Interference-Aware Multipath (IAM) Selection in Multi-Radio Multi-Channel Wireless Mesh Networks

Mian Hammad Ullah and Choonhwa Lee
Department of Electronics Computer and Communication Engineering, Hanyang University
17 Haendang-dong, Seongdong-gu, Seoul 133-791, South Korea.
{hami, lee}@hanyang.ac.kr

Abstract

Recent research work has unearthed that multi-radio multi-channel wireless mesh networks offer considerable capacity gains over single-radio wireless mesh networks. In this paper, we present a new routing metric for multi-radio multi-channel wireless mesh networks. The goal of the metric is to choose multiple link/node disjoint paths between a source and destination node that, when used concomitantly, impart high end-to-end throughput. The proposed metric selects high fidelity paths that will produce elevated throughput with maximum fault tolerance.

1. Introduction

Recently, the multi-radio multi-channel network architecture has been recognized as a promising approach towards improving the capacity of wireless networks [1]. With the aim of exploiting the bandwidth available on multiple channels in a multi-radio network, WCETT [2] metric opts for high throughput and channel diverse path. Nonetheless, a solitary path may not use the bandwidth available on all the channels available when the radios are tuned to different frequency bands. This can occur when the channel diversity on a single path does not guarantee the utilization of all offered channels. Consequently, use of multiple paths is needed to make the most of the bandwidth obtainable on the supplementary channels.

2. The Selection Metric

2.1 Route Discovery

In the route discovery algorithm, a node $N_{(k,l)}$ (i.e., l^{th} node on k^{th} path) informs source node S of the channels on which it communicates with its previous and next node. For each channel, the interference factor I_{ki} is then calculated using Equation (1) and is exhibited in Fig. 1.

$$I_{ki} = \sum_{\substack{Hop\ l\ \ is\ on\ Channel i\ \ and\ (l+1) \\ or\ (l-1)\ \ is\ \ also\ on\ \ channel i}} ETT_{kl} \qquad (1)$$

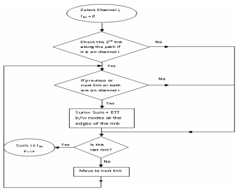

Fig.1. Flow chart to determine ETT on a single path.

In CAM [3], the partial end-to-end characteristics of the two paths R_1 & R_2 is calculated using the load distribution factor r_1:r_2 as follows:

$$Y(r_1, r_2) = \left[r_1 * WCETT(R_1) + r_2 * WCETT\ (R_2)\right] / (r_1 + r_2) \qquad (2)$$

Where WCETT [3] for a path R_k with m_k channels and n hops is given by:

$$WCETT\ (R_k) = \eta * \max_{1 \le i \le m_k} I_{ki} + (1-\eta) * \sum_{i-1}^{n} ETT_{ki} \qquad (3)$$

Equation (2) does not account for the mutual interference among multipath but only accounts for the end-to-end characteristics. Therefore, we modified CAM [3] to portray the interference among the multipath appropriately.

2.2 Neighbor Discovery and Information Sharing

In the neighbor discovery process, each node informs the source node of the connections it has to its neighbors. Let this information be stored in the set $S_{(k,j)}$. Subsequently, if there is no common node (node disjointness) in the sets $\sum_{j=1}^{n_k} S_{(k,j)}$ and $\sum_{j=1}^{n_{k+1}} S_{(k+1,j)}$ (where k and n_k represent the path and total number of nodes on path k, respectively), which means that any frequency channel on route R_k does not interfere with the same frequency channel on route $R_{(k+1)}$, even if present in some links.

2.3 Inter-path Interference

For inter-path interference, every node shares the information of its active and passive connections

---

This work was supported by the Korea Science and Engineering Foundation (KOSEF) grant funded by the Korea government (MEST) (No.R01-2008-000-10692-0).

(connections that are not active but can be used later) with its neighbors, as shown in Fig. 2.

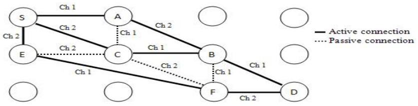

Fig. 2. Active and Passive Connections

This information is beneficial in order to select high throughput paths as the source node has the topology information and can select node/link-disjoint paths. Therefore, the interference impact on channel j in the set of channels of route $R_{(k)}$ and set of channels of route $R_{(k+1)}$ can be given as:

$$Y_j\left(r_k, r_{(k+1)}\right) = \left\lfloor r_k * I'_{ki} + r_{(k+1)} * I'_{(k+1)i} \right\rfloor / \left\lfloor r_k + r_{(k+1)} \right\rfloor \tag{4}$$

$$\text{Where } I'_{ki} = \sum_{\substack{\textit{Hop } l \textit{ is on channel } i \\ \textit{to hop}(l+1) \textit{ and it} \\ \textit{is also on channel } i \\ \textit{with its neighbors of path} \\ (k+1). \textit{Also, if the neighbors of} \\ \textit{node } l \textit{ are on channel } i \textit{ with} \\ \textit{their neighbors.}}} ETT_{kl} \tag{5}$$

Equation (5) accounts for those links that are operating on same channels in the multipath. In other words, Equation (4) accounts for the interference from source to destination node and is demonstrated in Fig. 3.

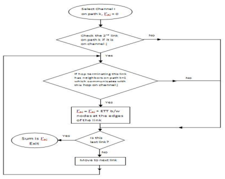

Fig. 3. ETT on multipath.

Consequently, the interference index (λ) is:

$$\lambda = \max\left\lfloor Y\left(r_k, r_{(k+1)}\right)\right\rfloor \tag{6}$$

Equation (6) specifies the channel that is affected by interference the most in multipath and has a vital effect on the throughput of the network. Therefore, the transmission time of a channel with the greatest value is considered to indicate the presence of potential bottleneck channel.

2.4 Interference Aware Multipath (IAM)

The new metric for the multipath selection can thus be given as:

$$IAM = \eta * \lambda + (1-\eta) * Y$$

(7) Equation (7) unequivocally considers the interference among links in multipath in addition to single path. The 1st constraint considers links that may interfere with other links on multipath from source to destination. Additionally, the 2nd constraint considers the end-to-end characteristics of the paths with the surety that only those links that may interfere with each other in a single path are considered. A low value of IAM corresponds to high throughput and vice versa.

It is also obvious that the metric is very supportive for the depiction of interference in the network. For instance, links close to the source node may not interfere with those that are close to destination node on longer paths. Accordingly, links that have an effect on the throughput with respect to interference are considered as opposed to other approaches [2, 3]. Also, it provides fault-tolerance through link or node disjointness.

3. Simulation study

As the proposed algorithm clearly accounts only for those links that may interfere with each other on single and multipath, we predict that it will select high throughput paths even when the interference increases in the network. Since [3] assumes that all the links in the multipath interfere with each other, it is not able to select links that may not interfere and can produce high throughput. Therefore, the achievable throughput using our proposed algorithm is expected to be higher. Moreover, as our approach is optimistic (considering only the true interference in the network); the achievable throughput will use fewer routes.

4. Conclusion

Multi-radio multi-channel mesh networks provide significant capacity gains over single-radio mesh networks. Single path routing is unlikely to utilize the bandwidth available on all the channels in the vicinity.

In this paper, we proposed a new algorithm based on the physical interference of the network. The proposed algorithm accounts for only those links which can interfere with each other in a single or multipath. Additionally, it allows to tradeoff channel diversity and path length by changing the value of the control parameter η. Furthermore, the information disseminated by intermediate nodes is used to select node/link disjoint paths depending upon the node density in the network.

References

[1] P. Bahl, A. Adya, J. Padhye, and A. Wolman. “Reconsidering Wireless Systems with Multiple Radios” *ACM CCR*, Jul 2004.

[2] R. Draves, J. Padhye, and B. Zill. “Routing in Multi-Radio, Multi-Hop Wireless Mesh Networks”. *In Proc. of MobiCom,* October 2004.

[3] I. Sheriff Elizabeth Belding-Royer “Multipath Selection in Multi-radio Mesh Network”. *In Proc. of IEEE Broadnet* 2006.