한국컴퓨터정보학회 동계학술대회 논문집 제20권 제1호 (2012. 1)

Multiradio Multichannel WMNs의 라우팅 프로토콜 및 메트릭: 연구 및 설계 고려 사항

고 휘°, 이형옥*, 남지승*
°*전남대학교 전자컴퓨터공학과
e-mail: ghuier@daum.net, narcis@freechal.com, jsnam@chonnam.ac.kr

On Routing Protocol and Metric for Multiradio Multichannel WMNs: Survey and Design Considerations

Hui Gao°, Hyung-ok Lee*, Ji-seung Nam*
°*Dept. of Electronics and Computer Engineering, Chonnam National University

● 요 약 ●

Wireless mesh networks are considered a promising solution to last mile broadband. The unique characteristics of WMN impose unique requirements on designing routing protocols and metrics for WMN. However, existing routing schemes that are designed for single-channel multi-hop wireless networks may lead to inefficient routing paths in multichannel. This paper focuses on the routing problem for multi-radio multichannel WMNs. We list the challenges in designing routing algorithms for multi-radio multichannel WMNs. Then we examine the requirements and considerations for designing routing metrics according to the characteristics of multi-radio multichannel WMNs. Finally we survey and investigate the existing routing metrics in terms of their ability to satisfy these requirements.

키워드: wireless mesh networks(WMNs), multiradio multichannel, routing protocol, routing metric

Ⅰ. Introduction

Mesh networks, motivated by wireless neighborhood networks, are composed of static wireless nodes that have ample energy supply. Each of these wireless nodes can be equipped with multiple radios, called a multi-radio/multichannel node, and each of the radios can be configured to a different channel to enhance network capacity. All wireless nodes cooperatively route each other's traffic to the Internet through one or more Internet Transit Access Points (TAPs), which are gateways to the Internet. Nodes may also communicate with each other directly through the mesh network without going through TAPs.

In WMNs each node plays the roles of both a host and a router, and packets are forwarded in a multi-hop fashion to and from the gateway to the Internet. With multiple channels, each radio interface on adjacent links can be assigned a different channel such that the interference among links can be eliminated and the network capacity can be improved. In general, with proper design, leveraging multiple channels available today has several benefits such as increasing system throughput, decreasing end-to-end delay, achieving better load balancing and preventing the starvation problem in single-channel WMNs.

Although there are many routing algorithms proposed for single-channel multi-hop wireless networks, they may lead to inefficient routing paths in multi-radio multichannel WMNs. To fully exploit the availability of multiple channels in WMNs, routing algorithms should account for the existence of channel diversity on a path in the network.

The unique characteristics of multi-radio multichannel WMN invalidate existing solutions from both wired and wireless networks and impose unique requirements on designing routing metrics for mesh networks. In this paper, we focus on identifying these requirements and design considerations. In section II we highlight the challenges in designing routing algorithms for multi-radio multichannel WMNs. In section III we survey and investigate the existing routing metrics in terms of their ability to satisfy these requirements. Section IV concludes our work.

Ⅱ. Challenges in Designing Routing Algorithm

1. New Issues for Routing Metric

The routing metric is a criterion to evaluate the performance of a path in routing algorithms. The most typical routing metric for multi-hop wireless networks is the hop count which cannot capture the quality of a path in wireless environments. In [1] it is showed that using a radio-aware routing metric incorporating the link condition can result in much better performance than the minimum hop count approach. The study in [2] deals with that a routing metric accounting for multi-rate delivery and interference can discover paths with much higher capacity than other routing metrics.

In multi-radio multichannel WMNs the channel diversity is another key factor since the end-to-end performance of a routing path is governed not only by which nodes this path concludes, but also by to which channels the links of this path are tuned. In [3] the authors show that a routing metric which accounts for channel diversity.

2. Distributing Traffic among Channels

Utilizing multiple channels allows parallel transmissions on non-overlapping channels. However, without accounting for the traffic load distribution among channels, traffic may be put together on certain channels, thus degrading network utilization. In order to solve this problem, multichannel routing algorithms should compare different possible routes composed of alternative nodes as well as alternative channels, between source and destination.

3. Channel Assignment

For routing in multi-radio multichannel WMNs. Channel assignment is a companion issue [5, 4, 6]. The objective is to assign a channel to each radio interface such that the network capacity is maximized. Since two adjacent nodes can communicate with each other only if they are assigned a common channel, the channel assignment controls the network topology and consequently the available routes between any pair of nodes are confined. Therefore, a well-designed routing algorithm for multichannel WMNs may become useless without considering channel assignment issue.

III. Routing Metrics

The routing metric is the key component of the multichannel routing algorithm and significantly influences network performance. Generally, to guarantee good performance routing metrics must have several capabilities including route stability, good performance for minimum weight paths, efficient algorithms to calculate minimum weight paths and loop-free routing.

1. Routing Metrics for Mesh Networks

We discuss several routing metrics that have been proposed for mesh networks and whether they satisfy the required properties. All these routing metrics are topology-dependent and each routing metric was proposed as an improvement over the previous one.

1.1 Hop Count

Hop count is the most commonly used routing metric in existing routing protocols and it reflects the effects of path lengths on the performance of flows. Since a hop count metric is isotonic, efficient algorithms can find loop-free paths with minimum hop count. However, hop count does not consider the differences of the transmission rates and packet loss ratios between different wireless links, or the interference in the network. Hence, using a hop count metric may not result in good performance.

1.2 Expected Transmission Count (ETX)

ETX is defined as the expected number of MAC layer transmissions that is needed for successfully delivering a packet through a wireless link. The weight of a path is defined as the summation of the ETX's of all links along the path. Since both long paths and lossy paths have large weights under ETX, the ETX metric captures the effects of both packet loss ratios and path length.

However, the drawbacks of ETX are that it does not consider interference or the fact that different links may have different transmission rates.

1.3 Expected Transmission Time (ETT)

The ETT routing metric improves ETX by considering the differences in link transmission rates. The ETT of a link l is defined as the expected MAC layer duration for a successful transmission of a packet at link l. The weight of a path p is simply the summation of the ETT's of the links on the path.

The remaining drawback of ETT is that it still does not fully capture the intra-flow and inter-flow interference in the network. For example, ETT may choose a path that only uses one channel, even though a path with more diversified channels has less intra-flow interference and hence higher throughput.

1.4 Weighted Cumulative ETT (WCETT)

To reduce intra-flow interference, WCETT [1] was proposed to reduce the number of nodes on the path of a flow that transmit on the same channel. For a path, WCETT is defined as the weighted average of the sum of SETT and BGETT:

$$WCETT \equiv (1-\beta)\times SETT + \beta \times BGETT \quad (1)$$

where SETT is the sum of ETTs for all links of the path, which corresponds to an estimation of the end-to-end delay experienced by the packet, and BGETT is referred to bottleneck group ETT which is to quantify the channel diversity. The group ETT (GETT) of a path for channel c is defined as the sum of ETTs for the path's links which operate on channel c. The BGETT is the largest GETT of the path.

The total path throughput is dominated by the bottleneck channel. That is to say the busiest channel on the path decides the path throughput. Thus, while low SETT implies short paths, low BGETT implies channel-diverse and high bandwidth paths.

Accordingly, the routing algorithm is to select the path whose WCETT is the lowest. The WCETT metric strikes a balance between channel diversity and path length (or between throughput and delay) by changing the weighting factor β.

Equation (1) counts the maximum number of times that the same channel appears along a path. It captures the intra-flow interference of a path since it essentially gives low weights to paths that have more diversified channel assignments on their links and hence lower intra-flow interference.

1.5 Metric of Interference and Channel switching (MIC)

The MIC[8], improves WCETT by solving its problems of the inability to capture inter-flow interference. The MIC of a path p is defined as following equation:

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

where *N* is the total number of nodes in the network and *min (ETT)* is the smallest *ETT* in the network, which can be estimated based on the lowest transmission rate of the wireless cards. IRU_l means Interference-aware Resource Usage and *CSCi* is channel switching cost.

The physical meaning of the IRU_l component is the aggregated channel time of neighboring nodes that transmission on link *l* consumes. It captures the inter-flow interference since it favors a path that consumes less channel times at its neighboring nodes. The *CSCi* part of MIC represents the intra-flow interference since it gives paths with consecutive links using the same channel higher weights than paths that alternate their channel assignments, essentially favoring paths with more diversified channel assignments.

1.6 Normalized Bottleneck Link Capacity (NBLC)

NBLC[7] is a routing metric designed for multichannel multi-radio multi-rate WMNs. The NBLC metric is an estimate of the residual bandwidth of the path, taking into account the radio link quality (in terms of data rate and packet loss rate), interference among links, path length and traffic load on links. The main idea of the NBLC metric is to increase the system throughput by evenly distributing traffic load among channels and among nodes.

For a path *p* of length *L*, the NBLC metric is defined by:

$$NBLC_p \equiv \min_{link\, i \in p} \left(\frac{RLC_i}{CEBT_{i,p}}\right)\gamma^L \quad (3)$$

where γ is a tunable parameter implicitly indicating the probability of a packet being dropped by an intermediate node. Briefly speaking, the NBLC metric represents the residual capacity of the bottleneck link on a path normalized to the path length. A larger NBLC value indicates a shorter, less loaded, more channel-diverse path with a favorable link quality. Accordingly, the routing algorithm is to choose the path whose NBLC is the largest.

IV. Conclusions

In this article we focus on the routing problem and design issues in multi-radio multichannel WMNs. We identify several design challenges and survey existing routing metrics designed for multi-radio multichannel multi-rate WMNs (i.e. WCETT and NBLC). Also we investigate these routing metrics in terms of their ability to satisfy these requirements. Both the WCETT and NBLC metrics take channel diversity into account, but NBLC further considers the traffic load on links when judging the goodness of a path.

Acknowledgement

This research was supported by the MKE (The Ministry of Knowledge Economy), Korea, under the ITRC (Information Technology Research Center) support program supervised by the NIPA (National IT Industry Promotion Agency) (NIPA-2011-(C1090-1111-0001)).

References

[1] R. Draves, J. Padhye, and B. Zill, “Comparison of Routing Metrics for StaticMulti-Hop Wireless Networks,”

ACMSIGCOMM, 2004.

[2] H. Zhai and Y. Fang, “Impact of Routing Metrics on Path Capacity in Multi-Rate and Multi-Hop Wireless Ad Hoc Networks,” *IEEEICNP*, 2006.

[3] Sung-Hee Lee, Young-Bae Ko, Youg-Geun Hong and Hyoung-Jun Kim, “A new MIMC routing protocol compatible with IEEE 802.11s based WLAN mesh networks”, ICOIN, 2011.

[4] J. Tang, G. Xue, and W. Zhang, “Interference-Aware Topology Control and QoS Routing in Multi-Channel Wireless Mesh Networks,” ACM MOBIHOC, 2005.

[5] A. Raniwala and T.-C. Chiueh, “Architecture and Algorithms for an IEEE 802.11-Based Multi-Channel Wireless Mesh Network,” IEEE INFOCOM, 2005.

[6] P. Kyasanur and N. H. Vaidya, “Routing and Interface Assignment in Multi-Channel Multi-Interface Wireless Networks,” IEEE WCNC, 2005.

[7] T. Liu and W. Liao, “Capacity-Aware Routing in Multi-Channel Multi-Rate Wireless Mesh Networks,” IEEE ICC, 2006.

[8] Yaling Yang, Jun Wang, and Robin Kravets, .Interference-aware Load Balancing for Multihop Wireless Networks,. Tech. Rep. UIUCDCS-R-2005-2526, Department of Computer Science, University of Illinois at Urbana-Champaign, 2005.