Understanding Channel-diversity Oriented Routing Metrics for Multicast in Wireless Mesh Networks

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요 약

Issues on design of routing scheme and routing metric for multicast in multi-channel multi-radio (MCMR) wireless mesh networks (WMNs) are discussed. Emphasis is placed on channel-diversity oriented routing metrics. From case study the conclusion to be drawn is that the key for design of channel-diversity oriented routing metrics is how to construct an optimization function to quantify interdependence between channel assignment and multicast routing throughput.

1. Introduction

Wireless Mesh Networks (WMNs) have been attracting much attention due to its desirable characteristics such as auto configuration, bandwidth fairness, low cost, easy deployment, self-healing and self-organization.

Major problem in WMN is the degradation of performance due to the interference problem. Utilization of multi-channel multi-radio (MCMR) can solve the problem by concurrent transmissions on orthogonal channels. However existing routing protocol for single channel WMNs may not be adapted to MCMR environment [1]. With increasing demand for multicast streaming such as IPTV, video conference and online games, design of multicast routing scheme becomes an interesting research topic for WMNs.

2. Related Research on Design of Multicast Routing Scheme for WMN

Ajish Kumar K.S. et al. [2] suggest that design of multicast routing scheme for mesh network consider the following issues: effect of multiple channels and channel assignment (CA), availability of static mesh router infrastructure backbone, load balancing, selection of multicast routing metrics, effect of guaranteed quality of service (QoS) and cross layer optimization.

The main design goal for multicast routing scheme is to find high-throughput paths between source and destination instead of only maintaining connectivity between the nodes. Conventional multicast schemes need not consider the wireless broadcast advantage (WBA) and the channel assignment (CA) which are characteristics of MCMR WMNs. Wireless broadcast advantage (WBA), namely, the fact that transmission of a data packet from a given node to its neighbors in a broadcast medium can be done with a single data transmission in WMNs.

Channel assignment first or routing first in MCMR mesh network? It becomes an interesting topic for researchers. "Routing first, CA second" approach assumes that a multicast tree is first constructed and CA is then applied. In the case, CA is referred to load-aware CA. "CA first, routing second" approach constructs multicast routing tree for a MCMR mesh network with allocated channels. Routing is called interference-aware routing. "Joint CA and routing" approach attempt to solve the problems concurrently. Anyway an effective routing protocol with appropriate selection of routing metrics is desired.

3. Routing Metrics for Multicast in MCMR WMN:

The routing metric is a criterion to evaluate the performance of a path in routing algorithms. Key issues that should be taken into account to compose a routing metric for WMN are number of hops, link capacity, link quality and channel diversity [4]. Optimization function is the mathematical model by which a routing metric is constructed.

It is true a routing metric incorporating the combination of these factors does result in better performance than the minimum hop count approach. But complexity and high-overhead is the penalty.

4. Link-quality Metrics:

Due to differences between unicast and multicast, the routing metrics proposed for unicast may be not appropriate for multicast for mesh network. S. Roy et al. [5] adapt unicast link quality metrics for multicast in WMN according to two major rules: i) consideration of the link quality of forward direction and ii) product of the metric values of individual links along the path. Routing metrics for multicast routing and the link characteristic is summarized in Table 1. These metrics in the table are usually incorporated with other issues to compose new sophisticated metrics or optimization functions such as channel-diversity oriented metrics we will discuss in the following section.

<Table 1> Link quality routing metrics for multicast [5]

Characteristics	*Metrics*
Loss	METX, ETX, SPP
Loss + delay	PP
Loss + B/w	ETT

5. Channel-diversity Oriented Metrics

Incorporating channel diversity into multicast routing metric introduces two issues: i) balancing trade-off between network throughput and per-node throughput and ii) quantization of the channel diversity of a path [1].

Irfan Sheriff et al. [6] propose a channel aware multipath metric (CAM) that is composed of inter-path interference index λ and independent path quality index γ. CAM metric accounts for both channel diversity between the paths and the end-to-end characteristics of the individual paths in selection of multipath combination. CAM improves channel utilization and increase effective throughput by using multiple concurrent paths. CAM attempts to quantify the channel diversity by means of weighted average of intra-path and inter-path issues using a weighted factor β.

Zeng et al. [7] introduce a metric named interference factor δ_t that is defined as the ratio of the interference range by the transmission range when the channel separation of two links is t. They also propose a level channel algorithm (LCA) which partitioned all the nodes into different levels according to the hop count distances from the source when constructing the multicast tree. Depending on physical-layer properties, interference factors obtained in one network area may not applicable to others. Although LCA algorithm improves multicast throughput to a certain extent there is a risk of hidden channel problem (HCP).

H. L. Nguyen et al. [8] develop a new metric denoted by an optimization function:

$$\mathrm{F}\,(\mathrm{c}) = \frac{\prod_{\forall w \in N(v)} |c - c_w|}{\max_{\forall i \in N(v)}\{|c - c_i|\} \div \min_{\forall j \in N(v)}\{|c - c_j|\}}$$

F(c) solves the interference factor problem by using the channel separations that are difference between the channel pairs. The maximum and minimum in the denominator are designed to balance the channel separation by avoiding both over-separated channel pairs and overlapping channel pairs. N(v) denotes the set of one-hop and two-hop neighbors of node v. By taking into account two-hop neighbors, this new metric eliminates hidden channel problem (HCP). S. Lee et al. [9] also propose a routing scheme considering two-hop nodes.

A multicast routing algorithm called multi-channel minimum number of transmissions (MCMNT) is proposed in paper [3]. MCMNT attempt to minimize the number of transmissions in a multicast group in MCMR mesh network as its name implies. A new channel metric δ is defined as :

$$\delta_u(c) = (1 + \alpha(M_{max} - \mu_u(c)))$$

$\mu_u(c)$ denotes the number of links incident to node u that are assigned channel c and acts as channel utilization of channel c at node u. M_{max} is the maximum value taken over all nodes and all channels in the network. The cost of a directional link (u, v) from node u to node v is denoted by $\delta_u^\beta(c)/\delta_v(c)$ to show that the transmitter u prefers a channel highly utilized and the receiver v prefers a channel lowly utilized. The cost of a path is the sum of the individual directional links on the path. The least cost path will be chosen. But it is not mentioned how to decide the values of α and β.

6. Conclusion

The recent research cases show that the key for design of channel-diversity oriented metrics is how to construct an optimization function to quantify interdependence between channel assignment and multicast routing throughput. Accuracy of the quantification can be improved with further study on these factors such as α, β and γ mentioned in the preceding section. Furthermore incorporating cross-layer approach with information exchange across different layers of the protocol stack will improve efficiency.

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