International Journal of Electronics and
Communication Engineering (IJECE)
ISSN 2278-9901
Vol. 2, Issue 3, July 2013, 33-40

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

A FAIR CHANNEL SCHEDULING IN MULTI CHANNEL MULTI INTERFACE WIRELESS MESH NETWORKS

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ABSTRACT

The problem of MAC layer in Wireless Mesh Network (WMN) which has potential to integrate all types of wireless networks is addressed. The MAC layer issues and challenges of wireless mesh networks based on Channel Selection or assignment, Interference or collision, Fairness and Scheduling are analyzed. We also present some related works done to solve the issues. Finally this paper provides a solution to some of the issues.

KEYWORDS: WMN-Wireless Mesh Network, MAC- Medium Access Control

INTRODUCTION

Wireless mesh networks (WMNs) are regarded as a viable solution to provide broadband Internet access flexibly and cost efficiently. They have the potential to combine the coverage of mobile networks with the capacity of WiFi-based access points. Their ability to forward data over multiple hops at a high data rate eliminates the requirements to connect each access point to the wired infrastructure and therefore reduces costs. At the same time, capacity can be increased, either by deploying new wireless technology (WiMAX) or by equipping access points with multiple interfaces (WiFi) [1].

Wireless Mesh Networks

Wireless Mesh Networks (WMNs) are comprised of two types of nodes, mesh routers and mesh clients. Mesh routers form the infrastructure backbone for clients. WMNs are multi-hop Ad-Hoc wireless networks. Compared to conventional Ad-Hoc wireless networks, WMNs contain wireless nodes, which can be either mobile or fixed. Communication in WMNs between two nodes in WMNs mostly relies on infrastructure. The majority of the traffic is user-to-gateway oriented, whereas in conventional Ad-Hoc networks, traffic is mostly user-to-user oriented. Through multi-hop communication, the same coverage area is achieved by mesh routers but with lower transmission power [2].

Wireless Mesh Networks (WMNs) are the ultimate solution for the next decade wireless networking. The attractions of WMNs include easy set-up on the fly, off-the-shelf cost, flexible interoperability with other networks, and highly reliable connectivity. Because of these advantages over other wireless networks, WMNs are undergoing rapid development [2].

Applications of WMN:Due to their versatility, WMNs can efficiently satisfy the needs of multiple applications. Some of the common applications of WMNs are [3]:

- Broadband Internet Access
- Indoor WLAN Coverage
- Mobile User Access

- Providing Network Connectivity

WMNs also provide services in many areas, such as enterprise, campus, hospital, public surveillance, etc [2].

MAC Protocols of WMN

The MAC layer in the mesh networks is used to provide end-to-end QoS within the mesh networks and differentiated QoS in the physical and link layers within one wireless router's neighborhood in the wireless broadcasting environment. The information about the ability to support QoS parameters in the mesh to the Resource and Admission Control Subsystem (RACS) is provided by the MAC and routing layer [1].

Recently two trends of MAC protocols are present in wireless mesh networks. Though Random access protocols such as Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) is used in the IEEE 802.11 standard it fails to support QoS using IEEE 802.11e. Therefore, for the future mesh networks, controlled access protocols such as Time Division Multiple Access (TDMA) are currently under construction [1].

The current 802.11 standard does not specify a mechanism for nodes to switch the channel to which a radio is tuned on a per packet basis. The use of a mesh MAC protocol allows a node to switch to a different channel for each neighbor [4].

In this proposal, we will analyze the MAC layer issues and challenges of wireless mesh networks. We also present some related works done to solve the issues. Finally we provide a solution to some of the issues.

MAC LAYER ISSUES OF WMN

Basically the challenges of the physical layer of WMNs are same as other wireless technologies. We mainly analyze the challenges based on

- Channel Selection or assignment
- Interference or Collision
- Fairness
- Scheduling

Based on Channel Selection

A conventional multi-hop wireless network includes several common issues. The channel assignment problem in multi-hop wireless networks with a single radio is a specific issue and it is exposed to several studies in the literature [4]. A natural way to increase network capacity and utilization is by exploiting the use of multiple channel and channel reuse opportunities. Thus, an efficient channel assignment algorithm is crucial to the reduction of interference due to neighboring transmissions using the same channel [5].

The key challenge is how channels can be chosen throughout the network in order to get optimal network performance in terms of throughput, delay, or other metric [6].

Based on Collision or Interference

Basically the challenges of the physical layer of WMNs are same as other wireless technologies. The undesirable effects of fading and interference are well understood [3].

Due to the broadcast nature of the wireless medium, the capacity scaling of a wireless network is mainly limited by interference due to simultaneous transmissions on any given channel. One of the important issues that need to be considered while designing a multi channel, multi-radio wireless network is the co channel and adjacent channel interference effects due to the close proximity of the radios in a node [9].

The physical layer of a WMN should be reliable. The resistance to interference is more important in the case WMNs since their MAC protocol is commonly contention based. [3]. We are aware that the throughput is dependent on other factors such as the number of collisions and the transport protocol as well [15]. In WMN, since the number of channels is limited, some links in the WMNs may be allocated to the same channel. In this case, interference will occur if these links are close to each other. Interference between neighboring links can potentially cause network congestion [6].

Based on Fairness

One of the main problems in WMNs based on IEEE 802.11 is unfair bandwidth sharing among flows with different hop distances to the gateway node [10]. In WMNs, there are obscure interdependencies among neighboring wireless links that greatly complicate the problem of fair bandwidth allocation [13].

An efficient but unfair channel allocation may cause some flows to starve. Most of the previous works mainly focus on network *efficiency* i.e., increasing the network throughput, while the issue of *fairness* has not been studied [12].

There are several difficulties in achieving max-min fairness over an 802.11-based WMN [13]:

- Intra-flow Dependency
- Shared Radio Channel
- MAC Dependent Capacity
- Asymmetric MAC Contention

Based on Channel Scheduling

The right scheduling strategy is essential for providing good end-user quality in the delay sensitive traffic such as Voice over IP (VoIP). In the scheduling approach, the important information such as traffic priority should be considered as an input parameter [15].

The priority of the packets is not considered by the most schedulers. Since a channel with delay-insensitive packets is served before, the packets with smaller delay budget are delayed unnecessarily long. This will reduce the apparent quality of the delay sensitive traffic such as VoIP [15].

In order to set-up interference free TDMA schedules, many distributed MAC schemes have been proposed. However, these approaches provide equal channel access opportunities for each flow without considering the traffic demand which is not optimal for end-to-end performance [16].

RELATED WORK

Based on Channel Allocation or Selection

A. Hamed Mohsenian Rad et al [6] have formulated the Joint Optimal Channel Assignment and Congestion Control (JOCAC) as a decentralized utility maximization problem with constraints that arises from the interference of the neighboring transmissions. Their JOCAC algorithm is able to assign not only the non-overlapping (orthogonal) channels, but also the partially overlapping channels within the IEEE 802.11 frequency bands. Their simulation results show that our algorithm provides a higher aggregated goodput than the recently proposed load-aware algorithm by 20%.

Stefan Bouckaert et al [6] have presented a protocol performing on demand distributed channel selection in multi channel, multi interface wireless mesh networks, based on the exchange of control messages. Their protocol is simulated and implemented using the IEEE 802.11b/g protocol. They have shown that in a raster topology, their protocol successfully optimizes the local spectrum usage at 87% of the nodes, and that globally, an equal amount of links is allocated to each of the channels used for the transport of data packets.

Chi-Yu Li et al [7] presented a new MAC protocol which is specially designed for multi-channel and multi-interface WMNs. Their proposed MAC protocol employs a hybrid channel assignment strategy to solve the rendezvous problem and a waiting time scheme for updating network allocation vectors (NAVs) to solve the multi-channel hidden terminal problem. Their simulation result shows that the proposed protocol can achieve a better utilization of both interfaces and channels.

Vijay Raman et al [8] have discussed simple local-balancing and interference-aware channel allocation algorithms for reducing the overall interference in the network. They have evaluated the relative performance of their algorithms using actual implementations on a multi-channel, multi-radio testbed. Using overall network throughput as a metric, through experiments they have shown that the channel allocation which is aware of the node's transmission activity performs better than the simple local balancing algorithm, irrespective of the number of channels used for allocation. Moreover, they have shown that the performance benefit of an interference-aware allocation over the local-balancing allocation improves as the number of flows in the network increases.

Based on Fairness

Janghwan Lee et al [9] have proposed a fair bandwidth allocation scheme for multi-radio multi-channel WMNs. Their scheme provides fair bandwidth sharing among the nodes in a WMN regardless of their hop distance from the gateway node. To achieve the fairness, first they have estimated the number of active nodes attached to each router, and calculate effective weights of routers based on the estimation. Then, they differentiate the contention window of them using their weights. Their proposed scheme is fully distributed, and does not require any global information. Through an extensive simulation study, they have shown that their scheme ensures per node fairness without loss of the total aggregate throughput.

Qizhi Cao et al [10] have proposed an approach which makes use of the TXOP mechanism in combination with an automatic contention window size tuning algorithm based on channel state sensing. Their simulation results shows that their proposed approach can provide a good approximation to per-flow max-min fairness and it is achieved regardless of the active number of flows and when the channel is noisy.

A. Hamed Mohsenian Rad et al [11] have mathematically formulated a cross layer fair bandwidth sharing problem as a non-linear mixed integer network utility maximization problem for a given logical topology of the network. An optimal joint design, based on exact binary linearization techniques, is proposed which leads to a global maximum. A near-optimal joint design, based on approximate dual decomposition techniques, is also proposed which is practical for deployment. Their results shows that their proposed designs can lead to multi-channel WMNs which are more efficient and fair compared to their single channel counterparts.

Ashish Raniwala et al [12] have proposed a co-coordinated congestion control algorithm that performs global bandwidth allocation and provides end-to-end flow-level max-min fairness despite weaknesses in the MAC layer. Their proposed algorithm features an advanced topology discovery mechanism that detects the inhibition of wireless communication links, and a general collision domain capacity re-estimation mechanism that effectively addresses such inhibition. Their simulation results demonstrate that their proposed algorithm substantially improves the fairness across flows, eliminates starvation problem, and simultaneously maintains a high overall network throughput.

Based on Channel Scheduling

Nguyen H. Tran et al [13] have proposed a greedy algorithm to investigate the problem of how to schedule a set of feasible transmission under physical interference model by using the spatial time-division multiple-access (STDMA) scheme. They have also considered the fairness in scheduling to prevent some border nodes from starvation. Their simulation result shows that their algorithms can achieve better aggregate throughput and fairness performance than 802.11 standards.

Marcel C Castro et al [14] have proposed a novel channel scheduler for the Net-X platform that takes into account packet priorities. They have evaluated their algorithm on the KAUMesh testbed. Their algorithm outperforms the standard round-robin scheduler both in terms of average delay and jitter.

PROPOSED SOLUTION

From the above sections 2 and 3, we can come to a conclusion that there is a need to provide a combined solution to the problems of interference, fairness, throughput improvement and scheduling. So our objective is to develop a channel scheduling algorithm as a combined solution to the problems of interference, fairness and throughput improvement.

In this proposal, we propose to develop an algorithm to perform on demand distributed channel scheduling in mesh networks with multi channel, multi interface mesh router. Our algorithm is designed to work with multi-hop flows and takes into account both inter-flow and intra-flow dependency and selects channels based on the priority of the current channel and the priority of all other channels, which have packets to send. If packets with different priorities are queued, the highest priority among all packets is used. Here Best Effort (BE) traffic is considered as low priority, and Real Time traffic (RT) as high priority.

In our channel scheduling algorithm, a *Channel Status Metric* (CSM) is used by each node at a specific channel. The channel with low CSM can be selected for scheduling. The CSM is estimated based on the following factors:

- Channel condition (contention level)
- Current Load
- Link Quality

This distributed algorithm computes the max-min fair share of individual wireless links based on the latest traffic loads. It eliminates the intra-flow and inter-flow contentions by creating a schedule based on the traffic demand across all end-to-end routed paths.

The proposed approach has the following advantages:

- It eliminates the contention-based channel access latencies and the multiple collisions that may occur in a multi-hop wireless networks.
- It avoids wastage of bandwidth arising in fixed TDMA slot assignment.
- It provides max-min fairness among the wireless links thus increasing the bandwidth utilization.
- It improves the throughput efficiency of the real time traffic flows.

CONCLUSIONS

The protocol will be simulated and implemented in NS-2 using the IEEE 802.11 protocol. Our channel scheduling scheme is very scalable and can be used in conjunction with any routing protocol which holds information about the next hop.

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AUTHOR DETAILS

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