by the user, whether in the center or another place, then link the random nodes according to the range that have selected from the "rang" slider.
5. The linking among these nodes are done based on the coverage area. Each node checks all its surrounded nodes that are within the range or less and make a link with them, which means that there will be more than one possible path leading to the sink node.
6. All the nodes are connected to create a mesh network.
7. Selecting four sensor nodes as an example to sense data from the surrounding environment and sends their sensed data to the sink through some sensor nodes on a path. Two approaches were suggested; namely the first is random selection while the other is by the user.
8. The process of the shortest path means choosing the shortest path from the sensing nodes that have been selected (random or by the user) to the sink node.
9. Common paths (contains common nodes) will appear in two, three, or four paths. In the case of choosing nodes far from each other, common paths may not appear, but rather each path separately leads to the sink node. When common nodes appear in paths, the loss of the messages will occur. To avoid this problem, this study suggested an alternative disjoint paths. One of these paths must be fixed and an alternative path must be chosen for the rest of the source nodes. The transmission will be done via the shortest path, and if there are common nodes, the transmission will be done via the alternative paths to avoid the problem of losing the messages.

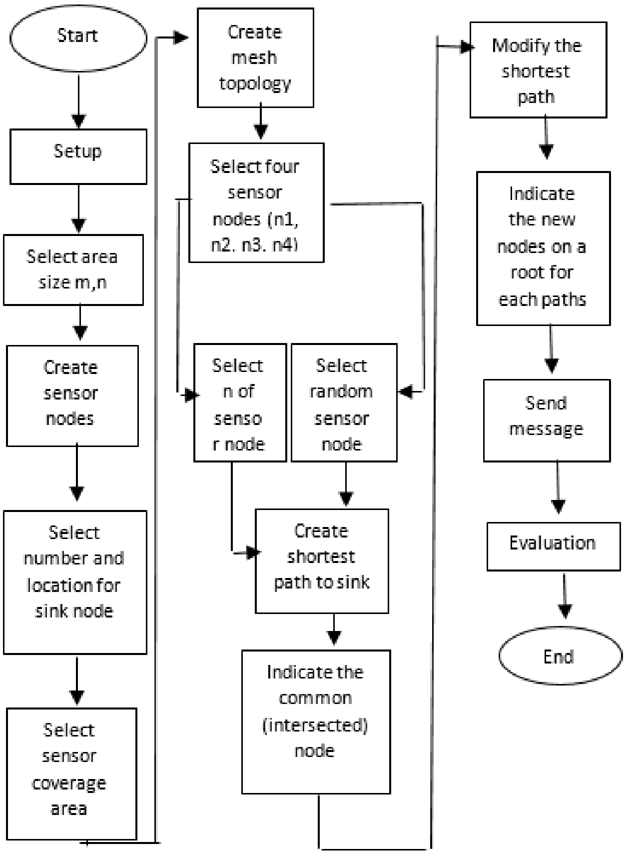

Fig.2. Suggested methodology steps.

V. RESULTS

Net logo simulator [22] was used to apply the simulation process in establishing, implementing and evaluating wireless sensor networks. The wireless sensor network is created by selecting specific area and creating different number of sensor nodes with one sink node located at the area center. TABLE I presents the simulation setup parameters in this paper study.

TABLE I. SIMULATION SETUP PARAMETERS

Parameter	Value
The simulator	Net Logo 6.0.2 version (2017)
Nodes number	(100, 150, 200,....,1000)
Algorithm	Random approach
Coverage Range	1m, 2m, 3m, 4m,.., 100m

Based on TABLE I the number of created nodes is implemented in different cases varying from 100 to 1000 nodes with a step of 50 nodes, and the node coverage area (range) are implemented in different cases from 1 to 100 meters. Choosing small number of nodes with low range produces weak connections as shown in Fig.3.

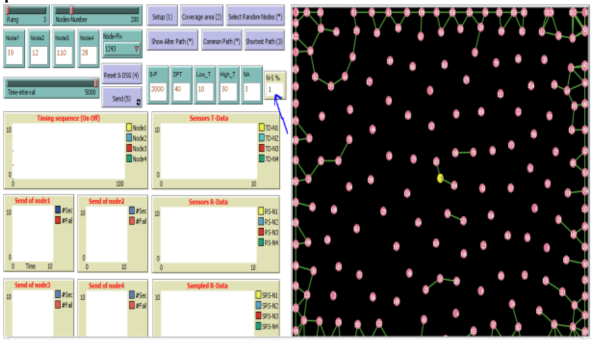

Fig.3. Connections of small number of nodes with low coverage area.

The link length between some selected source node (End1) and one of its neighbors (End2) is tested with different coverage ranges. This generated link is representing the shortest path between each node and their neighbours. TABLE II shows the simulation results between a node and its neighbour with different coverage area.

TABLE II. SIMULATION RESULTS FOR LINKS WITH VARIABLE COVERAGE AREA

Range	End1	End2	Link Length (m)
3	Node 61	node 143	2.451
5	Node 110	Node 111	4.228
6	Node 10	Node 89	5.515
10	Node 10	Node 153	6.921
13	Node 57	Node 148	7.729
15	Node 99	Node 170	14.855
20	Node 97	Node 178	17.210
22	Node 78	Node 126	20.686

From TABLE II , it is clear that when the coverage increases the link length will increase also.

In order to implement a simulation process when number of nodes are sensing at the same time. As an example let four nodes send messages to the sink at the same time. Fig.4. shows the random selection of certain nodes.

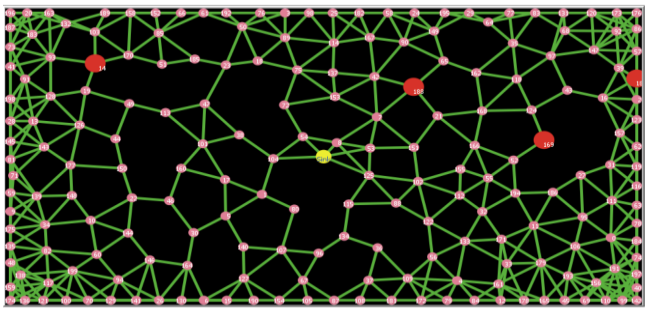

Fig.4. example of selecting four nodes randomly.

Figure 5. shows the shortest paths from these nodes to the base station. TABLE III specifies another example to build an environment to create shortest path for the different number of nodes.

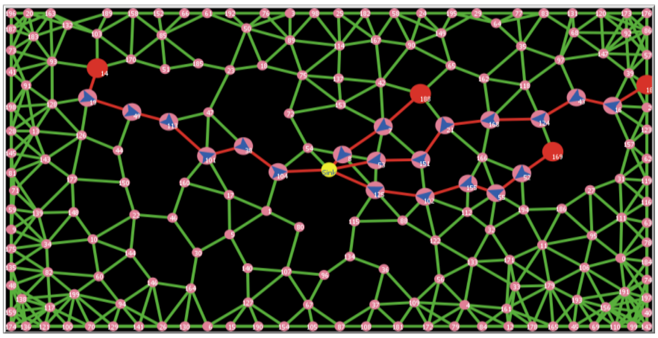

Fig.5. example of shortest path from number of nodes to the sink node.

TABLE III is a sample to show the number of hops from these nodes to the sink and the nodes located on a shortest path from these nodes to the sink.

TABLE III: SHORTEST PATH FOR SAMPLE OF NODES

Node	number of intermediate nodes to sink	Shortest paths nodes	Shortest Path	Shortest Path length
99	4	[(node 99) (node 143) (node 65) (node 55) (sink 200)]	[(link 99 143) (link 143 65) (link 65 55) (link 55 200)]	15.791
10	8	[(node 10) (node 30) (node 70) (node 137) (node 101) (node 160) (node 128) (node 195) (sink 200)]	[(link 10 30) (link 30 70) (link 70 137) (link 137 101) (link 101 160) (link 160 128) (link 128 195) (link 195 200)]	28.718

As an example from TABLE III , the node 99 represent a source node which requires 4 intermediate nodes to reach a sink node (node number 200). This shortest path length is 15.791meter . Fig.6. presents the case when the coverage area is small. From this figure the links between most nodes are either weak or not available. This means that most of the nodes are isolated.

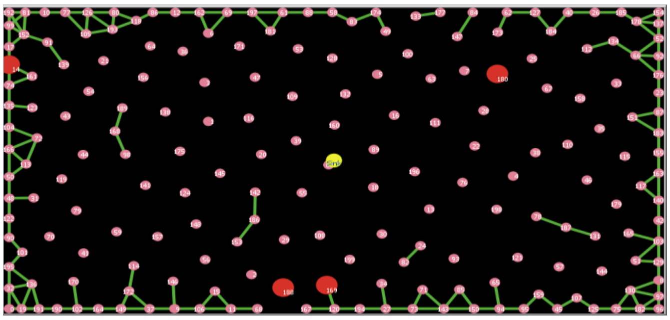

Fig.6. example of creating links when the coverage is small.

Figure7. presnts an example of selcting four sensing nodes close to each other at the same time. Such process will let the shortest paths from these nodes to the sink node may pass through same nodes. These common nodes located at two or more shortest paths resulted in certain problem which affects the sent message. TABLE IV specifies a sample of this built environment.

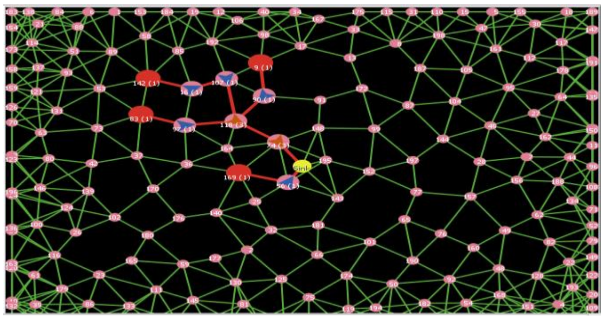

Fig.7. shows common nodes on the shortest paths

Based on fig.7. TABLE IV presents the details of this process.

TABLE IV. SPECIFIES THE DETAILS OF THE COMMON NODES ON THE SHORTEST PATHS.

Nodes	**Common paths between these two nodes**
[(node 142),(node 9)]	[(node 118) (node 74)]
[(node 142),(node 83)]	[(node 118) (node 74)]
[(node 9),(node 83)]	[(node 118) (node 74)]

Another example of selecting four different nodes to send at the same time is shown in fig.8. TABLE V also presents these four source nodes and their nodes on the shortest path to the sink node

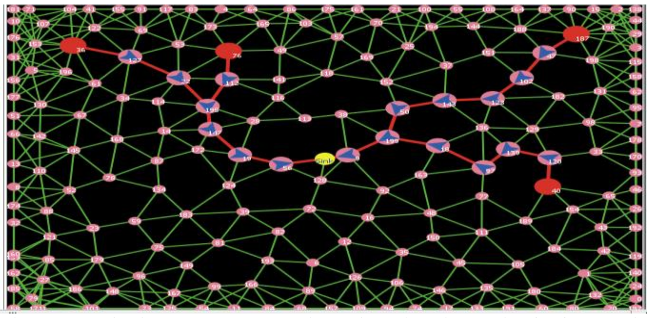

Fig.8. example show no common points when choosing nodes far from each other.

When common nodes are located on the more than one shortest path at the same time, a decision must be taken to select an alternative path for one of these paths to avoid the busy case.

TABLE V : AN EXAMPLE OF SELECTING FOUR SENDING NODES AT THE SAME TIME

Nodes	**Common nodes between these two nodes**
[(node 77),(node 68)]	[(node 181)]
[(node 77),(node 15)]	No Common nodes
[(node 77),(node 190)]	No Common nodes

Creating an alternative path by avoiding the common nodes can be used for sending the message from certain node to the sink to avoid losing messages. Fig.9. represents an example to show the common nodes on the shortest paths. Fig.10. represents a suggested process to aviod the common nodes by creating an alternative path by creating an alternative path. TABLE VI specifies the common nodes and the alternative nodes.

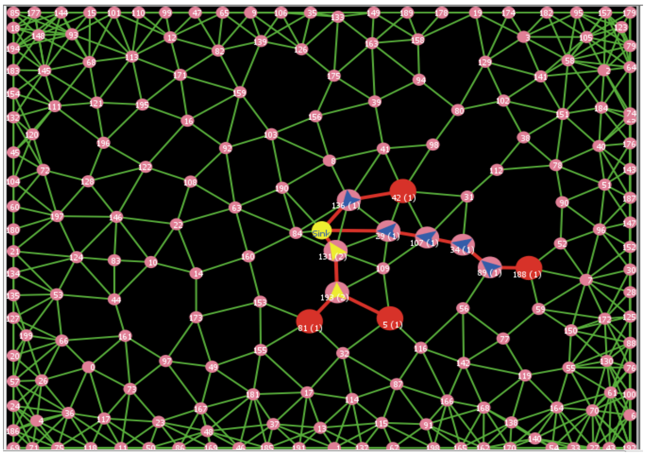

Fig.9. .example to show common nodes.

The common nodes on different paths appear when certain close nodes (in the same arsea zone) are sending at the same time. The suggested solution in this study is to solve the problem of losing or droping the messages. The suggested solution is by creating an alternative path to avoid any common intermediate node at the transmission time.

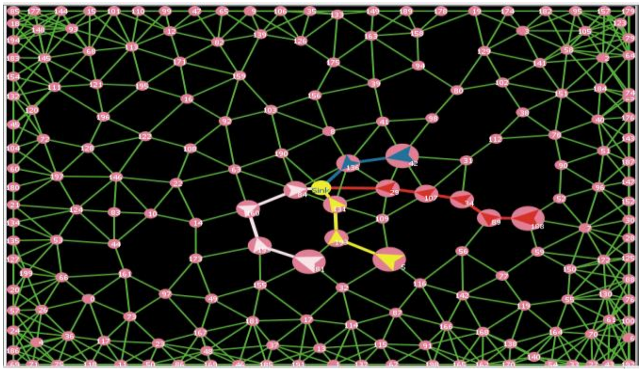

Fig.10. example to show the alternative paths

TABLE VI represents a sample of taking the shortest path for certain nodes. The common nodes are indicated in addition to the alternative nodes on the new suggested path.

TABLE VI : AN EXAMPLE OF THE COMMON AND THE NEW SUGGESTED NODES ON PATHS

Source Node	**Old Shortest-Path**	**New Alternative Path**
188	[(link 188 89) (link 89 34) (link 34 107) (link 107 29) (link 29 200)]	[(link 188 89) (link 89 34) (link 34 107) (link 107 29) (link 29 200)]
5	[(link 5 193) (link 193 131) (link 131 200)]	[(link 5 193) (link 193 131) (link 131 200)]
81	[(link 81 193) (link 193 131) (link 131 200)]	[(link 81 153) (link 153 160) (link 160 84) (link 84 200)]

Figure 11. is an example of selecting four nodes to send messages at the same time. The shortest paths from these nodes to the sink are isolated and no common nodes are located on these paths. In this case no action is required to select an alternative path. TABLE VII shows the source and the intermediate nodes.

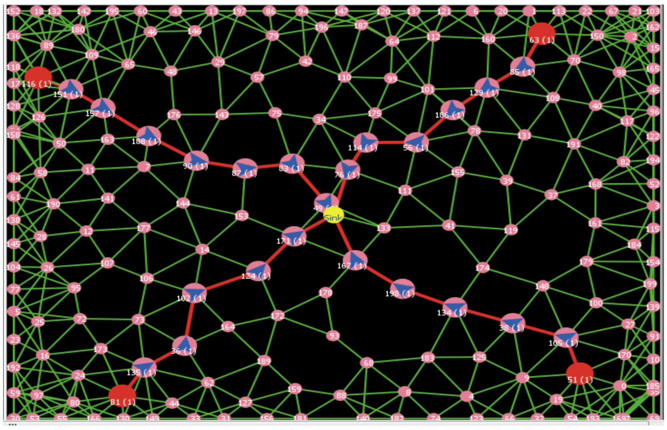

Fig.11. example paths for four sending nodes in an ordinary case

TABLE VII: SOURCE AND INTERMEDIATE NODES FOR AN ORDINARY CASE

Node	Old S-Path	Alter path
77	[(link 77 19) (link 19 2) (link 2 184) (link 184 6) (link 6 28) (link 28 181) (link 181 200)]	[(link 77 19) (link 19 2) (link 2 184) (link 184 6) (link 6 28) (link 28 181) (link 181 200)]
68	[(link 68 86) (link 86 121) (link 121 135) (link 135 181) (link 181 200)]	[(link 68 86) (link 86 121) (link 121 135) (link 135 22) (link 22 200)]
15	[(link 15 82) (link 82 60) (link 60 65) (link 65 8) (link 8 200)]	[(link 15 82) (link 82 60) (link 60 65) (link 65 8) (link 8 200)]

Figure 12. shows an example of sending messages from different four nodes at the same time through the shortest path with no common nodes. The other measures are also indicated.

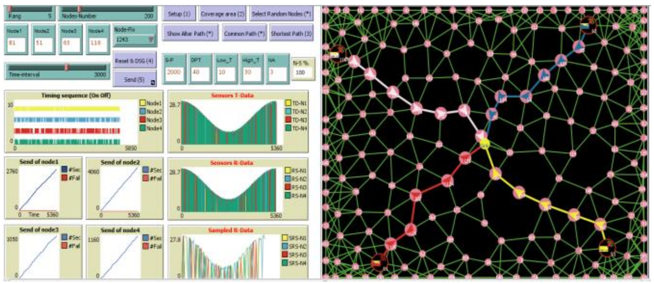

Fig.12. example of sending messages through the shortest path with no common nodes.

There is a timing sequence for each node that is send messages which represents a transmission time. Fig.13. shows the sending message times and sequences for four selected nodes at the same time.

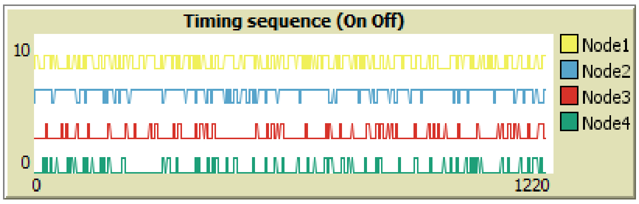

Fig.13. messages timing sequence for four nodes

Figure14. shows the transmission times from each of the four nodes to the sink node.

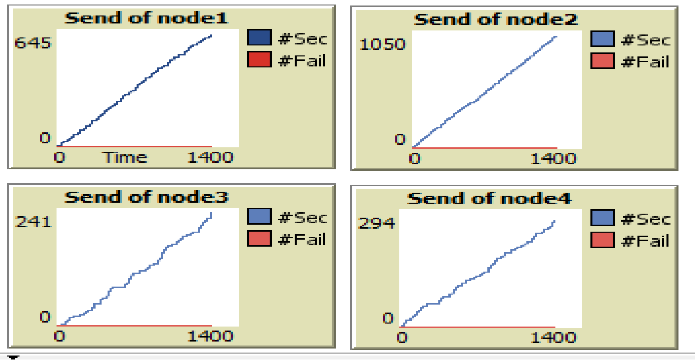

Fig.14. the plot shows The number of successful and failed transmissions for each node.

The simulation time (time interval) for messages from these nodes are indicated for succeful or failure.
To show the process of sending messages through alternative paths, fig.15. Present a case where alternative paths are required. The process of sending messages from four nodes on the suggested new alternative paths are presented successfully with their durations.

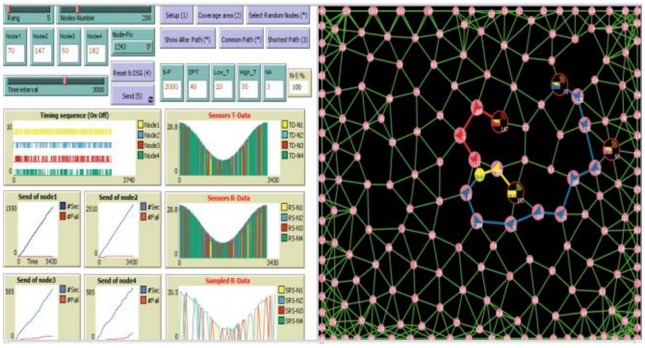

Fig.15. example of sending a message through an alternative paths.

VI. CONCLUSION

A modeling and simulation approach is implemented to analyze and extend message alternative routes in large-scale WSNs. The aim of this study is to solve the case of allocating one or more intermediate nodes on sending paths for different source nodes at the same time. Presence of certain nodes on the paths at the same time results in message losses. To avoid the busy case of the nodes on a path and selecting an alternative path by avoiding the common nodes, a proposed approach had been illustrated.

The suggested alternative path will be ready to forward the message from the source to the sink without losses. Such case is happened when different nodes trying to send messages to the sink at the same time. The suggested approach is tested by simulation for different cases.

REFERENCES

[1] F. Ye, H. Luo, J. Cheng, S. Lu, and L. Zhang, "A two-tier data dissemination model for large-scale wireless sensor networks," in *Proceedings of the 8th annual international conference on Mobile computing and networking*, 2002, pp. 148–159.

[2] X. Lu, P. Wang, D. Niyato, D. I. Kim, and Z. Han, "Wireless networks with RF energy harvesting: A contemporary survey," *IEEE Commun. Surv. Tutorials*, vol. 17, no. 2, pp. 757–789, 2014.

[3] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "Wireless sensor networks: a survey," *Comput. networks*, vol. 38, no. 4, pp. 393–422, 2002.

[4] I. F. Akyildiz and M. C. Vuran, *Wireless sensor networks*, vol. 4. John Wiley & Sons, 2010.

[5] O. Yilmaz, S. Demirci, Y. Kaymak, S. Ergun, and A. Yildirim, "Shortest hop multipath algorithm for wireless sensor networks," *Comput. Math. with Appl.*, vol. 63, no. 1, pp. 48–59, 2012, doi: https://doi.org/10.1016/j.camwa.2011.10.070.

[6] D. Kwon, S. Yu, J. Lee, S. Son, and Y. Park, "WSN-SLAP: Secure and lightweight mutual authentication protocol for wireless sensor networks," *Sensors*, vol. 21, no. 3, p. 936, 2021.

[7] M. S. Parwez, D. B. Rawat, and M. Garuba, "Big data analytics for user-activity analysis and user-anomaly detection in mobile wireless network," *IEEE Trans. Ind. Informatics*, vol. 13, no. 4, pp. 2058–2065, 2017.

[8] S. Boubiche, D. E. Boubiche, A. Bilami, and H. Toral-Cruz, "Big data challenges and data aggregation strategies in wireless sensor networks," *IEEE access*, vol. 6, pp. 20558–20571, 2018.

[9] X. Fu, G. Fortino, P. Pace, G. Aloi, and W. Li, "Environment-fusion multipath routing protocol for wireless sensor networks," *Inf. Fusion*, vol. 53, pp. 4–19, 2020.

[10] H. Kharrufa, H. A. A. Al-Kashoash, and A. H. Kemp, "RPL-based routing protocols in IoT applications: A Review," *IEEE Sens. J.*, vol. 19, no. 15, pp. 5952–5967, 2019.

[11] S. Jarupadung, "Event processing in wireless sensor networks." University of Surrey, 2015.

[12] M. G. Kibria, K. Nguyen, G. P. Villardi, O. Zhao, K. Ishizu, and F. Kojima, "Big data analytics, machine learning, and artificial intelligence in next-generation wireless networks," *IEEE access*, vol. 6, pp. 32328–32338, 2018.

[13] B.-S. 444Kim, K.-I. Kim, B. Shah, F. Chow, and K. H. Kim, "Wireless sensor networks for big data systems," *Sensors*, vol. 19, no. 7, p. 1565, 2019.

[14] A. Andoni, C. Stein, and P. Zhong, "Parallel approximate undirected shortest paths via low hop emulators," in *Proceedings of the 52nd Annual ACM SIGACT Symposium on Theory of Computing*, 2020, pp. 322–335.

[15] V. Katiyar, N. Chand, G. C. Gautam, and A. Kumar, "Improvement in LEACH protocol for large-scale wireless sensor networks," in *2011 International Conference on Emerging Trends in Electrical and Computer Technology*, 2011, pp. 1070–1075.

[16] S. H. Lee, S. Lee, H. Song, and H. S. Lee, "Wireless sensor network design for tactical military applications: Remote large-scale environments," in *MILCOM 2009-2009 IEEE Military communications conference*, 2009, pp. 1–7.

[17] S. Wan, Y. Zhang, and J. Chen, "On the construction of data aggregation tree with maximizing lifetime in large-scale wireless sensor networks," *IEEE Sens. J.*, vol. 16, no. 20, pp. 7433–7440, 2016.

[18] H. H. Yang, C. Xu, X. Wang, D. Feng, and T. Q. S. Quek, "Understanding age of information in large-scale wireless networks," *IEEE Trans. Wirel. Commun.*, 2021.

[19] D. N. Wategaonkar, S. V Nagaraj, and T. R. Reshmi, "Multi-hop Energy-Efficient Reliable Cluster-based Sectoring Scheme Using Markov Chain Model to Improve QoS Parameters in a WSN," *Wirel. Pers. Commun.*, pp. 1–29, 2021.

[20] A. Senthilkumar, S. Lekashri, and D. R. M. Abhay Chaturvedi, "DATA TRAFFIC TRUST MODEL FOR CLUSTERED WIRELESS SENSOR NETWORK," *Inf. Technol. Ind.*, vol. 9, no. 1, pp. 1225–1229, 2021.

[21] N. Mazumdar, A. Nag, and S. Nandi, "HDDS: Hierarchical Data Dissemination Strategy for energy optimization in dynamic wireless sensor network under harsh environments," *Ad Hoc Networks*, vol. 111, p. 102348, 2021.

s[22] F. Amblard *et al.*, "Introduction to NetLogo," in *Agent-based Spatial Simulation with Netlogo*, Elsevier, 2015, pp. 75–123.