Design of Routing Protocols for WMN: Factors and Case Study

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요 약

Wireless Mesh Network (WMN) can be defined as a communication network consisting of radio nodes organized in a mesh topology, which has been attracting much attention due to its promising technology. This paper addressed the factors on how to design routing protocols for WMN. 2 examples of designing routing metric and routing algorithm are given for case study. With consideration of those factors such as wireless broadcast advantage (WBA)/channel assignment (CA) or intra-flow/inter-flow interference high throughput is achieved.

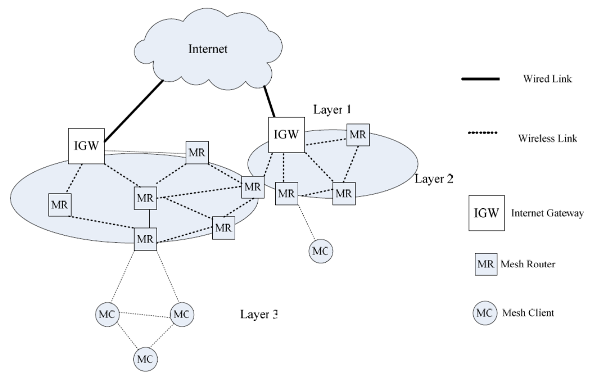
1. A brief introduction to WMN

Wireless Mesh Network (WMN) can be defined as a communication network consisting of radio nodes organized in a mesh topology, which is a special type of wireless ad hoc network. It has been attracting much attention due to its promising technology.

1.1 Network structure of WMN

Wireless Mesh Network is comprised of two types of nodes: mesh routers and mesh clients. Mesh router performs gateway, repeater and routing functions and is usually equipped with multiple wireless interfaces and much lower transmission power compared with traditional routers [1].

Mesh client covers a higher variety of devices including laptop, desktop, pocket PC, PDA, IP phone, RFID reader and so on. Figure 1. shows the structure of WMN.



(Figure 1.)Network structure of WMN

1.2 The architecture of WMN

The architecture of WMN is classified into 3 main groups based on the functionality of the nodes: Infrastructure/Backbone WMNs, Client WMNs and Hybrid WMNs [2].

1.3 Characteristics of WMN

WMN is Multi-hop wireless network. It supports for ad hoc networking and multiple types of network access with capability of self-forming, self-healing, and self-organization [4].

2. Design of Routing Protocols for WMN

Routing can be referred to as the process of determining the end-to-end path between a source node and a destination node . Routing protocols for unicast and multicast communications in conventional networks (wired infrastructure) and mobile ad hoc networks should be adapted for wireless mesh environments [8]. The factors on design of multicast protocols for WMN are listed in the following [3].

- The effect of multiple channels and channel assignment
- Availability of static mesh router infrastructure backbone
- Load balancing
- Selection of routing metrics
- Effect of guaranteed quality of service (QoS)
- Cross layer optimization

Each of these factors play an important role on design of routing protocols. We will give a good example to show the details of routing protocol design in section 3.

3. Case Study

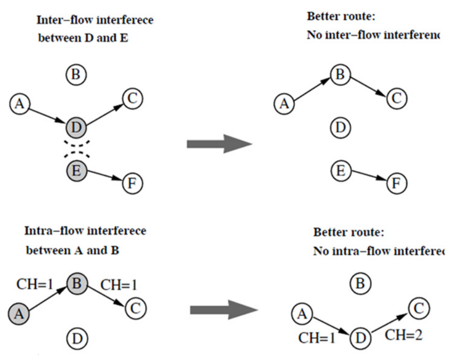
3.1 Metric of Interference and Channel switching (*MIC*)

The routing metric *MIC* [5] of a path *p* is defined as following equation:

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

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 CSC_i 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 paththat consumes less channel times at its neighboring nodes. The CSC_i 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.



(Figure 2.) intra-flow and inter-flow interference

The routing metric is a criterion to evaluate the goodness of a path in routing algorithms. This case shows that the selection of MIC as routing metric can keep trade-off between intra-flow and inter-flow interference.

3.2 Design of routing protocol considering other factors such as WBA and CA

Traditional routing algorithms need not consider the wireless broadcast advantage (WBA) or the channel assignments (CA) (i.e., channel diversity) in a Multi-channel multi-radio (MCMR) WMN. The WBA refers to the fact that the transmission of a data packet from a given node to any number of its neighbors in a broadcast medium can be done with a single data transmission.

Paper [7] proposed a routing metric for MCMR WMNs that takes into account both the WBA and the channel diversity in order to minimize the amount of network bandwidth consumed by the routing tree.

Maximum channel utilization value taking over all channels at node *u* is defined as

$$\mathcal{M}_u = \max_{\forall c \in C} \{\mu_u(c)\}$$

where channel utilization $\mu_u(c)$ at node *u* is the number of incident links on *u* that are assigned channel.

Maximum *Mu* value taking over all nodes *u* in the network is defined as

$$\mathcal{M}_{max} = \max_{\forall u \in V} \{\mathcal{M}_u\}$$

Channel metric $\delta_u(c)$ at node *u* is defined as

$$\delta_u(c) = \left(1 + \alpha\left(\mathcal{M}_{max} - \mu_u(c)\right)\right)$$

where small δ values imply high channel utilization.

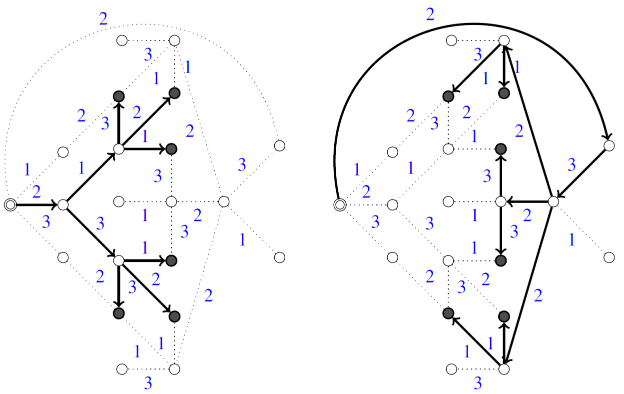
The cost *w(u, v)* of a directional link *(u, v)* in network is defined as

$$w(u,v) = \frac{\delta_u^{\beta}(c)}{\delta_v(c)}$$

where the term $\delta u(c)$ in the link cost favors a transmitter with a highly utilized channel so that the channel can be used for as many receivers as possible.

This is to maximize the wireless broadcast advantage (WBA).

Given link *(u,v)* on channel *c*, the next-hop link *(v,z)* to be added should avoid channel *c* so that transmissions from *u* and *v* do not interfere. Therefore, given a transmitter *u* with highly utilized channel *c*, we should choose *v* with lowly utilized channel *c*. This explains the term $1/\ \delta v(c)$ in the link cost. This is to minimize interference among forwarding neighbors.



(Figure 3.) Multicast trees constructed by MST (left) and MCMNT (right) algorithms

Figure 3. shows that the total number of transmissions (per packet) of multicast trees constructed by MST (left) is 9 while that of MCMNT algorithms (right) is 6. And the experiment results also shows that MCMNT routing algorithm which takes into account wireless broadcast advantage (WBA) or the channel assignments (CA) performs better than MST.

The main design goal for routing protocols is finding high-throughput paths between source and destination nodes instead of maintaining connectivity between the nodes. Those protocols considering only hop-count metric often choose long links which tend to be lossy and give low throughput [3].

Through this case, we investigate that sophisticated routing metrics achieve higher throughput than the simple metrics such as hop-count do.

4. Conclusion

This paper gave a brief introduction to wireless mesh network (WMN). Several factors that should be considered when designing multicast algorithm in WMN are addressed. 2 example for design of routing metric are discussed as case study. With consideration of those factors such as wireless broadcast advantage (WBA)/channel assignment (CA) or intra-flow/ inter-flow interference high throughput is achieved. Sophisticated routing metrics achieve better performance than the simple metrics such as hop-count do.

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