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Energy Aware On-Demand Routing Protocol Scheme of DSR Protocol (EAORP)

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Abstract

Recently, there has been a need for connectivity in places with no infrastructure. In order to meet this need, new technology known as MANET is used to fulfil the market demand. Despite the many benefits that MANET will provide, a number of shortcomings still need to be further studied, especially the energy consumption problems, that stand in the way of not allowing widespread acceptance of this technology. Because wireless devices use batteries with a finite amount of power, energy efficiency in these networks becomes a concern. In this paper, we present a design of energy aware on-demand routing protocol (EAORP), a new energy efficient algorithm that aims to overcome the shortcomings of DSR and provide a scalable traffic based and energy aware routing algorithm which aims to address energy issues in DSR by making it more aware and sensitive to nodes' energy, traffic loads, and transmission power management.

Keywords: Dynamic Source Routing (DSR), Energy Efficient Routing, Mobile Ad Hoc Network, Transmission Power Control

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1. Introduction

The use of mobile technologies that enable ubiquitous communications is currently quite popular. In mobile ad hoc network (MANET), there is no predetermined order made for the roles that each node should take. No prior arrangement has been specified regarding the roles that each node must play. Instead, each node independently decides what to do based on the current state of the network and without using any preexisting network infrastructure. By finding and maintaining the routes to other nodes, each node in a MANET is expected to take the role of a router [1].

There are many advantages associated with wireless networks that have led to their popularity and widespread acceptance compared to wired networks such as ease of deployment and use, mobility, cost-effectiveness, and flexibility [2,3]. Mobile ad hoc networks (MANETs) are important and very useful branch of wireless networks. However, there is a cost associated with using such adaptable networks. The challenge of energy efficiency in these networks arises from the short battery life of wireless devices.

It is necessary for routing protocols in MANETs to have a mechanism that sends data fast and more effectively to reduce the amount of time needed to send packets, which will reduce energy consumption and increase network performance [4,5]. Nodes in MANETs are highly dynamic; as a result, links regularly fail, increasing the routing overhead required to fix or replace these routes. The pressure on the finite energy resource (Batteries) increases as a result, and network longevity is seriously threatened. To maximize network lifetime and improve overall network performance, there is a high demand for a routing protocol that uses less energy.

MANET is considered a multi benefit network, it has not achieved a good quality of service due to the constant topology change and unpredictable nature of the wireless

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medium [6]. Power management is an important factor in MANETs since nodes operate on limited battery energy, and therefore a power control mechanism is necessary. Power control provides efficient use of a node's transmission power in order to reduce interference and energy consumption.

DSR is commonly used routing protocol in MANETs. Although DSR has many advantages [7], it does have some demerits, which degrades its performance in certain scenarios. DSR's unawareness of traffic load during route creation and packets forwarding process leads to more congested routes, which results to packet loss and more routing overhead. Furthermore, all packets are transmitted with maximum power in DSR, which results in greater energy consumption and less network lifetime. Therefore, this paper aims to overcome the shortcomings of DSR and provide a scalable traffic based and energy aware routing algorithm which aims to address energy issues in DSR by making it more aware and sensitive to nodes' energy, traffic loads, and transmission power management.

2. Related Research Work

A novel algorithm called LS-MDSR has been introduced [8]. The proposed algorithm could improve the performance of ad-hoc network in terms of average end to end delay, average jitter, residual power and throughput. The algorithm reduced the flooding of route request packets. This approach reduced the energy consumption and congestion. In comparison with DSR, the LS-MDSR used better utilization of bandwidth, increased throughput and average residual batter power. It reduced the jitter and end to end delay.

The authors [9] considered the problem of adjusting the transmission power of the nodes to an optimal power level and incorporated low power consumption strategies into the routing protocol through cross-layer model between MAC Layer and Network Layer.

The authors evaluated the performance of their proposed energy efficient cross-layer design to AODV. They investigated and implemented the required changes in the route discovery process using cross-layer approach in the AODV. Cross-layer routing protocol, compared to AODV, delivers performance improvements in terms of total transmission power, energy efficiency, energy consumption per node, and throughput, according to simulation results.

In [10] paper, the main potential factors to energy depletion are looked into. In an effort to increase network lifetime, routing metrics in the routing decision technique were devised and implemented into the standard routing protocol for evaluation. According to the authors, the modified routing extends the network lifetime by between (5%-10%) and it results in a small improvement in performance, in terms of Packet Delivery Ratio. and End-to-End delay.

The authors took into consideration three metrics in their proposed routing scheme: RSSI and residual energy. The RSSI factor ensures that packets with acceptable received signal strength value are processed, in order to prolong the communication session between source and destination nodes. Residual energy is crucial, because they wanted to choose paths, which include less depleted nodes. Finally, node degree contributes to reducing the energy consumption due to overhearing in the neighbour nodes of a possible intermediate node of the selected path.

A new mechanism called DPCM (Density Power Control Mechanism) [11], it adapts power transmission by using a cross-layering strategy between the lower layers and the AODV routing protocol. It aims to lower collisions, keep or enhance AODV performance, and conserve power in the nodes. The results from the research indicated that this mechanism can improve the performance of the network and save power at the same time. Moreover, it is especially useful for low and medium densities scenarios.

The authors [12] worked on link quality issues in AODV and attempted to improve it. Cross-layer design (CLD) interaction in the OSI communication model can be used to fix link quality issues. They proposed a technique called Reliable-AODV. The OSI model's physical and network layers interact to implement cross-layer design (CLD). Their findings indicate that the system's performance has improved in terms of parameters like throughput, Packet Delivery Ratio (PDR), and a reduction in packet losses and network delay. According to their finding the proposed technique shows performance gain throughput increased by 10%, PDR increased by 7%, and packet loss and latency decreased.

3. Dynamic Source Routing (DSR)

DSR is based on the concept of source routing. In DSR every node is required to keep a route cache where it stores learned source routes. Every time new routes are learned; the route cache is updated with new entries. DSR does not require a periodic routing update, which lowers network bandwidth, preserves battery life, and avoids network routing updates. DSR relies on support from lower layers in the event of a link failure. Route discovery and route maintenance are the two important phases of DSR. When a node wants to deliver a packet to a target node, it first checks its route cache, to see if it already has a path to the destination. If a route entry is discovered, the packet will be sent through this route. On the other side, if no entry is discovered, a route discovery is initiated by broadcasting a route request packet. The source address, the destination node's address, and an individual identification number are all included in the route request [7]. When a packet arrives, each node checks to see if it already has a route to the destination; if not, it adds itself to the route record before sending the packet to the outgoing link. In order to reduce the amount of route requests propagating on the outbound links, a mobile will only forward a route request if it hasn't already seen it, and if its address doesn't already exist in the route record. A route reply is created and it contains a route record with the hop-by-hop information when a request packet either reaches its destination, or reaches an intermediary node that has a valid route for the destination in its cache. Figure 1 and Figure 2 show the ROUTE REQUEST and ROUTE REPLY process respectively.

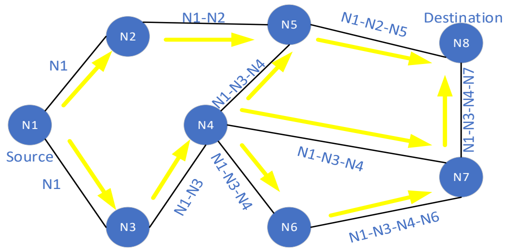

Figure 1. DSR - Route discovery and building the route record

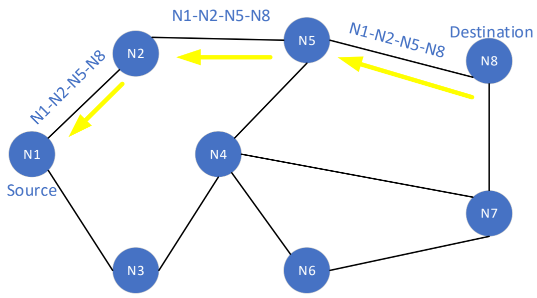

Figure 2. DSR - Route reply with the route record

The mechanism of Route Maintenance comes in when a link failure is discovered. When the data link layer encounters a problem, a route error is produced. The node's route cache is flushed when an error packet is received, removing its entry. Additionally, acknowledgements are utilized for verification to guarantee the proper operation of the route links.

4. Overview of (EAORP) Protocol

Although DSR is commonly used routing protocol in MANETs. By adopting this routing protocol in MANETs, the network performance degrades due to the movements of nodes from one area to another. Since mobile nodes operate on limited energy batteries, their radio frequency (RF) coverage is also limited. This affects the network negatively because mobile nodes lose connection with their neighbouring nodes, and hence unable to update their routing tables properly. The moving process from one area to another consumes more energy in terms of exchanging control packets. Therefore, there is a need for a modification of DSR in order to be energy efficient.

The main strategy of the proposed algorithm (EAORP) is to reduce the nodes' energy usage together with the modification of transmission power as required and taking into account the nodes' traffic loads.

4.1. Route Creation of EAORP Protocol

The proposed algorithm consists of two phases: (a) Route Discovery and (b) Route Maintenance. In order to enhance energy efficiency, new modifications are introduced in the form of route request (RREQ) and route reply (RREP) packets. Two fields are introduced to the RREQ packet, where one field reveals the present location of a node, and the second is used to register connection efficiency factor (CEF). On the other side, two fields are introduced to the RREP packet, where one field is used to hold recommended adaptive transmission power (APOWt), and the second is used to register the route reply efficiency factor (RREF).

The proposed route discovery strategy attempts to avoid routes that are low on energy and overloaded with packets. Moreover, the signal strength of reply packets and data packets is adjusted via the chosen path according to the dimension between each pair of subsequent nodes, reducing the nodes' energy usage.

When a source node Ns wants to connect to a destination node Nd, it looks for a route in its routing cache. If it doesn't have a routing entry for that specific destination, the proposed protocol's route discovery procedure is initiated, which contains the coordinates of the source node and a field of connection efficiency factor (CEF)=3 to the nearby nodes. After receiving an RREQ packet, if an intermediary node has the correct route for the destination node, then the RREQ packet's reverse path is used to transmit an RREP packet to the source node. If otherwise, the intermediary node computes its efficiency factor (NEFFf) and suggested adaptive transmission power (APOWt), then stores (APOWt) in the route cache, and follows the steps below as shown in Figure 3.

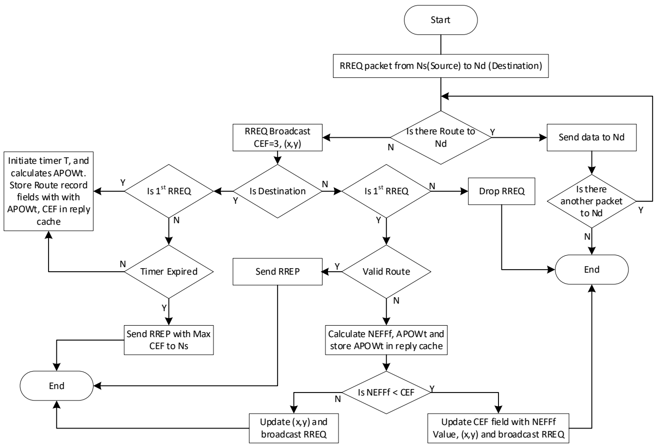

Figure 3. Routing Mechanism of EAORP

The intermediary node rebroadcasts the RREQ package and updates the (CEF) field with the value of (NEFFf) and the (x, y) field with its present position if (NEFFf) is less than (CEF). Else, it only rebroadcasts the RREQ package and updates the (x, y) field with its current location.

Repeated rebroadcasting occurs until the RREQ packet reaches the destination node. The lowest efficiency factor of the node via the path between the source node and the destination node is included in the RREQ package that has been received at the destination node, according to this context.

The RREQ may arrive at the destination node via different paths as a result of the rebroadcasting procedure. Thus, by letting the destination node wait for time period T to receive the identical RREQ packet several times, the destination node can compute its suggested adapted transmission power (APOWt) for each RREQ package it receives and store both (CEF) and (APOWt) in the reply cache. The destination node then selects the first two routes with the highest (CEF) after expiry time T. For each route selected, the destination node transmits an RREP packet via transmission power APt to the next intermediate node headed in the direction of the source node, carrying (REF):= (CEF) and (APT):= (APOWt). When an intermediate node receives an RREP packet, it modifies the field with the recommended (APOWt) value after storing the value of the APT field in its reply cache, also retransmits the route reply (RREP) packet to the following intermediate node along the route with the recommended (APOWt). The process continues until the source node receives the RREP packet.

4.2. Route Maintenance of EAORP Protocol

In the EAORP protocol, route maintenance is the method used to maintain the proper operation of an active route. In the event of a broken link during data packet transmission, a route error RERR packet is generated as shown in Figure 4.

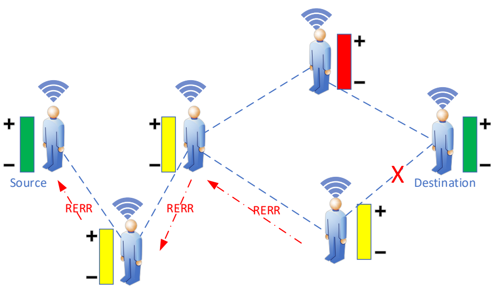

Figure 4. Route Maintenance Mechanism of EAORP

If this route is still needed and there isn't a backup in the cache, the source node must start a fresh route discovery process. if an alternative route is found, source node Ns resumes transmission of remaining data packages via this route.

5. Performance Evaluation

5.1. Simulation Model and Parameters

Network Simulator (NS-3.37) software was employed in order to evaluate EAORP Protocol. The Random Waypoint mobility model (RWP) [13] was employed. Table 1 displays the values for the energy model parameters that we utilized in our research, and Table 2 displays the values for the parameters that we used in our simulation scenarios.

Table 1 Parameters values of energy model

Parameter	Value
Initial Energy	1000 Joule
Transmission power	1.65 W
Receiving power	1.15 W
Idle power	0.8 W
Sleep power	0.01 W

Table 2 Parameters values of simulations scenarios

Parameters	Values
Number of Nodes	50
Number of Connections	5, 10, 15, 20, 25, 30
Simulation time	500 seconds
Topological area	1000x1000 m2
Node Speed	10 m/s
MAC Type	802.11
Channel Type	Wireless Channel
Routing Protocols	DSR, EAORP
Antenna Model	Omni Antenna
Radio propagation model	Two Ray Ground
Mobility model	Random Waypoint
Interface Queue Length	50
Interface Queue Type	DropTail/PriQueue
Pause time	4,10,50,100,250,500 sec
Traffic Type	CBR
Network Loads	4 packet/sec
Data Payload	512 bytes/packet

5.2. Simulation Results and Discussion

We have simulated 50 mobile nodes, two factors were used: the number of data connections and the pause time. Four main performance metrics are used to evaluate the researched protocol: Packet Delivery Fraction, Energy Consumed per Packet, Network Lifetime, and End-to-End Delay.

5.3. Scenario One

In this Scenario the Figure 5 illustrates the packet delivery fraction (ratio) percentage (%) of EAORP and DSR with respect to the number of connections.

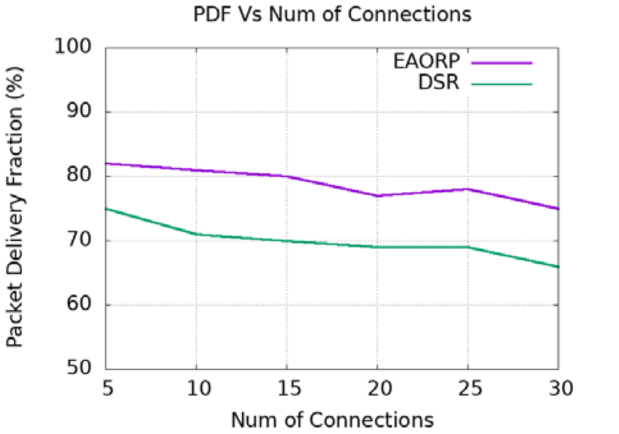

Figure 5. Scenario one - PDF Vs No of Connections

The proposed protocol clearly outperforms standard DSR, in term of the packet delivery fraction, the figure also shows the proposed protocol maintain a higher percentage of PDF over DSR with an improvement of 8-10% for most of the varying number of connections. This is a result of the EAORP routing algorithm, which takes into account more reliable routes with longer lifetime. While the DSR route discovery algorithm just considers the shortest route based on the number of hops between the source and the destination, overlooking the traffic load on the network or the remaining energy of the nodes, it simply broadcasts RREQ packets, which may pick an unreliable path that probably causing more data packet loss. However, even for a large number of connections, DSR performance does not decline significantly.

Overall, we can clearly see the performance deterioration of both protocols as the number of connections increases. The PDF for both protocols declines as the number of concurrent connection increases. This is due to the fact that an increase in the number of concurrent connections increases the likelihood of transmitted packets collision, which results in more data packets loss, thus reducing PDF.

The Figure 6 shows the effect of number of connections on the average energy consumption of the network.

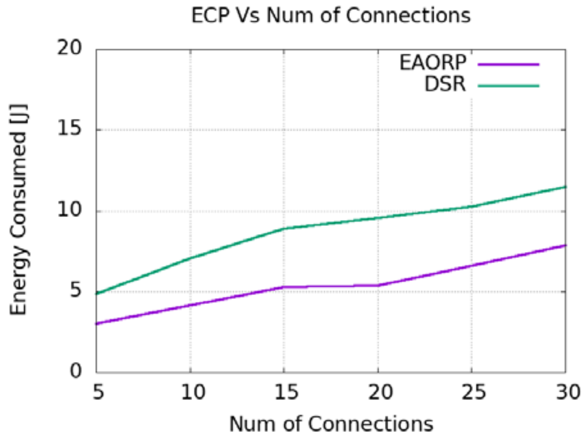

Figure 6. Scenario one – ECP Vs No of Connections

The energy consumption of the two protocols is rather low, similarly to scenario-one. Mainly, the proposed protocol outperforms standard DSR and uses less energy because EAORP has lesser routing overhead of routing overhead than the other routing protocol. From the figure we can clearly see that the proposed protocol is more energy efficient than its counterpart, with an improvement in energy efficiency of up to 42%.

This outperformance by the EAORP routing protocol is because of the selection of more reliable routes, and also because of the adaptive transmission power (APOWt) mechanism for sending RREP packets and data packets.

Figure 7 shows the network lifetime of the two compared routing protocols. We can see how the network lifetime decreases as network density increases.

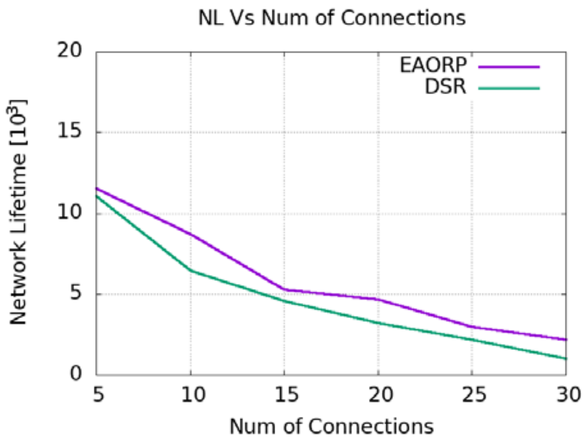

Figure 7. Scenario one - NL Vs No of Connections

This is because there are more RREQ packets flowing through the network, each node must process more routing packets, which consume node energy. Nevertheless, the proposed protocol performs better and prolong the network lifetime, even if the number of nodes is greater, because DSR protocol consumes more energy per packet than the EAORP.

As shown in the figure, as soon as there is a rise in the number of connections and with comparison to the proposed protocol, DSR performed poorly and its nodes depleted their energy more quickly, and this is as a result of the DSR route discovery and route selection mechanism. On the other hand, EAORP's routing mechanism is based on avoiding routes that are low on energy and overloaded with packets. This allows low-power nodes that are overloaded with packets to save energy for later use, hence extending the network lifetime.

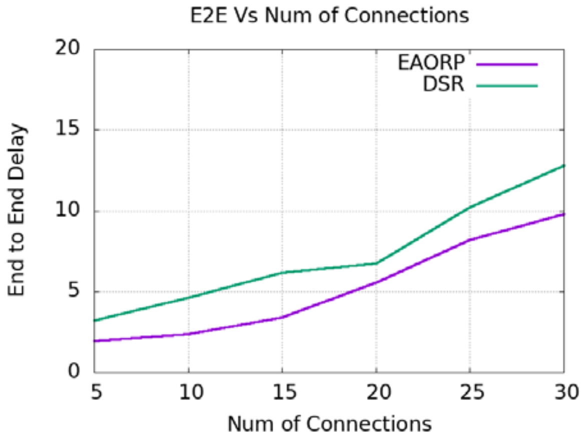

Figure 8. Scenario one – E2E Vs No of Connections

The Average End-to-End delay of EAORP and DSR protocols is represented in the Figure 8. The result shows that DSR experienced more delay than our proposed protocol. The figure illustrates that both protocols E2E delay will increase as the number of connections increases. This is due to the fact that the greater number of connections there are the more congested the network, which eventually increases the amount of time data packets must wait in the buffer along the route between the source node and destination node. As the figure illustrates, the proposed protocol is more efficient in terms of average delay time than its counterpart, with an improvement of approximately 30%.

5.4. Scenario Two

In this Scenario the Figure 9 illustrates the packet delivery fraction (ratio) percentage (%) of EAORP and DSR with respect to the pause time.

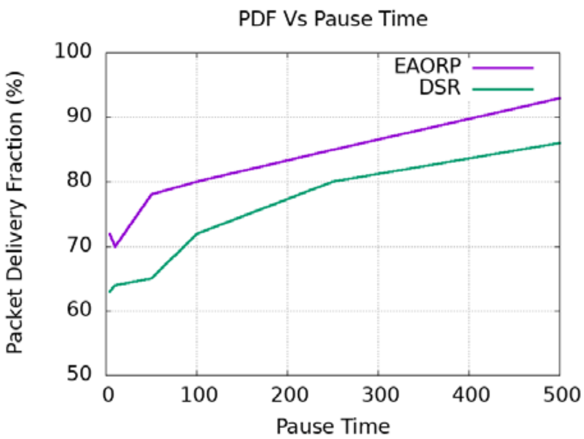

Figure 9. Scenario two - PDF Vs Pause Time

The node speed was kept constant in our research at 10 m/s, but the pause time value varied and took the following values: 4, 10, 50, 100, 250 and 500 seconds. The proposed protocol clearly outperforms standard DSR, in terms of the packet delivery fraction, the figure shows the proposed protocol maintain a higher percentage of PDF over DSR with an improvement of up to 15% for most pause time values. This is due to the routing method used by EAORP, which considers more reliable routes with longer lifetime, whereas DSR offers unsatisfying packet delivery ratio. However, for higher amounts of pause time, DSR performance gradually improves. Overall, we can clearly see the performance improvement of both protocols as the value of pause time increases. This is due to the stability of the topology between the connected nodes.

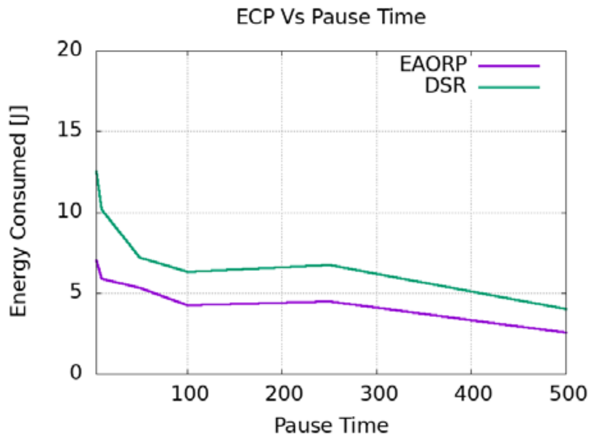

Figure 10. Scenario two - ECP Vs Pause Time

In General, the energy consumption of the two protocols is rather low, similarly to scenario-one. The Figure 10 shows the two routing protocols have an inverse relationship with the pause time, this is normal, because as the pause time increases, i.e., in a network relatively more stable, the route discovery processing will decrease. Due to this increasing stability of the network, the routes from the sending node to the receiving node, are much less prone to link failure, which eventually lead to less computation and decrease node energy consumption. Mainly, the proposed protocol outperforms standard DSR and uses less energy because EAORP uses less overhead than the other routing protocol. From the figure we can clearly see that the proposed protocol is more energy efficient than its counterpart, with an improvement in energy efficiency of up to 35%.

The EAORP routing protocol outperforms the other routing protocol because of its selection of more reliable routes as well as its adaptive transmission power mechanism for transmitting RREP packets and data packets.

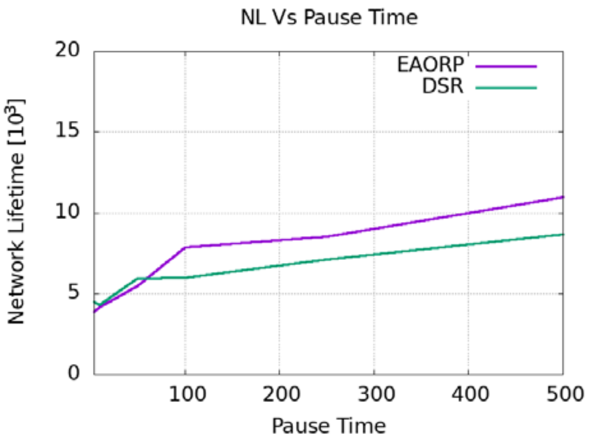

Figure 11. Scenario two - NL Vs Pause Time

In this scenario, we can see how the network lifetime decreases as network density increases as illustrated in Figure 11. This is because there are more RREQ packets flowing through the network, each node must process more routing packets, which consume node energy. Nevertheless, the proposed protocol performs better and prolong the network lifetime, even if the number of nodes is greater, because DSR protocol consumes more energy per packet than the EAORP. As shown in the figure, as soon as there is a rise in the pause time, compared to the proposed protocol, DSR performed badly and had nodes that depleted their energy more quickly, and this is as a result of the DSR route discovery and route selection mechanism. On the other hand, EAORP's routing mechanism is based on avoiding routes that are low on energy and overloaded with packets.

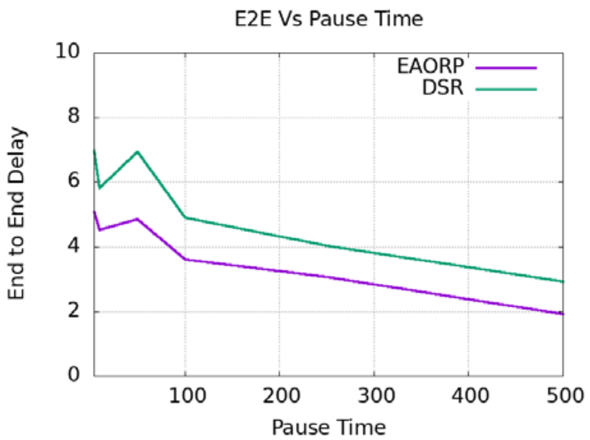

Figure 12. Scenario two – E2E Vs Pause Time

The EAORP and DSR protocols' average end-to-end delays are shown in Figure 12. The result shows that DSR experienced more delay than our proposed protocol. This is as a result of the route creation mechanism of EAORP, which avoids routes that overloaded with packets. Thus, decreasing the amount of time data packets must wait in the buffer. As the figure illustrates, the proposed protocol is more efficient in terms of average delay time than its counterpart, with an improvement of up to 27%.

It is clear that, E2E delay of both protocols decreases, with the increasing values of pause time. This is due to the fact that, the greater values of pause time there are the more stable the network, and this reduces the route discovery process, which eventually leads to reducing E2E delay time.

6. Conclusion

The development of energy-efficient routing protocols is essential in MANET. An energy-efficient routing protocol may perform poorly than a standard routing protocol if careful design has not been taken into account. In this paper, we propose an improved version of standard DSR, called (EAORP), by modifying the phases of route creation and route reply in a way that reduces nodes' energy usage and balances their traffic loads, along with adapting the transmission power of sent data packets among transmitting nodes, this results in longer node lifetimes, and generally more stable networks. Our performance studies show that EAORP protocol outperform original DSR with respect to: packet delivery fraction, energy consumed per packet, network lifetime, and end-to-end delay, and under several factors represented in terms of network density, load, and pause time.

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Declaration of interests
The authors declare that they have no known competing financial interests in this paper.

Conflict of Interest
All authors have no conflict of interest to report.

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