Impact of Node Density on Scalable Routing Protocol in Wireless Mesh Networks

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ABSTRACT
As for today Wireless Mesh Networks (WMNs) is emerging technology due to their rapid deployment. WMNs are dynamically self-organizing, self-configuring and self-healing with the nodes in the network automatically establishing an ad hoc network and maintaining the mesh connectivity. In order to Design a routing protocol for WMNs requires several criteria to be taken into consideration, such as wireless networks, wired applications, mobile applications, scalability, better performance metrics, efficient routing within the infrastructure, load balancing, throughput enhancement, interference, robustness etc. In order to support communication, various routing protocols are designed for various networks. All available protocols are not suitable for WMNs, due to the architectural difference between the networks. In this paper, a detailed simulation based performance is evaluated on the routing protocols to verify the suitability of these protocols as applicable to WMN. Landmark Ad Hoc Routing (LANMAR), Optimized Link State Routing (OLSR) and Dynamic MANET On-demand (DYMO) routing protocol are taken into consideration as a part of routing protocols. The performance differentials are investigated using varying traffic load and the number of nodes. Based on the simulation results, how the performance of each protocol can be improved is also recommended.

Keywords
Wireless Mesh Networks (WMNs), LANMAR, OLSR, DYMO, Routing in WMNs.

1. INTRODUCTION
Wireless mesh network (WMN) [1] is emerging technology which can replace conventional wired networks and can be easily set up and maintained. With more attractive features WMN as gained popularity due to this reason same is used in the military and disaster. WMNs consists of mesh clients and mesh routers form a wireless infrastructure and interwork with the wired networks to provide multi-hop wireless Internet connectivity to the mesh clients. WMN is fundamentally similar to the standard IEEE 802.11infrastructure with respect to its basic service set and extended service set. Potential application scenarios for WMN include backhaul support for cellular networks, home networks, enterprise networks, community networks, and intelligent transport system networks. WMN basically uses three types of routing protocols such as reactive, proactive and hybrid. In order to increase scalability in the networks hybrid protocols is used. This paper will focus on the challenge of routing in WMN. Routing is an important challenge to deal with, especially in commercial WMNs applications. The rest of the paper is structured as follows: Section I contain related work. Section II Overview of reactive protocols. Section III simulation environment tool used QUALNET 5.01. Section IV has results with analysis and finally a conclusion in section V.

2. RELATED WORKS
Several wireless routing protocols are developed in order to establish communication in wireless environment, namely Landmark Ad Hoc Routing (LANMAR), Optimized Link State Routing (OLSR) and Dynamic MANET On-demand (DYMO) routing protocol [2-6], [11].

Performance comparison among some set of routing protocols are already performed by the researchers as applicable to ad hoc networks. No comparison is performed on protocols over wireless mesh network. Therefore, evaluating the performance of routing protocols in wireless mesh network environment is still an active research area and in this paper we study and compare the performance of a DYMO, LANMAR and OLSR routing protocols.

3. DESCRIPTIONS OF ROUTING PROTOCOLS
3.1 The Dynamic MANET On-demand (DYMO):
DYMO [10], routing protocol is a simple and fast routing protocol for multi-hop networks. It determines uni-cast routes between DYMO routers within the network in an on-demand fashion, offering an improved convergence in dynamic topologies. To ensure the reliability of this protocol, digital signatures and hash chains are used. The route discovery and route management are basic operations of the DYMO protocol. The route discovery and route management are basic operations of the DYMO protocol. Discussed in detail in the following sections.

3.1.1 Route Discovery:
Route discovery is the process of creating a route to a destination when a node needs a route to it. When a source node wishes to communicate with a destination node, it initiates a Route Request (RREQ) message. The route discovery process is illustrated in Figure 1.

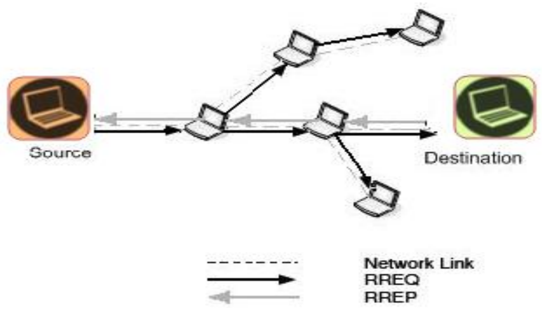

Fig 1. Route discovery process for DYMO

In the RREQ message, the source node includes its own address and its sequence number, which is incremented before it is added to the RREQ. It can also include prefix value and gateway information if the node is an Internet gateway capable of forwarding packets to and from the Internet. Finally, a hop count for the originator is added to the value 1. Then information about the destination node is added. The most important part is the address of the destination node. If the originating node knows a sequence number and hop count for the target, these values are also included. Upon sending the RREQ, the originating node will await the reception of a RREP message from the target. If no RREP is received within the RREQ waiting time the node may again try to discover a route by issuing another RREQ. When the RREQ reaches the destination node, a RREP message is then created as a response to the RREQ, containing information about destination node, i.e., address, sequence number, prefix, and gateway information, and the RREP message is sent back along the reverse path using unicast. Similar to the RREQ dissemination, every node forwarding the RREP adds its own address to the RREP and installs routes to the destination node.

3.1.2 Route Maintenance:

Route maintenance is the process of responding to changes in topology that happens after a route has initially been created. To maintain paths, nodes continuously monitor the active links and update the valid timeout field of entries in its routing table when receiving and sending data packets. If a node receives a data packet to a destination it does not have a valid route for, it must respond with a Route Error (RERR) message. When creating the RERR message, the node makes a list containing the address and sequence number of the unreachable node. In addition, the node adds all entries in the routing table that is dependent on the unreachable destination as a next hop entry. The purpose is to notify about additional routes that are no longer available. The node sends the list in the RERR packet. The RERR message is broadcasted. The dissemination process is illustrated in Figure 2. A link breakage node (LBN) receives a data packet for the destination node. When it finds a link is broken, it will wait up to node timed out period after that the entry has become invalid. LBN generates a RERR message, which is propagated backwards towards source node.

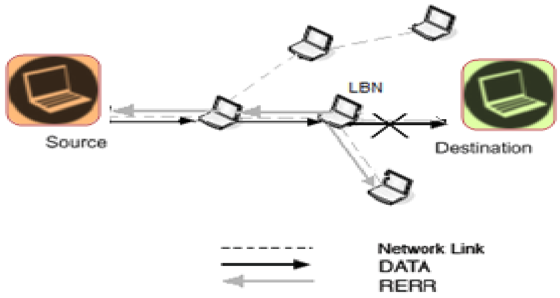

Fig 2: Generation and dissemination of RERR messages

3.2 Landmark Ad hoc Routing Protocol (LANMAR)

Landmark [7] routing protocol proposed for wired networks includes the predefined hierarchical address of each node reflects its position within the hierarchy and helps find a route to it. Route of each node is known to all the nodes within it hierarchical partition. In addition each node knows the routes to various "landmarks" at different hierarchical levels. Packet forwarding is consistent with the landmark hierarchy and the path is gradually refined from top level hierarchy to lower levels as a packet approaches destination. LANMAR share from the notion of landmarks to keep a record of logical subnets. A subnet consists of members which have a commonality of interests and are likely to move as a group. Identification of landmark node is done in each subnet. The routing scheme itself is modified version of FSR. The main difference is that the FSR routing table contains "all" nodes in the network, while the LANMAR routing table includes only the nodes within the scope and the landmark nodes. This feature greatly improves scalability by reducing routing table size and update traffic overhead. When a node needs to relay a packet, if the destination is within its neighbor scope, the address is found in the routing table and the packet is forwarded directly. Otherwise, the logical subnet field of the destination is searched and the packet is routed towards the landmark for that logical subnet. The packet however does not require passing through the landmark. Rather, once the packet gets within the scope of the destination, it is routed to it directly. The routing update exchange in LANMAR routing is similar to FSR. Each node periodically exchanges topology information with its immediate neighbors. In each update, the node sends entries within its fisheye scope. It also piggybacks a distance vector with size equal to the number of logical subnets and thus landmark nodes. Through this exchange process, the table entries with larger sequence numbers replace the ones with smaller sequence numbers.

3.3 OLSR routing protocol

The Protocol Optimized Link State Routing (OLSR) [8] is developed for WMNs. Basically operates with table driven, proactive protocol, i.e., Exchanges topology information with other nodes of the network continuously. Every node chooses a set of its neighbor nodes as multi point relays (MPR). In these protocols only nodes, selected as such MPRs are responsible for controlling traffic, forwarding, intended to propagate within the entire network. MPRs provide efficient criteria for flooding control traffic by suppressing the number of links required. Nodes, selected as MPRs, have additional responsibility when declaring link state information in the network. The basic aim of the OLSR to provide shortest path routes to all destinations is that MPR nodes declare link-state information for their MPR selectors. In addition to available link state information may be utilized for redundancy. Nodes which have been selected as multipoint relays by some neighbor nodes advertise this information at regular interval in their control messages. Thereby a node announces to the network, that it has reached ability of the nodes which have selected it as an MPR. For calculation of the route, the MPRs are used to form the route from a given node to any destination within the network. In addition to this the protocol uses the MPRs to facilitate efficient flooding of control messages in the network. A node selects MPRs from among its one hop neighbors with "symmetric", i.e. Bi-directional, linkages. So the selection of the route through MPRs automatically avoids the problems associated with data packet transfer over unilateral links. OLSR is developed to work independently from other protocols. Similarly, OLSR makes no assumptions about the underlying link-layer. OLSR inherits the concept of forwarding and relaying from HIPERLAN.

4. SIMULATION ENVIRONMENTS

The overall target of this simulation study is to analyze the performance of different existing wireless routing protocols in WMNs. The simulations have been performed using QUALNET 5.01, a network simulator that provides scalable simulations of Wireless Networks and it is the commercial version of GloMoSim. In our simulation, we consider a network of 15,20,25,30 nodes placed randomly within a 100m X 100m area and operating over 300 seconds. Multiple runs with different seed numbers are conducted for each scenario and collected data is averaged over those runs. A two-ray propagation path loss model is used in our experiments with lineman shadowing models. The transmission power of the routers is set constant at 20 dBm and the transmission range of the routers is 100 meters. The data transmission rate is 2Mbits/s. At the physical layer 802.11b and at MAC layer MAC 802.11 is used. The traffic source is implemented using Constant Bit Rate (CBR), sending at a rate of 1 packet per second. The packet size without header is 512 bytes. The length of the queue at every node is 50 Kbytes where all the packets are scheduled on a first-in-first-out (FIFO) basis.

Table I: Simulation environment

Simulator	QualNet 5.0.1
Nodes	15, 20, 25, 30
Node Mobility	10 (m/s)
Simulation Period	300s
Area	100X100m^2
Antenna	Omni-Directional
Communication Model	CBR
Transmission range	100m

In order to evaluate the performance of routing protocols, both qualitative and quantitative metrics are needed. Most of the routing protocols ensure the qualitative metrics. Therefore, we use four different quantitative metrics to compare the performance.

Average Jitter: Jitter is the variation in the time between packets arriving, caused by network congestion, timing drift, and change in route.

Average End-to-end delay: End-to-end delay indicates how long it took for a packet to travel from the source to the application layer of the destination.

Throughput: This is the actual output of the networks. The throughput is also defined as the total amount of data a receiver R receives from the sender divided by the times it takes for R to get the last packet.

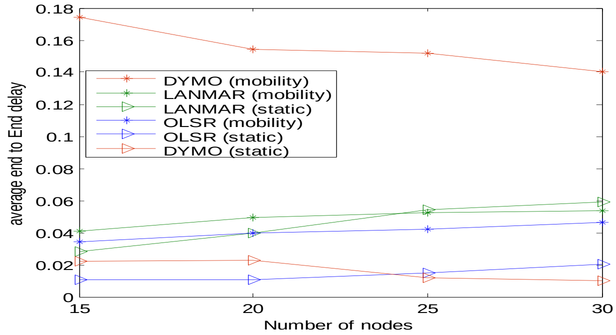

Fig 3: Average end to end delay versus node density

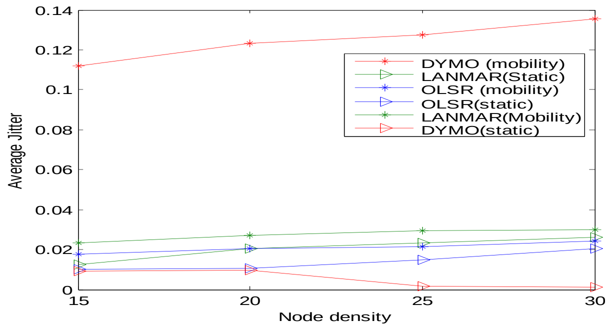

Fig 4: Average jitter versus node density

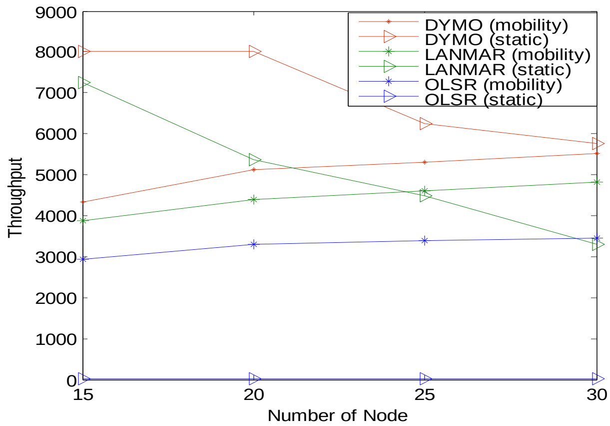

Fig. 5: Throughput versus node density

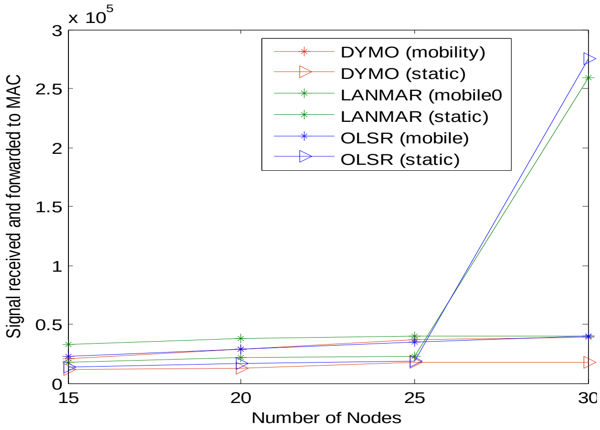

Fig 6: Signal received and forwarded to MAC versus node density

4.1 Result and Discussion

In this paper we have discussed the impact of node density and traffic load on routing protocols like DYMO, OLSR and LANMAR in WMN.

5.1.1 Scenario 1: When nodes are static in nature

Average end to end delay: in this case OLSR shows the lower end to end delay compared to routing protocols DYMO and LANMAR as shown in figure 3. In case of DYMO the end to end delay decreases as the node density increases. OLSR and LANMAR show an increment at the end to end delay as the node density increases.

Average Jitter: DYMO routing protocols shows the lower value of average jitter than OLSR and LANMAR as shown in figure 4. Average jitter in case of OLSR and LANMAR increase with node density increases but the DYMO provide decrement in average jitter as node density increases.

Throughput: DYMO routing protocol provides more throughput to OLSR and LANMAR as shown in figure 5. The value of throughput decreases LANMAR and DYMO as node density increases but OLSR shows very less value of throughput and it does not show any change throughout the node density variation.

Signal Received and forwarded to the MAC: DYMO shows the lower value of these metric but routing protocols like LANMAR and OLSR shows higher values as shown in figure 6.

4.1.2 Scenario 2: When nodes are Dynamic in nature

Average end to end delay: in this case DYMO shows higher end to end delay compared to routing protocols OLSR and LANMAR as shown in figure 3. All routing protocols in this paper show an increment at the end to end delay as the node density increases.

Average Jitter: in this case DYMO shows higher average jitter compare to routing protocols OLSR and LANMAR as shown in figure 4. All routing protocols in this paper show increment in average jitter as the node density increases

Throughput: DYMO routing protocol provides more throughput to OLSR and LANMAR as shown in figure 5.
Value of throughput increases for LANMAR, DYMO band OLSR as node density increases.

Signal Received and forwarded to the MAC: LANMAR show higher value of this metric to OLSR and DYMO. For all routing protocols this value increases as node density increases

5. CONCLUSIONS

A simulation based performance comparison of three different protocols (DYMO, LANMAR, and OLSR) is described in this paper. Simulation has been conducted over the wireless mesh environment. From the result of our studies and analysis, it can be concluded that, on an average DYMO performed better to compare to routing protocols OLSR and LANMAR for static scenario but does not show better performance for dynamic scenarios. In this case we consider that all nodes have same energy but in future we would like to perform the same things by including the heterogeneity.

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