Enhanced MPR Selection Strategy for Multicast OLSR

Safaa S. Matter[1†, 2††], Imad F. Al Shaikhli[1†], Aisha H. A. Hashim[3†††], Abdelmoty M. Ahmed[4††††], Mahmoud M. Khattab[4††††]

[1]Department of Computer Science, Kulliyyah of Information and Communication Technology, International Islamic University Malaysia, Kuala Lumpur, Malaysia
[2]Department of Computer Science, Applied College, King Khalid University, Abha, Saudi Arabia
[3]Department of Electrical and Electronic Engineering, International Islamic University Malaysia, Kuala Lumpur, Malaysia
[4]College of Computer Science, King Khalid University, Abha, Saudi Arabia

Summary
Wireless community networks (WCNs) are considered another form of ownership of internet protocol (IP) networks, where community members manage and own every piece of equipment in a decentralized way, and routing for traffic is done in a cooperative manner. However, the current routing protocols for WCNs suffer from stability and scalability issues. In this paper, an enhanced routing protocol is proposed based on the optimized link state routing (OLSR) protocol to meet the standards of efficiency in terms of stability and scalability. The proposed routing protocol is enhanced through two phases: multicasting expansion and multipoint relay (MPR) selection based on an analytical hierarchical process (AHP). The experimental results demonstrate that the proposed routing protocol outperforms the OLSR protocol in terms of network control overhead and packet delivery ratio by 18% and 1% respectively.
Keywords:
WCNs, routing, MPR, OLSR.

1. Introduction

The internet has made the world a little community in recent years, linking millions of people, organizations, and equipment for different purposes. Sometimes WCNs become the only solution for people who can't access the internet services directly from internet service provider (ISP) [1]. WCNs are large, heterogeneous, dynamic, and decentralized networks. Such complex characteristics raise different challenges, such as the effect of wireless communications on the performance of networks and routing protocols [2].

As current routing protocols are inefficient when faced with the dynamic changes and poor links that occur in real-life and self-managed deployments. This results in too much overhead during communications due to flooding as most of the current routing protocols use unicast traffic. The MPR is a selection strategy that used to minimize the amount of repeated retransmissions which leads to minimizing the control overhead. Furthermore, the network topology is maintained through the MPR selector set, which can be used as information. This means that each node in the network must select reliable and consistent MPR nodes in order to maintain a stable and robust topology. For all the previously mentioned reasons, an enhanced routing protocol is proposed to achieve optimal routing performance. This protocol is designed to consider the heterogeneous characteristics of WCNs to produce a more efficient routing technique in terms of stability and scalability.

In this paper, we intend to enhance the efficiency of the OLSR routing protocol in terms of stability and scalability in order to improve the overall performance of WCNs. Therefore, the main contributions of this research paper are as follows:

I. Multicast traffic is expanded to the OLSR routing protocol in WCNs in order to decrease the overhead caused by flooding as OLSR uses unicast traffic. The multicast operations are composed of two phases: the tree initialization phase and the tree maintenance phase.
II. An enhanced strategy is proposed for the MPR selection algorithm of the OLSR routing protocol to maintain a stable topology using multi-criteria decision making (MCDM). There are several sub-disciplines of operations research called MCDMs, which are devoted to finding the best possible outcomes in a wide range of difficult situations. Multiple criteria are taken into account simultaneously in the MCDM method to create a flexible decision making process. Multiple metrics can be weighted according to MCDM: AHP. Each node establishes an MPR set based on a single cost determined by the given metrics.

The rest of this paper is organized as follows. Section 2 illustrates the OLSR routing protocol. Section 3 describes the design of the proposed framework. Sections 4 and 5 show the components of the proposed approaches according to multicasting expansion and MPR selection based on AHP. Finally, Section 6 conducts extensive experiments and critical analysis of results in order to explore the reliability and efficiency of the proposed routing protocol in comparison with the standard OLSR protocol, and the paper is concluded in Section 7.

Manuscript received October 5, 2022
Manuscript revised October 20, 2022
https://doi.org/10.22937/IJCSNS.2022.22.10.18

2. OLSR Routing Protocol

The experimental RFC3626 contains documentation of the OLSR protocol, which has been created for mobile ad hoc networks. OLSR is table-driven and proactive, and it makes use of an optimization technique known as MPR to limit the flooding of traffic. The OLSR protocol is broken down into its basic functionality and a collection of auxiliary functions. In a stand-alone MANET, the basic functionality defines a protocol that may enable routing. Additionally, there are a variety of auxiliary functions available, each with their own set of potential scenarios. It is possible to implement any auxiliary function along with the core since all auxiliary functions are compatible with one another. It is also claimed that the protocol may accommodate nodes that implement various subsets of the auxiliary functions in the network [3].
The optimization part of OLSR comes in the flooding mechanism [4]. The main technique that the OLSR protocol depends on is MPRs. Where, broadcast messages are forwarded by only some selected nodes, which are called MPRs during the flooding process. Therefore, by using this technique, the traffic overhead is reduced when compared to the original flooding technique, as the broadcast messages are forwarded by all nodes [4].

- Neighborhood discovery

OLSR performs neighborhood detection by sending periodic "Hello" messages. The Hello message includes a sequence number that increases internally, as well as the links known to the neighbors of the sender and the quality of links. The Hello messages are sent periodically every two seconds [4]. Fig. 1 shows a typical neighborhood discovery for the OLSR routing protocol.

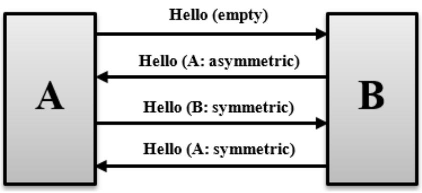

Fig. 오류! 지정한 스타일은 사용되지 않습니다.1 A typical neighborhood discovery for OLSR routing protocol

- Topology distribution

OLSR works like other link-state routing protocols, where topology control (TC) messages are flooded into the network in order to disseminate the partial view of the entire topology to every node in the network. Every node in the network generates the TC messages periodically and forwards them throughout the network without any changes. The TC message defines the nodes in the path from the source of the message and the quality of links involved in the path [4]. Fig. 2 shows the OLSR topology distribution mechanism.

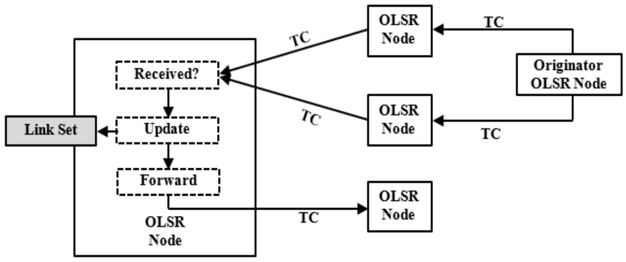

Fig. 2 OLSR topology distribution mechanism

3. The Design of the Proposed Framework

Our research focuses on designing and implementing an enhanced routing protocol for WCNs based on the OLSR protocol that meets the standards of efficiency in terms of stability and scalability. The proposed routing protocol is developed using the C++ programming language for the purpose of simulation. Enhancements include multicasting expansion and MPR selection based on AHP. The proposed framework consists of three components, as shown in Fig. 3. A description of each component is given in the following sections.

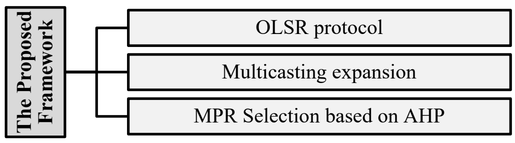

Fig. 3 The proposed framework

4. Multicasting Expansion

In order to decrease the overhead caused by flooding as OLSR uses unicast traffic, multicast traffic is expanded to the OLSR routing protocol in WCNs. In order to communicate with the multicast group, the most recent sequence numbers are utilized. Unicast, multicast, and broadcast capabilities are all included in the multicast extended OLSR. A major benefit of using multicast expanded OLSR is that it prevents bandwidth waste by allowing each node inside the group to deliver multicast data packets instead of sending unicast data packets to a group of receivers. This loss of bandwidth is caused by sending unicast data packets to the group of receivers. The multicast operations are composed of two phases: the tree initialization phase and the tree maintenance phase as detailed in the following subsections.

4.1 Tree Initialization Phase

In a multicast group, the node that joins first becomes the group leader and is responsible for updating the group sequence number and broadcasting it periodically using the group hello message. When a group's members continue to be connected within a multicast tree, the multicast expanded OLSR are not required to do any tasks. However, when a node decides to join or leave a multicast group, it has a significant role. A unicast route request (RREQ) message is sent to the multicast group leader by a node that wishes to join the multicast group and has the address of the leader. The nodes that do not have the group leader's IP address broadcast the group Hello message to the network. A route reply (RREP) message is sent by the member of the group. It is now possible to get to a multicast tree via the RREP message being unicasted back to the RREQ message. Recipient node distance from the group leader and recent group sequence number are included in this RREP. The receiver node receives many RREPs, from which it chooses the most recent and shortest path and then transmits the multicast activation (MACT) message. The routes are activated by the MACT message.

4.2 Tree Maintenance Phase

The nodes that are in the multicast group have very high dynamic behavior. All multicast group members have the ability to join or leave freely at any moment. For the node to exit the tree, one of two things must happen: the node must either be a leaf node or it must be an intermediary tree with a preceding node that departs from the tree as well. In the event that a leaf node wishes to leave the group, it can send a prune message to the nodes that are upstream from it, which can be sent higher in the tree. Next hop link status is monitored continuously by nodes in the multicast tree. Therefore, if there is any link break, the nodes detect it and repair it through the RREQ, RREP, and MACT messages. An example of multicast route discovery is shown in Fig. 4.

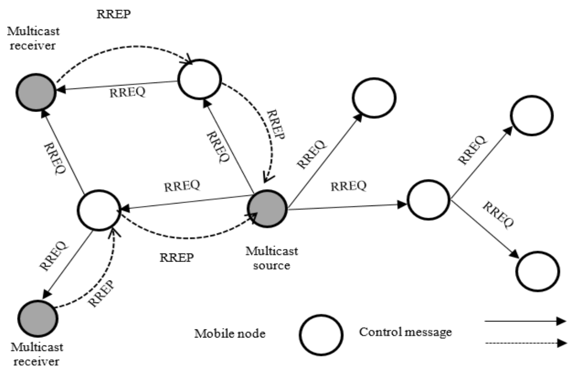

Fig. 4 Multicast route discovery process

5. MPR Selection Based on AHP

The MPR selection strategy is at the heart of OLSR's mechanism. The core benefit of the MPR algorithm is reducing the TC messages, which leads to minimizing the control overhead. Furthermore, the network topology is maintained through the MPR selector set, which can be used as information. This means that each node in the network must select reliable and consistent MPR nodes in order to maintain a stable and robust topology. OLSR, on the other hand, only considers connectivity, or the number of two-hop neighbors, when making an MPR choice. No matter how many two-hop neighbors the selected MPR node covers, there is a possibility that the MPR selection set is no longer valid because of the node's movement. As a result, the worst-case scenario is that the incorrect network topology can be kept until the TC message hold timer expires.

In this paper, an enhanced strategy is proposed for the MPR selection algorithm of the OLSR routing protocol to maintain a stable topology using a MCDM. There are several sub-disciplines of operations research called MCDMs, which are devoted to finding the best possible outcomes in a wide range of difficult situations. Multiple criteria are taken into account simultaneously in the MCDM method to create a flexible decision making process. Multiple metrics can be weighted according to MCDM: AHP [5]. Each node establishes an MPR set based on a single cost determined by the given metrics. The detailed explanation of the AHP technique, metrics for MPR selection, and the modified MPR selection algorithm are presented in the following subsections.

5.1 AHP Description

When it comes to making multi-criteria decision analysis, the AHP is a robust and adaptable method [5]. AHP can be broken down into four steps, as indicated in Fig. 5:

1. A hierarchical representation of a difficult decision problem.
2. Comparing the weight (importance or priority) of multiple items by comparing them in pairs.
3. In order to assess the relative weight (importance) of distinct elements at various levels of the hierarchy, pair-wise comparisons are used. As a result, we can calculate what is known as the score for each level inside each element.
4. Incorporate the weights from steps 2 and 3 to generate a final score for decision alternatives. After that, the option with the highest total score will be chosen.

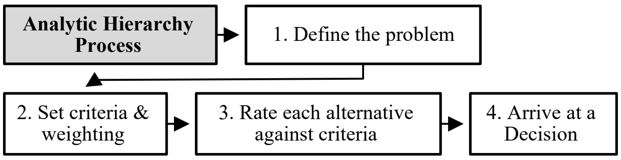

Fig. 5 The main steps of AHP technique

5.2 Metrics for MPR Selection

In order to choose a stable MPR set in WCNs, we can use the following two metrics in the MPR selection algorithm:

1. Link change rate (LCR)

The LCR is a measure of how much the neighbor table entry has been modified throughout the time interval t. As a result, the greater the value of LCR, the greater the connection loss owing to the movement of nearby nodes. It is possible to compute the LCR using the formula [6]:

$$LCR_i = \frac{Countnew_i + Countlost_i}{t} \qquad (1)$$

Where $Countnew_i$ is the number of new links formed by node i during time interval t. The $Countlost_i$ indicates the number of lost links of node i during the time interval t. The *Countnew* and *Countlost* can be calculated by referencing the entry in the neighbor table. Generally, since the neighbor table is updated when each node receives the Hello message from a neighboring node, we set the time interval t as a hello interval.

2. Received signal strength indicator (RSSI)

We use the RSSI as a link quality metric. There are many prediction models for estimating RSSI, and we adopt the free space propagation model. The free space propagation model is based on the assumption that there are no obstacles between transmitter and receiver, and they are in line of sight. A simplified estimation model can be defined as [7]:

$$RSSI_{i,j} = C_f \frac{P_t}{d^2} \qquad (2)$$

Where $RSSI_{i,j}$ means the received signal strength between nodes i and j, C_f indicates the constant value depending on a transceiver, and P_t represents transmitting power. The d means the distance between the transceiver and the receiver.

5.2 AHP-Based MPR Selection Strategy

In this subsection, we discuss how to apply the AHP to design an MPR selection strategy. The AHP module takes multiple criteria as input values and returns the final score as shown in Fig. 6. The final score is the weighted sum of all the individual metrics, and this number is used to decide which option is best.

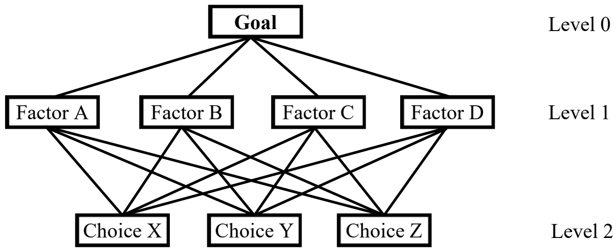

Fig. 6 AHP hierarchy process

Two new fields are added to the header of the Hello packet. Until it has covered all of its two-hop neighbors, each node keeps track of two metrics for its one-hop neighbors and uses the one-hop neighbor with the highest final score as an MPR. Keep in mind that the RSSI refers to the average RSSI value with one-hop neighbors. You can see how the MPR selection algorithm has been changed in Algorithm 1. Our research does not take into account a node's willingness; instead, we weight two metrics equally. The final score is used to choose one of the nodes with the same degree who can be an MPR.

Algorithm 1: The proposed MPR selection algorithm

Input: t, n, TwoHopSet, MprCandidate, and degree_i
Where t is the total number of two-hop neighbors, n represents the number of one-hop neighbors, TwoHopSet refers to a two-hop neighbor set which can only be accessed through one-hop neighbor, MprCandidate refers to a candidate which has the potential to be chosen as an MPR amongst one-hop neighbors, and degree_i is the number of two-hop neighbors that connect to the one-hop neighbor of node_i.

Output: FinalScore
Whereas FinalScore is a weighted sum of every one of the metrics used to choose MPRs.

```
while t > 0 do
  for i = 1 to N do
    if node_i = MPR then
      continue
    end if
    FinalScore = AHP_MODULE (LCRi, RSSIi)
    if degree_i > MaxDegree then
        MprCandidate = node_i
        MaxDegree = degree_i
    else if degree_i=MaxDegree and FinalScore>MaxScore then
        MprCandidate = node_i
        MaxScore = FinalScore
    end if
  end for
  SelectMPR (MprCandidate)
  UpdateMBRSet (TwoHopSet, t)
end while
```

6. Simulation Results and Analysis

This section highlights and explains the primary findings of this research paper. It proceeds as follows: In order to guarantee that all simulation scenarios are compared fairly, the simulation environment is initially defined in Section 6.1, which presents simulation parameters and scenario details. Section 6.2 illustrates the performance evaluation metrics, which can be used to measure the performance between both the proposed routing protocol and OLSR. Section 6.3 conducts extensive simulation scenarios and critical analysis of results in order to explore the reliability and efficiency of the proposed routing protocol in comparison with the standard OLSR protocol. An overall discussion is offered in Section 6.4.

6.1 Simulation Environment

In order to evaluate the efficiency of the proposed routing protocol, the network simulator V2.35 (NS-2) [8] has been used for simulation and analysis. Moreover, OLSR is used as a benchmark in our experiments. Primarily because our enhanced routing protocol is proposed to act as an improvement to OLSR. In addition, OLSR remains one of the most common routing protocols employed for WCNs and is widely used as the reference WCNs' routing protocol by the research community [9-13]. Therefore, the performance of the proposed routing protocol in WCNs is compared with that of the OLSR routing protocol through NS-2. In this paper, our goal is to examine the effects of multicast expansion and MPR selection using AHP.
In this simulation, a random topology is considered, with a 1000 m x 1000 m area with 51 nodes. Only one of them is configured to act as a base station and is positioned in the middle of the network. A screen capture of the network topology is demonstrated in Fig. 7.

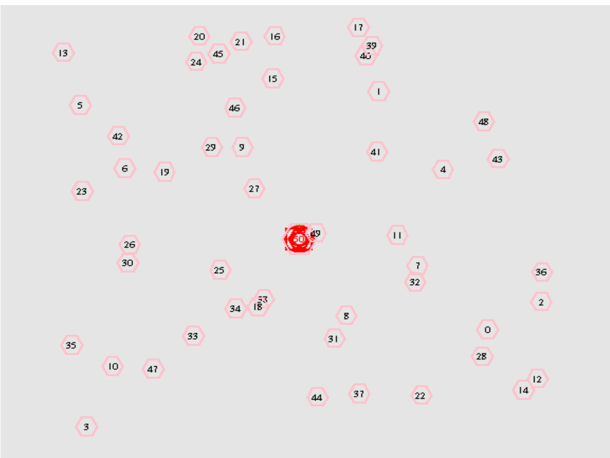

Fig. 7 The topology of the network as represented in NS-2

The PHY802.11b model and the 802.11 MAC protocol are both used by every node. In addition, a CBR traffic source that uses data packets of 512 bytes is also taken into consideration. We are going to assume that the bandwidth of the link is 2 Mbps and that the sending rate of CBR traffic is 4 packets per second. Simulations are performed with network densities varying from 5 to 50. The interface queue (IFQ) of all protocols is 50 packets. The IFQ is a first-in-first-out (FIFO) priority queue. In this queue, routing packets are given a priority that is higher than data packets. Trace files record all the MAC layer and network layer procedures on wireless network interfaces. Each trace file is parsed using parsing language to calculate network control overhead and packet delivery ratio after the simulation is complete. Table 1 summarizes the simulation's parameters.

Table 1: Network simulation parameters

Parameters	Values
Simulator	NS-2.35
Size	1000 m X 1000 m
Simulation Time	600 seconds
Number of Nodes	51
Node Placement	Random topology
Node Density	5,10,15,20,25,30,35,40,45,50
Propagation Model	Two-ray ground
Wireless Standard	802.11b
Routing Protocol	OLSR
Size of Queue	50 packets
Transport Layer	UDP
Traffic Type	CBR
Packet Size	512 Byte

6.2 Performance Evaluation Metrics

In this paper, we evaluate and analyze the performance of both the proposed routing protocol and OLSR in terms of network control overhead and packet delivery ratio.

6.2.1 Network Control Overhead (NCO)

NCO refers to the proportion of the total number of control packets that are sent across the network by each node to the total number of data packets that are received by destinations. Control packets consist of route request packets, route reply packets, and error packets.

$$NCO = \frac{No\ of\ control\ messages\ sent}{No\ of\ data\ received} \tag{3}$$

The WCNs' routing protocol scheme's efficiency is proven through the measurement of network control overhead. Furthermore, we keep track of the quantity of control messages that are exchanged inside the network so that we can accurately reflect the stability of the network topology [14].

6.2.2 Packet Delivery Ratio (PDR)

The PDR of a network is the proportion of data packets that reach their intended destination successfully in comparison to the total number of packets that are sent by the sender. The PDR may be computed by getting the total number of packets that are delivered and dividing it by the total number of packets that are sent. The aim is to deliver as many data packets as possible to the final destination. Increased PDR results in improved network performance [15].

$$PDR = \frac{\sum_1^N CBR_{recv}}{\sum_1^N CBR_{send}} \quad (4)$$

Where N represents the number of data sources, CBR_{recv} refers to the total number of CBR packets that have been received. CBR_{send} refers to the total number of CBR packets that have been sent per source.
This metric is very important because it provides a description of the loss rate that can be experienced by the transport layer, which operates on top of the network layer. As a result, the PDR serves as a reflection of the maximum throughput that the network is capable of supporting.

6.3 Simulation Results

As previously stated, the NS-2 simulator is used in this research work to evaluate our proposed routing protocol. The extensive experiments are executed to evaluate the effectiveness of our proposed routing protocol compared to the standard OLSR. Two performance measurement metrics have been used to evaluate this approach, which are:

- NCO: It is the additional load created by the broadcasting of routing packets that helps to keep up-to-date routing information about the network.
- PDR: It measures how many packets are successfully delivered versus how many packets are sent out.

The number of nodes in the network is the main input parameter in this evaluation. This presents the descriptive statistics of how the parameter affects the proposed routing protocol. In addition, it's worth looking into how the size of the network affects the output parameters. The movement of each node in the network is completely random. The network size has been increased from 5 to 50 nodes. The number of mobile nodes is raised by 5 after each run. A random number is assigned to each node in order to facilitate mobility. At random intervals, each node moves in a random direction and subsequently changes its direction randomly. Every node has an initial energy level that is decreased as the network runs. Continuously using energy can lead to the full failure of nodes in a case when all of their energy has been consumed. Both OLSR and the proposed routing protocol are examined in this scenario. Afterwards, data is gathered in order to compare the proposed routing protocol with OLSR. Experiments and their results are detailed in the next subsections.

6.3.1 NCO

Fig. 8 shows the comparison between the proposed routing protocol and OLSR by using the NCO as a function of node density. The number of nodes is shown in X coordinates, while the NCO is shown in Y coordinates in percentage. It is obvious that the larger the network size, the greater the overhead of the network. Overhead goes up slightly for both OLSR and the extended OLSR as the network size increases. This is due to many factors:

- The exchange of control packets (e.g., routing packets, route requests, route replies) increases as the network size increases in order to update the routing tables.
- Furthermore, the exchange of control packets in order to update the MPR set.

The extended OLSR minimizes the NCO as compared to standard OLSR at small and large network sizes. This is due to the extension of multicast that leads to decreasing the flooding of control packets as well as modifying the MPR algorithm that leads to guaranteeing the stability of routes. From Table 2, we can find that the proposed routing protocol achieves a high improvement percentage compared to OLSR in both large network size and small network size. For network densities of 5, 10, and 15 nodes, the proposed routing protocol improves the NCO by approximately 19%. While, for a network density of 50 nodes, the proposed routing protocol improves the NCO by 11% compared to OLSR. This happens due to an increase in the total number of nodes. Results show that our proposed routing protocol outperforms the OLSR routing protocol by 18% on average in terms of network control overhead.

Table 2: NCO vs. network size

Network density	5	10	15	20	25	30	35	40	45	50
OLSR	0.7	0.75	0.76	0.79	0.82	0.85	0.89	0.93	0.96	0.99
Extended OLSR	0.52	0.56	0.57	0.59	0.61	0.67	0.7	0.76	0.79	0.88
Improvement (%)	18%	19%	19%	20%	21%	18%	19%	17%	17%	11%

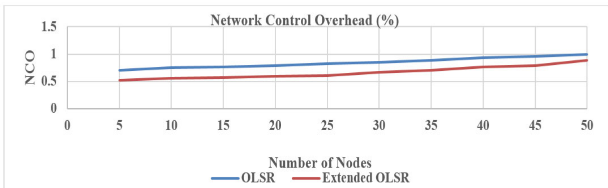

Fig. 8 NCO vs. network size

6.3.2 PDR

Fig. 9 shows the performance of the proposed routing protocol compared with OLSR in terms of PDR as a function of node density. The number of nodes is shown in X coordinates, while the PDR is shown in Y coordinates in percentage. It is obvious that the larger the network size, the more the PDR of the network. PDR goes on increase for both OLSR and the extended OLSR as the network size increases. This is due to the fact that with more nodes, it becomes easier to select a better MPR from neighboring nodes because the number of options grows. Moreover, from this figure it's obvious that the proposed routing protocol performs better than standard OLSR. This is due to the new modified MPR algorithm, which leads to the selection of MPR nodes that are more stable and robust. As a result, our proposed routing protocol decreases the frequency of link breaks when compared to existing techniques, and also decreases the frequency of queue overflow, which results in improving the PDR in the network. Table 3 shows that our proposed routing protocol slightly outperforms the OLSR routing protocol by 1% as an average in terms of PDR.

Table 3: PDR vs. network size

Network Density	5	10	15	20	25	30	35	40	45	50
OLSR	92.42	92.83	93.25	93.67	94.08	95.18	94.92	95.73	95.75	96.17
Extended OLSR	93.41	93.81	94.22	94.63	95.03	96.08	95.85	96.65	96.66	97.07
Improvement (%)	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%

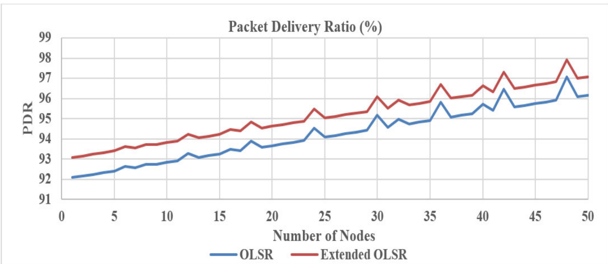

Fig. 9 PDR vs. network size

6.4 Discussion and Analysis

The extension of multicast leads to decreasing the flooding of control packets as well as modifying the MPR algorithm that leads to a guarantee of the stability of routes. Therefore, our proposed routing protocol minimizes the NCO as compared to standard OLSR on small and large scale networks by 18%. For network densities of 5, 10, and 15 nodes, the proposed routing protocol improved the NCO by approximately 19%. While, for a network density of 50 nodes, the proposed routing protocol improved the NCO by 11% compared to OLSR. This is due to the large-scale network.

The new proposed MPR algorithm leads to the selection of more stable and durable MPR nodes. As a result, it reduces the chances of path break as compared to other approaches, and also the chances of queue overflow are reduced in our proposed routing protocol, which results in improving the PDR in the network. Therefore, our proposed routing protocol slightly outperforms the OLSR routing protocol by 1% on average in terms of PDR. Furthermore, with more nodes, it becomes easier to select a better MPR from neighboring nodes because the number of options grows. Therefore, PDR goes on increasing for both OLSR and the extended OLSR as the network size increases.

7. Conclusion

In this paper, we propose an enhanced routing protocol for WCNs based on the OLSR protocol to meet the standards of efficiency in terms of stability and scalability. Enhancements include multicasting expansion and MPR selection based on AHP. Firstly, the extension of multicast leads to decreasing the flooding of control packets as well as improving the MPR algorithm that leads to a guarantee of the stability of routes. Secondly, the new proposed MPR algorithm leads to selecting more stable and durable MPR nodes. As a result, it reduces the chances of path break as compared to other approaches, and also the chances of queue overflow are reduced in our proposed routing protocol.

References

[1] H. M Kadhim and A. A Oglah, "Congestion Avoidance and Control in Internet Router Based on Fuzzy AQM," Engineering and Technology Journal, vol. 39, pp. 233-247, 2021.
[2] M. Abdel-Nasser, K. Mahmoud, O. A. Omer, M. Lehtonen, and D. Puig, "Link quality prediction in wireless community networks using deep recurrent neural networks," Alexandria Engineering Journal, vol. 59, pp. 3531-3543, 2020.
[3] U. K. Addanki and B. H. Kumar, "Enhancement OLSR Routing Protocol using Particle Swarm Optimization (PSO) and Genrtic Algorithm (GA) in MANETS," International Journal of Computer Science & Network Security, vol. 22, pp. 131-138, 2022.
[4] A. Nabou, M. D. Laanaoui, and M. Ouzzif, "New MPR computation for securing OLSR routing protocol against single black hole attack," Wireless Personal Communications, vol. 117, pp. 525-544, 2021.
[5] Y. Liu, C. M. Eckert, and C. Earl, "A review of fuzzy AHP methods for decision-making with subjective judgements," Expert Systems with Applications, vol. 161, p. 113738, 2020.
[6] B.-S. Kim, S. Ullah, K. H. Kim, B. Roh, J.-H. Ham, and K.-I. Kim, "An enhanced geographical routing protocol based on multi-criteria decision making method in mobile ad-hoc networks," Ad Hoc Networks, vol. 103, p. 102157, 2020.
[7] V. Bianchi, P. Ciampolini, and I. De Munari, "RSSI-based indoor localization and identification for ZigBee wireless sensor networks in smart homes," IEEE Transactions on Instrumentation and Measurement, vol. 68, pp. 566-575, 2018.
[8] M. H. Rehmani and Y. Saleem, "Network simulator NS-2," in Encyclopedia of Information Science and Technology, Third Edition, ed: IGI Global, 2015, pp. 6249-6258.

[9] C. Barz, C. Fuchs, J. Kirchhoff, J. Niewiejska, and H. Rogge, "OLSRv2 for Community Networks: Using Directional Airtime Metric with external radios," Computer Networks, vol. 93, pp. 324-341, 2015.

[10] A. Neumann, E. López, and L. Navarro, "An evaluation of bmx6 for community wireless networks," in Wireless and Mobile Computing, Networking and Communications (WiMob), 2012 IEEE 8th International Conference on, 2012, pp. 651-658.

[11] A. Neumann, E. López, and L. Navarro, "Evaluation of mesh routing protocols for wireless community networks," Computer Networks, vol. 93, pp. 308-323, 2015.

[12] P. Millan, C. Molina, E. Medina, D. Vega, R. Meseguer, B. Braem, et al., "Tracking and predicting link quality in wireless community networks," in Wireless and Mobile Computing, Networking and Communications (WiMob), 2014 IEEE 10th International Conference on, 2014, pp. 239-244.

[13] Y. Tsado, K. A. Gamage, B. Adebisi, D. Lund, K. M. Rabie, and A. Ikpehai, "Improving the reliability of optimised link state routing in a smart grid neighbour area network based wireless mesh network using multiple metrics," Energies, vol. 10, p. 287, 2017.

[14] L. Lassouaoui, S. Rovedakis, F. Sailhan, and A. Wei, "Evaluation of energy aware routing metrics for RPL," in 2016 IEEE 12th International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob), 2016, pp. 1-8.

[15] H. Kaur and S. Saxena, "UWDBCSN analysis during node replication attack in WSN," in Handbook of Research on Information Security in Biomedical Signal Processing, ed: IGI global, 2018, pp. 210-227.

Safaa Saad-Eldeen Ahmed Matter, she received her Bachelor's degree in Information Technology from Menofiya University, Egypt. She obtained her Master's degree in Information Technology from Menofiya University, Egypt. Currently she is a Ph.D. candidate at International Islamic University Malaysia. The area of her research interest lies in Wireless Computer Networks, Evaluating and improving routing protocols performance using network simulators. She is also working as a lecturer in Computer Science department, at King Khalid University, Saudi Arabia Kingdom since 2010. She has been Head of Computer Science department since 2013 till 2017. She is a member in Quality and Academic development committee.

Prof. Dr. Imad Al-shaikhli is a professor and the head of research at IIUM (International Islamic University Malaysia). He is also a lecturer at the Faculty of Information and communication Technology. He is a IEEE senior member, obtained his BSc (Hon) in Mathematics, MSc in Computer Science from Iraq, and Ph.D degree from Pune University, India, 2000. He has been the editor in chief of International journal on Advanced Computer Science and Technology Research since 2011 now, and the general chair of the international conference on Advanced Computer Science Applications and Technologies since 2012 till now. He obtained a US patent for his work with his Ph.D student on smart traffic light with accident detection system on 2nd December 2014. Prof. Imad has published more than 100 papers, journals and book chapters in addition to three books.

Prof. Dr. Aisha Hassan Abdalla Hashim is a professor and the deputy director of the office of international affairs at IIUM (International Islamic University Malaysia). She is also a lecturer at the Faculty of Engineering. She obtained her BSc in Engineering Technology from University of Gezira - Sudan, MSc in Computer Science from University of Khartoum – Sudan, and Ph.D in Engineering from International Islamic University Malaysia. She is IEEE computer society member, IEEE Computer Society. Also, she is IET Member, Institution of Engineering and Technology, UK. She is a working in the GIAD - IAT Project since 2018, Fundamental study of blood glucose solution models using a novel stepped impedance RF sensor for improved continuous monitoring of diabetic patients since 2017, Modeling Novel Maximum power point Tracking Algorithm for Small Scale Wind Turbine System since 2017, Training Teachers from Sudanese International Schools since 2016, Dynamic Scheduling Algorithm for Cloud Computing since 2016.

Abdelmoty M. Ahmed received his B.Sc., M.Sc. and PhD degrees from Systems and Computers Engineering, Faculty of Engineering, Al- Azhar University in Cairo, Egypt. His research interests include Digital image processing, Artificial intelligent, pattern recognition, Human Computer Interaction, Computer Graphics, machine learning ,Deep Learning , E-Learning, Intelligence Systems Engineering , Computer Vision and IOT systems., he is senior lecturer in computer engineering department at College of Computer Science, King Khalid University, Abha, Saudi Arabia, He is also interested in researching the technical fields that serve deaf and dumb and also works in the automatic translation of the Arabic Sign Language. he is having 20 years of teaching and research experience at various reputed Universities of Egypt and Saudi Arabia. His Ph.D thesis focused on the automatic translation of the Arabic Sign Language. He has published more research articles in reputed SCI and scopus indexed journals and conferences.

Mahmoud M. Khattab received his B.Sc. (2005) and M.Sc. (2009) degrees in computer science from faculty of computers and information, Menofiya University, Egypt. He earned his Ph.D. (2022) degree in computer science from kulliyyah (faculty) of information and communication technology, International Islamic University Malaysia (IIUM), Kuala Lumpur, Malaysia. The area of his research interest lies in super-resolution, image processing, pattern recognition, artificial intelligent, and computer vision. He is a lecturer in computer science department at King Khalid University (KKU), Saudi Arabia.