A Study on WMNs Based Routing Metrics for High Throughput Multicast

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요 약

There has been growing interest in multicast technologies for wireless mesh networks with increasing demand for enjoying seamless multimedia broadcast service such as mobile IPTV anytime anywhere for any content on any device. This paper addressed the factors that should be considered when designing multicast algorithm in WMNs. Several routing metrics which are adapted for WMNs based multicast are described in detail to show that the main design goal for multicast metric is to achieve high throughput. Those metrics that take into account the characteristics of WMNs such as wireless broadcast advantage or channel diversity can arrange load balancing more effectively.

1. Introduction

Wireless Mesh Networks (WMNs) have been attracting much attention due to its desirable characteristics including multi-hop routing, auto configuration, bandwidth fairness, low cost, easy deployment, self-healing and self-organized etc. Wireless Mesh Network is a radical network form of the ever-evolving wireless network that marks the divergence from the traditional centralized wireless system such as cellular networks and wireless local area networks (WLANs). Wireless Mesh Network (WMN) is known as "community wireless network" for constructing a resilient, locally networked access to communication infrastructure.

Wireless Mesh Network is comprised of two types of nodes: mesh routers and mesh clients. Mesh router performs gateway, repeater and routing functions. Mesh client covers a higher variety of devices including laptop, desktop, pocket PC, PDA, IP phone, RFID reader and so on.

With increasing demand for multicast streaming such as IPTV, video conference and online multicast based game, the multicast communication becomes an even more important research topic in the WMNs.

Multicast is a bandwidth conserving technology that reduces traffic by simultaneously delivering a single stream of packets to a group of receivers. It uses the most efficient strategy to deliver the messages over each link of the network only once, creating copies only when the links to the multiple destinations split. IPTV service in WMNs is usually Internet oriented, and thus, the traffic is directed from the Internet gateway to mesh clients. Once the multicast data travel through the WMN backbone and reach a destination mesh router, the destination mesh router will transmit the data to the mesh clients in its coverage. In WMNs, the reliable multicast scheme should involve both WMN backbone and mesh-router coverage (data transmission from the mesh router to mesh clients) [1].

With the proliferation of all kinds of mobile devices and the support of efficient multicast streaming in WMNs, mobile IPTV technology provides so-called seamless multimedia broadcast service and allows users to enjoy TV programs anytime, anywhere for any content on any device (4A).

2. Challenges for Multicast in WMNs

There are a number of research aspects of multicast in WMNs. All these factors that are 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 should be considered when designing multicast routing algorithm in the WMNs [2]. This paper focuses on selection of multicast routing metrics among all the factors for WMN.

The routing metric is a criterion to evaluate the goodness of a path in routing algorithms. Due to differences between unicast and multicast, directly taking the link-quality based routing metrics proposed for unicasting is not appropriate for multicast in WMNs.

The main design goal for multicast routing protocols is finding high-throughput paths between source and destination nodes instead of maintaining connectivity between the nodes. Towards this goal, more sophisticated routing metrics than the hop-count metric need to be used to find paths that achieve high throughput, as protocols based on the hop-count metric often choose long links which tend to be lossy and give low throughput [3].

Important routing metrics used in WMNs are Expected Transmission Count (ETX), Expected Transmission Time (ETT), Weighted Cumulative Expected Transmission Time (WCETT), Packet Pair (PP), Success Probability Product (SPP), and Multicast ETX (METX). ETX measures the expected number of MAC transmissions and retransmissions needed to successfully deliver a packet from a sender to receiver. ETT explains the expected MAC transmission time of a packet over certain link. It improves on ETX by making use of data rate in each link. WCETT is based on ETT and aware of loss rate due to ETX and bandwidth of the link [4]. Adapted ETX, ETT, PP, METX and SPP for multicast in WMNs is described in section 3. In addition several metrics for multi-radio multi-channel WMNs are addressed.

3. Metrics for Multicast in WMNs

3.1 PP (packet pair)

The packet pair (PP) metric was to measure the delay between a pair of back-to-back probes to a neighboring node. A weight of 90% to the accumulated average and 10% to the current one is assigned. In case either the large or the small packet is lost, a 20% penalty is imposed. The value of the metric for a path is the sum of the PP values of the individual links [4].

3.2 ETX

Without consideration of reverse path link quality, it is defined as

$$ETX = \frac{1}{d_f}$$

The probe packets no longer contain any information and each node simply counts the number of the probe packets it received in the past 10 probing intervals.

3.3 ETT

Since multiple channels are not assumed, ETT adapted for multicast instead of WCETT is given by

$$ETT = ETX \times \frac{S}{B}$$

where S is the packet size and B the bandwidth of the link.

The receiver uses the small packets received to calculate ETX. The bandwidth of each link is estimated by dividing the size of the big packet by the inter-arrival time between the small and the large packets.

3.4 METX(Multicast ETX)

METX can be expressed as

$$METX = \sum_{i=1}^{n} \frac{1}{\Pi_{j=1}^{n}(1 - p_{err_j})}$$

Where i denotes the ith link along a path from a source to a destination comprising n links.

3.5 SPP (Success Probability Product)

SPP for a path consisting of n links is given by

$$SPP = \Pi_{j=1}^{n} d_{f_j}$$

$$d_{f_j} = 1 - p_{err_j}$$

SPP gives the probability for the destination node to receive a packet properly over a path with link-layer broadcast. 1/SPP reflects the expected number of transmissions at the source itself.

The routing algorithm selects the path with the maximum SPP or minimum 1/SPP. As a product, SPP is more effective in avoiding paths containing bad links than ETX. In [3], an example is given to demonstrate that SPP performed better than ETX.

3.6 Metric of Interference and Channel switching (MIC)

The 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.

3.7 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:

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

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.

3.8 A weighted average metric considering wireless broadcasting advantage and channel diversity

Additional capacity is gained through simultaneous data transmission on multiple frequency channels . Traditional multicast routing algorithms do not consider the wireless broadcast advantage (WBA) or channel diversity in a multi-channel multi-radio (MCMR) WMN. Paper [8] proposed a multi-path routing metric CAM that takes into account both the WBA and the channel diversity. Multiple paths here refers to multiple concurrent paths between 2 nodes to increase effective throughput instead of backup paths used only when the primary path fails.

High throughput multicast requires high channel utilization for WMN. A simple network topology in figure 1. shows how the multipath scheme improve the channel utilization. Here are two paths available from S to D: path I with nodes S, A, D and path II with nodes S, B, D. Suppose we use path I for delivering packets from S to D. The maximum achievable throughput is limited by the bottleneck ETT of 30 ms on the channel 6. The achievable bottleneck throughput is thus one packet every 30 ms. At this rate, channel 1, with an ETT of 15 ms, is only about 50 percent utilized while channel 6 is 100 percent utilized. Further, channel 11 remains unused with 0 percent utilization. It is the same case that we route the data through a single path II. How about the distribution of the traffic on the two paths? For every two packets transmitted by S, 30 ms is spent on channels 1, 6 and 11 concurrently since ch 1 can deliver the data from ch 6 during first 15 ms time slot and deliver the data from ch 11 during second 15 ms time slot. A 100 percent improvement of channel utilization can be achieved with full utilization of channels 6, 11 and 1. But how to select a multipath combination to improve the throughput?

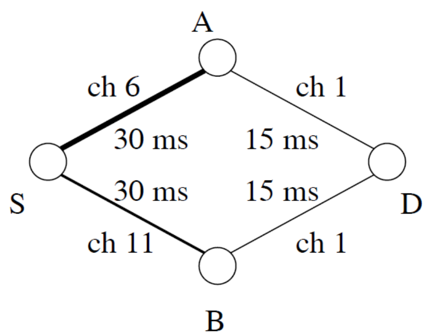

Figure 1. A two-radio network topology

Channel Aware Multipath(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 is defined as:

$$CAM = \beta \times \lambda + (1-\beta) \times \gamma$$

where *inter-path interference index* λ accounts for the interference among the common channel links on the two paths and *independent path quality index* γ accounts for end-to-end characteristics of the two paths . The main idea of CAM is weighted average evaluation of intra-path and inter-path factors. The simulation results show the effectiveness of CAM metric for selection of multipath combination which improves throughput of the networks [8].

4. Conclusion

This paper addressed several factors that should be considered when designing multicast algorithm in WMNs. Several routing metrics which are adapted for WMNs based multicast are described in detail to show that the main design goal for multicast metric is to achieve high throughput. Those sophisticated metrics that take into account wireless broadcast advantage or channel diversity can minimize the amount of network bandwidth consumed by the routing tree and improve multicast throughput. Also weighted average evaluation of combination of the factors is effective idea to improve network performance.

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