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RESEARCH PAPER

Improved Routing Algorithm in IoT Network by TOPSIS method.

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A B S T R A C T:
Low energy utilization and reliability in packet transmission are factors that seriously affect the performance of Wireless Sensor Network (WSN) and Quality of Service (QoS) in general. Regarding routing strategy, the efficient forwarding methods can cause more throughput, less packet loss with less energy usage. To this purpose multi-attribute, decision-making (MADM) methods are proposed in hop-by-hop sending data scenarios, as the most efficient methods in selecting the reliable path towards the sink node. In such a decision-making environment, various routing metrics are taken into account. This paper compares Wise Route routing protocol and modified-Wise Route (MwiseRoute) by TOPSIS with indexes (signal to noise ratio, residual energy, distance from the node, farness from the sink node) balances by self-sets weights (0.3, 0.5, 0.1,0.1) respectively. The evaluation has been tested on Mixim 3.2 in Omnet++.4.6. The result shows MwiseRoute with TOPSIS is more appropriate in gaining more throughput and significantly decreases packet drop in mac by less power drain.

KEY WORDS: Wireless Sensor Network (WSN); Routing; TOPSIS; Sink node; Wise Route.
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1. INTRODUCTION:

One of the hopefully developed technologies currently is Internet-of-Things (IoT) that development in communication and computing has been created by it. Smart appliances, communication equipment, intelligent mobile devices are included in covering networks of the community (Ghafoor et al., 2018). According to (Kamble and Patil, 2020) nowadays WSNs functions are involved in many aspects such as environment and constructions and healthcare industry, and energy proficiency.

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During the growth of wireless communication and electronic IT, what has been extensively used in different areas is Wireless Sensor Network (WSN) as the cost is very low, minimization and its various functional features. As the nodes are power-driven by batteries in WSN and it makes it difficult to fill the energy because they are installed in outside areas or unsafe locations. There is a high cost in unnecessary distribution as well as in substitute of the node. As a result, if we want to reduce the consumption of energy, improve the network congestion and packet transmission reliability, particularly in converge casts such as Wise Route, handling of multi-attributes in an efficient decision-making method is quite supportive (Aziz and Aznaoui, 2020). That would lead to the most satisfying selection of intermediate packet-holder. To this purpose, the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method is proposed.

Wise Route by default uses Received Signal Strength Indication (RSSI) to estimate link quality in the routing-tree building. While the Sink node generates a flooding packet, each node compares the RSSI values with its previously-stored threshold. If the received RSSI value is higher than the threshold, the sensor receives the messages and selects the sink node as the parent node (Kaur and Malhotra, 2015), (Kazmi et al., 2014). For sending packets, flooding is a way to transmit packets to the destination node. As a result, each node initializes the data-packet in SensroApplLayer (Application layer) and sets the destination address to (-1) address (Kodali and Malothu, 2016). In most events building routing-tree and flooding data in parallel by different nodes can cause network congestion. As a consequence, the packet or flood message drop in the Mac layer. Therefore, to provide a reliable routing strategy, some changes have been applied to the routing function to select the next eligible node forwarder. Building routing tree, in Modified WiseRoute (MwiseRoute), is generalized over all nodes that exist in the system, not just sink node.

As previously provided, In Wise Route the same packet is received by all hosts in the ground. The node suffers more energy wasting. To overcome this issue, Multi-Attribute Decision Making (MADAM) is an accessible solution. (Kim et al., 2019a)Different indexes are proposed in selecting the middle packet-taker, To this end, the journey of the packet will divide into (source, packet-forwarder-destination) schemes. The number of intermediate nodes varies depends on the distance from the sink and the number of available nodes. TOPSIS is applied as one type of (MADAM) method. Firstly, TOPSIS is proposed by Yoon & Hwang in 1981 (Karami, 2011).TOPSIS works on the preferable next-node by finding the distance between nodes and Ideal-best and ideal-worst. In such a way the selected node is far from ideal-worst, and close to the ideal-best [10]. Four various indexes adopt into TOPSIS which consist of (Signal to noise ratio, Residual energy, distance from a neighbor, distance from the sink) with applying four weights (0.3,0.5,0.1,0.1). The scenario has been evaluated on three different node density (50,75,100). While two configured projects (Wise Route, MwiseRoute) have the same properties and network parameters.

Many argue as in (Foubert and Mitton, 2021)TOPSISI method has an issue in reordering the ranking alternative while one alternative is missing. Ranking reversal would change the path of a packet in Wireless sensor networking especially in the broken link in this research when any node is dead or has already visited during the transmitting packet. It is suggested that the problem should not consider it, because already link quality depends on some factors, and in the project, each node has its own decision on selecting the next-coming packet holder. The main contributions of this paper are as follows:

- Whether the sink node is a neighbor, send the packet directly.
- multiple parameters (four indexes) lead us to choose a suitable node to hold the packet.
- The procedure is implemented on Omnet++ 4.6, Mixim 3.2 frameworks on the Windows platform. With the help of matplotlib in python 3.9.5 for plotting.

The rest of the paper is arranged as follows: Section II provides the most relevant research articles on routing and forwarding solutions in sensor networks. Section III sheds light on the methodology and routing strategy in Wise Route and modified protocol. This is followed by the network environment model, where we highlight the important metrics for packet forwarding toward the sink node, and. Section IV shows the evaluated results and precise comparison. Finally, section V concludes the paper.

2. RELATED WORK

This section presents the more relevant work on using MADM in WSN and in particular (the TOPSIS) method as the most common method. In some articles, the performance of TOPSIS is compared with other routing protocols. Providing the weights of indexes in TOSIS one step toward the right decision.

MADAM methods have many features, the most important one is improving the evaluation efficiency. simulation results illustrate that the

MADM method overcomes the shortcoming of other methods in terms of the network structure. Examples of methods in MADM are AHP, TOPSIS, SAW, GRA. In the case of network performance, the key nodes discovered by the MADM method have better effect compared with other methods, for instance in (Kim et al., 2019a) which recent works present that employ Multi-Attribute Decision Making (MADM) scheme. In addition, all mentioned methods can interchangeably use in both MANET and VANET types of Ad Hoc Networks.

Many factors affect the performance of Mobile crowdsensing (MCS). In their research, (Ghafoor et al., 2018)tried to count all factors and combine them into a Fuzzy logic-based Routing (FR) method. Residual energy is specifying the quality of node, SNR, detects the quality of a link. After selecting the best of mentioned metrics, the fuzzy inference system outcomes all neighbor's costs. The great cost is approved. It is noted that the weight is set based on gaining a good result. The results show outperforms FR over ESR protocols in having more alive nodes per certain time, and significant change in residual energy.

Efficient packet forwarding has emerged as a significant problem, especially in wireless sensor networks. In particular, such network energy of sensors is depleting in a short amount of time. TOPSIS is selected by many researchers in dealing with WSN issues. In (Khan et al., 2018), TOPSIS plays a vital role in Wireless sensor networks (WSNs) routings to rank and make decisions of cluster heads selection. It has been found that TOPSIS is better outperforms comparing with LEACH in terms of enhancing network lifetime and saving energy. According to the simulation results, Fuzzy-TOPSIS is better as compared with LEACH, Fuzzy-TOPSIS reaches substantial energy saving and enhances network lifetime. Taking the same scheme in another attempt (Shelebaf and Tabatabaei, 2020) TOPSIS is evaluated with other protocols such as IEEE802.15.4. some crucial parameters are inserted into TOPSIS such as distance from sink, neighborhood, the remaining energy, and organize and carry out of workload.

In the last attempt of (Foubert and Mitton, 2021), which made use of TOSIS in maximizing the advantage of Multiple Technologies Network (MTN), Foubert1, Mitton1 customize their routing strategy. They introduce Routing Over Different Existing Network Technologies protocol (RODENT), which performs dynamically retaking the best path and Radio Access Technologies (RATs) over time. This results in enhancement in network lifetime and expansion the coverage. For networking such Sigfox, that hoping between RAT and cause node bear delay, huge throughput or even outdoor communication can suffer unsteady weather. In such an environment, decision relay on the method for each node to select the best technology that meets the requirement of data. Through this Network Interface Selection (NIS) problem can face each node. Even the TOPSIS method would outcome issues like a rank reversal. While modification in the TOPSIS normalization algorithm can overcome all issues in MTN.

3. THE PROPOSED MULTI-ATTRIBUTE DECISION MAKING (MADM) FUNCTION ON WISE ROUTE

In this part, WiseRoute is discussed. Then applying MADM is presented. TOPSIS is a method of MADM is explained after.

3.1 WiseRout

Wise Route is a wireless Sensor Network (WSN) routing protocol, by looping over all established sensors in the ground the routing tree is built. In such a one-to-many flooding scenario the central node flood the route-flood message, every single sensor receives flooding and add the source node in its flood table. The forwarding packets broadcast as the previous strategy (Varga and Hornig, 2008, Smolka, 2011, Kodali and Malothu, 2016). To move from the broadcasting message into unicast mode the path divides into sub-optimal paths. To decide the optimal path various irrelevant criteria are inserted into the multi-attribute decision-making method (MADM). Assigning weights for the MADM is play an important role in balancing the ranking alternatives accordingly (Kim et al., 2019b) (Odu, 2019), (Aziz and Aznaoui, 2020),(Karami, 2011).

In Mixim the transmitting packet goes through two phases, first, the sink node (node 0) broadcasts route- flood message (figure 1), whenever each node receives this message updates its route-table directly and inserts the source sensor address. The second phase is sending data for all nodes in the playground. In contrast, in modified Wise Route all nodes are involved in flooding flood messages in aim all host addresses exist in the flood tables in each particular host to let each node rank its preferable neighbor node(Kodali and Malothu, 2016). In the second stage for sending data, each node selects the best nearby node till it reaches the destination.

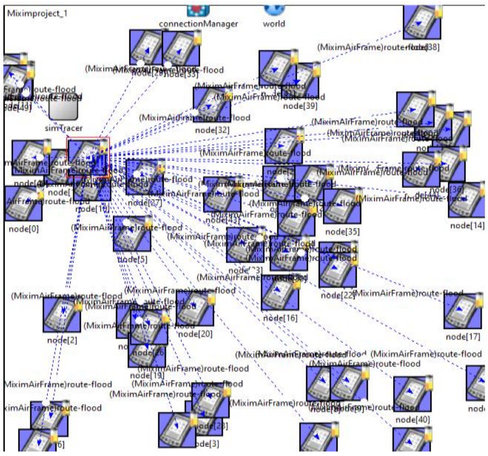

Figure 1: flooding flood message between nodes.

3.2 TOPSIS method on Wise Route

Technique for order preference by similarity to ideal solution (TOPSIS) in 1981 was proposed by Yoon & Hwang (Shelebaf and Tabatabaei, 2020),(Karami, 2011),(Hajji et al., 2018). In TOPSIS each multi-metric problem is tackled geometrically. All Alternatives are ranked, then the best solution is selected which is located near to the best possible and far from the worst possible. (See figure below) (Shelebaf and Tabatabaei, 2020). In this method, attributes are ordered with n alternatives in a matrix. In a way attributes are features or indexes that cooperate for the decision-making process and choosing acceptable alternatives. In WiseRoute each node with attributes is inserted in the map data structure which <key, value> structure stores as <node, attributes> pair. Among indexes, in the routing table, four parameters are selected, Singal to Noise ratio (SNR), Residual Energy (RE) of the node, distance from the neighbor node, distance from the Sink node. Then all steps of the TOPSIS method are mentioned below;

Step 1: - Obtaining decision map

In the routing table, the address of the nodes and four previously mentioned metrics are stored. Signal-to-noise ratio (SNR or S/N) is a measure used in a wireless sensor network that compares the level of the desired signal to the level of background noise [Wikipedia]. In WiseRoute the SNR value is obtained in the Decider802.154Narrow module through modulation type Minimum-Shift Keying (MSK) in the physical layer, while in the mac layer CSMA802154 protocol is utilized. The remaining power is calculated after the initial energy is used by five ((sleep, RX, Tx, switching, decoding) activities in each node. Distance between each host is calculated by the Euclidean distance formula where the x-position and y-position are provided. For the further from the sink node, the same formula is utilized, in which at first the position of the destination node is selected. It is worth pointing this out, all nodes are randomly deployed. The new place of each host is updated per interval time. Table [1] illustrates the sample route table for 10 nodes.

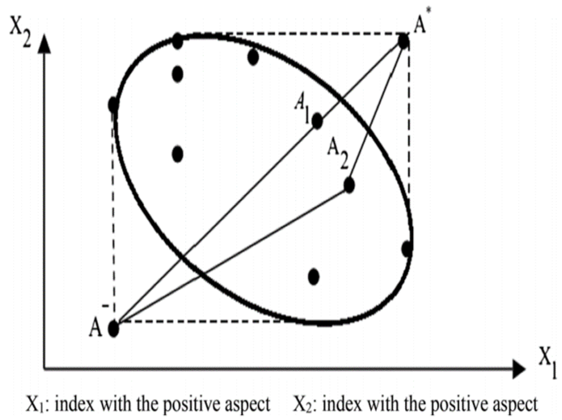

Figure 2. Distance measure between ideal-best and selected attribute(A).

Table (1) Four attributes in route table.

N0.node	SNR (dB)	RE (mW-s)	Dist-neighbour (m)	Dist-Sink (m)	SimulationTime(s)
0	48745256913.204681	2755.826293	248.039688	0.000000	398.556314
1	228623763037.408203	3065.927610	260.401928	17.803576	398.556314
2	13242261914.225908	2602.00917	434.154131	272.439999	398.556314
4	9698989019.081202	2602.009175	257.975547	257.946344	398.556314
5	5825235356.785823	2602.009175	445.519480	212.962578	398.556314
6	959106397.048754	3222.143137	352.249219	210.569774	398.556314
7	12012436	2602.	104.	178.	398.556314
8	23505973627.834736	2602.009175	48.727544	200.900340	398.556314
9	5100314270.371751	3065.927610	419.661030	182.008432	398.556314

Step2: Normalizing decision map by a set of weights

According to the TOPSIS method, the normalization process is done by finding the sum of each criterion then power after square root power results.

$$n_{ij} = \frac{C_{ij}}{\sqrt{\sum_{i=1}^{n} C^2{}_{ij}}} \qquad (1)$$

Where n_{ij} is the normalized value of C_{ij} parameters in the decision map, n provide the number of sensors in the ground.

Step4: Set weights for the normalized table.

In this evaluation stage, the set of weight (0.3,0.5, 0.1,0.1) is multiplied to (SNR, RE, Dist_neigh, Dist_sink) respectively. The weights are balanced in a way summation of all weights equal to one. Table [2] shows the weighted normalized values of the four indexes at a particular time.

Table (2) Normalized attribute-value in normalized map.

Node-Number	WSNR	WRE	Dist-neighbour	Dist-Sink	simulation time
0	5.528867e-002	1.639573e-001	2.619852e-002	0.000000e+000	398.55631 4
1	2.593135e-001	1.824067e-001	2.750425e-002	3.070466e-003	
2	1.501986e-002	1.548060e-001	4.585636e-002	4.698595e-002	
4	1.100095e-002	1.548060e-001	2.724797e-002	4.448632e-002	
5	6.607197e-003	1.548060e-001	4.705680e-002	3.672827e-002	
6	1.087854e-003	1.917007e-001	3.720538e-002	3.631559e-002	
7	1.362495e-001	1.548060e-001	1.104848e-002	3.082646e-002	
8	2.666134e-002	1.548060e-001	1.104848e-002	3.464797e-002	
9	5.784964e-003	1.824067e-001	4.432557e-002	3.138981e-002	

Step3: Find ideal values

Taking the normalized-weighted table and selecting the deal values for each criterion. The pacifying process regards the beneficial and non-beneficial metrics. In this procedure, the SNR and RE are both desirable metrics in which the maxim values are the best and the minimum values are the worst. On other hand, distance from the node and distance from the sink (Dist_neigh, Dist_sink) are non-beneficial means, the lowest values are preferable and the highest distance is unpreferable.

Best index:

$S_i^+ = \{(max v_{ij} | j \epsilon J), (min v_{ij} | j \epsilon J') \quad where\ i = 1,2, \ldots, m\} = \{v_1^+, \ v_1^+ \ , \ldots \ldots \ldots v_j^+, \ldots, v_n^+\}$
(2)

Worst index:

$S_i^- = \{(min v_{ij} | j \epsilon J), (max v_{ij} | j \epsilon J') \quad where\ i = 1,2, \ldots, m\} = \{v_1^-, \ v_1^- \ , \ldots \ldots \ldots v_j^-, \ldots, v_n^-\}$
(3)

jj → J = (j = 1, 2, 3, … , n) represents beneficial criteria

jj → j'= (j = 1, 2, 3, … , n) represents non-beneficial criteria

Both S^+ and S^- envy the best and worst sample of each index regarding features of criteria, v_{ij} refers to the value of metrics in the weighted-normalized table.

Corresponding to the previous numerical instance the ideal values are:

Table (3) Ideal-best and Ideal-worst for each index.

Metric name	S^+	S^-
SNR (dB)	0.187041	2.471978e-289
Energy (mW-s)	0.177732	1.658608e-001
Distance from neighbor (m)	0.000000	0.047119
Distance form Sink (m)	0.003273	0.050089

$S_{i+} = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_{ij}{}^{+})^2} \quad i = 1,2, \ldots \ldots \ldots \ldots m$
(4)
By the equation (4), the ideal-best of the current host is produced by the Euclidean distance formula where the metrics of the host are differentiated with the best alternative of each metric.

$S_{i-} = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_{ij}{}^{-})^2}$
$i = 1,2, \ldots \ldots \ldots \ldots m$ (5)
S_{i-} is the ideal-worst for the reached-node, where the distance between all four worst-selected indexes and metrics of the node is found.

Step4: put scores for each node

The step of comparing the idealness of nodes is here, the following equation provides the score for each host:

$p_{i*} = \frac{S_i^-}{S_i^- + S_i^+} \qquad 0 < p_{i*} < 1$
(6)

While each node has a performance score, so prioritizing the next forwarder is effortless.

Table (4) The performance-score of nodes.

No. node	**Performance-Score**	**Simulation-Time in second**
0	0.253767	398.556314
1	0.481694	398.556314
2	0.740807	398.556314
4	0.341483	398.556314
5	0.567897	398.556314
6	0.579508	398.556314
7	0.290811	398.556314
8	0.290357	398.556314
9	0.572628	398.556314

The previous ranking system by TOPSIS shows node [2] is superior to hold the packet.

4. SIMULATION ENVIRONMENT

For building network simulators, Objective Modular Network Testbed in C++(OMNET++) is used. It is open-source-C++-based libraries and modules that allow researchers to build network simulation, and events discretely. Each module customizes and defines the model topology through Network Description(NED) language. Mixed simulator (MiXiM) is an OMNeT++ modeling framework For creating and modification in mobile or fixed WSN scenarios. The sample node structure in omnet and Mixim is presented in figure [3]

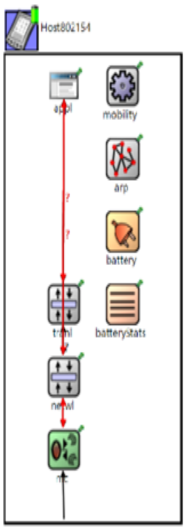

Figure 3: Wireless Node structure in Mixim

This structure of Wireless node, which name is (Host802154), means The MAC protocol is (CSMA802154), the type of mobility is ConstSpeedMobility.Othe network parameters are shown in table [4]. The physical layer and mac layer combined into Network Interface Card (NIC). The mobility module is used to control the mobility of nodes in the ground. The network type is Wise Route (Varga and Hornig, 2008),(Smolka, 2011),(Kodali and Malothu, 2016). In WiseRoute each node has its routing table, in which all routing tables are placed into flooding table by their unique routing table-key. The sink node floods a message and introduces itself to all hosts fixed in the area. To this end, In the flooding Table of the sink, all nodes-routing table's features are stored. In modification WiseRoute, every node has to flood and build this routing tree. TOPSIS method with a set of weights is used.

Table (5) Network parameters.

Parameters	Value
Simulation time	400 s
Simulation area	500 mX500 m
Transmission range	50 m
Battery.nominal	5mAh
Battery.capacity	2.5mAh
Battery.voltage	1.65V
Route-flood-interval	0.1 s
Data packet size	24 bytes

4.1 Evaluated metrics

Various metrics can evaluate the performance of the network. Some metrics indicate the quality of the node, while others indicate the link between nodes. To estimate the function of two projects, The following metrics are compared:

•The number of dropped frames in Mac layer, In the mac layer many reasons cause setting packet drop, most of the time the queue is full.

•Mean power consumption equals to differentiate initial power from final remaining power over simulation time in (mW-s).

•The throughput of Sink node it refers to the number of received- packet in Sink node over the sum of packets sent by all other nodes.

4.2 Result analysis

Even the number of sending floods increases in both (MwiseRoute by TOPSIS) while the power consumption is not increased dramatically, although, in some nodes, the customized protocol used a low amount of energy even smaller than WiseRoute. This thanks to the TOPSIS method, which precisely selects the best node with high energy to transfer the packet. Figure 4 presents this.

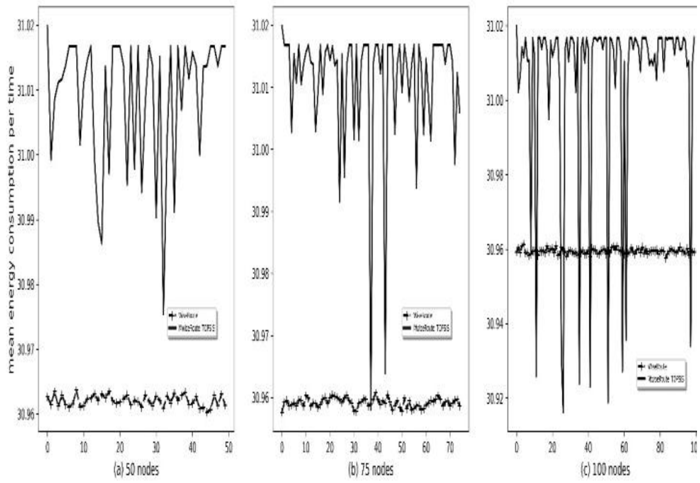

Figure 4: Mean power consumption rate over (50,75,100) nodes for WiseRoute and MwiseRoute.

To illustrate the throughput of the Sink node in two sicarios, it appears that more packets reach the destination node in MwiseRoute with modification methods TOPSIS which weights are provided statically more than Wise Route itself. The figure below expresses this truth. Especially when node number is equal to 50 nodes, moreover in 75, and 100 nodes the changes are significant.

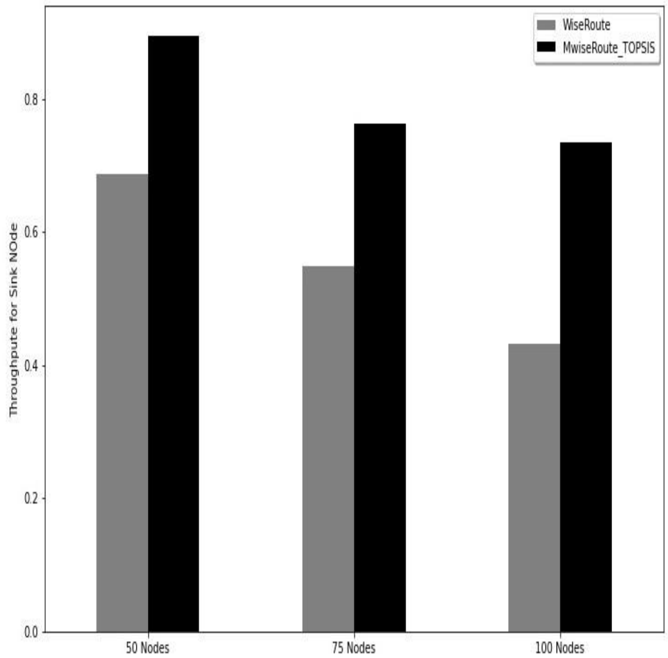

Figure 5: Throughput rate for Sink node over (50,75,100) nodes for WiseRoute and MwiseRoute.

The packet missing is great in WiseRoute. On the other side in MwiseRoute with TOPSIS, and the number of dropping a packet in MwisRoute-TOPSIS is dramatically enhanced and decreased. This regard in multi-hop transmission mode. Each node sends the packet to the selected node and the path goes toward the destination node. Figure 6 shows the substantial improvement in packet loss at the mac layer in both MwisRoute-TOPSIS.

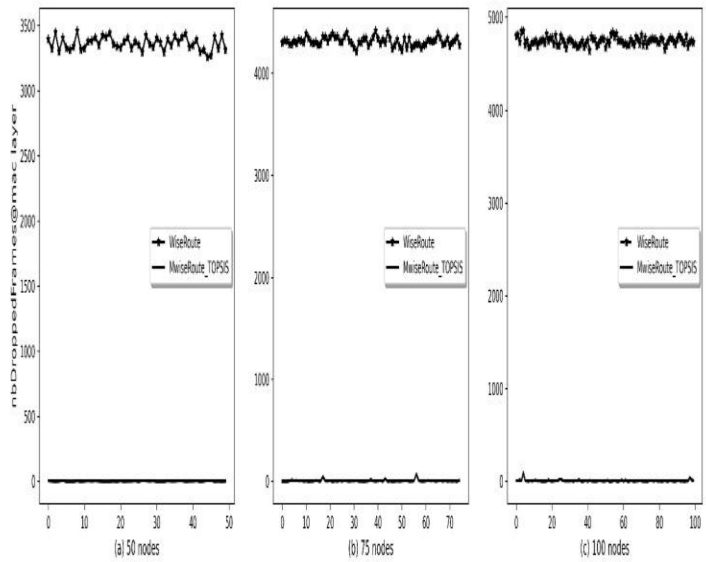

Figure 6: Packet drop at the mac layer over (50,75,100) nodes for WiseRoute and MwiseRoute.

5. CONCLUSIONS AND FUTURE WORK

Wise Route is a WSN routing protocol, is designed for sensor networks and convergecast traffic. Transmitting packets is many-to-one. This model of routing packets results in more packet loss and wasting energy. Considering important attributes into MADM methods would change the sending packet data into a unicast mode with broadcasting the flood to collect information about nearby nodes. TOPSIS is selected as a mainly used MADAM scheme to help in decision-making problems. In the beginning, balancing the metrics in TOPSIS is done randomly. After that for initializing the weights Entropy method was promoted. The combination of WiseRoute-TOPSIS outperforms of default Wise Route protocol in gaining more throughput, consuming in some nodes less energy at the same network topology. For future work it is recommended to arrange apply the weight values based on mathematical method.

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