 ISSN: 2321-8169
64 – 68

MMC: Multiple Metric Cost Routing Metric for Wireless Mesh Networks

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Abstract— Wireless Mesh Networks (WMNs) are bringing revolutionary changes in the field of wireless communication. Routing metric is the most important factor to find the optimized route. Researchers have shown that integrating multiple performance metrics into a routing protocol is effective for attaining optimal performance because a single metric will not be able to satisfy the comprehensive requirements of WMNs. In this paper, we propose a new routing metric for WMNs, Multiple Metric Cost (MMC), integrating three metrics: 1) Available bandwidth, 2) Residual energy and 3) Expected Transmission Count (ETX).MMC results in a better throughput. We evaluated the performance of MMC for proactive, reactive and opportunistic routing protocols using the OMNET++ network simulator. Our evaluation shows that MMC performs well in all three classes of routing protocols.

***Keywords**- Wireless Mesh Networks; Routing Metric; Multiplt Metric Cost; SOAR; AOMDV; OLSR.*

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I. INTRODUCTION

Wireless Mesh Networks (WMNs) are an emerging technology that could revolutionize the way wireless network access is provided. WMNs are self-organized multi-hop networks comprising of stationary and mobile nodes. Nodes in a WMN consist of mesh routers and mesh clients [1]. Mesh routers are not very mobile and they are considered as the mesh backbone for clients. Mesh clients have additional functions for mesh networking and can also work as routers.

Routing Metric is a crucial issue for the design of WMN for achieving good performance and reliability. Several link quality metrics have been designed for WMNs such as Expected Transmission Count (ETX) and Expected Transmission Time (ETT). But, a single metric fails to describe the QoS as all important factors are not included in one metric. Multiple Metric Cost (MMC) is a new routing protocol consisting of three routing metrics 1) ETX, 2) links available bandwidth and 3) residual energy of nodes.

We know that routing protocols are classified as proactive, reactive and opportunistic. To demonstrate effectiveness of MMC, we have implemented three multipath routing protocols from each class in the OMNET++ network simulator. We have implemented Simple Opportunistic Adaptive Routing Protocol from opportunistic, Ad-hoc On Demand Multiple Path Distance Vector (AOMDV) from reactive and Optimized Link State Routing (OLSR) from proactive routing routing protocols. It has been already proved that Expected Transmission Count (ETX) performs better than hop count, so we compare MMC with ETX. Our extensive evaluation shows that MMC performs better for all three protocols.

The rest of the paper is organized as follows: Section II discusses commonly used routing protocols for wireless mesh networks. In section III Multiple Metric Cost routing metric is presented. Simulation work and results are discussed in section IV. Finally, we conclude in Section V.

II. ROUTING PROTOCOLS FOR WIRELESS MESH NETWORKS

Routing protocols are classified as: 1) Opportunistic 2) Reactive and 3) Proactive. Opportunistic routing protocols exploit the broadcast nature of wireless networks and selection of next forwarder is done after the actual data transmission. Reactive protocols seek to set up routes on-demand. If a node wants to initiate communication with a node to which it has no route, the routing protocol will try to establish such a route. On the other hand a proactive approach seeks to maintain a constantly updated topology understanding. The whole network should, in theory, be known to all nodes. This results in a constant overhead of routing traffic, but no initial delay in communication.

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This work we have selected SOAR, AOMDV and OLSR routing protocol for simulation due to their edges over other protocols in various aspects.

A. *Simple Opportunistic Adaptive Routing Protocol (SOAR)*

SOAR [3] is a straight forward representative of opportunistic routing, i.e. the selection of the next forwarding node is done after the actual data transmission.

Consider a packet appearing at one of a set of mesh nodes running the SOAR protocol. If the destination of the packet is not the node itself, the default path is calculated by Dijkstra's shortest path (DSR) algorithm. Then, a list of forwarding nodes ordered by priority is calculated and added to the packet. The highest priority node is the one with the lowest remaining path cost (i.e. With lowest ETX) to the final destination [4].

Receivers drop packets if they are not in forwarding list. The highest priority node immediately forwards the packet, while the others start forwarding timers. If a node overhears the forwarding of a packet by a higher priority node for which it has a forwarding timer running, it cancels its timer and drops its copy of the packet. Or else, as soon as the forwarding timer elapses, it forwards the packet by itself [4].

To support opportunistic routing, each node maintains a routing table of the following format: (destination, default path, forward List), where the default path is the shortest path from the current node to the destination and the forwarding list includes a list of next-hop nodes that are eligible to forward the transmission [3].Here the main interest area is how forwarding nodes are selected using ETX metric. The forwarding list selection algorithm is discussed below. Consider the calculation of the forwarding list from the current node i to the destination d. Let ETX(a,b) be the ETX of the link a-b, and let pETX(a,b) be the total ETX of the shortest path from a to b. When node I am on the default path, I select the forwarding nodes using the algorithm: I [3], [4] given below:

```
Forwarders = ( )
for each node x in topology
do
if pETX(x, d) is less than pETX(i, d) and
ETX(i, x) less than threshold
{
add x to forwarders
}
prune (forwarders)
done
```

With that, a node is added to the forwarding list, if and only if two conditions match. First, the ETX to the destination from the candidate node has to be less than from the current node. Second, the ETX of the link from the candidate to the current node must be lower than a given threshold. At last, the forwarding list is pruned, meaning it is ensured that the link ETX of all node pairs are also within the before mentioned threshold.

B. *Ad-hoc On Demand Multiple Path Distance Vector Routing Protocol (AOMDV)*

Optimized Link State Routing Protocol (OLSR) [6, 7] is a proactive routing protocol basically sued for MANETs, but also used for routing in WMNs. The OLSR protocol is an optimization of a pure link state protocol by compacting the size of the control packets that contain link-state information and reducing the number of transmissions needed to flood these control packets to the entire network [6,7].

The Optimized Link State Routing Protocol (OLSR) [6] operates as a table driven, proactive protocol, i.e., exchanges topology information with other nodes of the network regularly. Each node selects a set of its neighbor nodes as Multi-Point Relays (MPR). In OLSR, only nodes, selected as such MPRs, are responsible for forwarding control traffic, intended for diffusion into the entire network. MPRs provide an efficient mechanism for flooding control traffic by reducing the number of transmissions required.

III. MULTIPLE METRIC COST (MMC)

Many different routing protocols have already been proposed. However, these protocols are unable to answer all the needs of WMNs, because each of them was developed to deal with a specific application. For example ETX have decent throughput, but only deals with small packets, similarly using available bandwidth leads to selection of a path with low congestion but fails to say about links error quality.

Hence, merely establishing a path using one metric is not justified. Therefore, we propose a new metric Multiple Metric Cost (MMC) [16] which consider three routing metrics:1) link's available bandwidth, 2) residual energy of nodes and 3) ETX. Multiple-Metric cost is calculated as:

$$MMC = ETX \times (1/BW)\,Mac) \times (1/E(t)) \qquad (1)$$

Where, BW_{mac} = Link's available bandwidth and E(t)= Node residual energy.

A. *Available Bandwidth (BWmac) Calculation*

The Bandwidth can be conceptually defined as the number of packets, which a link can accommodate. In this work we have used MAC bandwidth. A MAC bandwidth is the available throughput sensed by a node in a link. Mathematically, it is defined as:

$$BW_{mac} = \alpha \text{ x } T_d \quad (2)$$

where,

α is weighted factor between [0,1] and T_d is transmission delay.

To calculate transmission delay T_d, a synchronized system is assumed. Hello message is broadcasted periodically to all nodes. When the hello message arrives at a neighbor node, the difference between the time when a packet leaves the sender node and the time the packet arrives at the destination node is measured. This measured time is T_d. We may also consider average Round Trip Time (RTT) as transmission delay.

B. Energy calculation

We use the residual energy model at the physical layer, to calculate E at instant t [8].

$$E(t)=E(t-1) - ErxPrxlen(Prx)d^n - ErxPtxlen(Ptx)d^n \quad (3)$$

Where,

Erx energy lost per reception and Etx amount of energy needed for every transmission in bit/m. Parks and Ptx are the number of packets received and transmitted by the node respectively between interval t and t-1. E(t-1) is the energy of the node at (t-1) instance. D is the distance over which packets are traversed and is determined as Euclidean distance. n is a constant between 1 and 2 and is considered as 2 here.

IV. SIMULATION AND RESULTS

A. Simulation Setup

SOAR, AOMDV and OLSR routing protocols are simulated in OMNET++. All the protocols are implemented using ETX for baseline comparison. SOAR, AOMDV and OLSR are modified using MMC metric as Multiple Metric-SOAR (MM-SOAR), Multiple Metric-AOMDV (MM-AOMDV) and Multiple Metric-OLSR (MM-OLSR) respectively. For simulation essential parameters are listed in table 1.

Table1. Simulation parameters

Parameter	Value
Propagation Model	Rayleigh fading model
Physical layer standard	802.11
Radio sensitivity	-90dB
Simulation time	900s
Radio range	250m
MAC protocol	Linklayer.ieee802.11.mac
Network size	950mX950m
Mobility model	Random WayPoint
Packet size	512 Packets
No. of nodes	35
Topology	Random topology

B. *Evaluation Metrics*

• **Throughput:** average rate of successful message delivery over a communication channel [6].

• **Packet Delivery Ratio (PDR):** ratio of the number of delivered data packets to the destination. This illustrates the level of delivered data to the destination [7].

• **Control overhead:** Control and signalling bits are known as overhead.

• **Latency:** It is a measure of time delay or in other words the time from the source sending a packet to the destination receiving it [8].

C. Simulation Results

We used random topology to evaluate the performance of MMC. We varied transmission rate from 100 pkts/s to 2000 pkts/s to measure the performance of the protocol (i.e. Throughput, control overhead, and Packet Delivery Ratio). The total bandwidth of the network is 11MHz and Nodes are communicating within 4 hops. So effective bandwidth at each node is around 2.5Mbps. Each packet is of 512 Bytes and hence bottleneck transmission for each node is 2.5 Mb/512B = 2000 packets approx. Fig. 1 compares the throughput of all three protocols. (a) Compares throughput of MM-SOAR with SOAR, 1 (b) compares MM-AOMDV with AOMDV and MM-OLSR with OLSR. For all three protocols MMC gives higher throughput than ETX. But, MM-SOAR gives highest throughput, MMC gives best results when used with opportunistic routing protocols.

Fig. 2 compares control overhead of all three protocols. Fig 2 (a) shows that MM-SOAR has lower overhead than SOAR as we are integrating residual energy in MMC. Residual energy limits the number of forwarders, due to this node will have less interference and thus lower overhead. Fig. 2(b), 2(c) shows that MM-AOMDV and MM-OLSR has higher overhead than AOMDV and OLSR respectively. MMC uses three link quality metrics which increases overhead slightly.

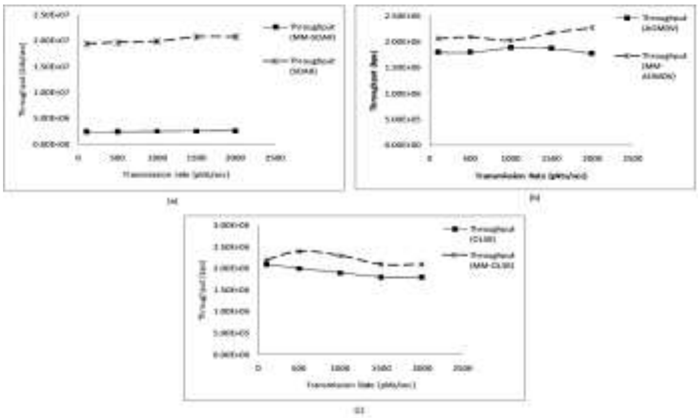

Figure 1. Throughput comparison of (a) SOAR, (b) AOMDV and (c) OLSR routing protocol for variable transmission rate.

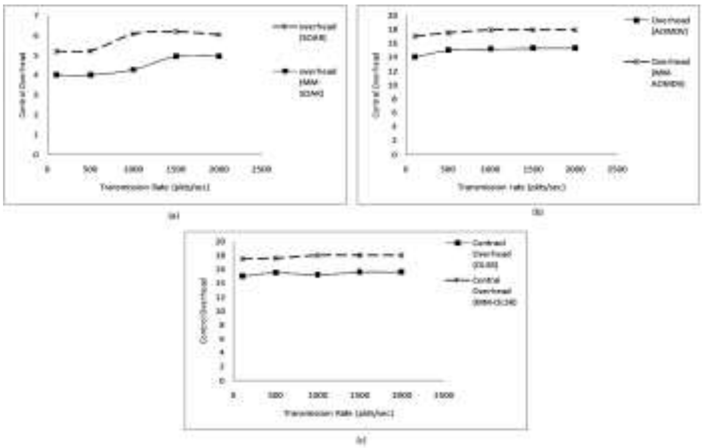

Figure 2. Overhead comparison of (a) SOAR, (b) AOMDV and (c) OLSR routing protocol for variable transmission rate.

Fig. 3 shows end-to-end delay (Latency) of three protocols. MM-SOAR gives lower delay at a lower transmission rate, but as the rate increases delay increases. But both MM-AOMDV and MM-OLSR have a higher delay than their AOMDV and OLSR respectively.

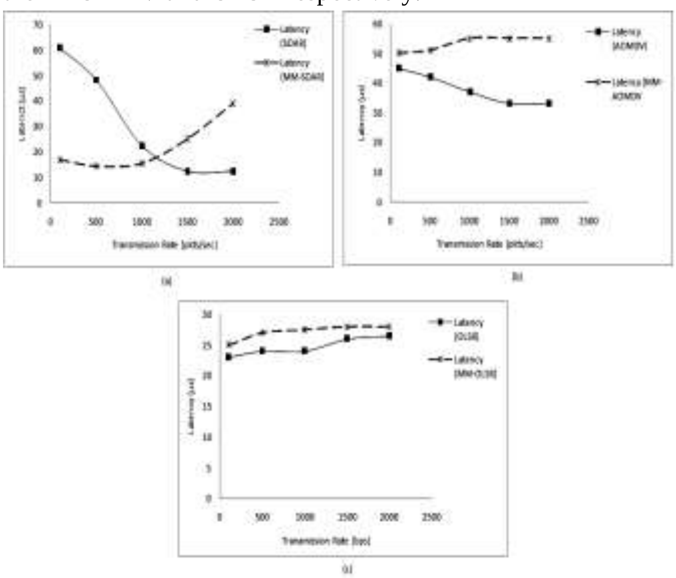

Figure 3. Latency comparison of (a) SOAR, (b) AOMDV and (c) OLSR routing protocol for variable transmission rate.

Node density plays an important role in network performance. We measured throughput of SOAR, AOMDV and OLSR by varying the node density from 35 nodes to 55 nodes. We observed that even node density increases all three protocols performs better in terms of throughput.

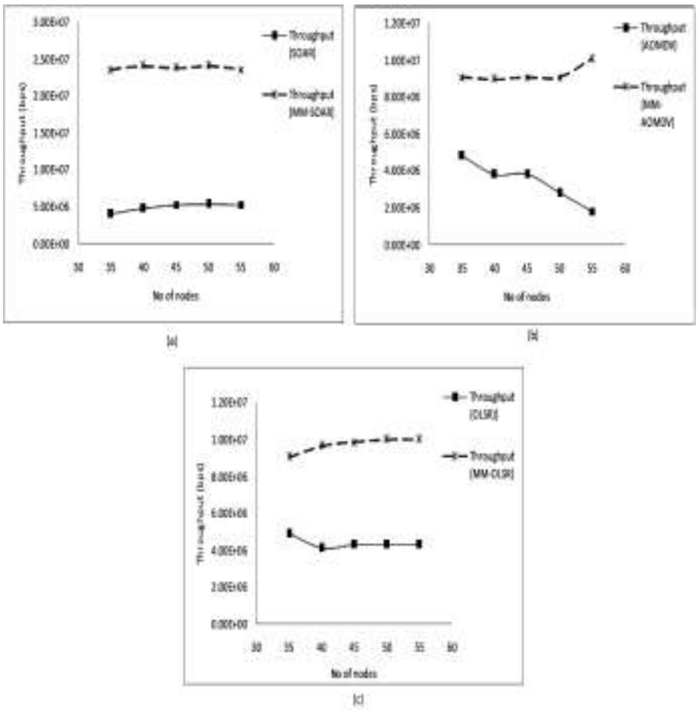

Figure 4. Throughput comparison of (a) SOAR, (b) AOMDV and (c) OLSR routing protocol for variable transmission rate.

V. CONCLUSION

This work, we have evaluated the performance of Multiple Metric Cost (MMC) routing metric for Wireless Mesh Networking. We simulated three routing protocols one opportunistic (SOAR), one reactive (AOMDV) and one proactive (OLSR) using ETX and MMC. OMNET++ simulator is used to show that MM-SOAR, MM-AOMDV and MM-OLSR gives better throughput. MM-SOAR gives lower overhead, but MM-AOMDV and MM-OLSR give higher overhead and delay as compared to their basic protocols. Thus we can say that MMC works better for all three routing classes. Even though MM-AOMDV and MM-OSLR gives more overhead and delay, but much more throughput than AOMDV and OLSR.

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