A Proposed QoS Multicast Routing Framework for Next-Generation Wireless Mesh Network

W.A. Shittu [*], Aisha-Hassan A. Hashim[*], F. Anwar[*], & W. Al-Khateeb[*]
[*]Department of Electrical and Computer Engineering, Faculty of Engineering, IIUM, P.O.Box 10, 50728 Kualar Lumpur, Malaysia

Abstract
Wireless Mesh Network (WMN) is the network architecture where nodes (e.g. APs, mesh routers) can communicate with one another via multi-hop routing or forwarding. This is possible because of its dynamic self-organization, self-configuration and self-correction characteristics, which enable flexible integration, quick deployment, easy maintenance, low-cost, reliable services and its capability for capacity enhancement, connectivity and throughput. Although the current standard defines Multicast as well as QoS as important issues for considerations on this type of network, how to merge these two, especially at the Network layer, has been left to the discretion of different service providers. This paper describes a framework for the QoS Multicast routing provisioning problems in the Next-Generation IEEE 802.11s. We assume a working QoS MAC layer protocol and propose a framework for ensuring QoS Multicasting at the Network layer.

Keywords:
Wireless mesh network, QoS, QoS Manager, Multicast Routing

1. Introduction

In recent time, accessing the Internet has evolved from the traditional wired Ethernet access technology to the hot spots and hot zones of Wireless Local Area Network (WLAN), which has been highly successful and has enjoyed widespread usage. Paradoxically, the Wireless LANs are connected to the internet through wired DSL cable or cable modem. Incredibly large numbers of access points (APs) are needed to achieve connection of a sizeable geographical area [1]. Worse still, DSL and cable modems cannot be easily deployed in certain areas/buildings due to their architectural beauty and the difficulty involved in laying these cables. This has, collectively, led to the recent research efforts in using Wireless Mesh Network technology [2, 3] as an alternative means of "last mile" access to the Internet owing to its dynamic self-organisation, self-configuration, and self-correction characteristics. These characteristics enable flexible integration, quick deployment, easy maintenance, low-cost, reliable services, etc., over the traditional DSL or Cable modem 'last mile access' technologies. However, despite these numerous advantages of WMN, the dismal performance of the first and second generation of this technology calls for more concerted research efforts [4], in order to reap the inherent advantages of this technology.
Although the area of wireless mesh networking can build on the huge amount of results from a decade of research in mobile ad hoc networking, the special properties of WMNs require optimizations in order to meet the performance goals for the use of this type of network. Furthermore, it is envisaged that subscribers of broadband communication system would desire such real-time applications as VoIP, video conferencing, streaming media, audio and video for news, etc, along with best effort applications, e.g. file sharing, web surfing, over wireless mesh networks, which they currently enjoy over traditional wired Internet. These applications require a guarantee on delay, jitter, packet loss and throughput in order to give acceptable level of QoS to end-users. Although multicasting is an enabling technology for bandwidth management, however, owing to the limited bandwidth and the shared nature of the wireless medium, designing multicast routing algorithms and protocols capable of satisfying a set of QoS constraints for different application services on wireless mesh networks is still a challenging research problem [5].

This paper is organized as follows: Section two discusses related work concerning QoS multicasting in wireless mesh network. Section three describes open issues that need further investigation in respect of wireless mesh networks while section four presents our proposed framework for achieving QoS Multicasting in the next-generation 802.11 wireless mesh networks. Discussion is given in section six while section seven gives the conclusion.

2. Related Work

Although the current single-hop Wireless Local Area Networks (WLANs) has enjoyed widespread application with tremendous success, as a means of last access to the Internet, it however lacks QoS capability. Realizing the importance of QoS for multimedia applications, the IEEE

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established a working group 802.11e to specify a set of standards for enhancing the Physical and Medium Access Control (MAC) layers [6] in order to achieve QoS in WLAN network. However, these QoS enhancements are only suitable for single-hop networks and not multi-hop networks like wireless mesh networks. Consequently, another task group, TGs has been established to define mechanisms for establishing 802.11-based wireless mesh networks, and this group has specified some MAC layer schemes, e.g. *Mesh Deterministic Access* (MDA) and *multi-channel MAC protocols* for achieving QoS in wireless mesh network [7]. Our framework makes use of the MMAC protocol at the MAC layer.
The current IEEE 802.11s draft standard [8] specifies Hybrid Wireless Mesh Routing Protocol (HWMP) and Radio-Aware Optimized Link State Routing (RA-OLSR) Protocol as mandatory and optional routing protocols respectively for wireless mesh network. These protocols are unicast routing protocols. However, no multicast routing protocol has been specified in the standard. Given the importance of multicasting for group-oriented communication and the envisaged prevalent desire of subscribers for QoS-related multimedia applications, there is a need for QoS multicasting routing framework to provision these services.

According to Tehuang Liu, et al., [9] and J. Tang, et al., [10], to provision QoS in WMNs, QoS Routing algorithm/protocol is needed. Although ODMRP and MAODV, which are reactive protocols, used for mobile ad hoc networks (MANETs), these protocols do not have support for QoS. Also Proactive multicast routing protocols for MANETs, e.g. CAMP [11], FGMP [12], and NSMP [13], have been proposed and successfully implemented for MANETs. However, none of these protocols has QoS capability.
According to Uyen Trang Nguyen [14], shortest path tree (SPT) and minimum cost tree (MCT) are popular multicast routing algorithms employed for WMNs in the construction of routing trees. The SPT is based on distance vector and usually used to compute the least distance in terms of hop count between source and destination. The MCT, on the other hand, is often used to compute the overall cost of transmissions, and often employs link state algorithm in its path computation. However, these algorithms have no capability for QoS multicast routing.

Furthermore, Bo Rong, et al [15] have proposed a prioritized admission control policy and Traffic Engineering for QoS Multicast routing in WMNs. However, only mesh backbone was considered. A QoS multicast mechanism that considers both backbone mesh routers and end-user STAs is needed. Similarly, Xiaowen Chu [16], proposed admission control and scheduling algorithms for constant bit rate (CBR) and variable bit rate (VBR) traffic flows. However, this proposal was targeted for VBR traffic without delay guarantee. Most practical VBR (Multimedia) traffic requires delay guarantees to provision acceptable QoS. Moreover, this proposal does not consider multicasting. Chiang Kang Tan et al [17] proposed a Diffserv framework which is based on per-hop behaviour. However, end-to-end per-flow behaviour between source and destination is a requirement for efficient QoS provisioning in WMNs. Also, multicasting was not considered in this proposal.

The problem of QoS multicast routing in communication networks has been identified to be NP-complete problem [18]. The challenge is how to build a least-cost multicast tree to deliver multicast data from source to destinations in such a way that a set of QoS requirements are met. Generally, to solve this problem, two approaches are often used [19]: an optimal solution in exponential time; and a near-optimal solution by a heuristic algorithm. Although the first approach produces an optimal solution, it is impracticable due to its NP-hard nature and the complexity of computation involved. The second method is a feasible solution and is often applied to multicast routing problems, which has become an important topic in combinatorial optimization studies. In a study performed by Salama et al [20], it has been shown that most of the heuristic algorithms either work too slowly or cannot compute the delay constrained multicast tree with least cost.

However, meta-heuristics, which include Tabu search (TS) [21], genetic algorithm (GA) [22] and simulated annealing (SA) [23] have been found to perform better in solving QoS multicast routing problems. These approaches have been more widely applied to wired internet networks with limited applications to wireless mesh networks. Recently, Ke et al. [24] applied the concept of genetic algorithm to QoS multicast routing problems in wireless mesh networks. They proposed a multi-constrained QoS-based multicast routing algorithm based on GA. They argued that their algorithm converges to the global optimum because the GA is a Markov chain which maintains the best solution found over time; and that the selection operator they employed always keeps the best solution to the next generation. However, Ke and his colleagues considered only delay and bandwidth (throughput) in their GA development with no consideration given to other performance metrics such as delay jitter and packet loss ratio. Furthermore, how the GA is to be incorporated to a multicast routing protocol to achieve acceptable performance of QoS-oriented multimedia applications over the wireless mesh networks was not specified.
Consequently, our goal is to use memetic algorithm, a type of metaheuristic optimization approach and an improved version of GA, to solve the problem of QoS multicast routing in WMNs. This algorithm will then be

incorporated into our proposed hybrid QoS multicast routing protocol for the next-generation WMNs.

3. Open Issues

From the foregoing survey of related literature on WMN, the following have been identified as open issues:

1. Current Wireless Mesh Network implementations lack a central control, and due to this problem, as network size increases, providing end-to-end quality of service guarantees for different service types in multi-hop WMNs is still a challenge.

2. Efficient operation of practical WMNs depends on close interactions between different layers of the Protocol Stack. How to exploit cross-layer interactions in the design of high-performance WMNs and how to optimize the performances of WMNs are still challenging issues.

3. In the design of QoS multicast routing protocol, important issues including system architecture design, capacity, performance analysis and optimization, quality of service, resource management, scheduling, MAC and Network Routing Protocol design still need to be addressed.

4. Although address resolution protocol (ARP), Dynamic Host Configuration Protocol (DHCP), and Internet Protocol (IP) may work for WMNs, an efficient support for broadband multicast traffic is still needed.

5. Other Open issues in relation to wireless mesh networks are: QoS routing, Multicast routing and multipath routing.

4. Proposed Framework for QoS Multicasting in Wireless Mesh Network

4.1 *Network Architecture Design*

To address the problems of QoS Provisioning of multicast routing in next-generation wireless mesh network, we propose to use a combination of Proactive/mesh and Reactive/tree multicast routing solution framework on backbone mesh routers and client STAs nodes respectively. This would be coupled with appropriate MAC QoS mechanisms as well as admission control mechanisms. The first solution approach serves to address problems of delays while the second addresses problems of congestion of data packets in both backbone mesh and end STAs devices. Figure 1 shows an example of our wireless mesh network architecture scenario while Figure 2 shows a flowchart of our QoS Multicast routing framework.

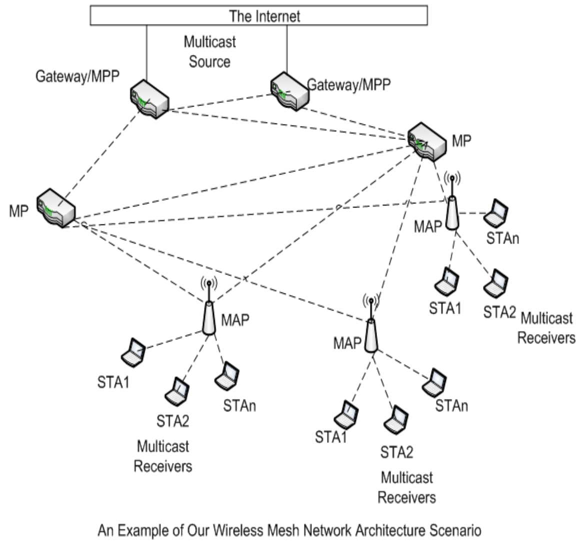

Figure 1: Our Wireless Mesh Network Architecture

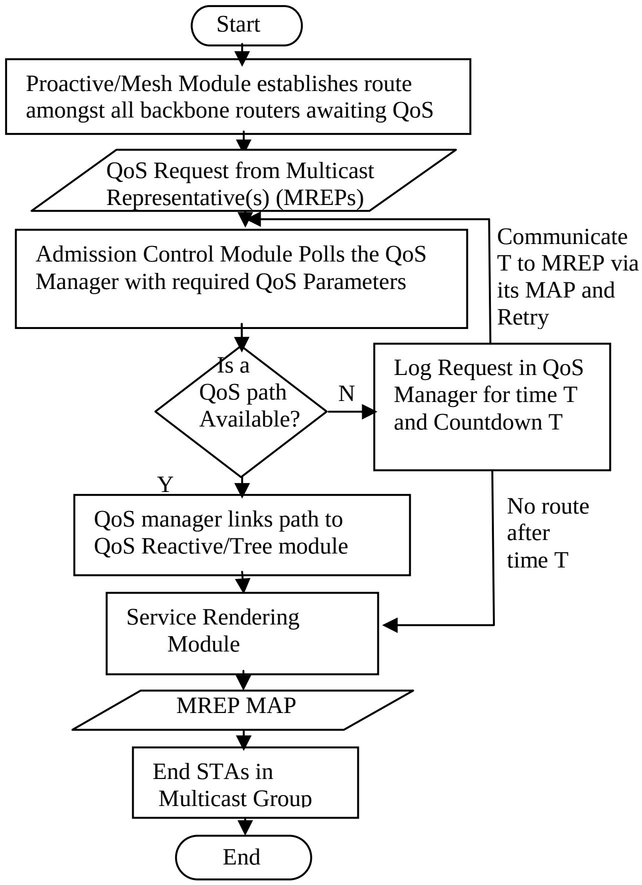

Figure 2: Our QoS Multicast Routing Framework

4.2 *The Protocol Description*

Our proposed routing protocol for the next-generation WMN is a hybrid QoS Multicast routing protocol (HQMRP), which is comprised of a proactive/mesh-based multicast routing protocol running on backbone mesh routers, and a reactive/tree-based multicast routing protocol running between the mesh access points (MAPs) and the client end stations (STAs). The philosophy of our protocol design is that in the former case, a path is always available prior to a QoS request; hence delays in setting up the paths are eliminated, whereas in the latter case, the path between MAPs and end STAs in multicast group are set up only after a QoS request. This helps to minimise routing overheads incurred.

5. Discussions

In Figures 1, our network architecture for achieving QoS multicast routing in WMNs is given. It comprises of gateway(s) or mesh portal point (MPP), which are connected to the Internet by wired means. In our own case, these MPPs are the multicast sources. The MPPs are then connected to mesh points (MPs) via wireless means and these, in turn, serve the mesh access points (MAP), to which a group of multicast receivers (STA1 up to STAn) are logically connected.
Figure 2 gives a flowchart of the framework upon which our network architecture operates. At the start of the network operation, our proactive/mesh protocol establishes paths amongst different MPPs and the MPs, awaiting a request for QoS-oriented applications. When members of multicast receivers require QoS-oriented applications, they make a request via the MREP of that particular multicast group. This help to minimize channel access contention problems. The MREP communicates the request to the MAP of that group, and through admission control module, liaises with the QoS manager, which then links the path that satisfies the QoS requests with the MAP, thereby serving the MREP's request by multicasting the requested data to all members in its multicast group. This is possible because the QoS manager keeps an up-to-date record of links' conditions on the backbone mesh.

However, when no path exists on the backbone mesh to service the QoS request, the admission control module logs the request in the QoS manager, which then starts a countdown timer, T, and retry. Simultaneously, T is communicated to MREP via its MAP. When a path becomes available after time T, the QoS request is serviced, otherwise, the request is dropped.

6. Acknowledgement

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7. Conclusion and Future Work

In this paper, we propose a new hybrid QoS Multicast routing framework for wireless mesh network, which comprises a proactive/mesh multicast routing protocol on the backbone mesh routers and a reactive/tree multicast routing protocol between the MAP and client end STAs, for each multicast group. Our proposal helps to eliminate unnecessary delays in setting up routes amongst the backbone mesh routers and also minimize control overhead as paths are only set-up between MAPs and end STAs on-demand.
This is part of our on-going work. In the future, we plan to report the evaluation results of our HQMRP for different scenarios and the details of our hybrid QoS multicast routing algorithm, based on memetic algorithm- a metaheuristic optimization approach; used to achieve end-to-end per flow behaviour of QoS Multicast requests on WMNs.

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