EXTENSION OF OPTIMIZED LINKED STATE ROUTING PROTOCOL FOR ENERGY EFFICIENT APPLICATIONS

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ABSTRACT

Mobile Ad-hoc network (MANET) is infrastructure less network in which nodes are mobile, self reconfigurable, battery powered. As nodes in MANET are battery powered, energy saving is an important issue. We are using routing protocol to save energy so as to extend network lifetime. We have extended original Optimized Linked State Routing (OLSR) protocol by using two algorithms and named it as Enhancement in OLSR using Residual Energy approach (EOLSR-RE) and Enhancement in OLSR using Energy Consumption approach (EOLSR-EC). To analyze relative performance of modified protocol EOLSR-RE and EOLSR-EC over OLSR, we performed various trials using Qualnet simulator. The performance of these routing protocols is analyzed in terms of energy consumption, control overheads, end to end delay, packet delivery ratio. The modified OLSR protocol improves energy efficiency of network by reducing 20 % energy consumption and 50% control overheads.

KEYWORDS

MANET, OLSR, EOLSR-RE, EOLSR-EC, QoS parameters.

1. INTRODUCTION

Ad-hoc network is one of the emerging trends in wireless communication. In conventional wireless communication there is need of base station for communication between two nodes. These base station leads to more infrastructure and more cost. An ad hoc network facilitates communication between nodes without the existence of an established infrastructure. Nodes are connected randomly using ad-hoc networking and routing among the nodes is done by forwarding packets from one to another which is decided dynamically. In general, MANET's are formed dynamically by an autonomous system of mobile nodes that are connected via wireless links without using any centralized administration [1]. Mobile nodes that are within each other's radio range communicate directly via wireless links, while those that are far apart rely on other nodes to relay messages as routers. Node mobility in an ad hoc network causes frequent changes of the network topology. The scopes of the ad-hoc network are also associated with dynamic topology changes, bandwidth-constrained, energy constrained operation, limited physical security, mobility-induced packet losses, limited wireless transmission range, broadcast nature of the wireless medium, hidden terminal problem, packet losses due to transmission errors [2].

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In Energy constrained operations, it is important to save energy which results in improvement in network lifetime. For example, in battle fields soldiers are unable to charge node batteries so there is need for them to save battery power in such a way that communication can be possible for longer time. To improve network lifetime there are different methodologies used at different layers of OSI model. Network layer is used for routing of packets from source to destination. There are number of routing protocols defined in MANET, for example DSDV, AODV, DSR, OLSR, ZRP etc. The main objective is to design routing protocol in such a way that it works effectively in energy constrained applications. The main focus is on OLSR routing protocol modification in network layer.

The paper is organized as follows. Section II explains different types of routing protocols. Section III discusses the basics of OLSR protocol and study of related energy aware techniques. Section IV discusses the proposed modification in OLSR. Section V represents the simulation details and QoS parameters. Section VI discusses results obtained by Qualnet simulator. Finally section VII concludes the paper with future work in section VIII.

2. CLASSIFICATION OF ROUTING PROTOCOL

In MANET, each node between source and destination acts as routers. The routing of data packets from source to destination are controlled by different routing protocols. Different routing protocols are classified as shown in Figure;

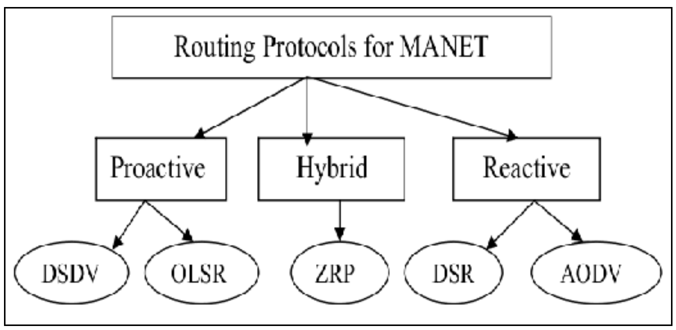


Figure 1.Classification of Routing Protocols

2.1. Proactive routing protocols

In proactive routing, each node has one or more tables that contain the latest information of the routes to any node in the network. Each node maintain routing tables and respond to the changes in the network topology by propagating updates throughout the network in order to maintain a consistent view of the network. Many proactive routing protocols have been proposed, for e.g. Destination Sequence Distance Vector (DSDV), Optimized Linked State Routing (OLSR) and so on.

2.2. Reactive protocols

Reactive routing protocols take a lazy approach to routing. They do not maintain or constantly update their route tables with the latest route topology. This type of routing creates routes only when desired by the source node. The source node initiates a process called route discovery when it requires a route to the destination. This process is completed when a route is found or when all the possible routes are examined. The process of route maintenance is carried out to maintain the established routes until either the destination becomes unavailable or when the route is no longer required.Several reactive protocols have been proposed such as Dynamic Source Routing protocol (DSR), Ad hoc On-demand Distance Vector (AODV), Temporary Ordered Routing Algorithm (TORA), and so on.

2.3. Hybrid routing protocols

This type of protocol is combination of table-driven (Proactive) and on demand (Reactive) routing protocol i.e. it contains features of proactive as well as reactive protocol.Several hybrids routing protocols have been proposed such as Zone Routing Protocol (ZRP), Zone-based Hierarchical Link State (ZHLS) and so on, but the most popular protocol is ZRP.

3. OLSR OVERVIEW AND RELATED WORK

OLSR [3] is proactive in nature, having routes immediately available in each node for all destinations in the network. OLSR is an optimization of pure link state routing protocol like Open Shortest Path First (OSPF) [4]. This optimization is related to concept of multipoint relay (MPR). A multipoint relay reduces the size of control messages. The use of MPRs also minimizes flooding of control traffic. Multipoint relays forward control messages, providing advantage of reduction in number of retransmissions of broadcast control messages. OLSR contains two types of control messages: neighborhood and topology messages, known as Hello messages and Topology Control (TC) messages. OLSR provides two main functionalities: Neighbor Discovery and Topology Dissemination. With the help of these two functionalities, each node computes routes to all known destinations.

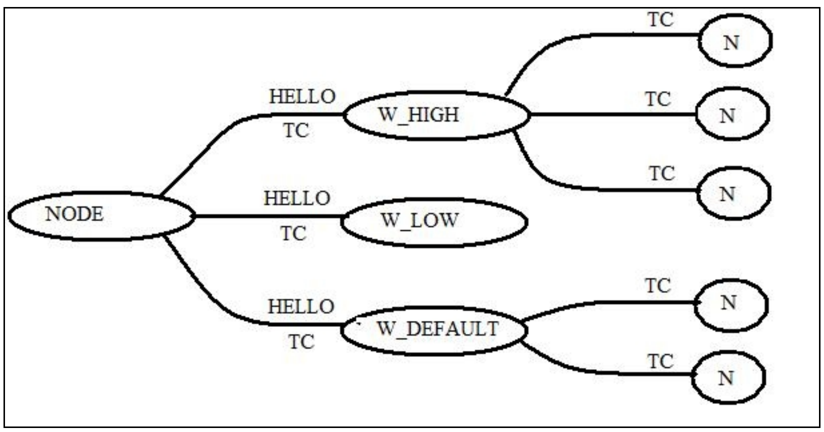


Figure 2.Selection of MPR and Broadcasting TC packets

3.1. Neighbor Discovery

Each node periodically broadcasts Hello messages, containing list of neighbors known to node and link status. The link status can be either symmetric or asymmetric, multipoint relay, or lost link. The Hello messages are received by all one-hop neighbors and not forwarded. Hello messages discover one-hop neighbors as well as its two-hop neighbors. Hello messages are broadcast at regular interval (Hello_interval). The neighborhood and two hop neighborhood information has holding time (Neighbor_hold_time), after which it is not valid. With the help of this information node selects its own set of MPRs among one-hop neighbors. Multipoint relays computed whenever there is change in one-hop neighborhood and two-hop neighborhood. MPR is one-hop neighbors with symmetric link, such that all two-hop neighbors has symmetric link with multipoint relays. Figure 2 shows selection of MPR node using HELLO packets. Node is selected as MPR node when it has willingness high i.e. W_HIGH or default i.e. W_DEFAULT otherwise rejected.

3.2. Topology Dissemination

Each node of the network maintains topological information about the network obtained with help of TC messages. Each node selected as MPR, broadcasts TC message at regular interval

(TC_interval). The TC message originated from node which declares MPR selectors of that node. If change occurs in MPR selector set, then TC message can be sent earlier than pre-specified interval. The TC messages are sent to all nodes in the network by taking advantage of MPR nodes to avoid number of retransmissions. Thus, a node is reachable directly or via its MPRs. The topological information collected in each node has holding time (Top_hold_time), after which information is not valid. Figure 2 shows broadcasting of TC message with the help of MPR nodes.

3.3. Route Calculation

The neighbor information and the topology information are refreshed periodically, and they enable each node to compute the routes to all known destinations. These routes are computed with Dijkstra's shortest path algorithm [5]. Hence, they are optimal with respect to the number of hops. Moreover, for any route, any intermediate node on this route is a MPR of the next node. The routing table is computed whenever there is a change in neighborhood or topology information.

3.4. HELLO and TC packet format

Reserved		Htime	Willingness
Link Code	Reserved	Link Message size	
Neighbor Interface Address			
Neighbor Interface Address			

Figure 3.OLSR HELLO Packet Format

ANSN	Reserved
Advertised Neighbor Main Address	
Advertised Neighbor Main Address	
....	

Figure 4.OLSR TC Packet Format

Figure 3 shows HELLO packet format for OLSR. The *Reserved* portion in HELLO packets is used for further modification. *Htime* specifies time before transmission of next HELLO packet. *Willingness* entry specifies node willingness to forward traffic. *Link Code* gives the information about link between sender node and neighbor node. It represents status of neighbor node. *Neighbor interface address* denotes address of interface of neighbor node. *Link Message size* gives total length of link messege.

Figure 4 represents TC packet format for OLSR. *Advertised Neighbor Sequence Number (ANSN)* which increments sequence number whenever there is change in neighbor set. *Reserved* field is used for further modification in TC packets. *Advertised Neighbor Main Address* field contains main address of neighbor node.

3.5. Study of Energy Efficient Routing Schemes

There are various ways to save energy from physical layer to application layer. In network layer energy saving can be possible by selecting energy efficient path for sending data from source to destination. The surveys of different energy saving techniques are discussed as below;

I. Stojmenovic and X. Lin [6] proposed localized power aware routing algorithms which are devised on the assumption that each network node has accurate information about the location of its neighbors and the destination node. Nodes exchange location information via control messages.

Three algorithms are proposed in [6]:

- Power-efficient routing: Each node decides to forward packets that are intended for a certain destination to a neighbor based on the minimum transmission power between this sending node and its neighbors.

- Cost-efficient routing: The node chooses the neighbor to send to, if the destination is not within reach, based on a cost function that can consist, for example, the sum of the cost of sending node to this neighbor plus the estimated cost of the route from the neighbor up to the destination. This latter part of the cost is assumed to be proportional to the number of hops in between.

- Power-cost efficient routing algorithms: Uses a combination of the two above metrics, in the form of either the product or the sum of these metrics.

C.K.Toh [7] explains MTPR (Minimum Total Transmission Power Routing) mechanism, where route having minimum transmission power is selected. The information of total energy consumption is provided along route using HELLO and TC packets in OLSR. Based on this information route is selected for sending data to destination.

CMMBCR (Conditional Max Min Battery Capacity Routing) [18] mechanism considers both the total transmission energy consumption of routes and the remaining power of nodes. When all nodes in some possible routes have sufficient remaining battery capacity, i.e. above a threshold, route with minimum total transmission power among the routes is chosen. Since less total power is required to forward packets for each connection, the load for most of the nodes must be reduced, and their by lifetime will be extended. But, if all routes have nodes with low battery capacity i.e. below the defined threshold, a route including nodes with lowest battery capacity must be avoided to extend the lifetime of these nodes.

Energy efficient technique for selection of MPR nodes is proposed by Saoucene Mahfoudh and Pascale Minet [8] where node considers residual energy for selection of MPR. The node having minimum residual energy is not selected as MPR. There are three policies are considered for selection of MPR.

- E: considers only residual energy of node itself.
- M1E: considers weighted residual energy of node itself and 1-hop neighbors.
- M2E: M2E considers weighted residual energy of node, 1-hop and 2-hop neighbors.

Minimum Drain Rate (MDR) mechanism is proposed for selection of path having maximum lifetime value in [9]. MDR mechanism calculates cost function which takes into account the drain rate index and residual battery power. Maximum lifetime value of a given path is determined by minimum cost value over the path. From the set routes, the route having highest maximum lifetime is selected for transmission.

The J. H. Chang and L. Tassiulas [10] proposed two algorithms with the aim of extending the network lifetime via optimizing the routing from an energy consumption perspective.

1. Flow augmentation (FA) algorithm: is based on creating a link cost function. This function considers the following parameters: energy cost for unit flow over the link, the initial energy and the remaining energy at the transmitting node. A good candidate for the selected path should consume less energy and should avoid nodes with low remaining energy.

2. Flow redirection (FR) algorithm: If we have multiple sources and destinations, then under the optimal flow (i.e. minimum lifetime over all nodes is maximized) the minimum lifetime of every path from the source to the destination is the same. The minimum lifetime of this set of paths can be increased by redirecting an arbitrarily small amount of flow to the paths whose lifetime is longer than these paths such that the minimum lifetime of the latter path after the redirection is still longer than the system lifetime before the redirection.

4. PROPOSED IDEA

In this section, the modification steps for OLSR protocol are discussed. The modified protocol is named as EOLSR. The OLSR protocol is modified in two processes i.e. while selecting MPR nodes and while calculating route for forwarding data.

4.1. MPR Selection

The existing OLSR consumes more energy in energy constrained applications which results in less network lifetime. To improve network lifetime as well as energy efficiency OLSR is modified by using two approaches as below;

1. By setting threshold for Residual Energy
2. By setting threshold for Energy Consumption

For MPR selection we have decided a threshold value, which is one third of initial energy for both residual energy and energy consumption approach.

- If the residual energy of node is less than threshold value then node having LOW-MPR-WILL while residual energy of node is greater than threshold value than node having HIGH-MPR-WILL.
- If the energy consumed by node is less than threshold value then node having HIGH-MPR-WILL while residual energy of node is greater than threshold value than node having LOW-MPR-WILL.

4.1. New HELLO and TC packet format

Residual Energy		Htime	Willingness
Link Code	Reserved	Link message size	
Neighbour Interface Address			
Neighbour Interface Address			

Figure 5.EOLSR-RE HELLO Packet Format

Energy Consumption		Htime	Willingness
LinkCode	Reserved	Link message size	
Neighbour Interface Address			
Neighbour Interface Address			

Figure 6.EOLSR-EC HELLO Packet Format

ANSN	***Residual Energy***
Advertised Neighbour Main Address	
Advertised Neighbour Main Address	
....	

Figure 7.EOLSR-RE TC Packet Format

ANSN	***Energy Consumption***
Advertised Neighbour Main Address	
Advertised Neighbour Main Address	
....	

Figure 8.EOLSR-EC TC Packet Format

HELLO packets are used for selection of MPR nodes. For selection of MPR each node having,

- Highest residual energy
- Lowest energy consumption

There is need to update residual energy of each node at regular interval. For this purpose the value of residual energy and energy consumed by node is included in HELLO packet as shown in Figure 5 and Figure 6 respectively. The reserved part in OLSR HELLO packet format as shown in Figure 3 is assigned to residual energy in EOLSR-RE and energy consumption in EOLSR-EC. Each node sends HELLO packet with entry for current residual energy and depending on threshold value set it selects MPR node.

The reserved part in TC packet as shown in Figure 4 is modified with entry for residual energy and energy consumption of node as shown in Figure 7 and Figure 8 respectively. The TC packets are forwarded to entire network with the help of MPR nodes. The TC packets are used to disseminate topology information over entire network. The modified TC packet format distributes residual energy of each node and energy consumed by each node over entire network. After knowing topology information for each node in network the route calculation is performed.

4.2. Steps for Modifications

1. Remove all entries from MPR table.
2. Selection of MPR
    - Residual Energy Approach
        a) Send HELLO packets with energy (residual energy) and willingness entries. Willingness is obtained by setting threshold value for residual energy.
        b) Select MPR nodes using willingness of that node in the network.
    - Energy Consumption Approach
        a) Send HELLO packets with energy (energy consumption of node) and willingness entries. Willingness is obtained by setting threshold value for energy consumption.
        b) Select MPR nodes using willingness of that node in the network.
2. If willingness of the node is HIGH then it is selected as MPR otherwise rejected.
3. After fixing MPR nodes TC packets are transmitted or broadcasted in the network. Only MPR nodes can retransmit or broadcast TC packets, other nodes cannot retransmit or broadcast TC packet.
4. After knowing topology information of all the nodes in network, route calculation is performed for getting all possible routes to destination in the network.
5. Route calculation:
    - Residual Energy Approach
        i. Remove all entries for route.
        ii. Residual energy of each node is compared with threshold value then following steps are taken into consideration for route selection,

    If residual energy of node is greater than threshold value then;
        a) Add new routing entries with symmetric neighbors (h=1) as destination nodes i.e. 1-hop neighbors
        b) New route entries for destination nodes h+ 1 hop are recorded in routing table. The new route entry is recorded by incrementing h by one each time till the destination node is achieved.
    - Energy Consumption Approach
        i. Remove all entries for route.
        ii. Energy consumed by each node is compared with threshold value then following steps are taken into consideration for route selection,

    If residual energy of node is greater than threshold value then;
        a) Add new routing entries with symmetric neighbors (h=1) as destination nodes i.e. 1-hop neighbors
        b) New route entries for destination nodes h+ 1 hop are recorded in routing table. The new route entry is recorded by incrementing h by one each time till the destination node is achieved.

4.3. Working of EOLSR-RE and EOLSR-EC

Figure 2 shows working of modified protocol from network initialization to routing of data packets from source to destination.

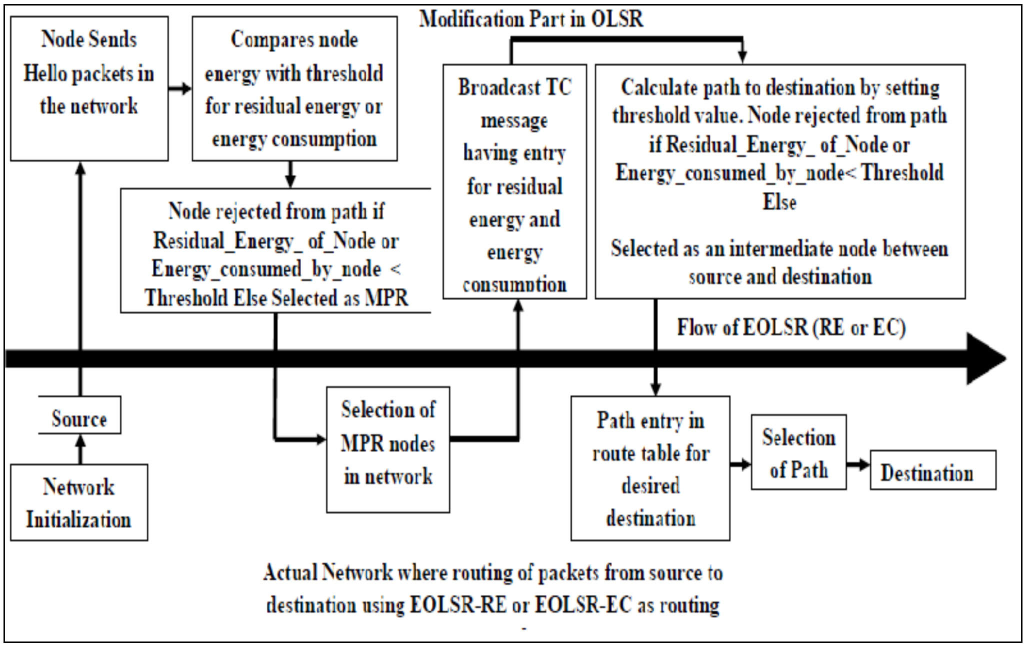


Figure 8.Working of EOLSR-RE and EOLSR-EC

5. Simulator Details and QoS Parameters

QualNet [11] is the first commercial simulator developed at the University of California, Los Angeles (UCLA). QualNet has a graphical user interface (GUI) for creating the model and its specification. So it is easier to specify small to medium networks by using the GUI compared to specifying all connections in a special model file manually. QualNet is a network simulator targeting at large wired and wireless networks. Qualnet is simulation software that provides simulations of MANET under different network conditions. Its environment and libraries are very sophisticated, which makes it very easy to simulate a real network with QualNet. It is used to predict the behaviour and performance of networks. In simple words, QualNet is described by using features such as speed, scalability, portability and extensibility. To analyze performance of EOLSR-RE over OLSR in Mobile Ad-hoc environment, we used QualNet version 5.0.2.

5.1. Simulation Models

A simulation model consists of Energy Model, Battery Model, Traffic Model and Mobility Model. The specifications for these models used in our experimentation are discussed as below;

5.1.1. Energy Model

The User-defined energy model [12] is a configurable model that allows the user to specify the energy consumption parameters of the radio in different power modes. The total power required for transmission, reception, idle (node is listening the medium) and sleep (node is not capable to detect signals so communication is not possible) modes is given in Table.

Table 1. Power requirement for different modes

Power requirement for different modes (Supply	**Power Values**
Transmission Power	0.84 Watts
Reception Power	0.612 Watts
Idle Power	0.534 Watts
Sleep Power	0.042 Watts

5.1.2. Battery Model: Linear Model

Nodes in the mobile ad-hoc network are battery operated. Hence, battery models are useful tools for such types of system design approach; because they enable analysis of the discharge behaviour of the battery under different design choices for example power management policies. We used Linear Battery Model for the experimentation.

5.2.3. Traffic Model

Constant Bit Rate (CBR) sources represent voice sources and ftp sources are the ones used for file transfer applications. We focus on Constant Bit Rate (CBR).The packet size is limited to 512 bytes. The source-destination pairs are chosen randomly over the network. The source-destination numbers are fixed (called connection number).

5.2.4. Mobility Model

We used random way point mobility model where nodes in network moves randomly in any direction with given speed.

5.2. Quality of Service (QoS) Parameters

5.2.1. Average End to End Delay

It is the average source-to-destination data packet delay including propagation and queuing delay [13]. For a highly interactive application such as IP phone, end-to-end delays smaller than 150 ms are not perceived by human listeners. Lesser end-to-end delay implies better performance.

5.2.2. Packet Delivery Fraction (PDF)

Ratio of number of packets successfully received by destination nodes to number of packets sent by source nodes.PDF describes information about packet loss rate [14]. Higher value of PDR for network indicates the better reliability of protocol.

5.2.3. Energy Consumed

Total energy consumed required to transmit all data packets to destination node. To achieve better energy efficiency, energy consumed should be as low as possible [15]. The less energy consumption by nodes extends the network lifetime i.e. nodes in the network can communicate for longer period.

5.2.4. Control Overheads

The total number of routing packets transmitted for each delivered data packet [16]. Lesser control overheads indicate that saving of energy in the network. Larger overheads utilise large bandwidth which cause congestion in the network. Hence, control overheads should be less.

6. Simulation Results and Performance Analysis

6.1. Impact of Variation of Node Density and Node Speed

To analyze performance of EOLSR-RE and EOLSR-EC over OLSR, the numbers of nodes as well as node speed are varied and compared with the help of QoS parameter discussed in section 5. Numbers of nodes are varied from 20 to 100 for fixed area to analyse performance of sparse and dense network. Speed is varied to study the impact mobility of node on network. Number of connections for simulations should be half as that of nodes present.

Table 2.Simulation Table

Parameters	**Variation of Number of Nodes**	**Variation of Node speed**	**Variation of Network Area (in square meter)**
Area	870x870	870x870	500,750,1000,1250,1500
Nodes	20,40,60,80,100	50	50
Node Speed	3m/s	1,3,5,8.10 m/s	3 m/s
Simulation Time	500 s	500 s	500 s
Traffic Type	CBR	CBR	CBR
Traffic Sources	9,18,27,36,45	20	16,18,20,22,24
Packet Rate	2 packets/sec	2 packets/sec	2 packets/sec
Initial Power	30 mAHr	30 mAHr	30 mAHr
Routing Protocol	EOLSR,OLSR	EOLSR,OLSR	EOLSR,OLSR

6.1.1. Average end to end delay

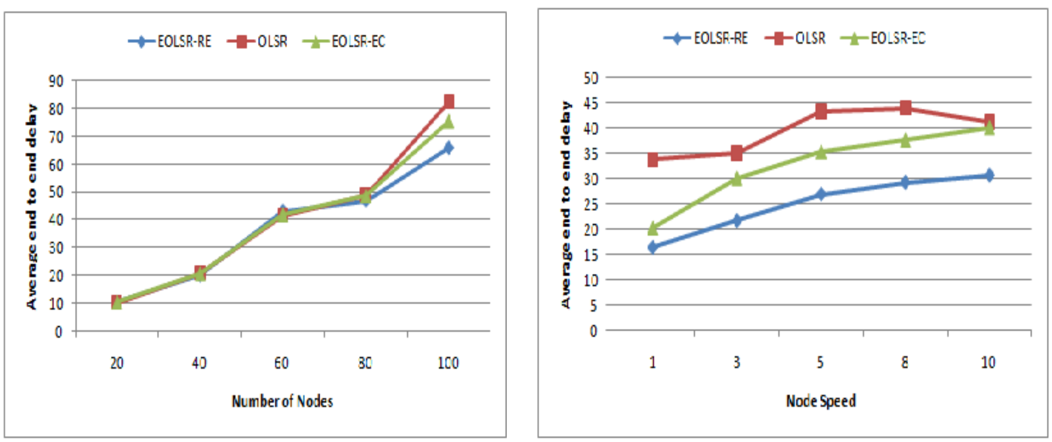


Figure 10: Impact of Variation of Number of Nodes and Node Speed on Average end to end delay

Figure10 depicts end to end delay for EOLSR-RE, OLSR and EOLSR-EC protocols for number of nodes from 20 to 100 and node speed 1 to 10 m/s. It is clear that EOLSR-RE has shortest delay than EOLR-EC and OLSR. On an average EOLSR-EC shows better performance than OLSR after 80 nodes and for all speed. For sparse network delay is almost same for all three protocols while for dense network EOLSR-RE shows shortest delay.

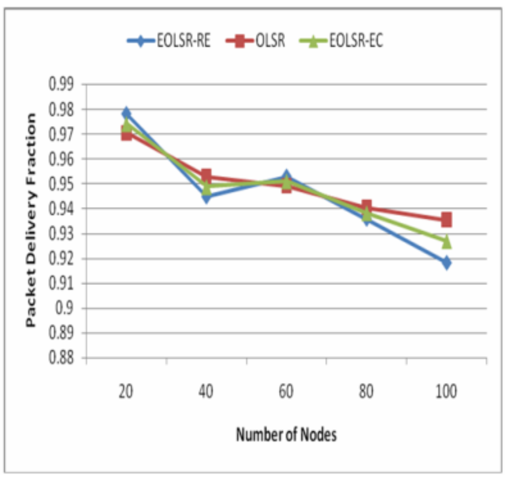
Table 3.Impact of variation of Network Area on Average end to end delay

Network Area	**Average end to end delay**				
	EOLSR-RE	**OLSR**	**EOLSR-EC**	**% Change in EOLSR-RE**	**% Change in EOLSR-EC**
500	20.4776	20.4522	20.4255	0.254424	0.130548
750	30.603	30.651	30.6912	-0.28821	-0.13115
1000	26.3986	30.551	32.0975	-21.5879	-5.06203
1250	29.9792	31.5423	32.7616	-9.2811	-3.8656
1500	28.0124	29.1243	30.3985	-8.51801	-4.37504

As shown in Table 3, the average end to end delay increases with increase in network area. On an average, there is 10% less delay in EOLSR-RE and 5% less delay in EOLSR-EC. It is seen that as network area increases delay has higher value in all three protocols.

Note: In presented Tables, +ve sign shows higher value of EOLSR parameter as compared to OLSR while –ve sign shows lesser value.

6.1.2. Packet Delivery Fraction (PDF)



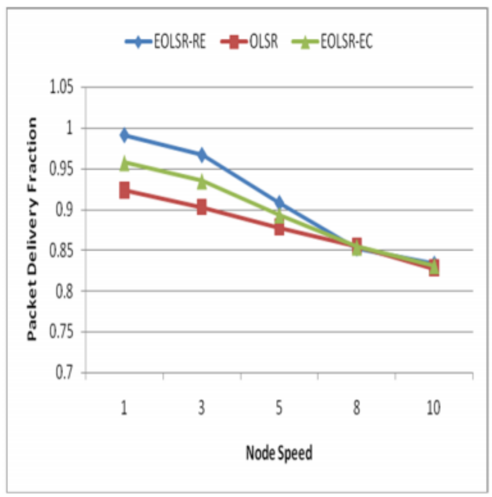


Figure 11: Impact of Variation of Number of Nodes and Node Speed on Packet Delivery Fraction

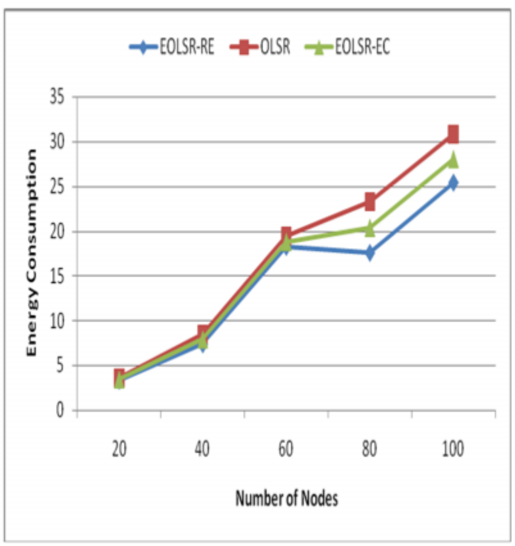
The impact of variation of nodes and node speed on packet delivery is as shown in Figure 11.It is seen that packet delivery is almost same over the entire node range and it shows decreasing trend. For lower speed EOLSR-RE has better packet delivery than OLSR and EOLSR-EC while for higher speed packet delivery is almost same for all three protocols. It is observed that PDF falls with increasing node speed.

Table 4.Impact of variation of Number of Connections on Packet Delivery Fraction (PDF)

Network Area	Packet Delivery Fraction (PDF)				
	EOLSR-RE	OLSR	EOLSR-EC	% Change in EOLSR-RE	% Change in EOLSR-EC
500	0.9825	0.98	0.974	0.2551	-0.612245
750	0.9163	0.9041	0.9095	1.34941	0.59728
1000	0.8884	0.879	0.88	1.0694	0.11377
1250	0.782	0.763	0.7715	2.49017	1.11402
1500	0.7311	0.725	0.7295	0.84138	0.62069

As shown in Table 4, packet delivery decreases with increase in network area. It is seen that for network area from 500 to 1000, packet delivery is above 90%.

6.1.3. Energy Consumption



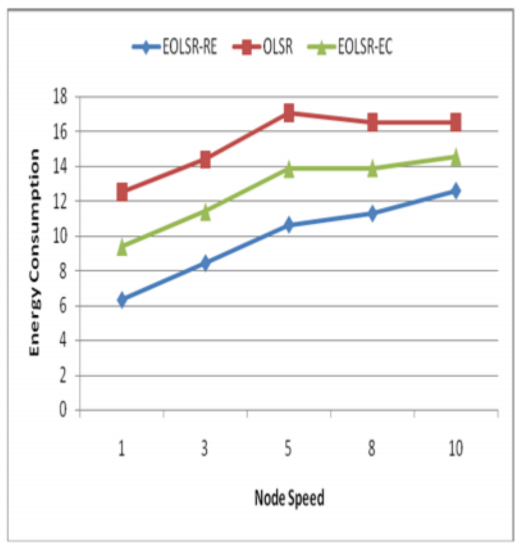


Figure 12: Impact of Variation of Number of Nodes and Node Speed on Energy Consumption

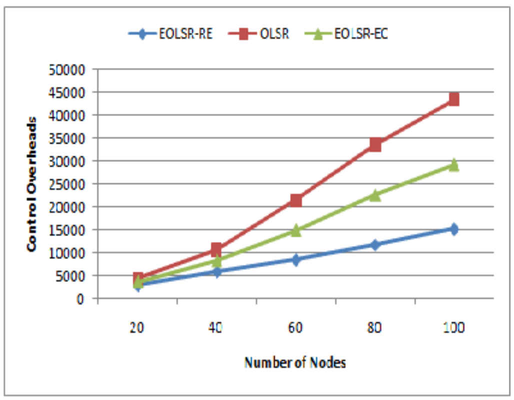
Figure 12 shows effect of node variation and speed variation on energy consumption. In case of EOLSR-RE, energy consumption has lesser value than OLSR and EOLSR-EC which is almost 20% less than OLSR and 10% less than EOLSR-EC. It is seen that for three protocols there is increasing trend of energy consumption for both cases number of nodes and node speed variation.

Table 5.Impact of variation of number of connections on Energy Consumption

Network Area	Energy Consumption				
	EOLSR-RE	OLSR	EOLSR-EC	% Change in EOLSR-RE	% Change in EOLSR-EC
500	8.75221	8.7973	8.773	-0.512544	-0.276221
750	11.8435	12.1369	12.003	-2.417421	-1.103247
1000	12.5696	14.7226	13.651	-14.62378	-7.278606
1250	11.484	13.6699	12.654	-15.99061	-7.431656
1500	10.7062	11.0749	10.991	-3.32915	-0.757569

The energy consumption reduces by 15% in EOLSR-RE and 7% in EOLSR-EC as shown in Table 5. It is observed that energy consumption decreases with increase in network area.

6.1.4. Control Overheads



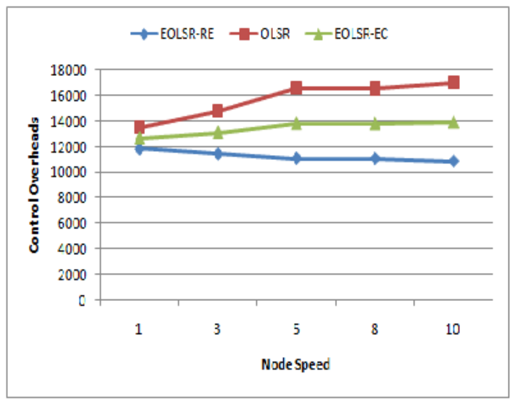


Figure 13: Impact of Variation of Number of Nodes and Node Speed on Control Overheads

The control overheads for EOLSR-RE are 50% less than OLSR and 25% less than EOLSR-EC as shown in Figure 13. The control overheads are increases with increase in number of nodes while remains constant for increase in node speed.

Table 6.Impact of variation of number of connections on Control Overheads

Network Area	Control Overheads				
	EOLSR-RE	OLSR	EOLSR-EC	% Change in EOLSR-RE	% Change in EOLSR-EC
500	10471.18	11019.04	10922.11	-4.971939	-0.879659
750	7661.66	13119.86	9211.21	-41.60258	-29.79186
1000	7382.28	17389.76	8654.32	-57.54812	-50.23324
1250	9352.72	16247.58	14312.21	-42.43623	-11.91174
1500	8256.58	14394.06	12346.12	-42.63898	-14.22767

There is almost 40% reduction in control overheads in EOLSR-RE and 15% reduction in EOLSR-EC as shown in Table 6. Control overheads decreases with increase in network area which indicates there is more impact of network area on control overheads.

7. CONCLUSION

Experimental results demonstrate that the proposed EOLSR-RE protocol results in a 20 percent and EOLSR-EC protocol results in 10 percent of energy saving and this saving is obtained starting from the transmission of the first packet. Subsequent packets transmitted using the EOLSR-RE and EOLSR-EC protocol will result in further energy savings. From this discussion, we can say that EOLSR-RE is best protocol in terms of energy efficiency.

Using the Qualnet simulator, we compared EOLSR-RE and EOLSR-EC with OLSR for number of nodes variations. After analyzing results, it is seen that EOLSR-RE is delivering approximately similar number of packets than OLSR, consuming less energy, requires less control overheads and less end to end delay. Our simulations showed that OLSR-RE is able to improve network lifetime and save energy. This indicates EOLSR-RE is an energy efficient routing protocol and can be used where energy saving is an important criteria. EOLSR-RE is suitable choice in military applications, disaster recovery areas and remote areas such as forests where energy saving is important need.

8. FUTURE WORK

Future work can be extended for combination of both energy consumption and residual energy. Later comparison of all three techniques can be done to check the best approaches as per requirement.

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