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Performance Evaluation of Cross Layer Routing Metrics in Multi-Radio Wireless Mesh Network

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Abstract: Wireless Mesh Networks (WMNs) have recently attained lot of popularity due to their rapid development and instant communication capability. The two factors that influence the performance of wireless routing are routing metrics and routing algorithms. Most of these metrics are designed using cross layer approach for specific type of mesh networks. Therefore there is a need for evaluating the performance of these routing metrics in infrastructure WMN. In this paper we study and evaluate the performance of three cross layer routing metrics of OLSR (optimized link state routing protocol) using NS-2. The routing metrics that we compare include Expected Transmission Count (ETX), Contention Aware Transmission Time (CATT) and Metric for Interference and Channel Switching (MIND). The results show that MIND and CATT improves the throughput and decreases the delay. However, ETX performance is poor compared to other metrics.

Keywords: Wireless Mesh Networks, Routing Metrics, QoS, OLSR, ETX, MIND, CATT

I. INTRODUCTION

The wireless mesh network [1] is communication network which consist of set of nodes structured in a mesh topology. It is comprised of mesh routers, mesh clients and gateways. In mesh topology one or certain number of nodes can be selected as mesh gateway to enable communication with other networks such as internet and some of the nodes can be acting as access point to provide communication to client stations. In this network nodes have less mobility and high energy. The important characteristics of mesh network are they are self-furnishing, self-arranging, self -healing. The route computation algorithms along with cross layer routing metric and routing protocols are significant factors of wireless mesh network. Routing metric are expressed in mathematical form to measure the quality of the link in terms of throughput, pdf and end to end delay.

In this paper, we carry out extensive performance evaluation of three routing metrics-ETX, CATT and MIND using NS-2. We choose OLSR as routing protocol on which these routing metrics are implemented. The performance differentials are analyzed using performance metrics such as throughput and end-to-end delay.

The section II describes the overall architecture and components of wireless mesh network, section III discusses various cross layer routing metrics along with their pros and cons, section IV includes analysis of simulation results of routing metrics and section V concludes the study of routing metrics.

II. RELATED WORK

This section describes architecture of wireless mesh network and functionality of OLSR routing protocol.

A. Wireless Mesh Network Architecture

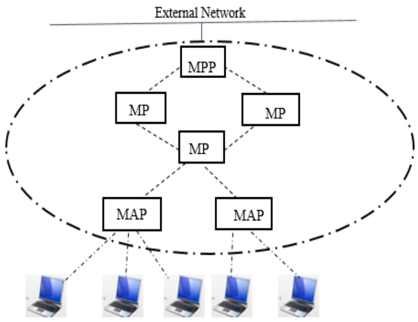

Fig.1. Architecture of wireless mesh network

The IEEE 802.11 standard supports for communication among the nodes by defining the overall architecture. The figure 1 shows the architecture of wireless mesh network. It includes following components.
Portal point: the IEEE mesh networks consist of number of portal points which are connected to the gateway. The routing protocols identifies which portal point to use in order to access the wired infrastructure. The portal points indicate their presence by broadcasting the messages to all other nodes in the network.
Mesh point (MP): It determines how to forward the data packets through backbone network to the destination. It acts as layer 2 router and has less functionality.
Access point: The functionality of access point is similar to the mesh point and provides legacy 802.11 interface.

B. Optimized Link State Routing (OLSR)
Optimized Link State Routing Protocol (OLSR) is a proactive routing protocol, in which the routes are always immediately available when needed. To reduce the overhead in the network protocol uses Multipoint Relays (MPR). The use of MPR is to reduce flooding of broadcasts by reducing the same broadcast in some regions in the network. Also, it reduces the time interval for the control messages transmission.
OLSR uses two kinds of the control messages: Hello and Topology Control (TC). Hello messages are used for finding the information about the link status and the host's neighbors. With the Hello message the Multipoint Relay (MPR) Selector set is constituted which describes which neighbors has chosen this host to act as MPR and from this information the host can calculate its own set of the MPRs. The Hello messages are sent only one hop away but the TC messages are broadcasted throughout the entire network. TC messages are used for broadcasting information about own advertised neighbors which includes at least the MPR Selector list.

III. SIMULATED ROUTING METRICS

In this section we discuss three routing metrics along with their characteristics, merits and demerits.

A. Expected transmission count:
Expected Transmission count (ETX) [2] is stated as the number of transmissions and retransmissions needed to successfully deliver a packet over a wireless link. This metric is the amalgamation of path length and packet loss ratio.
ETX of the link is calculated as follows:

$$ETX = \frac{1}{d_{fwd} \cdot d_{rvs}} \quad (1)$$

Where d_{fwd} is the probability of successful reception of the packet at the destination and d_{rvs} is the probability of successful reception of acknowledgement at the source node. Performance of ETX is good compared to minimum hop count routing metric because ETX is based on delivery ratios which affects the throughput. ETX does not predict channel diversity in MCMR multi-hop wireless networks because it is aimed to consider for single channel single radio.

B. Contention aware transmission time
CATT [6] metric is the combination of contention aware routing metric and iAWARE [5] routing metric. It can be used in link state protocols, with the help of CATT it is possible to balance the load on the links and to obtain path that optimizes total packet transmission time.
It can be calculated as follows:

$$CATT_i = ETX_i * \sum_{k \in N_i} \left(\sum_{k \in N_j} \frac{R_k}{L_k} \right) * T_j * \frac{R_j}{L_j} \quad (2)$$

Where N_i is the number of connections that interfere with the transmission on connection i, N_j is number of connections that interfere with transmission on the connection *j*. R_k and R_j indicate the packet size of the connections containing 1 and 2 hop neighbors respectively. *Bk* & *Bj* estimates the bandwidth of connections in 1 and 2 hop neighbors respectively. T_j is defined as data transmission attempt rate on connection *j*.
Delay does not consider the traffic load in an accurate manner. It assumes that all interfering links interfere constantly with transmission over link which can result in overestimation of link quality.

C. Metric for interference and channel switching
MIND [7] metrics considers interference and load aware factors by passive supervision mechanism hence reduces overhead caused by active probing technique. It can be defined as

$$MIND = \sum_{link_{i \in p}}^{n} INTERLOAD_i + \sum_{node_{j \in p}}^{m} CSC_j \quad (3)$$

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INTERLOAD factor is for inter-flow interference and load, CSC considers intra-flow interference, n estimates the number of wireless connections, m is the number of nodes over route p. INTERLOAD factor can be defined as:

$$INTERLOAD_j = \left(\left(1 - IR_j\right).\tau\right).CBT_j \quad (4)$$

Where $0 \leq RI \leq 1$ and $0 \leq CBT \leq 1$.
IR is the interference ratio and estimates the interference between the connections and is given by:

$$IR_j = \frac{SINR_j}{SNR_j} \quad (5)$$

The channel busy time is given as

$$CBT_j = \frac{Total\ time - Idle\ time}{Total\ time} \quad (6)$$

Total time is the time between the first attempt to send packet and reception of its acknowledgement. Idle time is the time to sense that the channel is free for data access. Thus CBT is the estimation of time spent during data transmission, reception and reside in states. This metric does not employ ETX estimates and avoids disadvantages of these metrics such as reduced performance in high loads. MIND provides the Methodology that combines both physical and logical interference. The isotonic property is achieved in this metric by CSC component and virtual networks.

IV. PERFORMANCE EVALUATION

A detailed simulation study is carried out in order to analyze the performance of various cross layer routing metrics. It mainly consists of three parts. The First covers the simulation environment. Second part is composed of various parameters considered for evaluating the performance of routing metrics. In third part simulation results of routing metrics are undertaken for performance evaluation.

A. SIMULATION ENVIRONMENT

We conduct the simulation using NS-2.34 [8] to obtain the results for routing metrics. The CMU tool [9] was used to create the network topology with 10 flows which are generated randomly. We have used static scenario for comparing the performance of routing metrics. The CBR traffic is generated using traffic-scenario generator script cbrgen.tcl. the nodes are varied from 30 to 50. packets allowed to transfer are 50. The different parameters used are illustrated in table

Table I : Simulation Parameters

Parameters	**Values**
Number of Nodes	Varying nodes from 30 to 50
Number of CBR flows	25
Environment Size	750 m * 750 m
Transmission Range	250 m
Traffic Type	CBR
Packet Size	512 bytes

b. Performance Parameters

Average end to end delay: Dividing the total time difference between total number of CBR packets sent and received gave the average end-to-end delay for the received packets. Lower the end to end delay better is the performance of the protocol.
Average throughput: The throughput is average rate of successful packet delivery over a communication channel.

c. Simulation results

This section includes the comparison of various routing metrics such as MIND, CATT and ETX. Figure 1 and figure 2 show that ETX has lowest throughput and highest delay over MIND and CATT. ETX does not provide information about the traffic in the network and hence fails in load balancing. CATT considers effect of interference and traffic load cost of 1 and 2 links away from a link. Therefore the performance is better when CATT is used. MIND considers both physical and logical model to illustrate interference while using same measure to illustrate logical interference and load on network i.e. channel busy time. So MIND and CATT performance is better compared to ETX.

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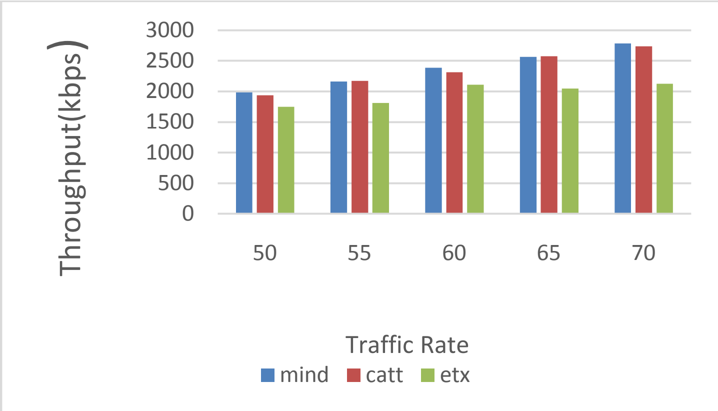

Fig 2 Throughput

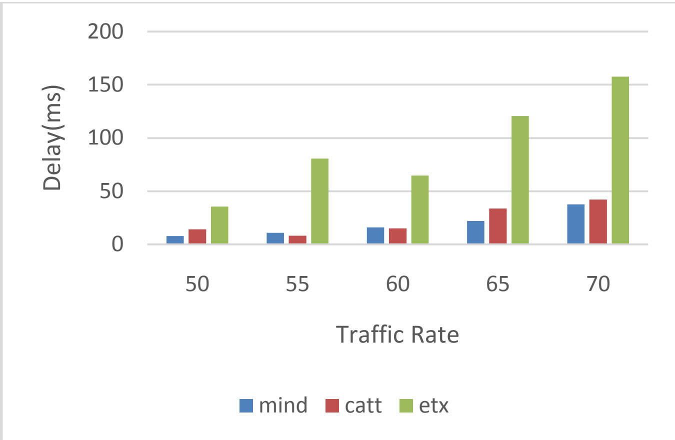

Fig. 3 Average End to End delay

V. CONCLUSION

This paper focuses on the rounting issues concerned in multi radio wireless network. The development of rouitng metrics has led to an increased difficulty in route computation by adopting new estimation.. The analysis results shows that MIND and CATT metrics performed better then other metric. MIND takes into account interference and channel busy time to measure the load accurately in the case of high congestion. The analysis results also showed that ETX performed the least.

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