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Routing Analysis in Wireless Mesh Network with Bandwidth Allocation

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Abstract— ***Wireless Mesh Network (WMN) is an important network to provide Internet access to remote areas and wireless connections in a metropolitan scale. As part of the Internet, WMN has to support diversified multimedia applications to all its users. It is essential to provide efficient Quality-of-Service (QoS) support to the networks. Searching the path with the maximum available bandwidth is one of the fundamental issues for supporting QoS in the WMN. The available path bandwidth is defined as the maximum additional rate a flow can push through saturating its path. Therefore, if the rate of traffic in a new flow on a path is no greater than the available bandwidth of this path, accepting the new traffic will not exit the bandwidth guaranteed of the existing flows. Due to interference among channel links, the bandwidth is a bottleneck metric in wired networks, is neither a defect nor additive in wireless networks. In this paper a computing path weight which captures the available path bandwidth information is proposed. This paper also show that the efficient routing protocol based on the new path weight which provides the consistency and loop-freeness to the network. The consistency property guarantees that each node makes an appropriate packet forwarding decision, so that a data packet does traverse through the exact path. The simulation experiments also show that the proposed path weight gives high-throughput paths.***

Index Terms—Wireless mesh networks, routing, efficient routing proactive hop-by-hop routing, distributed algorithm.

I. INTRODUCTION

A wireless mesh network (WMN) has large number of wireless nodes. The nodes form a wireless overlies to cover the service area whereas few nodes are wired to the Internet. As part of the global Internet, Wireless Mesh Network has to support diversified multimedia applications for all its users. It is essential to provide efficient Quality-of-Service support in this type of networks [1]. Searching the path with the maximum available bandwidth is one of the fundamental issues for supporting Quality of Service in the wireless mesh networks. The available path bandwidth which is defined as the maximum additional rate a flow can push through saturating its path [2]. For that reason, if the traffic rate of a new flow on a path is no greater than the available bandwidth of the path, then accepting the new traffic will not violate the bandwidth which guarantees the existing flows. This paper focuses on the problem to identify the maximum bandwidth path from the source to the destination, which is also called the Maximum Bandwidth Problem (MBP).

It is a sub problem of the Bandwidth-Constrained Routing Problem (BCRP), which is the problem of identifying a path with at least a given amount of available bandwidth [3].

Then finding the maximum available bandwidth path between the source and the destination in wireless networks is very difficult due to the wireless transmission interference. Commonly speaking, there are two types of interference: interflow interference and intraflow interference [4], [2].

In Fig. 1, according to the formula in [2] and [6] (will be described in detailed later), the upper path from v to d has a better available bandwidth than the lower path from v to d. However, by the formula in [2] and [6], the lower path from s to d is superior in terms of available bandwidth.

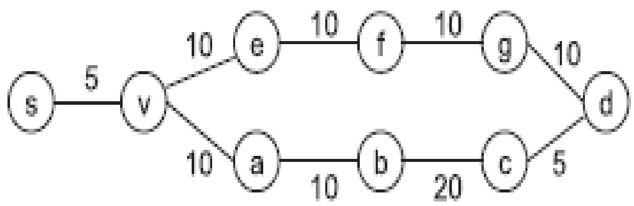

Fig. 1. Example of network topology

According to the usual distance vector protocol, node v just advertises the upper path information to its nearby nodes, so that node s cannot obtain the widest path from itself to d. Still s identifies the lower path to d which has the larger available bandwidth; the problem is not yet solved. When node v receives the data packet from s, then it will forward the packet to e but not to a by means of the traditional destination-based hop-by-hop routing, because the upper path from v to d has the larger available bandwidth value. Namely, the data packet actually does not traverse on the widest path from s to d. In actual fact, the above two challenges mean that a proper routing protocol should assure the consistency requirement and optimality requirement. The key in for designing such efficient routing protocol is to build up an routing metric.

In this work, we study how to perform routing in the 802.11-based Wireless Mesh Networks and make the following contributions.

1. Here we propose a new path weight that captures the idea of available bandwidth. We give the system to compare two bandwidth paths based on the new path weight. We officially prove that the proposed path weight is left-isotonic.

2. Then we illustrate how to construct the distance table and routing table, and develop a packet forwarding scheme. And we formally show that the routing protocol satisfies the consistency and optimality requirements.

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3. Lastly, we implement the routing protocol based on the DSDV protocol in the (Network Simulator)NS2 simulator. The general simulation experiments demonstrate that the routing protocol outperforms the present routing protocols for discover the maximum available bandwidth paths.

The rest of the paper is organized as follows: In Section II Related work is described; then in section III, we explain how to compute the available bandwidth on a path. Section IV describes our efficient routing protocol in detail, and in Section V the simulation results are shown. Finally we conclude our paper in Section VI.

II. RELATED WORK

To discover the widest path, many researchers develop the new path weights, and the path with the maximum /minimum weight is understood to be the maximum available bandwidth path of the network. In [9] and [10], the expected transmission count (ETX) metric was proposed. The ETX of the link is the predicted number of data packet transmissions which is required to send a packet over that particular link, is estimated by proactively sending a dedicated path link probe packet once in a while. The ETX metric of a path link is the sum of all the ETX metric links on this path. It is one of the earliest link metric developed and many other metrics are also extended from it [11]. The ETT [12] is an improved version of ETX which also considers the effect of raw data rate and packet size on the links because of the use of multiple channel paths. In this paper, we only consider the single-channel wireless mesh networks, and then assume that the raw data packet rates of all the links are the same, as well as all the data packets are of the equal size. In this case, the ETT is the same as ETX. Quite a lot of other metrics, such as IRU [14], iAWARE [13], and CATT [15], are all the extension of ETT. iAWARE is one of the ETT metric that adjusts based on the number of the interference links and also the existing traffic load relies on the interference links. IRU is the extension of ETT metric weighted with the number of the interference links, whereas CATT extends the IRU by considering the effect of data packet size and the raw data rate on the channel links because of the use of multiple channels.

Several existing Quality of Service (QoS) routing protocols which operate with the available bandwidth knowledge of each link [2], [4], [6], [16], [17], [18], [19]. All these works study how to compute the available bandwidth of a path which is based on the available bandwidth of each link on the particular path. Liu and Liao [17] has given a new link metric which is the available bandwidth path of the link which is divided by the number of interference links of this path link. The available path bandwidth is thus defined as the minimum value bandwidth of the new metrics of all the links on this path. The mechanism described in [18], is the available bandwidth of a path which is the minimum bandwidth among the links on the path which is then divided by 2, 3, or 4, depended on the number of node hops on the path. Such formula may not reflect the exact path bandwidth. But the path selection processes in [4], [19], [20], [21], and [22] imagine the path bandwidth requirement of a link connection request is known. The path metric proposed in [4] is based on the bandwidth requirement of a definite request. The routing protocol in [19] checks the local available bandwidth of each node path to determine whether it satisfies the bandwidth requirement. And some works [20], [21], [22] consider the TDMA-based MAC model which discuss how to assign the available time slots on each path link for a new flow in order to satisfy the bandwidth requirement of the packet flow.

III. PRELIMINARIES

The path based on the current flows on the each link in the network, denoted by $B(e)$ as the available bandwidth of link e. This means that if a new connection needs only to go through link e, and e can send at most $B(e)$ Kbits amount of information in a second by not affecting existing flows. The work in [5] describes how to obtain $B(e)$, and the following discussion considers $B(e)$ is known. Here that the bit error rate of a path link is considered in the link estimator, thus the available bandwidth of each path link becomes the expected available link bandwidth [23]. This denotes Q_p as the set of the maximal cliques containing only links on p. Generally speaking, when two links on a path interfere with each other, then all the links between them along the path conflict with each other, which implies that it is easy to find Q_p for the path p. The available bandwidth of path p is estimated as follows [5], [6]:

$$B(p) = \min_{q \in Q_p} C_q \quad ; \quad C_q = \frac{1}{\sum_{l \in q} \frac{1}{B(l)}}. \qquad (1)$$

The basis behind the formula is transmissions on the path links in a clique will not be concurrent but occur in a series manner. Thus, the time that it takes $\sum_{l \in q} \frac{1}{B(l)}$ for a 1 Mbit data to traverse properly in all the links of the clique q. The Cq is thus the bandwidth available over the clique q. Then the available bandwidth of the path link is the bandwidth of the bottleneck clique.

IV. EFFICIENT ROUTING PROTOCOL

In this section, an efficient path selection mechanism is done. This is based on the distance-vector mechanism. The distance vector mechanism gives the necessary and sufficient condition to find out whether a path is not worthwhile that is to be advertised. Then this describes a new path weight. Then routing is performed by implementing consistent packet forwarding and updating route based on this new path weight which satisfies the optimality requirement.

A. Path Selection

The distance-vector based mechanism is developed. Here, in the traditional distance-vector mechanism, the node only has to advertise the information of its own best path to all its neighbors of the node. Each neighbor then identifies its own best path. Then, if a node only advertises the widest path from its own perception, its neighbors may not be able to find its widest path.

B. Path Weight Calculation

A new isotonic path weight is introduced in this section, while in the next section it describes how to use the path weight to construct routing table's effectively. The isotonicity property of a path weight is the sufficient and necessary condition for developing a efficient routing protocol which satisfies the optimality and consistency requirements.

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This is done by calculating path bandwidth isotonic path weight A proposed left-isotonic path weight, called composite available bandwidth (CAB). If we are not able to find a path dominating path, then we call that path a nondominated path.

C. Constructing Table

The isotonicity property that proposed a path weight allows to develop a efficient routing protocol which can identify the maximum bandwidth path from all node to all destination one by one. Exactly, it tells us whether a path is worthwhile to be advertised among the nodes, to check whether a path is a potential subpath of a widest path. In the routing is performed, if a node finds a new nondominated path, then it will advertise this path information to all its neighbors. The packet which carries the path information is the route packet. For each and every nondominated path p from source to destination, s advertises the tuple to all its neighbors in a route packet. The NF(p), NS(p), and NT(p) represents the first next hop, the second next hop, and the third next hop on p from s, respectively. Based on all the information contained in a route packet, all nodes know its information about the first four hops of a path which is identified. The information is necessary for consistent routing in a network, which will be discussed in details later. Here, each node keeps two tables, one distance table and routing table. The node s puts all the nondominated paths which is advertised by its neighbors in the distance table. It also keeps all the nondominated paths that found by s by itself in its routing table. In the network, when s receives an advertisement from u which represents a nondominated path p that is from u to d, here, s removes all the locally recorded paths from u to d which are then dominated by p. The denote path as the path from s to d which is one-hop away from p, then s computes the CAB of path.

D. Forwarding The Packet

The consistent hop-by-hop packet forwarding mechanism is discussed in this section. In a traditional hop-by-hop routing protocol, the data packet carries only the destination of the packet, but when a node receives a packet, it looks for the next hop by the destination only. In this mechanism, apart from all the destination, the packet also carries a Routing Field which then specifies the next four hops the packet need to traverse. If a node receives this packet, then it identifies the path based on information in the Routing Field in the network. It also updates the Routing Field and sends it to the next hop periodically. In this packet forwarding mechanism, the intermediate node determines the fourth next hop but not the next hop as in the traditional DSDV mechanism. The packet forwarding mechanism needs each intermediate node to make route decision based on the routing table. Further, only the information of the first few hops of a path in the routing table is kept in each node and the routing field in a data packet. Therefore, the mechanism possesses the similar characteristics of a hop-by-hop packet routing mechanism, and is also a distributed packet forwarding scheme.

channel type	Wireless channel
Propagation model	Two Ray Ground
Network interface type	Physical interface
Layer	MAC
No of nodes	50
Routing protocol	AODV
X dimension	1000
Y dimension	1000
Transmission Range	250m
Time of simulation start	1
Time of simulation end	220

The advertisement complexity and the space complexity of the routing protocol are directly related to all nondominated paths from each node to each destination one by one. Denoting A as the average number of the neighbors of each node. While there is only one nondominated path which is going through the same first three links, maximum number of nondominated paths from each node to a destination is O(A). Consequently, the mechanism is a polynomial-time routing algorithm for which can compute the maximum throughput of a path. Note that the consistency that was discussed in the above assumes that each node has the perfect state information about its neighbors. The Route update may also cause inconsistency. Still, such inconsistency is independent on routing metric or what type of the packet forwarding mechanism is applied, as it is completely due to the delay of the route update broadcast. Hence, such inconsistency exists in all distributed routing protocols.

E. Updating Route

Once the network accepts a new flow or releases an available connection, the local available bandwidth of each and every node will change, and therefore the widest path from a source to a destination will be different. If the change of the local available bandwidth of a node is larger than the threshold, the node will advertise the new information to all its neighbors. Then after receiving the new bandwidth information, the available bandwidth of a path to the destination might be changed. Even though the node is static, the network information state changes very often. While, the routing protocol applies the route update mechanism in DSDV. Based on traditional mechanism DSDV, each routing entry is tagged with a sequence number which is normally originated by the destination, hence that nodes can quickly distinguish stale routes from that of new ones. All the nodes periodically transmit updates immediately when significant new route information is available in the network. When given two route entries from a source to a destination, the source always selects the one which has larger sequence number, which is newer, which is to be kept in the routing table. If two entries have the same sequence number, the path comparison is used to determine which all paths should be kept. Due to the delay introduced during route update propagation, it is possible that the route information kept in some nodes is inconsistent manner. For example, the widest path which is kept in the routing table may not be the widest anymore. The Routing loops may occur as well. These situations are referred as inconsistency due to temporary route updates. Thus, the packets are considered to be routed on the computed widest path when all the routing tables are stable.

V. RESULTS

A. Simulation Parameters

The simulation focuses on some of the network properties such as:

1. Throughput
2. Packet delivery ratio
3. End-End Delay

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4. Control Overhead
5. Data Packet Forwarding Overhead

The throughput is analyzed with time. The other parameters are analyzed with various numbers of nodes such as 25 nodes, 50 nodes, 75 nodes and 100 nodes.

B. Simulation Experimental Setup

Table. 1 Simulation Settings

C. Network Scenario

The simulation experiment settings which are listed above are implemented in NS2 simulation. The simulation network consists of 50 nodes. The Network scenario is shown below.

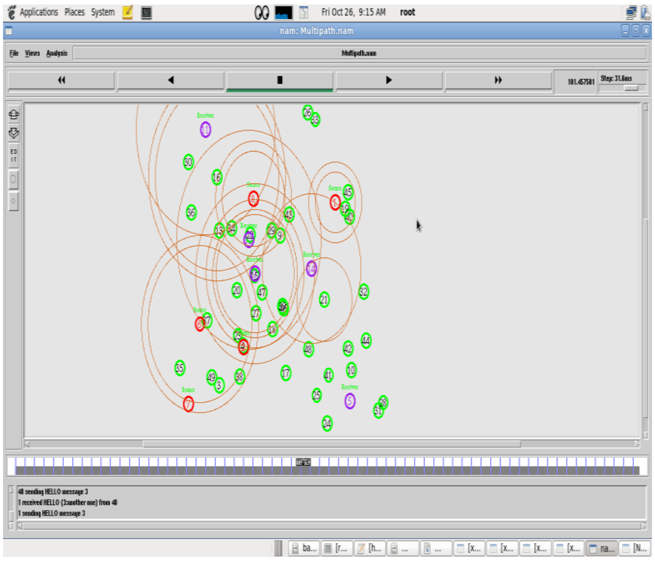

Fig. 1 Network scenario of 50 nodes

The simulation experiment settings which are listed above are implemented in NS2 simulation. The simulation network consists of 50 nodes. The Network scenario is shown above.

The Fig. 1 gives the network scenario with 50 nodes. In this setup five nodes are chosen as source and one node is chosen as destination. First, the distance is calculated from all the nodes to the destination. Based on this, path selection is done from source to destination; there may be one or more paths. Available Bandwidth is set as 2Mbps. Then each links bandwidth is estimated which is the path weight, also the maximum available bandwidth path is found and hop by hop routing is done. Packet forwarding is performed successfully to provide consistency. The routing table is constructed and also the routes are updated.

D. Simulation Results

i. Network Throughput

Throughput is the average rate of successful message delivery over a communication channel. This data may be delivered over a link, or pass through a certain network node.

In fig. 2 the throughput is plotted as packet received versus time. It is carried out with different evaluation time. As observed in the graph throughput of the network increases in both existing ETX and proposed Bandwidth method. Due to the maximum available bandwidth path routing, throughput is significantly increased in proposed method. This is because the delivery ratio is extremely high and packet drop is comparatively less.

ii. End To End Delay

End-to-end delay refers to the time taken for a packet to be transmitted across a network from source to destination.

End to End delay versus number of nodes is plotted in fig. 3. The different delays are queuing delay, propagation delay, processing delay, processing time. The delay is calculated for different number of nodes. As shown in figure, the end to end delay is compared with existing ETX method, which shows that the delay is less for the proposed Bandwidth system.

iii. Packet Delivery Ratio

Packet delivery ratio is defined as the ratio of data packets received by the destinations to those generated by the sources. It decreases with increasing number of hosts. As number of hosts increases the probability of successful delivery decreases due to various reasons like interference, distance between nodes etc. The packet delivery ratio increases with time.

In fig 4. Packet delivery ratio is plotted against number if nodes. The packet delivery ratio is compared with proposed methods and existing method. According to the above figure the packet delivery ratio is better for the proposed Bandwidth method when compared to the existing ETX method. The above figure shows the packet delivery ratio plotted for various numbers of nodes like 10, 25, 50, 75 and 100.

iv. Data Packet Forwarding Overhead

It refers to the time it takes to transmit data on a packet network. Each packet requires extra bytes of format information that is stored in the packet header, which, combined with the assembly and disassembly of packets, reduces the overall transmission speed of the raw data.

Packet received versus Number of nodes is plotted in fig. 5. The data packet forwarding overhead increases as number of nodes increases. The overhead occurs because of traffic, interference etc. Also while sending more data in the routing path the data packet overhead is occurred. The data packet overhead is compared with both proposed Bandwidth and existing ETX methods.

v. Control overhead

All source routes contained in any overheard route requests, route replies, or data packets to its route cache, as well as all sub-paths contained within those routes. Due to excess of these control packets control overhead occur.

In fig. 6, Control overhead is plotted as overhead versus number of nodes. The control overhead is due to excess of RTS, CTS control packets. As number of nodes increases the control overhead also increases. The control overhead is less in proposed method when compared with existing method.

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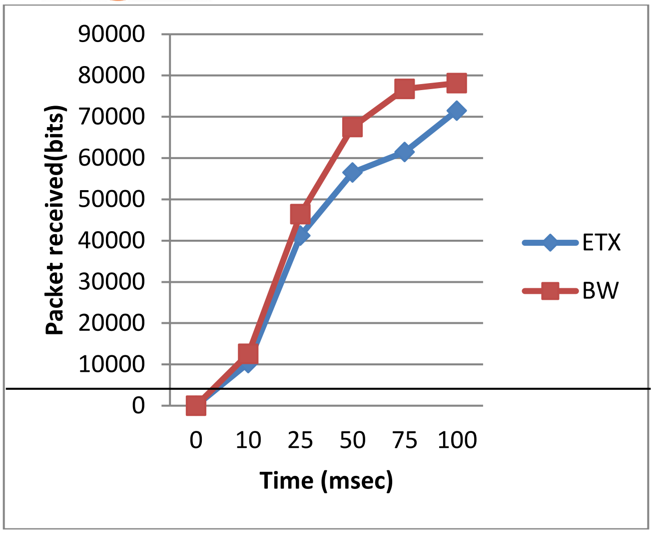

Fig. 2 Packet received versus time

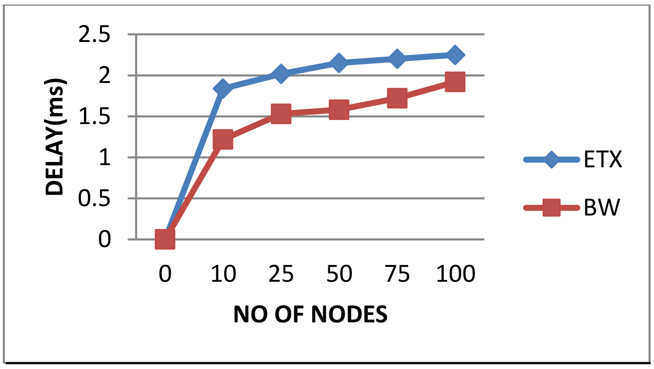

Fig. 3 Delay versus Number of nodes

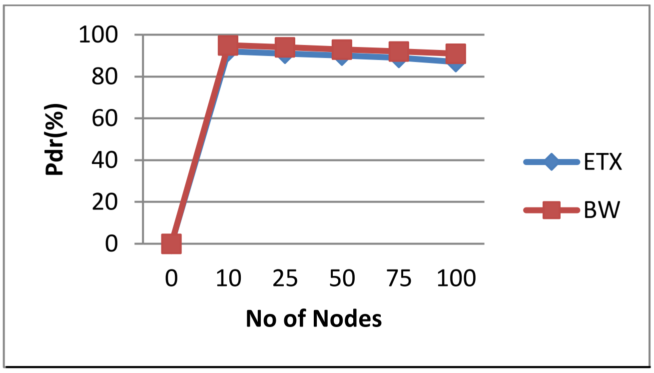

Fig. 4 Packet delivery ratio versus Number of nodes

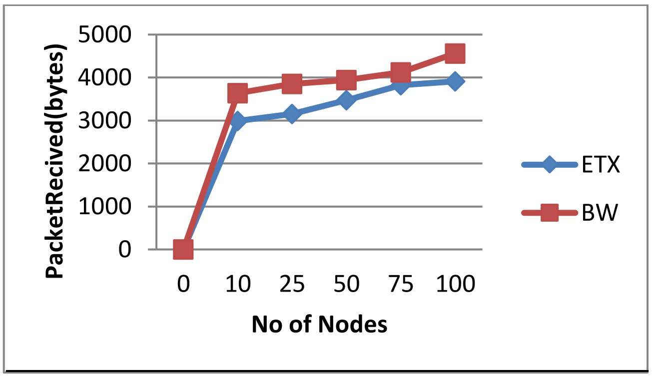

Fig. 5 Packet received versus Number of nodes

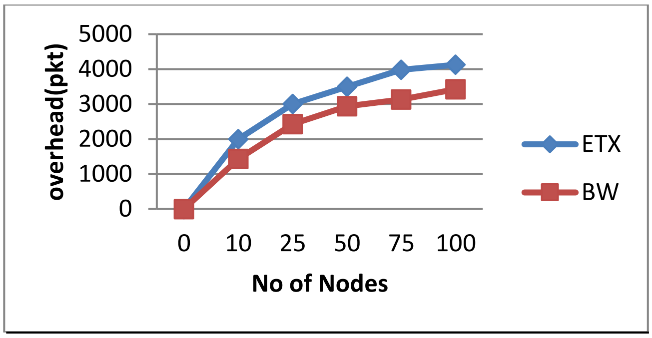

Fig. 6 Overhead versus Number of nodes

VI. CONCLUSION

Efficient routing is performed by selecting path, computing path weight, constructing routing table, Forwarding Packet with consistency and by Updating Route. There by selecting best routing path from source to destination. The overall network throughput is increased significantly by this hop by hop routing method which uses available path bandwidth information. Therefore, Packet-Delivery ratio is increased and the Packet Drop is decreased. The parameters like Throughput, End-End Delay, Packet-Delivery Ratio, Control overhead and Data Packet forwarding overhead are analyzed.

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