Maximizing Communication Quality with Bandwidth Guarantees in Wireless Mesh Networks

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ABSTRACT--Wireless Mesh Network (WMN) helps remote areas to gain access to Internet. There might be number of paths to gain access to Internet. Finding a path with maximum bandwidth is the problem to be addressed. Many solutions towards this came into existence. Recently Hou et al. presented a new path weight approach to capture in order to obtain path bandwidth information. In wireless networks the solution is not easier when compared to its wired counterpart. They used consistency property with respect to path weight to know the best that maximizes bandwidth consistently. In this paper we implement this strategy in WMN. We built a prototype, a simulator, application which demonstrates the proof of concept. The empirical results revealed that our approach is effective and outperforms existing path metrics.

Index Terms – Wireless mesh networks, quality of service, hop-by-hop routing, throughput

I. INTRODUCTION

Wireless Mesh Network (WMN) is made up of number of wireless nodes. The nodes are overlay nodes used to cover services. Some nodes are wired in nature that is used to connect to Internet. WMN supports plenty of applications. It is supposed to provide Quality of Service (QoS) [1]. One fundamental problem in WMN is to find the best path which has maximum bandwidth availability. The path which pushes maximum data though it is known as the available bandwidth path [2]. When the new traffic that comes in is not having more than certain threshold, the bandwidth is sufficient. If not the network has to find the best available path before sending data for quality reasons. Technically, this problem is known as Maximum Bandwidth Problem (MBP). The main problem actually Bandwidth Constrained Routing Problem (BCRP) in which MBP is a sub problem [3]. Widest path is another term used in the literature to denote the maximum available bandwidth path. It is very challenging to find widest path between source and destination in wireless networks as it has interference. Interference is of two types generally. They include intra-flow interference and interflow interference [2], [4]. As the name implies the interflow interference is the interference caused by the presence of other flows. Whereas the intra-flow interference is the interference caused within the flow. In [5] it is explored how to estimate the available bandwidth for each link. When a link carries 1 hop flow without violating bandwidth guarantees, it is said to have widest link. Hop by hop routing protocol gets problems with intra-flow interference while finding widest paths. With respect to intra-flow interferences a formula is presented in [6] and [2] for computing available bandwidth and finding widest path. Finding widest path accurately is still a challenging problem in hop by hop fashion. There are two challenges throws by the formula. They are some nodes will not be able to find the widest path when routing metric considered only available bandwidth; destination based, traditional hop-by-hop forwarding cannot result in consistent. Sample network is as shown in figure 1.

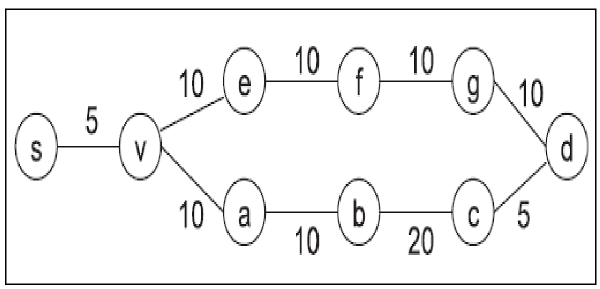

Fig. 1 – Sample network topology

As can be seen in figure 1, the nodes are labeled appropriately. The source and destination have multiple intermediate nodes. The bandwidth is mentioned on the links. As per the available bandwidth between the source and destination, the lower path is widest path. However, the source makes use of upper path as it is large enough to send data. It does mean that the source does not use the widest path. To overcome this problem a routing protocol has to consider two requirements. They are known as consistency requirement and also optimality requirement. Developing isotonic routing metric is the important key requirement of designing the routing protocol [7], [8]. The remainder of the paper is structured as follows. Section II provides review of literature. Section III describes the proposed routing protocol with Quality of Service (QoS). Section IV presents experimental results while section V concludes the paper.

II. RELATED WORKS

As identifying widest path is essential in WMN many researchers focused on this in terms of developing path weights and finding maximum available bandwidth path or the widest path in other words. A new metric by name ETX (Expected Transmission Count) was proposed in [9] and [10]. The estimated number of transmissions on a link is said to be its ETX value. This estimation is done by sending probe packets over network. The ETX of a path is the sum of ETX values of all links in that path. Many other metrics were extended from ETX [11]. For instance ETT [12] is an extension to the ETX metric which also take packet size into consideration besides raw data rate on the links over many channels. Single channel WMNs is considered in this paper. We also assume in this paper that all links have the same raw data rates. Interestingly in this case, the ETX value is same as that of ETT. Many other metrics like CATT [13], IRU [14], iAWARE [15] extended ETT metric. CATT extends IRU and considers raw data rate and packet size while IRU extends ETT metric using number of interference links.

Many routing protocols [4], [2], [16], [17], [18], [19] also work with links and their bandwidths for Quality of Service (QoS) reasons. A new link metric was proposed by Liu and Liao [18] that is link bandwidth divided by inference links. Then the path bandwidth is computed as all links' minimum values of new metrics in the given path. In [17] the bandwidth of path is computed as all links' minimum bandwidth of the given path divided by 4 or 3 or 2 based on the hop count exhibited by the path. Exact path bandwidth cannot be reflected by such formula. The bandwidth requirements are assumed by path selection processes [20], [21], [22], [16] based on the connection request. Based on the bandwidth requirement of request the metric is proposed in [4]. In [19] a protocol is proposed which finds the local available bandwidth to satisfy decisions. TDMA-based MAC is considered in some works for achieving the same [20], [21]. For given path, estimating available bandwidth is explored in prior works such as [23], [24], [25], [26] and [19]. In all these approaches bandwidth computation is made using a clique-based path. Certain formulae are used in [24], [25], and [26] for computing bandwidth available. The goal of this paper is to develop a routing protocol that facilitates sending packets through widest path with good Quality of Service. Our protocol is expected to work in new wireless devices with ease. The remainder of the paper is structured as follows.

III. QoS ROUTING PROTOCOL

In this section, we describe our widest path selection process. We discuss about path selection, isotonic path weight computations, table construction, and packet forwarding. Our mechanism for widest path selection is based on distance vector.

Path Selection

Out path selection approach is different from that of traditional approach. In traditional distance-vector mechanism a node is supposed to inform only its best path to its neighboring nodes. This way every node identifies its own best path. Advertising all paths to destination is not a viable solution. We should not do so in order to reduce overhead. Consider figure 1 where number given on each link represents the available bandwidth of that link. The proposed path comparison process is presented in figure 2.

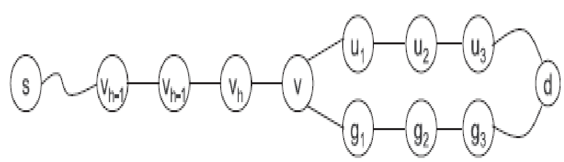

Fig. 2 – Illustrates path comparison process

As can be seen in figure 2, the link a to b has bandwidth represented as B(a,b). Provided a path p=<v1, v2, …, vh) let WB(p) = B(p), FB(p) = B(v1, v2), and TB(p) = WB(<v1, v2, v3>). And the value of HB(p) = WB(<v1, v2, v3, v4>). The bandwidth is taken as the bandwidth of bottleneck clique.

$$WB(p \oplus p_1) = \min\{WB(p), WB(p_{1,1}), WB(p_{1,2}), WB(p_{1,3}), WB(p_1)\}.$$

Isotonic Path Weight

In this sub section we introduce a new path weight known as isotonic path weight. This is used to construct routing table. Every path weight has isotonic property is the important condition for building routing protocols in order to satisfy the requirements of optimality and consistency. The isotonicity was first introduced in [7] and [8]. Considering two paths namely p1 and p2, which are from source to destination node, and assume that p1 is better path when compared to p2, the left isotonic path weight or CAB (Composite Available Bandwidth) is presented as follows.

$$(\omega_1(p), \omega_2(p), \omega_3(p), \omega_4(p))$$

Table Construction

Routing protocol can be developed using the isotonic property of proposed path weights. It is important to determine whether a path is worth advertising or not. In the proposed protocol a node will advertise non-dominating paths to neighbors. The packet which carries path information is known as route packet. Each node will come to know first four hops information based on the content present in the route packet. Each nodes in the network maintains two tables namely routing table and distance table. The distance table holds non dominated paths advertised by neighbors while the routing table holds the dominating paths itself. The composite available bandwidth is computed as follows.

$$\begin{cases} \dfrac{1}{\omega_1(p')} = \min\left\{\dfrac{1}{B(s,u)} + \dfrac{1}{\omega_2(p)}, \omega_1(p)\right\}, \\ \dfrac{1}{\omega_2(p')} = \dfrac{1}{B(s,u)} + \dfrac{1}{\omega_3(p)}, \\ \dfrac{1}{\omega_3(p')} = \dfrac{1}{B(s,u)} + \dfrac{1}{\omega_4(p)}, \\ \omega_4(p') = B(s,u). \end{cases}$$

Packet Forwarding

Packet forwarding has to be done along with widest path for best quality of service. When a node by name s wants to send data to the node d, the widest path has to be found as per the procedures discussed in the previous sections. For instance the path p=<s, v1, v2, v3, …, d>. Each node in the path should be able to take routing decision based on the computation of widest path. In the traditional routing protocol, destination address is carried by a packet. In our approach an additional field apart from that by name “Routing Field” holds the next four hops through which the packet should traverse. As the packet moves, the routing field of packet gets updated. More technical details can be found in [17].

IV. EXPERIMENTAL RESULTS

We built a prototype application, a custom simulator, to demonstrate the proof of concept. We built a simulator using Microsoft .NET platform. C# programming language is used to build simulation logic. The environment used to build the simulations is a PC with 4 GB RAM, core 2 dual processor running Windows 7 operating system. We made experiments in terms of hop count versus average improvement ratio to find how widest path selection helps in improving quality of service.

V. CONCLUSION

In this paper we studied a common problem encountered by Wireless Mesh Networks. The problem is to find the maximum available bandwidth path which is very essential to have good quality of service in WMN. In this paper a new path weight approach is used to determine the maximum bandwidth path. Using this path weight it is possible to create proactive hop by hop protocol for routing proposes. We implemented such protocol and tested with simulations. We built a custom simulator to demonstrate the proof of concept. The experimental results revealed that the approach to find maximum bandwidth path is effective and can be used in real world applications.

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