Multipath OLSR with Energy Optimization in Mobile Adhoc NETwork (MANET)

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Abstract. Mobile Adhoc Network (MANET) eliminates the complexity associated with an infrastructure networks. Wireless devices are allowed to communicate on the fly for applications. It does not rely on base station to coordinate the flow of the nodes in the network. This paper introduces an algorithm of multipath OLSR (Optimized Link State Routing) for energy optimization of the nodes in the network. It is concluded that this solution improves the number of nodes alive by about 10 to 25% by always choosing energy optimized paths in the network.

Keywords: OLSR, multipath, energy optimization, nodes alive.

1 Introduction

A Mobile Adhoc NETwork (MANET) is a multi-hop, distributed and self configuration network[1].The communication between two distant nodes is through the number of intermediate nodes which relays the information from one point to another. As nodes can move randomly within the network, routing packets between any pair of nodes become a challenging task. A route that is believed to be optimal for energy utilization at certain time might not be optimal at all, few moments later [4].

Traditional proactive routing protocols [3,5] maintain routes to all nodes. Even if traffic is unchanged, repeated topology interaction happens among nodes. Also, they require periodic control message to maintain routes to every node in the network. Optimized Link State Routing (OLSR) is such a proactive routing protocol. Requirement of bandwidth and energy will increase for higher mobility. The behaviour of routing protocol depends on the network size and node mobility.

OLSR is an optimization of pure link state routing protocol which inherits the stability of a link state algorithm and takes over the advantage of proactive routing nature to provide routes immediately when needed. Here, to achieve energy optimization of all nodes in the network; first OLSR has been modified to multipath OLSR.

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Among these multiple paths between the two distant nodes at given time, path containing all intermediate nodes with higher energies are considered.

The remaining of the paper is organized as follows. Section 2 discusses overview of OLSR routing protocol. Section 3 describes algorithm used for multipath and energy optimization in OLSRM by modification made in OLSR. Section 4 describes simulation parameters to analyse performance differences. Section 5 discusses results of the OLSR and OLSRM for parameters like nodes alive and end to end delay, considering the effect of node velocity, node density and pause time. Finally, conclusions are in Section 6.

2 Overview of OLSR Routing Protocol

OLSR, proactive routing protocol exchanges routing information with other nodes in the network. The key concept used in OLSR is of MPRs (Multi Point Relays)[6]. It is optimized to reduce the number of control packets required for the data transmission using MPRs. To forward data traffic, a node selects its one hop symmetric neighbours, termed as MPR set that covers all nodes that are two hops away. In OLSR, only nodes, selected as MPRs are responsible for forwarding control traffic. The selected MPRs forward broadcast messages during the flooding process, contrarily to the classical link state algorithm, where all nodes forward broadcast messages. So mobile nodes can reduce battery consumption in OLSR compared with other link state algorithms.

A. Control Message

There are three types of control messages: HELLO messages, Topology Control (TC) messages, Multiple Interface Declaration MID messages. To achieve energy optimized multipath OLSR, HELLO message and TC message format has been modified.

- The link status and one hop neighbours' information data is given by HELLO message.
- Topology information is received by a node by periodical TC message using Multipoint Relaying (MPR) mechanism.
- MID message is sent on network to announce that if node is running multiple interfaces.

B. Routing Table and Topology Table

As a proactive routing, the routing table has routes for all available nodes in the networks. It has Destination Address, Next Hop Address, Local interface address and number of hops. It is as presented as follows:

Dest	next	iface	dist
0	0	37	1
2	6	37	2
14	20	37	3

From the above table, distance between 37 and 0 is 1 hop, the path is 37-0, distance between 37 and 2 is two hop, the path is 37-6-2, distance between 37 and 14 is 3 hop, the path is 37-20-?-14. If the number of hops are more than two, then intermediated nodes on the path has to find out the next (?), which is not displayed in routing table.

The topology table gives the information about entire network. It informs about one hop. There is no information about Residual energy of the node in topology table format of OLSR.

Its original format is as follows:

Dest	Last	Seq
0	13	2
36	13	2
1	13	2
0	38	6

C. Routing Discovery

To work in distributed manner, OLSR does not depend on any central entity [5]. Each node chooses its as multipoint relays (MPR) which are responsible to forward control traffics by flooding. The nodes maintain the network topology information where MPRs provide a shortest path to a destination with declaration and exchange of the link information periodically for their MPR's selectors. The HELLO messages are broadcast periodically for neighbour's detection and MPR selection process. It contains how often node send HELLO messages. It also includes node's MPR willingness and information about neighbour node. The information of node's is in the form of its link type, interface address and neighbour type.

The neighbour type can be one of: symmetric, MPR or not a neighbour. Link type indicates whether link is symmetric, asymmetric or lost link. A node is chosen as MPR if link to the neighbour is symmetric.

A node builds a one hop routing table with the reception of HELLO message information. It discards duplicate packet with same sequence number. The node updates when there is change in neighbour r node or route to a destination has expired.

OLSR does not require sequenced delivery of messages as each control message contains a sequence number which is incremented for each message.

D. Source Routing

Multiple paths calculated between a pair of source destination are independent, and they have no common nodes. However, because of the characteristic of next hop routing in OLSR, node can forward data based on its own routing table, and it cannot get the correct next node, source will forward, so cross among multiple paths happens. To avoid the problem for the next-hop routing in standard OLSR protocol, we use the source path in our multipath_OLSR algorithm. When a node calculates a path, the information of the path is recorded in its routing table (R_dest, R_next, Rdist, Rbuffer, nexthopO, and nexthopI... nexthopl4}. So, when source send data along the path, it add the source path (nexthopO, nexthopI... nexthopl4) to the IP header in the data. Now the intermediate nodes only need to get the path information from IP header of data to forward the data, need not to query its routing table as in standard OLSR protocol. So, the mechanism of source path added to multipath OLSR can avoid the problem of next hop node.

E. Energy-Efficient Route Selection Metric

There are different Route selection metric based on transmission power, link distance or residual energy of the node.

A brief description of the relevant energy aware metric proposed are given below.

1. MTPR (Minimum Total Transmission Power Routing)[8]

The MTPR mechanism uses a simple energy metric. It repr esents the total energy consumed to forward the information along the route. MTPR uses shortest path routing. It reduces the overall transmission power consumed per packet. It does not take into account available residual energy of the node.

2. MBCR (Minimum Battery Cost Routing)[8]

The MBCR selects the route that minimizes the battery cost function. Battery cost function for a node is the reciprocal of available Residual energy of that node.

$$f(n_i) = \frac{1}{c(n_i)} \tag{1}$$

Where $c(n_i)$ denotes the residual energy of node n_i.

Therefore, the battery cost for a route l, length D, is given by:

$$P_l = \sum_{i=0}^{D-1} f(n_i) \tag{2}$$

The selected route P_k is the one that satisfies the following property,

$$P_k = min\{P_l : l \in A\} \tag{3}$$

Where A is the set of all the possible routes.

The main disadvantage of the MBCR is that selection is based only on the battery cost. In this one node may be overused.

3. MMBCR (Min-Max Battery Cost Routing) [8]

The MMBCR selects the route with the maximum values of the minimum battery cost of the nodes. Therefore, the equation for battery cost is modified to,

$$P_l = \max_{i \in route\ l} f(n_i) \tag{4}$$

The selected route P_k is the one that satisfies the following property:

$$P_k = min\{P_l : l \in A\} \tag{5}$$

4. CMMBCR (Conditional Min-Max Battery Cost Routing) [8]

This mechanism considers both the total transmission power consumption of routes and the residual energy of nodes. When all nodes in some possible routes have sufficient remaining battery cost, i.e. above a threshold [criteria for setting the threshold based on application are subjective], MTPR is applied, to find out optimal path.

But, if all routes have nodes with low battery, i.e. below defined threshold, then MMBCR technique is applied. The performance of CMMBCR totally depends on selected threshold value.

5. MDR (Minimum Drain Rate)[8]

Only the Residual energy cannot be used to establish the best route between source and destination nodes. If a node has higher residual energy, too much traffic load will be injected through it, results in unfair sharp reduction of battery power. To avoid this problem MDR is used.

In this metric, cost function is considering both Residual energy of node and Drain rate of that node. Maximum Lifetime for a given path is determined by minimum value of cost along that path. Finally, MDR selects the optimal path having the highest maximum lifetime value.

6. LCMMER (Low Cost Min-Max Energy Routing) [9]

The difference between MMBCR and LCMMER is that MMBCR avoids the path with lowest energy nodes, does not consider the cost of the path and may select excessively long paths, whereas LCMMER also tries to avoid least energy nodes.

3 Modified OLSR

OLSR applies shortest hop routing method for the transmission of data. It leads the congestion on specific path, or rise in energy expenditure of particular intermediate nodes.

If multiple paths are available, then congestion can be avoided, and energy expenditure of all nodes would be uniform. To achieve this, following changes are carried out.

Following are the changes made in OLSR protocol:

A. Changes in control messages

The ‘reserved’ field available in HELLO and TC message format is used to pass residual energy. This residual energy is further used to find out appropriate path.

B. Changes in Routing table and Topology table

As discussed in section II-B, in OLSR, user is not aware of intermediate nodes present on the path and also its residual energies.

The modified Routing Table of Multipath OLSR is as follows- from the modified routing table, information of residual energies of intermediate nodes are obtained.

Dest	next	iface	dist
14	20	37	3
20			
11			
14			

Residual energy of intermediate node1
Residual energy of intermediate node2
…….

So from the modified Routing Table, for the given source-destination pair, multiple paths are available.

Now to select one of the available path, energy aware metric is applied.

The energy expenditure (in Joules) needed to transmit a packet p is given by,[7]

$$E(p) = i * v * t_p \tag{6}$$

Where i is the current value,

v is the voltage,

t_p the time taken to transmit the packet p.

For our simulation, the voltage is chosen as 5 V.

Algorithm for modified OLSR

- Maintain all one hop ing nodes for each node using modified HELLO message, with the residual energy of the nodes.
- Based on its one hop table, insert the appropriate entries to its routing table.
- Match the entries with topology set and add to the routing table.
- For each node, see recursively its last address until reached to the destination node, record the complete path information in the routing table using modified TC message (with the residual energy of the nodes).
- Discard the loop entries.
- Get all the paths for given source-destination pair, with the residual energy of each node to the entire network.
- Select all paths, for given source-destination pair
- Find out minimum energy of node, E(min), on each selected paths.
- Find out maximum energy of node, E(max), out of that E(min) values.
- Use this selected path.

4 Simulation Parameters

We use network simulator ns2 [2] to analyse OLSR and OLSRM routing protocols and measure Number of node alive and Average end to end delay with varying Nodes' velocity and node density.

We use a movement pattern of the random waypoint mobility model, obtained from a tool called "setdest", developed by Carneige Mellon University. The performance of ad-hoc routing protocols greatly depends on the mobility model it runs over[10]. For simulation, Two ray ground propagation model is used. The nodes are 40 in the area of 1000 X 1000 square meter. Traffic type used is CBR (Constant Bit Rate), Packet send rate is 20 packets/sec and Packet size is 512 Bytes.

5 Simulation Results

Quality of Services (QoS) Parameters:
We evaluate essential Quality of Service parameters to analyse the performance differences of OLSR and OLSRM. Each node in the network has some constant Initial energy. The QoS parameter, alive nodes are chosen to show that more number of nodes alive for longer time in the network. More number of alive nodes implies the optimization of energy. The parameter Delay is chosen to study the effect of, addition of multipath technique and energy aware metric to the original OLSR

Number of Nodes Alive: This is one of the important metric to evaluate the energy efficiency of the routing protocol. It tells about Network Lifetime,

- The time to the first node failure due to battery outage
- The time to the unavailability of an application functionality[11]

First point gives the failure of first node, whereas second gives the time when only one node is alive (for communication at least two nodes must be alive). Both can be extracted from the trace file and tells about time at which first node died and the information about how alive nodes changes with the simulation time.

Average End to End Delay: This is the time difference between sending of data packets and time at which the same data packet is received.

A. Effect of Node Mobility, and Node Density on Number of Nodes Alive

In case of OLSR, the shortest hop path is always chosen; whereas in OLSRM the path for the data delivery is considered with the available energy of nodes (at that instant) on the path, even if the path is long (in terms hop). Therefore OLSRM has more number of nodes alive compared to OLSR. As the node mobility increases, the number of alive nodes in OLSRM increases implies that modified protocol is suitable for dynamic network.

By varying number of nodes, it has been observed that OLSRM has more number of nodes, for high node density. It is obvious, as multiple paths will be more for large number of nodes. So it can be seen from the results, OLSRM is best suitable for dynamic and dense network.

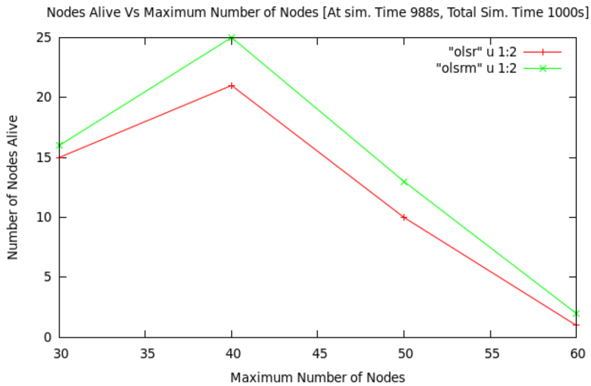

Fig. 1. Effect of node density on nodes alive

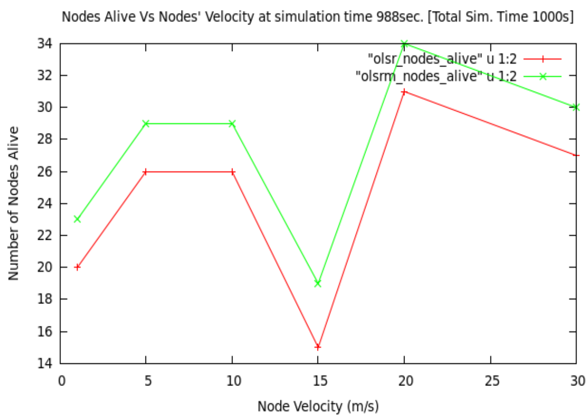

Fig. 2. Effect of node velocity on nodes alive

B. Effect of Node Mobility and Node Density on Average End-to-End Delay:

For various Node's maximum velocity, OLSRM has less end-to-end delay, as multiple paths are available, than that of OLSR.

By varying node density, it has been observed that end-to-end delay is less for OLSRM than that of OLSR.

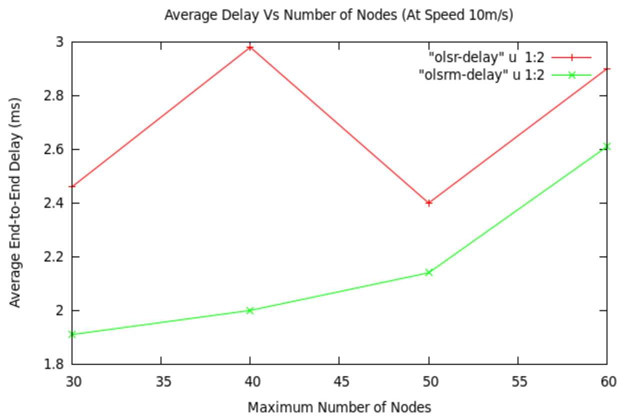

Fig. 3. Effect of node density on average end-to-end delay

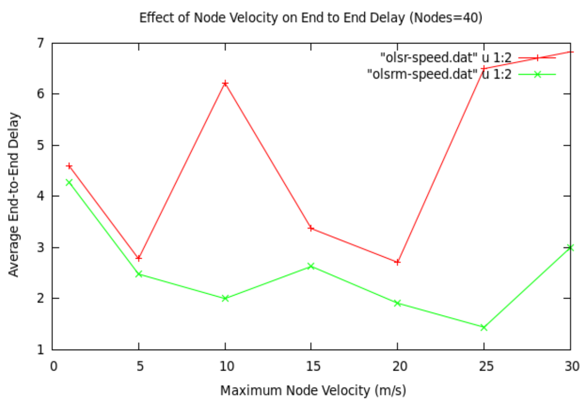

Fig. 4. Effect of node velocity on average end-to-end delay

6 Conclusion

We examine the performance differences of OLSR and OLSRM. We measure Number of alive nodes and average end to end delay as QoS parameters.

OLSR, always uses shortest hop route, so congestion occurs and distribution of load is not considered. Also, OLSR does not consider available node energy of nodes for path selection and communication purposes. In this paper, algorithm for multipath OLSR with the addition of energy aware metric is given and simulation is performed using NS-2. Our simulation results show that OLSRM (modified OLSR with multipath) outperforms OLSR for number of alive nodes by 10 to 25% with considering performance parameters as node velocity and node density.

Thus, congestion of the network disappears and load is transmitted uniformly throughout the network. The modified OLSR also gives the reduction in average end to end delay.

As a future work, we will evaluate optimum paths based on number of hops and available energy. Load will be mainly assigned to the main path, but if the energy of the intermediate nodes is reaching to threshold (given by the user and generally depends on data type), then another path to be considered. This will give the benefit of shortest hop route as well as optimum node energy consideration for longer life span of the network.

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