Multi-Radio Routing For Wireless Mesh Networks Using WMRCETT

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ABSTRACT

Wireless mesh networks (WMNs) are dynamically self-organized and self-configured, with the nodes in the network automatically establishing and maintaining the mesh connectivity. Previous works in multi-radio routing has been based on metrics like ETX (Expected Transmission Rate) , ETT (Expected Transmission Time) and WCETT (Weighted Cumulative Expected Transmission time). In this paper, we propose the metric WMRCETT(Weighted Multi-Radio Cumulative Expected Transmission time) for routing in multi-radio multi-hop wireless mesh networks that aims at choosing a high throughput path between a source and a destination in the presence of multiple radios.

INTRODUCTION

In this paper we focus on wireless mesh networks such as community networks. In such networks, the nodes are minimally mobile and the focus is on providing end-to-end mesh connectivity. The routing algorithms for these networks need to focus on finding efficient, high-throughput path rather than worrying about mobility and power constraints [1,2].

The major problem in such networks is the reduction in throughput owing to the interference caused by the usage of same radio (same frequency) by adjacent hops in a link. Owing to the decreasing costs of radios and minimal power constraints that we have, we can afford to provide multiple radios for a single node [2]. These radios can communicate without interference as they operate on different frequencies. By choosing to use different radios in a multi-hop path, the throughput can be dramatically improved.

Let us illustrate how throughput increases by the usage of multiple radios. In the given figure (1), (omit the times given in the figure for now) if the link between a and b and the link between b and c, use the same radio (same frequency), then only one link can be active at a given point of time. When a transmission from a to b is taking place, the transmission from b to c has to stop and vice-versa. But if both the links use different radios both the transmissions can go in parallel.

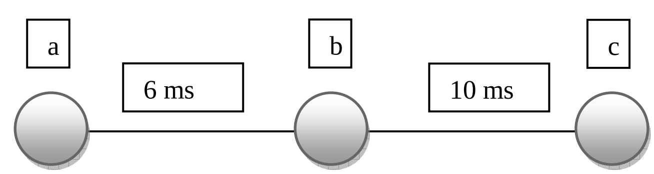

Figure (1) *. Example illustration of usage of multi-radios. Nodes are named as a, b and c. ETTs for the two hops are also provided.*

In this paper, we define the metric WMRCETT for routing in multi-radio wireless mesh networks. We use a link state routing algorithm that uses WMRCETT as a routing metric for path selection.

The rest of the paper is organized as follows. First we present the routing metrics ETT and WCETT [2]. Following that we define our routing metric WMRCETT and explain how routing can be done using WMRCETT. The final section deals with the conclusion of our work.

RELATED WORK

Our metric, like any other routing metric for multi-radio wireless mesh networks, needs to satisfy the following three design goals. One, the metric should take into account both bandwidth and loss rate. Two, the metric should increase with more hops added to the path. This is because of the fact that more resources are utilized with usage of more hops and also the impact that this flow has on other flows. Three, the metric should account for interference taking place due to the usage of same radio in adjacent hops and should effectively utilize the presence of multiple radios in the network.

The ETT is the Expected Transmission Time of a data transmission in a direct link. The transmission involves both data and the acknowledgment for the data received. The calculation of ETT is not of that much significance for our discussion. It is discussed detail in [2] and [3]. The ETT metric considers both bandwidth and loss rate into account [2].

The WCETT is defined as the end-to-end delay (It is inversely related to the throughput of a multi-hop path) [2]. WCETT is defined as the sum of ETTs of all the hops along the path.

Thus for a path with n hops,

$$WCETT = \sum ETT_i \quad ,$$

$$\text{where } i=1 \text{ to } n \qquad (1)$$

This definition of WCETT increases with multiple hops added to the path. But this metric does not utilize the presence of multiple radios.

Now, trying to bring in channel diversity, WCETT is defined in another way. Considering the network described in figure (1), if hop 1 and hop 2 use same radios then throughput will be the sum of ETTs (i.e. 6+10 = 16 , in this case). If hop 1 and hop 2 are going to use different radios, they can transmit simultaneously. The throughput is dominated by the channel that has the highest ETT (hop 2 having an ETT of 10 in this case). Generalizing the idea we define,

$$X_j = \sum_{\text{Hop } i \text{ is on channel } j} ETT_i \,,$$

$$\text{where } 1 <= j <= k \qquad (2)$$

where k is the number of different channels (radios) available.

The throughput is dominated by the bottleneck channel. Hence WCETT is defined as,

$$WCETT = \max_{j=1 \text{ to } k} X_j \qquad (3)$$

THE WMRCETT (WEIGHTED MULTI-RADIO CUMULATIVE ETT) METRIC

The WCETT defined in (3) is pessimistic towards longer paths (paths with many hops). WCETT metric assumes that two links using the same radio interfere no matter how many hops they are apart. Considering the network in figure (2), in computing the WCETT metric for a path from node 1 to node 6, we find that the metric assumes that link 1 and 5 cannot transmit simultaneously (which is not the actual case).

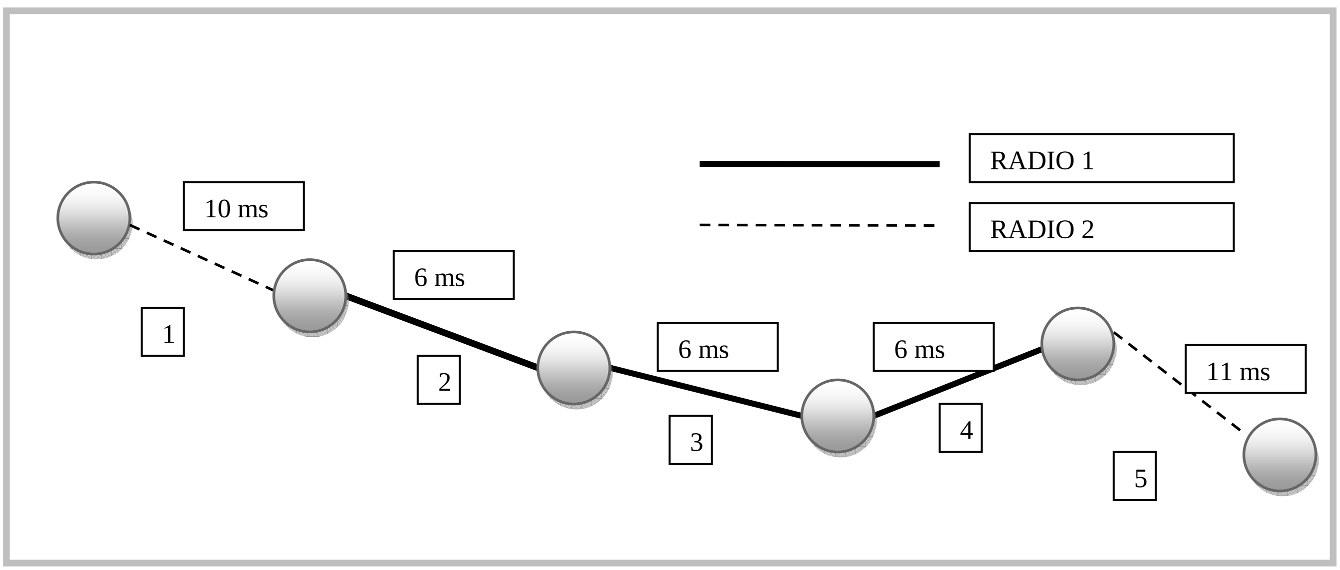

***Figure (2)**. Illustration of throughput measure using MRCETT in comparison with WCETT. ETTs of all the hops are provided. Hops are named from 1 to 5.*

$X_1 = 10+11 = 21$

$X_2 = 6+6+6 = 18$

$WCETT = \max(X_1, X_2) = 21$

We define a new metric MRCETT that optimally uses the presence of multiple radios to calculate the throughput of a multi-hop multi-radio path. We define M_i as follows,

If i^{th} node and $i+1^{th}$ node uses the same radio,

$$M_i = ETT_i + ETT_{i+1} \qquad (4)$$

If i^{th} node and $i+1^{th}$ node use different radios,

$$M_i = \max (ETT_i , ETT_{i+1}) \quad (5)$$

The MRCETT metric is defined as,

$$MRCETT = \max (M_i) ,$$

where i = 1 to n-1 (6)

Calculating MRCETT for network in figure (3),

MRCETT = max (10,12,12,11) = 12.

This metric assumes that two transmissions that are one hop away and using same radios can take place simultaneously. For example, in the network in figure (3) transmissions in hop 2 and hop 4 can take place simultaneously. As community wireless networks are built to provide connectivity, we expect nodes to be far apart rather than congested nodes as in case of ad-hoc networks. Hence the assumption that we make almost always holds true. Also when more radios are used then the hop distance between two links using the same radio in a multi-hop path is high, which eliminates the possibility of interference.

The MRCETT, like WCETT in (3), does not increase with the number of hops added as long as the new hops added are to non-interfering channels. To make the metric increase when more hops are added to the path, we take a weighted mean of MRCETT and WCETT defined in (1).

$$WMRCETT = \alpha \; MRCETT + (1-\alpha) \left(\sum ETT_i \right) \quad (7)$$

where the parameter α is such that, $0 < \alpha < 1$. Suitable value of α for different network configurations are determined and used.

ROUTING USING WMRCETT

We use a DSR based source routing algorithm along with a link state routing protocol. Each node identifies the links to its neighbors and calculates ETT for the respective links. The link state packets are built at every node and they carry triplets of the form (Destination Address, ETT, Radio). After the link state packets are built they are flooded across the network. Each node collects the link state packets of all the other nodes. After receiving the link state packets the WMRCETT value is calculated using the ETT values. The path having the least WMRCETT value is expected to have the highest throughput and that path is considered as the shortest path. Source routing is used to route the packets along the specified path.

To add robustness to the network multiple paths are stored in the order of throughput. Once the highest throughput path is broken, the next highest path can be chosen instead of starting the routing process from scratch.

CONCLUSION

In this paper we have proposed the metric WMRCETT for routing in multi-radio wireless mesh networks and incorporated the metric in a link state routing algorithm with source routing. The proposed idea is expected to work well in multi-radio wireless mesh networks with multi-hop paths. The WMRCETT is optimistic for longer paths and the throughput is expected to increase with increase in the number of radios used.

We are currently doing simulation studies by using the WMRCETT metric with the routing algorithm described in previous section with a test-bed with nodes that are equipped with multiple radios. We expect an increased throughput in comparison to the metrics like WCETT and ETX.

Choosing a proper value of α greatly influences the metrics performance. The simulations are being done using various values of α to find the exact α value that fits to the network under consideration.

The throughput is expected to increase with the increase in the number of radios. The throughput is to be observed by varying the number of radios and the results are to be compared with the throughput results got using WCETT metric. The metric is expected to gain significance over WCETT metric with the usage of more number of radios.

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