EVALUATION OF ROUTING METRICS IN WIRELESS MESH NETWORKING

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ABSTRACT

In wireless networks, users expect to get access to the network securely and seamlessly to share the data flow of access points anytime and anywhere. However, either point-to-point or point-to-multipoint methods in traditional wireless networks make the network bandwidth decrease rapidly, which cannot meet the requirements of users. Recently, a new wireless broadband access network, wireless mesh networks (WMNs), has emerged as one of the key technologies. Wireless routing protocols plays an important role in performance optimization of WMNs. Most multimedia communication focus on efficient provisioning of multimedia services but show lack of quality of service due to the reason that communication is affected by node mobility as well as wireless communication environment, such as channel fading effects. The capacity of WMNs is very limited. Two problems affect the capacity of mesh networks; i.e. load balancing and interference. One important direction for improving the capacity of WMNs is to use multiple radio interfaces and multiple channels simultaneously. In this paper we are evaluating the performances of metrics available for wireless mesh networking. The load balancing routing algorithm method provides the load balance for multi-radio mesh networks by using a good routing metric LARM (Load Aware Routing Metric), which captures the differences in transmission rates, packet loss ratio, traffic load and intra / inter flow interferences.

Keywords: *WMN, QoS, Load Balance, Interference.*

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1. INTRODUCTION

A wireless mesh network (WMN) is a communications network made up of radio nodes organized in a mesh topology. WMN often consist of mesh clients, mesh routers and gateways [1] [2]. The mesh clients are generally laptops, cell phones and other wireless devices. The mesh routers forward traffic to and from the gateways which may connect to the Internet. When one node can no longer operate, the rest of the nodes can still communicate with each other, directly or through intermediate nodes. The links in WMN may be wired or wireless as shown in Figure 1. WMN consists of heterogeneous networks such as wired Local Area Network (LAN), Worldwide Interoperability for Microwave Access (WIMAX) or sensor networks. There may be more than one gateway in Wireless Mesh Network. Capacity of wireless mesh networks is very limited. The concept of capacity indicates the amount of data links or network paths that can deliver packets per unit of time.

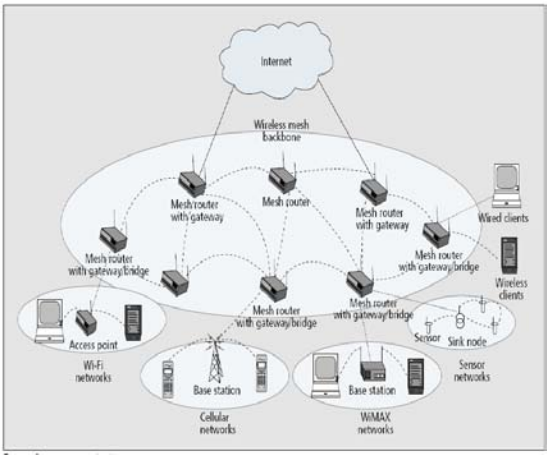

Figure 1: Wireless Mesh Network

The capacity of a link is defined as the number of packets that can be transmitted over the link during a limited period of time. The capacity can be termed as the capacity of an end-to-end path, which is the maximum packet rate that can be transferred from a source to its destination [3] [4] [5]. The capacity in the wireless mesh networks can be increased by deploying the mesh routers with multiple radio interfaces and multi non-overlapping channels. Many nodes can use interface channel to communicate with other nodes but it is not so easy to allocate channels to nodes to support various types of traffics in wireless mesh networks. The mesh backbone network must be designed to support the high capacity and speed over all links of mesh networks in order to minimize the congestion in them. Two techniques can be employed in order to improve the capacity of WMN are to provide better modulation, multi-antenna techniques and better MAC Protocol to support the increased data rate and second technique is to use all non-overlapping channels if possible. WMN equipped with multi-radio requires a multi-channel assignment and a routing scheme [29]. The multichannel assignment algorithm can choose the best channel with the lowest load among the non-overlapped channels to a specific radio interface at each node among the link paths. This helps to reduce the intra-flow and inter-flow interferences. Meanwhile, the routing scheme requires efficient, high-capacity routes to be computed between the source-destination pair of nodes [6], [7], [8], [9]. The channel assignment algorithm in a WMN provides binding of each network interface to a radio channel. This is done by using a path that will help transport a common channel available bandwidth on each link to balance the load and to reduce the interference by minimizing the number of neighbours interfering. Many multi-channel assignment algorithms for this purpose have already been proposed [10] [11]. The capacity in a wireless mesh network is reduced by the interference from the simultaneous wireless transmissions and the balancing load. Intra-flow interference exists between the adjacent nodes on the same routing path, whereas the inter-flow interference is caused by the neighbouring nodes on the other path [2] [12] [28]. The load-balancing routing (LBM) was proposed that can support the routing protocols in order to decrease the interference and balance the load in the wireless mesh networks (WMNs), Distance Vector AODV-MR protocol [6]. This work focuses on network capacity issues such as inter-flow/intra-flow interferences and balancing load and performance evaluation of available routing metrics for the wireless mesh networks. The simulation results showed how the LBM algorithm can affect the metric routing protocols in achieving a good balancing load capacity over all mesh networks.

The remaining paper is being described as follows: section 1 is introduction part, section 2 shows the Literature Review, section 3 gives the objectives and research methodology description, section 4 is about LBM (Load Balancing Multiradio Protocol) section 6 & 7 give performance evaluation and results describes the problem in channel assignment for WMNs.

II. LITERATURE REVIEW

Wireless mesh networks (WMNs) is a latest technology that envisages supplementing wired infrastructure with a wireless backbone for providing Internet connectivity to mobile nodes (MNs) or users in residential areas or offices so called the Web-in-the-sky. WMNs are characterized by self-organizing self-configuring capability, ease, and (quick) rapidity of network deployment. Since its inception in the early years of this millennium, it has been in the limelight of all researchers. However, for a WMN to be all it can be, considerable research efforts are still needed. A good routing metric should find the paths with the component links that have low loss ratio and high data rate, and experience low levels of interference. In recent year, there are increasing amount of related research [13]. Nodes in the WMN are generally quasi-static in their location. Thus, the focus of the routing studies in the WMN has moved to performance enhancement by using sophisticated routing metrics [27]. There are many routing metrics proposed for the multi-hop wireless mesh networks they are: Hop Count, Expected Transmission Count (ETX), and Expected Transmission Time (ETT). Per-hop Round Trip Time (RTT). Weighted Cumulative Expected Transmission Time (WCETT). Metric of Interference (MIC) and Channel Switching Interference Aware Routing Metric (IWARE) [10]. The concept of the hop count metric is simple: every link counts as one equal unit, independent of the quality or other characteristics of the link. The ease of implementation has made hop count the most widely used metric in wired networks; it is implicitly or explicitly the default metric in many popular wireless mesh net-work routing protocols, such as Optimized Link State Routing (OLSR), Dynamic Source Routing (DSR) [13], Destination Sequenced Distance Vector (DSDV) [16] and Ad hoc On Demand Distance Vector (AODV) [15]. ETX finds paths with the fewest expected number of transmissions (including retransmissions) required to deliver a packet all the way to its destination. The metric predicts the number of retransmissions required using per-link measurements of packet loss ratios in both directions of each wireless link. The primary goal of the ETX design is to find paths with high throughput, despite losses [17]. The routing metric ETT [6] improves ETX by capturing the data rate for each links. ETT is defined as the expected MAC layer for a successful transmission of a packet on a wireless link [1]. ETT impact the link capacity on the path to achieve better of performance. However, ETT does not fully capture the intra/ inter-flow interference in the network. ETX and ETT do not support multiple channels and they do not consider how link is busy. Weighted Cumulative Expected Transmission Time (WCETT) was established for multi-radio wireless mesh networks. It enhances ETT by capturing the data rate that used in each link; the drawback limitation of the WCETT metric is that it does not capture inter-flow interference. However, final result of WCETT is in poor throughput because it finding routes in more congested areas [18]. Metric of Interference and Channel Switching (MIC) [14] is designed as the routing metric for Load and Interference-Balanced Routing Algorithm (LIBRA) [19]. Routing metric MIC improves WCETT by scaling up the ETT , MIC captures inter-flow interference by the number of interfering neighbours, and the degree of interference caused by each node interfering is not the same. It depends on the signal strength of the interferer’s packet at the sender or the receiver. The disadvantage of MIC metric is very complexity. For estimation of routing metric, it requires each the total number of nodes and the smallest value of ETT in wireless mesh networks. Interference Aware routing metric (iAWARE) is proposed for multi-radio mesh networks. This metrics captures loss ratio, differences in transmission rate such as inter and intra-flow interference that effects of variation of link. The drawback of this metric is captures the interference from physical layer. There are a various load-balancing routing protocols have proposed, most of them are only represents for single channel wireless networks such as Dynamic Load-Aware Routing (DLAR). However, these metrics represent a single radio wireless network. Furthermore, many routing protocols have already been proposed for multi-radio mesh networks. Multi Radio Link-Quality Source Routing (MR-LQSR) protocol was proposed to find the highest throughput paths based on WCETT routing protocol [14]. Multiradio extension to the Ad-hoc On-Demand Distance Vector Routing (AODV) protocol was proposed in [20]. However, all these protocols do not support load balancing, and packets can be routed through hot spots. A good routing metric needs to captures the load correctly to balance load in WMNs, also a good routing protocol.

The above mentioned literature review made us motivated to do research work in the area of routing algorithms for wireless mesh networks.

III. OBJECTIVES AND METHODOLOGY

With the use of multiple radios in mesh routers the capacity problem in the wireless mesh networks can be alleviated. However, channel assignment presents a challenge because the collocated wireless networks are likely to be tuned to the same channels. The resulting increase in the interference can affect the overall performance of WMN [21]. On the other hand, the multi-channel wireless mesh network (WMN) architecture equips each mesh node with multiple 802.11 interface cards. The objectives of this design issues are channel assignment and routing proposed [22]. Moreover, the goal of channel assignment in a multi-channel WMN is to bind each network interface to a radio channel using the path to help transport the common channel available bandwidth on each link. This is to balance the load and to reduce the interference by minimizing the number of interfering neighbours [24]. Besides, the channel assignment algorithm protocol for multi-radio wireless mesh networks is used to address the interference problem and to propose the solution of intelligently assigned channels to radios in order to minimize the interference in the mesh network. Our objective in this research paper is to evaluate the performance of different routing schemes on the basis of existing routing metric. Our aim is to find out the packet delivery percentage for available routing metrics for single radio and multi radio. Existing multicast routing algorithms will be evaluated using network simulators NS2.

IV. LOAD-BALANCING ROUTING PROTOCOL FOR MULTI-RADIO MESH NETWORKS (LBM)

The objective of the load balancing routing algorithm protocol is to enhance the route between all traffic and to avoid the bottleneck links over the mesh network. Having mentioned that, load balancing describes the ability of a router to transmit packets to a destination over more than one path. This means that the routers send the packet from the source to the destination over the first path, the second packet for the same destination over the second path, and so on. Furthermore, load balancing guarantees equal load across all links. However, there is potential that the packets may arrive out of order at the destination because differential delay may exist within the network [26]. Hence, load balancing determines the outgoing interface for each packet by looking up the route table and picking the least used interface. This ensures equal utilization of the links [15].

V. PERFORMANCE EVALUATION

We considered wireless mesh networks, in first part each node was equipped with only one radio interface and all the radio interfaces were configured to the same channel. In the second part of the evaluation, each node had multiple radio interfaces that were configured to different channels. Since channel switching might reduce intra-flow interference, the ability to capture intra-flow interference affected the performance capacity of the routing metrics. The metrics that were compared in this part included WCETT, Metric of Interference (MIC) and Load Aware Routing Metric (LARM). The topologies of simulations were randomly generated. In the simulation of this study, all flows were destined to the Internet gateways and the sources of the flows were randomly located in the mesh network. All flows were Constant Bit Rate (CBR) flows with 512 bytes of packets. The transmission range was 250 m, and every node had two radios and each radio could be configured to one of the three channels. The packet rate was 4-8-12-16-20 packets/sec and buffer size was 50 packets. The study established using 1000 m × 1000 m wireless mesh networks, with 100 nodes generated randomly. NS-2(Network Simulator) simulation tool was used and three simulation scenarios were considered to evaluate the performance for WCETT, MIC and LARM metric protocols.

VI-SIMULATION RESULTS AND ANALYSIS

The simulation experiments revealed various useful results with the different metric protocols (i.e. LARM, WCETT and MIC). Each router was equipped with different radio channels and the packet rate was set up to four packets per second. The simulation was run with various numbers of radio channels on each router. The simulation showed how the number of channels affected the capacity performance.

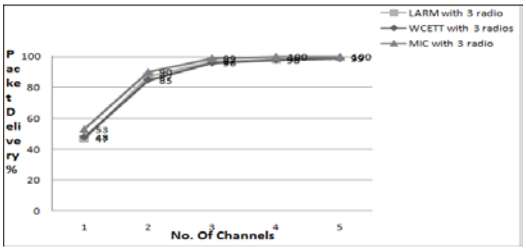

Figure 2. The number of radio interfaces

When one channel radio interface was used on the mesh routers, it was revealed that the simulation results reflected the amount of one channel of data and showed how the LARM metric protocol stile presented the packet delivery, as compared to WCETT and MIC in terms of percentage. In addition, when the mesh routers were equipped with multi-radio channels, the channel selection helped to balance the traffic if there were no non-overlapping channels.

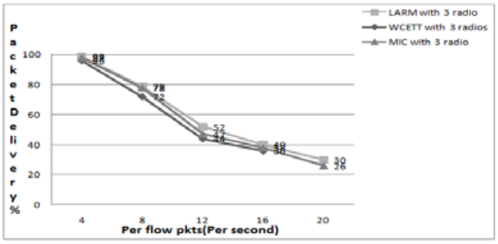

Figure 3 Simulation results with three-radio mesh router of varying traffic loads

In this simulation, the varying packet rate as a metric was used. The packets ranged from 4 to 20 packets per second where the number of flows stated 50 and the simulation ran with multiple radio channels. On the other hand, as shown in Figure 3, LARM metric protocol reduced the interference in the wireless mesh network as compared with MIC and WCETT. When the simulation was run with 20 packets /second, it revealed that the LARM metric protocol still gave the best rate compared with MIC and WCETT.

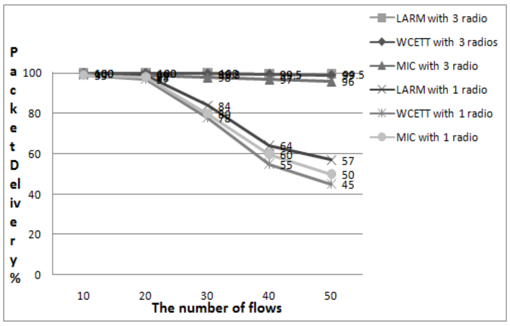

Figure 4. Simulation results with varying numbers of flows

Figure 4. Shows the percentage of packet delivery of the wireless mesh network. The results showed that the LARM metric protocol gave the best result compared to the WCETT and MIC metrics. For a single radio, LARM presented the highest percentage of packet delivery among all the mentioned networks, i.e. about 57% at 50 flows, compared with WCETT, i.e. about 45% at 50 flows and MIC, i.e. about 50% at 50 flows.

However, when the mesh routers were equipped with multiple radio interfaces, the traffic load was increased while the packet loss ratio was decreased. For the three-radio case, at 50 flows, LARM displayed the best result among all the selected routing metrics.

VII. CONCLUSIONS

In this paper we presented the major problems in multi-radio infrastructure mesh networks and we presented the major solutions for solving the balance loading and inter-flow interference and intra-flow interference problems. Also, we described the requirements that routing metrics need to ensure the capacity of mesh networks. In addition, this study investigated the possible choices of routing protocols for mesh networks which capture the difference in transmission rates, packet loss ratio, intraflow/inter-flow interferences and traffic load in multi-radio WMNs. These metrics were incorporated into a load-balancing routing protocol, which was used in this study to find the paths that are better in terms of balancing the load and reducing the inter-flow and intra-flow interferences in the multi-radio networks. Finally, the performance of these routing metrics was compared. It appeared that LARM displayed the best performance among all the selected mesh networks, i.e. WCETT and MIC routing metrics.

For future research, the development of new load balancing metric protocol is needed in order to enhance more router protocols in handling the problems of interference. Further investigation is also needed to identify the performance of all existing metrics in the real mesh networks based on actual hardware measurements. Finally, a study on how α affects the delay and throughput of flows overall load on the multi-radio mesh networks.

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