Fluctuating Interference Tolerant Routing Metric for Wireless Mesh Network

Dataset · December 2012

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***Abstract*- With increasing number of hand held devices, Quality of Service (QoS) has become an essential requirement for Wireless Mesh Network (WMN). Various routing metrics like Expected Transmission Count (ETX), Expected Transmission Time (ETT), Weighted Cumulative Expected Transmission Time (WCETT), Metric of Interference and Channel Switching (MIC) etc have been proposed for improving QoS, routing performance and network capability. But most of these metrics lack in effective reflection of link interference. In this paper a new routing metric called Weighted Metric of Interference and Channel Switching (WMIC) has been proposed. WMIC and other relevant existing routing metrics have been simulated in NS2 over OLSR routing protocol. It has been observed that WMIC metric performs better than other routing metrics with respect to throughput, delay, routing load and packet loss rate.**

***Keywords*- Wireless mesh networks, interference, routing metric, isotonic, OLSR**

I. INTRODUCTION

Wireless Mesh Network (WMN) has the ability of dynamic self-organization, self-configuration and self-healing. These features facilitate quick deployment, easy maintenance, low cost and high scalability. It also increases network capacity [1]. To support multimedia applications, Quality of Service (QoS) provisioning has become important in WMN. In this context, selection of path is a critical factor. Several routing protocols and metrics have been proposed. Since in wireless network nodes access shared wireless media, the neighboring nodes may compete for same bandwidth. This may result in intra-flow interference (interference caused by neighboring nodes transmitting packets from the same flow) and inter-flow (interference suffered among concurrent flows) interference. Therefore, link quality must be taken under consideration while taking the routing decisions.

Several routing metrics [2] such as Expected Transmission Count (ETX), Expected Transmission Time (ETT), Weighted Cumulative Expected Transmission Time (WCETT) and Metric of Interference and Channel Switching (MIC) have been proposed. The common problem with ETX, ETT and WCETT is that, these metrics are not capable of capturing interference fully [4]. On the other hand, MIC captures both types of interference but it cannot handle sudden and very temporary change in interference due to environmental effect [4].

For this reason a new routing metric, Weighted Metric of Interference and Channel Switching (WMIC) has been introduce. It has been implemented over Optimized Link State Routing (OLSR) routing protocol [9].

This paper is organized as follows. Section 2 describes some of the existing routing metrics for wireless mesh network. In section 3 a new metric named WMIC has been proposed. Section 4 talks about the simulation results of WMIC metric and its performance analysis compared to other relevant routing metrics and finally section 5 presents, conclusion.

II. RELATED WORK

This section discusses some of the related routing metrics for wireless mesh networks.

ETX [2] returns the average number of MAC layer transmissions including the re-transmissions needed to successfully deliver a packet over a wireless link. ETX is an isotonic routing metric [10] and it can be used for finding minimum weight paths [3]. ETX does not consider the interference. On the other hand, ETT [3, 7] represents the time required to successfully transmit a packet through the link**.** This metric is also isotonic**.** It does not fully capture intra-flow and inter-flow interference.

WCETT metric [3, 5] captures intra-flow interference. But it does not consider the inter-flow interference. It is not isotonic and cannot used to find shortest path by using Bellman-Ford or Dijkstra's algorithms.

MIC returns cost of a routing path by considering both inter-flow interference and intra-flow [2, 3] interference. Interference-aware Resource Usage (IRU) component of MIC capture inter-flow interference of a link and Channel Switching Cost (CSC) part capture intra-flow interference of a link. Total MIC for a path is obtained by adding the MIC of all the links of a routing path.

III. PROPOSED METRIC

This section describes about the proposed routing metric Weighted Metric of Interference and Channel Switching (WMIC). It is based on the MIC routing metric that captures both the intra-flow and inter-flow interference.

In case of MIC, link quality is measured only by taking the instantaneous value of MIC. A very good link may get affected by interference caused by vulnerable environment for a very short time. If at that point of time, quality of that link is measured using MIC metric, the link will be found to be a bad link. But this is not the reality. Thus it leads to selection of a wrong path. To overcome this problem, a MIC based metric named Weighted Metric of Interference and Channel Switching (WMIC) has been proposed. Unlike MIC, WMIC considers the previous value of WMIC apart from considering current value of MIC. As exponential moving average (EMA) of MIC is calculated to obtain current value of WMIC, temporary interference caused by the environment will not have immediate effect on the measured value of link quality but at the same time, WMIC will follow the tendency of change in MIC more closely. This will result in selection of a good communication path. Another advantage of using EMA is that, calculation of EMA does not demands for all previous data, rather the current value of MIC and previous WMIC is sufficient to calculate the WMIC. WMIC is defined as follows:

$$WMIC = (\alpha)\, MIC_{current} + (1-\alpha)\, WMIC_{previous} \qquad (1)$$

Here α is a tunable parameter between 0 and 1. It represents smoothing factor. The MIC [4] in eq. (1) is defined as:

$$MIC(p) = \frac{1}{N * \min(ETT)} \sum_{link\ l \in p} IRU_l + \sum_{node\ i \in p} CSC_i \qquad (2)$$

Here N is the total number of nodes in the network and min (ETT) [3] is the smallest ETT in the network, l is the number of links in a routing path p. Interference aware resource usage (*IRU*) [3, 11] in eq. (2) is defined as:

$$IRU_l = ETT_l * N_l \qquad (3)$$

N_l is the set of neighbors that the transmission on link *l* interferes [3] with. IRU_l is the aggregate channel time consumed by neighboring nodes those transmit on link l. It captures the inter-flow interference as it prefers a path that consumes less channel times at its neighboring nodes. CSC of a node *i* is [2] [3] defined as follows:

$$CSC_i = \begin{cases} w_1, \text{if } channel(prev(i)) \neq Channel(i) \\ w_2, \text{if } channel(prev(i)) = Channel(i) \\ 0 \leq w1 \leq w2 \end{cases} \qquad (4)$$

Channel (i) and prev(i) are the channels used by node i and its previous hop along the same path. If two links on a path are on the same channel, they may interfere. So, these are given weight w_2. Links that do not have conflicting channels are given weight w_1. The metric tries to avoid consecutive hops in a path operating on identical channels, by giving it a higher cost. Thus CSC component captures the intra-flow interference between links on the path.

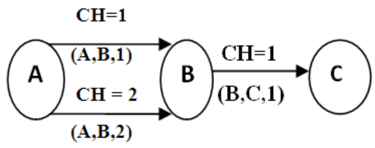

Fig.1 Non-isotonicity of WMIC

A. *Decomposition of WMIC Metric into a Virtual Network for Isotonicity*

Isotonicity is the most important issue for any routing metric to find a loop free shortest path by using Bellman-Ford or Dijkstra's algorithms [8]. In the example shown in fig.1 it has been assumed that link (A, B, 1) has a smaller IRU than link (A, B, 2). The weight of paths (A, B, 1) and (A, B, 2) satisfy: WMIC ((A, B, 1)) < WMIC ((A, B, 2)). However, due to reuse of channel 1 on path (A, B, 1) ⊕ (B, C, 1) (⊕ means concatenation of two paths), WMIC ((A,B,1) ⊕ (B,C,1)) > WMIC ((A,B,2) ⊕ (B,C,2)). This example shows the non-isotonic behavior of WMIC. This reason behind this is that, additional weight that link (B, C, 1) brings to a path not only depends on link (B, C, 1)'s own status, but is also related to the channel assignment of the link that precedes link (B, C, 1).

To solve this problem, WMIC metric is decomposed into virtual network [10]. It considers the possible channel assignments for the precedent link. WMIC can be decomposed into isotonic weight assignments to the links between these virtual nodes. For every channel c a node A's radios are configured to two virtual nodes $A_i(c)$ and $A_e(c)$. $A_i(c)$ represents that prev(A) transmits to node A on channel c. $A_e(c)$ indicates that node A transmit to its next hop on channel c.

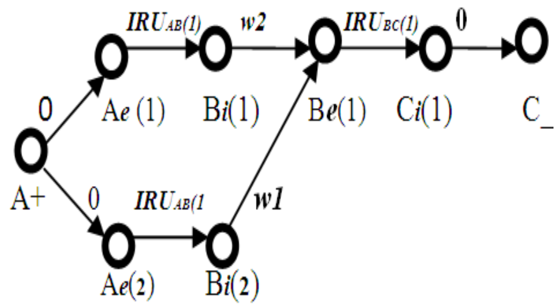

Fig: 2. Virtual Network of WMIC

The original paths in Fig. 1 are mapped to the virtual network shown in Fig. 2.

TABLE I

REAL NETWORK MAPPING TO THE VIRTUAL NETWORK

Real Path	**Virtual Path**	**WMIC**

(A,B,1) ⊕ (B,C,1)	Ae(1) →Bi(1) → Be(1) → Ci(1)	IRU*AB*(1) + IRU*BC*(1) + *w2*
(A,B,2) ⊕ (B,C,1)	Ae(2) →Bi(2) → Be(1) →Ci(1)	IRU*AB*(2) + IRU*BC*(1)+w1

IV SIMULATION AND ANALYSIS

This Section describes the performance of WMIC compared to ETX, ETT, and MIC. The metrics are implemented as routing metrics for path selection on OLSR routing protocol. Network Simulator 2 (NS2) [6] has been used as simulator. Simulation parameters are shown in Table 2. The routing metrics i.e. ETX, ETT, MIC and WMIC are compared with respect to throughput, delay, packet loss rate and routing overhead in varying the network load (20 kb to 140 kb).

TABLE II

SIMULATION PARAMETERS

Parameter	Value
Network Size	10
Topology Size	1000m
Transmission Range	500m
Propagation Model	TwoRay Ground
Load	20,40,60,80,100,120,140
Simulation Time	30s
Data Channel rate	2Mbps
PHY Specification	802.11 b/g
Antenna	Omni directional
Runs	5

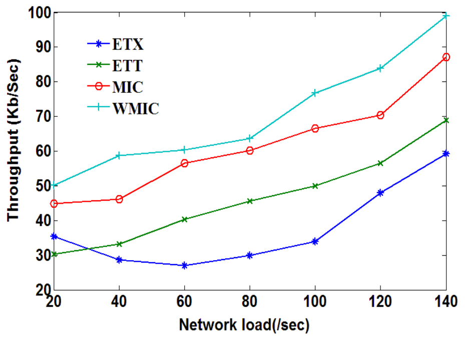

Fig. 3 Throughput vs. Network load

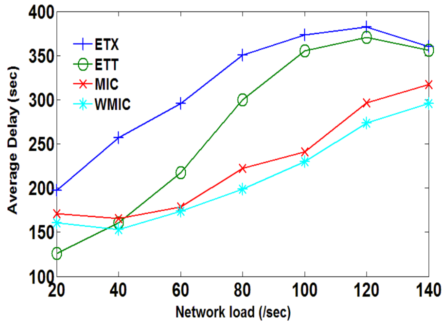

Fig. 4 Delay vs. Network load

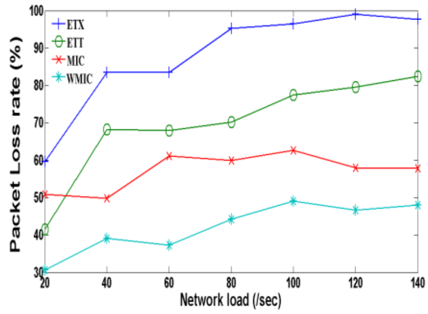

Fig. 5 Packet loss rate vs. Network load

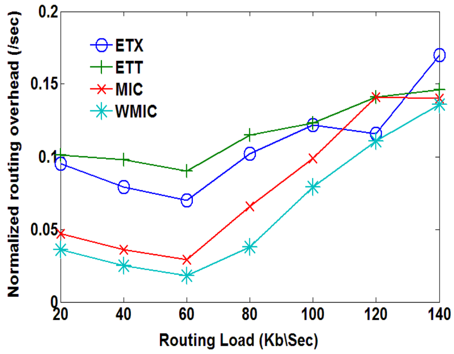

Fig. 6 Normalized routing overhead vs. Network Load

The average throughput is the average bandwidth of the protocol. Fig 3 shows throughput comparison with respect to network load. As network load increases WMIC metric gives higher throughput than ETX, ETT and MIC. From the mathematical eq. (1) it can be observed that WMIC has been smoothen out by using EMA on MIC. So, the routing process will not react much due to sudden but temporary change in MIC. Moreover since WMIC is derived from MIC, it will be aware of intra-flow as well as inter-flow interference.

End-to-end delay refers to the time taken for a packet to be transmitted across a network from source to destination. From fig 4 it can be observed that with the increase in network load use of WMIC metric leads to lower delay compared to ETX, ETT and MIC. This is because of reduced number of packet drops due to interference.

Packet loss refers loss of packets during a routing process. Fig 5 shows packet loss rate comparisons with respect to network load. With the increase in network load, loss rate also increases but in case of WMIC, the packet loss rate is the least among the rest three routing metrics. This is because WMIC prevents sudden data loss due to over estimation of link interference.

The normalized routing overhead is the number of routing packets transmitted per data packet delivered at the destination. Normalized routing overhead is the overhead offered by the protocol under the given scenario. Fig 6 shows normalized routing overhead comparisons with respect to network load. It can be observed that WMIC has lower Routing overhead compare to rest three, as the packet flow rate increases. The reason behind this is that, cost incurred for route setup is reduced since WMIC reduces number of route breakages.

Figures 3, 4, 5 and 6 shows that WMIC metric is able to achieve higher throughput, lower delay, lower loss ratio and lower normalized routing overhead compared to ETX, ETT and MIC for all network loads considered in this simulation. These results are due to the fact that WMIC uses EMA and considers both types interference.

V. CONCLUSION

This paper described the critical factors which are required to design interference aware routing metrics for Wireless Mesh Networks. After identification of few important characteristics which are not implemented in metrics like ETX, ETT and MIC a new metric WMIC was proposed and implemented. WMIC routing metric is based on MIC routing metric. But, unlike MIC WMIC is capable of handling fluctuations in interference. Performance analysis shows that if WMIC is used for path selection in OLSR, it gives higher throughput, lower average delay and lower packet loss rate compared to ETX, ETT and MIC.

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