



## Load Balance Enhancement Analysis in Wireless Mesh Networks

<sup>1</sup>Dr. Makarand D. Wangikar, <sup>2</sup>Dr. Mohnish M. Mahamune, <sup>3</sup>Dr. Mahesh S. Darak

<sup>1</sup>Assistant Professor, <sup>2</sup>Assistant Professor, <sup>3</sup>Assistant Professor

<sup>1,2,3</sup> School of Computational Sciences,

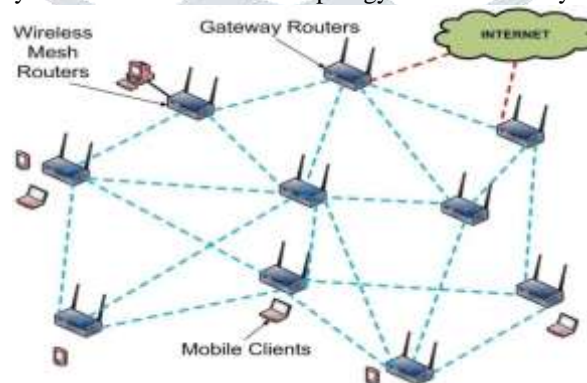
S. R. T. M. University, Nanded - 431605, Maharashtra, India

**Abstract:** In WMNs, load balancing reorganizes the communication quality to minimize jitter, error rate, and delay while improving bandwidth. This paper provides an overview of the various routing metrics and compares them with load balancing. Routing metrics are literally used to route traffic across a network and distribute the load among nodes.

**Index Terms -** Wireless mesh network; routing metric; Load balancing.

### I. INTRODUCTION

Wireless mesh networks (WMNs) is an emerging technology that uses wireless multi-hop networking to provide a cost effective way for community or enterprise users to have broadband internet access and share network resources [1]. Mesh networks are composed of three types of nodes they are gateways (access points), mesh routers, and mesh clients. Gateways enable the integration of WMNs with various other networks, including the Internet. As dedicated devices providing stable high throughput for mesh clients, the mesh routers have minimal mobility and form the mesh backbone. In order to further improve the flexibility and capacity of WMNs, the mesh routers are often equipped with multiple wireless interfaces. As a result, two transmissions of two nearby pairs can be simultaneously scheduled if non-overlapping channels are assigned. Mesh clients are usually end users, such as laptops and PDAs, which access the Internet through the mesh routers, so that the mesh clients are usually within one-hop of the mesh routers. The routing problem in WMN addresses the issue of determining which nodes to include on the routing path and which channel to use on each link of the path. To fully exploit the availability of multiple channels in WMNs, routing algorithms should account for the existence of channel diversity on a path in the network. The routing problem in multichannel WMNs is made worse by the fact that the network topology is determined by the channel assignment.



**Figure 1.** Wireless mesh architecture - mesh routers, mesh clients and gateway nodes

Traditionally in wireless networks, nodes were operating with a single radio, due to the cost associated with having multiple radios on a node, which was high. Several methods were proposed which aimed to improve the network throughput, for single-radio wireless mesh networks. However, with lowering costs, it has become possible to equip a node with multiple radios. Having multiple radios on a node opens several possibilities and options as to how these radios can be utilized to improve some of the important characteristics of the nodes and the performance of the network. Several interesting studies have been performed on multi-radio nodes and have concluded that in some cases, having multiple radios can considerably improve the throughput and network performance. In this thesis, we use the concept of a multi-radio mesh node to analyze the performance of wireless mesh networks in different conditions with different channel assignment schemes. We look at new ways to try and improve the network throughput in wireless mesh networks.

## II. PERFORMANCE CHALLENGES IN WMN

The routing protocol is an important factor in any network, but in WMNs it can mean the difference between failure and success. Several of the advantages of WMNs over competing technologies are enabled by the routing protocol alone: These challenges are summarized below:

### Scalability/Efficiency:

If the routing protocol has a high overhead and requires global information, it will be impossible to scale it to a large number of nodes.

### Reliability:

The routing protocol should be able to reroute fast around failed nodes, broken links, and upon the failure of a gateway it should be able to redistribute the orphaned clients among neighboring gateways. For this property, fast reconfiguration and support of multiple gateways is essential.

### Mobile User Connectivity:

To ensure seamless mobile user connectivity, the routing protocol should enable fast hand-offs.

### Flexibility:

The routing protocol should be flexible and adapt to different network topologies.

### Quality of Support:

In addition to support from the MAC layer and/or the forwarding engine, selecting the best routes for different traffic classes is an essential ingredient for Quality of Support (QoS) support.

In addition, the entire performance of a WMN is affected by its routing protocol. Load balancing, avoiding congested routes, and taking into account interference patterns existent in a WMN are just some of the factors that directly affect the performance of WMNs.

## III. ROUTING METRICS AND ROUTING PROTOCOLS FOR WMN

A good routing metric must accurately capture the quality of network links and aid in computation of good quality paths. Key components that can be utilized to compose a routing metric for mesh networks are: Number of hops, Link Capacity, Link Quality and Channel Diversity. Below we describe some of the desirable characteristics of a good routing metric for WMNs, that is, some of the criteria routing metric needs to address [3].

### 3.1 Characteristics of Routing Metrics

#### 3.1.1 Interference

Interference in a mesh network can be of three types

- Intra-low Interference [2]: Intra-low interference occurs when the radios of two or more links of a single path or low operate on the same channel and can be reduced by increasing channel diversity. i.e. by selecting non-overlapping channels for adjacent hops of a path. Interference range of a node is typically bigger than a single hop and hence links on same channel in a multi-hop path can still interfere with each other and not just restricted to immediate neighbors.
- Inter-Flow Interference: Inter-low interference is the interference caused by other lows that are operating on the same channels and are competing for the medium. Inter-low interference is harder to control than intra-low interference, due to the involvement of multiple lows and routes.
- External Interference: External interference occurs when a link experiences interference outside of the control of any node in the network. Here, we have two kinds of external interference: Controlled Interference, where other nodes external to the network use networking technologies that overlap with those used by the network, and Uncontrolled Interference, which is caused by is caused by any other source of radio signals emitted in the same frequency range, but not participating in the same MAC protocol.

#### 3.1.2. Locality of Information

Some metrics require information such as channels used on previous hops of a path, or other metrics observed on other nodes of the networks, such as packet delivery rate or noise levels. This non-local information can be part of routing metric and can be used to make more optimal routing decisions.

#### 3.1.3 Load Balancing

The ability of a metric to balance load and provide fairer usage of the networks distributed resources. This is a very important consideration especially when there is concentration of traffic at the Internet Gateways in mesh networks.

#### 3.1.4 Agility

The agility of a metric refers to its ability to respond quickly and efficiently to changes in the network in terms of topology or load. In order for a metric to be considered agile, the rate at which measurements are taken should be higher than the rate of change in the network.

#### 3.1.5 Isotonicity

The isotonic property of a routing metric means that a metric should ensure that the order of weights of two paths is preserved if they are appended or prefixed by a common third path. Isotonicity is the necessary and sufficient condition of a routing metric for the existence of efficient algorithms to find minimal weight paths, such as Bellman-Ford [4] or Dijkstra's algorithm.

#### 3.1.6 Throughput

In general, a metric should be able to select routes with greater throughput consistently.

### 3.2 Routing Protocols for Wireless Mesh Networks

In order to have a better understanding of the routing metrics, in this section, we describe three different routing protocols in which routing metrics are incorporated in wireless mesh networks to find best possible paths [5].

#### 3.2.1 Destination Source-Routing Protocol (DSR)

DSR [6] is an on-demand routing protocol that is based on concept of source routing. In source routing algorithm, each data packet contains complete routing information to reach its destination. Nodes are required to maintain route caches that contain source routes of which the node is aware. There are two major phases in DSR; the route discovery and route maintenance. For route discovery, the source node broadcasts a route request message which contains the address of the destination, along with source nodes address and a unique identification number. Every node which receives this packet checks if it has route information to destination. If not, it appends its own address to route record of the packet and forwards the packet to its neighbors. A route reply is generated if the route request reaches either the destination itself or an intermediate node which has route information to the destination. DSR has route cache to maintain route information to the destination. Route maintenance is done through the use of route error packets and acknowledgments. Main disadvantage of DSR is it has increased traffic overhead as it contains complete route information in each of its data packet. This degrades DSRs routing performance.

#### 3.2.2 Ad-hoc On-demand Distance Vector Routing Protocol (AODV)

AODV [8] is a reactive on-demand routing protocol which builds on both DSR and DSDV. AODV is an improvement on DSDV [7] as it minimizes the number of required broadcasts by creating routes on demand basis. It is also an improvement on DSR as a node only needs to maintain routing information about the source and destination as well as next hop, thereby largely cuts back the traffic overhead. The process of route discovery is similar to DSR. Route request (RREQ) packets are broadcasted for route discovery while route reply (RREP) packets are used when active routes towards destination are found. HELLO messages are broadcasted periodically from each node to its neighbors, informing them about their existence.

## IV. ROUTING METRICS FOR WIRELESS MESH NETWORKS

### Hop Count

Hop count is the traditional routing metric used in most of the common routing protocols like AODV, DSR, DSDV designed for multi-hop wireless networks. It finds paths with shortest number of hops.

### ETX

Expected Transmission count ETX [9] is defined as the number of transmissions required to successfully deliver a packet over a wireless link. The ETX of a path is defined as sum of ETX of each link along the path.  $P_f$  be the packet loss probability in forward direction and  $P_r$  is the packet loss probability in the reverse direction. Let  $P$  denote the probability that the packet transmission from node  $x$  to node  $y$  in a link is not successful

$$P = (1 - P_f) \cdot (1 - P_r)$$

The Expected number of transmissions to successfully deliver a packet in 1 hop can be expressed as

$$ETX = \sum_{k=1}^{\infty} k p^k (1 - p)^{k-1} = \frac{1}{1 - p} \cdot ETX$$

ETX is measured in link of a real network by

$$TX = \frac{1}{D_f * D_r}$$

where  $D_f$  is the forward delivery ratio ( $1 - P_f$ ),  $D_r$  is the reverse delivery ratio ( $1 - P_r$ ). The delivery ratios  $D_f$  and  $D_r$  are measured by broadcasting dedicated link probe packets of a fixed size every average period (a typical value is 1 second) from each node to its neighbors.

### ETT

The Expected transmission time (ETT) [10] metric is an extension of ETX which considers different link routes or capacities. ETT is expected time to successfully transmit a packet at the MAC layer and is defined for a single link as  $ETT = ETX * \frac{S}{B}$ ,  $S$  denotes the average size of packet and  $B$  denotes current link bandwidth. ETT path metric is obtained by adding up all the ETT values of individual links in the path.

### PDF

PDF or goodput is the ratio of TCP packets successfully delivered to the total number of TCP packets transmitted (which includes retransmitted packets)

$$PDF = \frac{\text{Total number of TCP packets received}}{\text{Total number of TCP packets transmitted}}$$

TCP <= 1 (always)

When the number of nodes are more, when route discover is initiated, the larger number of replies cause overhead. i.e. PREQ + HELLO msgs + RREP and so interference with data traffic so that result in performance degradation. As only one route per destination, so route discoveries are frequent.

## V. RESULTS AND DISCUSSION

### 5.1 Performance and environments of simulations

We will integrate our new routing metric in OLSR protocol and implemented in ns2 [11], 2.35 version, and we have incorporated a standard version of OLSR (UM-OLSR-1.0 [12]). The performance of the proposed LAmETX is compared with OLSR\_ETX, depending upon: packet loss rate, throughput, delay, and sensibility of our metric to traffic variation. During our simulation, we ignore the energy effect.

### 5.2 Simulation Setup

Our simulation parameters are as follow; For our simulations, the network have a varied number of mobile nodes (50,60,70) whose radio scope is 250 m, moving in an area of  $1000 \times 1000m^2$ . Each node displace depending on the RWP (Random Waypoint) mobility perfect [17],with maximum speed that varies between 5 and 30 meter/second with step of 5 and pause time of 0 second, and a fixed CBR traffic in the first scenario and maximum CBR traffic that varies between 5 and 20 with step of 5 and a fixed speed.

The scenario that defines the nodes movement is regenerated at the beginning of every simulation. In every simulation, for generating the traffic in the network, we select randomly 1/5 of nodes to be a source of CBR (Constant Bit Rate) traffic. We set the CBR packet size to 512 bytes. UDP (User Datagram Protocol) connections, used by nodes to send a packets (1024 bytes of size), such that every 2.5 second one packet is sent. The parameters used during simulations are resumes in table 1.

Table 5.1: Parameters Simulation

Parameter(s)	Value (s)
Area	1000m X 1000m
Maximum number of nodes	50,60,70 nodes
Radio scope	250 m
MAC Layer	IEEE 802.11
Transport Layer	UDP
Traffic Type	CBR
Package size	1024 Bytes
Rate	0.4
Number of connections	1/5 of number of nodes
Mobility model	RWP (Random Waypoint)
Pause Time	0 Sec
Maximum speed of nodes	5,10,15,20,25,30
Maximum CBR traffic of nodes	5,10,15,20
Simulation time	250 sec

### 5.3 Results and Discussions

We compare the performance of LAmETX, metrics implemented in OLSR with OLSR\_ETX and UM\_OLSR. We present our results by curves, with 100% of certitude, in table 1.

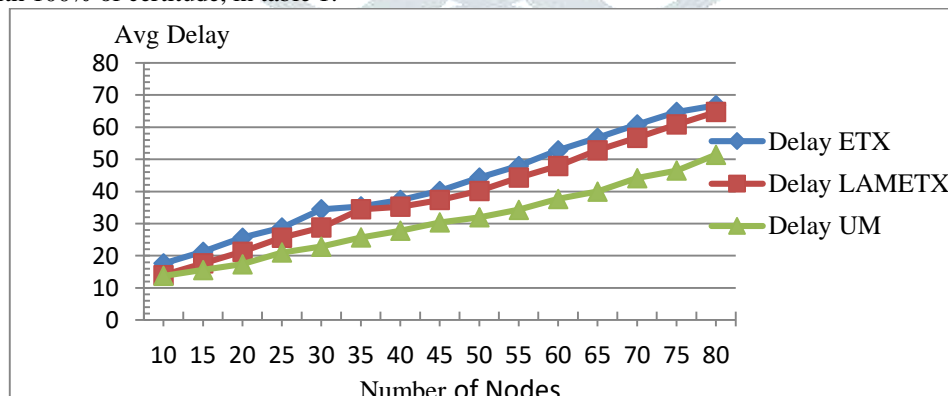
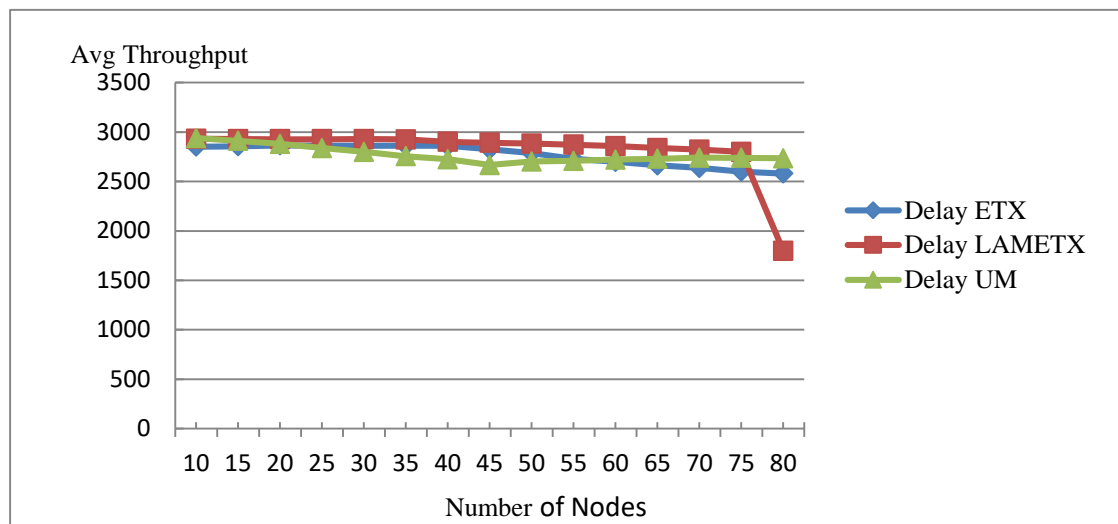


Figure 2. Avg- Delay Speed=5, CBR=20



**Figure 3.** Avg- Throughput Speed=30, CBR=5

During our measurements, we compare our new routing metric, with two others existing routing metric, depending on three parameters: Load balancing, Inter-flow interference, and Intraflow traffic; and we use three performances: Average end-to-end DeLay, Throughput, and Packet Delivery Rate.

## VI. CONCLUSIONS AND FUTURE WORKS

We compared Routing Metric with Interference Aware (LAmETx) with varied number of nodes that ensures the high throughput, lower packet delivery ratio and facilitate to discover a better path which minimize inter-flow and intraflow interferences.

We will integrate routing metric LAmETx in OLSR protocol and implemented it in ns2 [11], in multi-radio networks. As future work, we propose to implement LAmETx in OLSR routing protocol with random (irregular) topology.

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