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A Load Aware Proposal for Maximum Available Bandwidth Routing in Wireless Mesh Network

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Abstract: *Wireless Mesh Network (WMN) consists of a large number of wireless nodes. The nodes form a wireless overlay to cover the service area while a few nodes are wired to the internet. Seeking the path with the maximum available bandwidth is one of the fundamental issues in the wireless mesh networks. If the traffic rate of a new flow on a path is no greater than the available bandwidth of this path, accepting the new traffic will not violate the bandwidth guarantees of the existing flows. The routing protocols should be satisfying the optimality and consistency requirement. This survey analyses the different routing techniques which provides bandwidth guarantee and high throughput and also discusses different problems faced out by those methods and identifies a routing technique which route through the maximum available bandwidth path from source to destination with the satisfaction of optimality and consistency requirement, plot the throughput and delay graph and then analyses the results with other method. Finally propose a load aware bandwidth guaranteed routing protocol.*

Keywords: *Isotonicity, ETX, CAB, widest path, AVAIL*

I. INTRODUCTION

Mesh networking is a type of networking where each node in the network may act as an independent router. Mesh networks different from other networks in the sense that all component parts can connect to each other via multiple hops. Mesh networks can be seen as one type of ad hoc network. Because of several attractions self healing, self organizing, less connectivity etc. WMNs are undergoing rapid development. Such work has been done to realize and enhance WMN over the past few years. Routing in WMN has been a hot research area in recent years.

Routing is the process of selecting paths in a network along which to send network traffic. Routing metric is a key element of any routing protocol since they determine the creation of network paths [1]. The key components that can be utilized to compose a routing metric for wireless mesh networks are number of hops, link capacity, link quality and channel diversity. Some criteria must necessarily be met in order for a metric to choose better routes. Some of them are intra-flow interference, interflow interference, external interference, locality of information, load balancing, agility, isotonicity, and throughput. Seeking the path with the maximum available bandwidth is one of the fundamental issues for supporting QOS in the WMN. The aim of this paper is to analyze the different bandwidth guaranteed routing protocols in WMN and find out a research scope in the same field.

ETT the Expected Transmission Time (ETT) metric [7] is designed to augment ETX by considering the different link rates or capacities. This allows ETT to overcome the limitation of ETX that it cannot discriminate between links with similar loss rates but have a massive disparity in terms of bandwidth. The Weighed cumulative ETT (WCETT) metric [7] has been designed to improve the ETT metric by considering channel diversity. IRU [8] metric captures the total channel time of the neighbours that is affected by the transmission between i and j, which represents the level of inter-flow interference that the flow inflicts on the network.

II. ETX-EXPECTED TRANSMISSION COUNT

ETX[2] is the first metric proposed for WMNs which finds high-throughput paths on multi-hop wireless networks. ETX minimizes the expected total number of packet transmissions (including retransmissions) required to successfully deliver a packet to the ultimate destination. The ETX metric incorporates the effects of link loss ratios, asymmetry in the loss ratios between the two directions of each link, and interference among the successive links of a path.

In contrast, the minimum hop count metric chooses arbitrarily among the different paths of the same minimum length, regardless of the often large differences in throughput among those paths, and ignoring the possibility that a longer path might offer higher throughput.

The metrics overall goal is to choose routes with high end-to-end throughput. The number of received probes is calculated at the last T time interval in a sliding-window fashion. Example: the ETX of link AB considering the delivery ratio of probes sent on the forward (df) and reverse (dr) directions. Delivery

ratios are, at the same T interval, The fraction of successfully received probes from A announced by B. The fraction of successfully received probes from B. The ETX of link AB is :
ET X = 1/(df dr)

III. AVAIL-A MODEL BASED APPROACH

This work[3] construct an analytical model that accurately captures the 802.11 MAC protocol operation and predicts both throughput and delay of multi-hop flows under changing traffic load or routing decisions. The main goal of this model is to characterize each link by the packet loss probability and by the fraction of busy time sensed by the link transmitter, and to capture both intra-flow and inter-flow interference. It reveals that the busy time fraction experienced by a node, a locally measurable quantity, is essential in finding maximum throughput paths. Based on this analytical model, create a novel routing metric that can be used to discover high throughput path in a congested network. A two-step technique to estimate available path bandwidth is introduced. Step 1 - By considering the busy time fraction and packet loss probability and calculate link capacity in the path. Step 2 - The link capacities can be expressed as clique-based method. This method represents a graph called link conflict graph to express the interference relationship between links.

A. *Analytical Model*

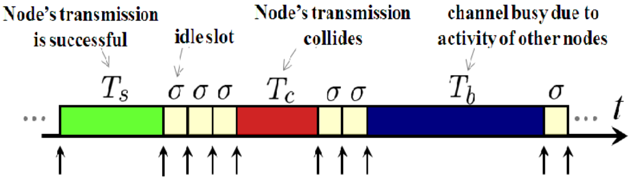

Fig 1: Example of evolution of the channel state perceived by a node

It is the general decoupling technique to analyze the behaviour of each node in an 802.11 network with arbitrary topology. First consider the case in which each source sends traffic to a single neighbouring node. Since this case allows to analyze only particular traffic patterns, then analyses to the general case in which a node transmits to multiple neighbours. The evolution of the channel state experienced by a node can be described as a renewal process with four different states, as illustrated in the example of Fig 1. The 4 states are : (i) idle channel; (ii) channel occupied by a successful transmission of the node; (iii) channel occupied by a collision of the node; (iv) busy channel due to activity of neighbouring nodes, detected by means of either physical or virtual carrier sensing . The time intervals during which the station remains in each of the four states above are denoted by , Ts, Tc, and Tb, respectively. While σ is constant, equal to one backoff slot, the duration of the other intervals can be variable , the frame size, and the sending rate of the transmitting station(s). Both Ts, Tc, and Tb include a deterministic idle slot .

The available bandwidth of a multi-hop flow over a path is the maximum throughput it can achieve subject to the condition that no queue along the path gets overloaded, i.e., the traffic intensity on each link is kept smaller than or equal to 1. Inter-flow and intra-flow interference can takes into account separately.

IV. EED –AN END TO END DELAY

This work[4] studies how to select a path with the minimum cost in terms of expected end-to-end delay (EED) in a multi-radio wireless mesh network. Different from the previous efforts, the new EED metric takes the queuing delay into account, since the end-to-end delay consists of not only the transmission delay over the wireless links but also the queuing delay in the buffer. In addition to minimizing the end-to-end delay, the EED metric implies the concept of load balancing. Then develop EED based routing protocols for both single-channel and multi-channel wireless mesh networks. In particular for the multi-radio multichannel case, we develop a generic iterative approach to calculate a multi-radio achievable bandwidth (MRAB) for a path, taking the impacts of inter/intra-flow interference and space/channel diversity into account. The MRAB is then integrated with EED to form the metric of weighted end-to-end delay.
EEDi = E[queuing − delay + transmission − delay]

V. CAB - HOP BY HOP PACKET FORWARDING

Work[6] study the problem of identifying the maximum available bandwidth path, a fundamental issue in supporting quality-of-service in WMNs. Due to interference among links, bandwidth, a well-known bottle- neck metric in wired networks, is neither concave nor additive in wireless networks. Here design a new path weight which captures the available path bandwidth information prove that our hop-by-hop routing protocol based on the new path weight satisfies the consistency and loop-freeness requirements. The consistency property guarantees that each node makes a proper packet forwarding decision, so that a data packet does traverse over the intended path. Fig 2. shows the detailed flow diagram of method[6].

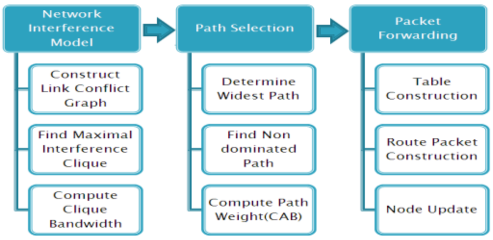

Fig 2: Detailed Flow Diagram.

V.A Network Interference Model

1) Construct Link Conflict Graph

Link conflict graph (or conflict graph for short) to reflect the interference relationship between links. A link in the wireless network becomes a node in the link conflict graph. If two links in the wireless network interfere with each other, we put a link between the corresponding nodes in the link conflict graph. We use an example to illustrate the link conflict graph. Fig 3 shows a five-link chain topology. The numbers on the links are the ids of the links. The link conflict graph of the network is shown in Fig 3. Links 1 and 2 interfere with each other since node b cannot send and receive simultaneously. Links 1 and 3 interfere with each other since the signal from c is strong enough to interfere the reception at b. Therefore, there are links between 1 and 2 as well as 1 and 3 in the conflict graph. Assume that links 1 and 4 do not interfere because the signal from d cannot affect b in successfully receiving the signal from a. Then, there is no link between 1 and 4 in Fig 3.

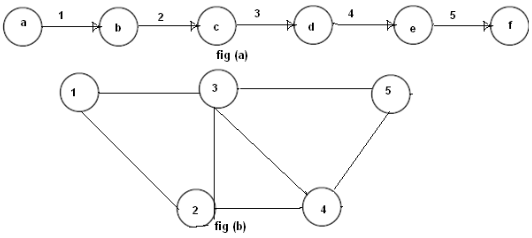

Fig 3: Illustration for interference model (a) The original graph (b) The conflict graph .

2) Find Maximal Interference Clique

An interference clique is the set of links which interfere with each other. In the conflict graph, the corresponding nodes of these links form a complete sub graph. In Fig 3 b, (1, 2), (1, 3), (1, 2, 3), and (3, 4, 5) are interference cliques. A maximal interference clique is a complete sub graph that is not contained in any other complete sub graph. For instance, (1,2,3) and (3, 4, 5) are maximal cliques while (1, 2) and (1, 3) are not maximal cliques. In this method[6], we consider single-channel single rate wireless networks, and so the original capacity of each link is the same, denoted by C. Denote Q1,Q2....QK as the maximal interference clique set of the network. The size of a maximal clique depends on how many links interfere with each other, which depends on the interference model adopted in the network.

3) Compute Clique Bandwidth

Given a path p =< v1, v2, ...Vh > let B(k) be the estimated available bandwidth on the link between Vk and Vk+1. Under the TRCA interference model, the formula for estimating the available bandwidth of path p is as

$B(p) = 1 \leqslant k \leqslant h - 4 \min C_k$

$C_k = \left(\frac{1}{B(k)} + \frac{1}{B(k+1)} + \frac{1}{B(k+2)} + \frac{1}{B(k+3)} \right)^{-1}$ Given path p =< v1, v2, ...vh >

let p0 =< v2, ...vh > and p1 =< v1, v2, v3, v4, v5 >, as illustrated in Fig 4. It can easily verify that B(p) = min(B(p1); B(p0). This formula allows the estimated path bandwidth to be computed in a hop by hop manner. Although the works in [3], and [4] apply this mechanism to compute the path bandwidth, no work has been found to propose an efficient path selection mechanism which satisfies the optimality requirement. That is, no existing protocol can provide the performance guarantee for finding the maximum available bandwidth path by using above equation.

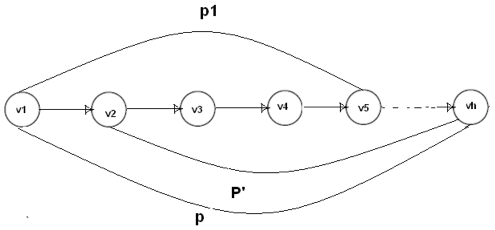

Figure 4: Path bandwidth computation in hop by hop manner.

V.B Path Selection

For path selection the distance vector based mechanism is using. In the traditional distance vector mechanism, a node only has to advertise the information of its own best path to its neighbours. Each neighbour can then identify its own best path. But in this method[6] a node only advertises the widest path from its own perspective, its neighbours may not be able to find the widest path. In order to assure that the widest path from each node to a destination can be identified, a trivial way is to advertise all the possible paths to a destination. This is definitely too expensive. On the other hand, as long as we advertise every path which is a sub path of a widest path. Thus, to reduce the overhead, we should not advertise those paths that would not be a sub path of any widest path. So there is need a sufficient and necessary condition for a node to determine whether a path must not be the sub path of any maximum bandwidth path.

1) Determine Widest Path

The bandwidth of the link from a to b is B(a, b) and a path p =< v1, v2, ..vh >, let W B(p) = B(p), F B(p) = B(v1, v2), T B(p) = W B(< v1, v2, v3 >), and H B(p) = W B(< v1, v2, v3, v4 >). In other words, WB(p) is the bandwidth of the whole path, FB(p) is the bandwidth on the first link, TB(p) is the bandwidth of the sub path composed of the first two links, and HB(p) is the bandwidth of the sub path composed of the first three links. Concatenation of paths p1 and p2 as p1 ⊕ p2. According to Fig 5 let P 1 =< v, u1, ..., un, d >, p2 =<v, g1, g2, ..gm, d >, P =< s, v1, ..vh, v >, P 1, 1 =< vh−2, vh−1, vh, v, u1 >, P 1, 2 =< vh − 1, vh, v, u1, u2 >, P 1, 3 =< vh, v, u1, u2, u3 >, Also find P2,1 and p2,2 and p2,3. Bandwidth of a path is the bandwidth of the bottleneck clique, and each clique consists of four links.

$$WB(p\oplus p1) = \min\{WB(p), WB(p1, 1), WB(p1, 2), WB(p1, 3), WB(p1)\}$$

$$WB(p\oplus p2) = \min\{WB(p), WB(p2, 1), WB(p2, 2), WB(p2, 3), WB(p2)\}$$

Pruning condition is a sufficient condition for V to determine p2 is not worthwhile to be advertised because p1 must be better than p2 for every p, which implies p2 can never be a sub path of a widest path. That is p1 prunes p2 if W B(p1) ⩾ W B(p2) for every p.

2) Find Non dominated Path

Given two paths p1 and p2, If (w1(p1) ⩾ w2(p2), w2(p1) ⩾ w2(p2), w3(p1) ⩾w3(p2), and w4(p1) ⩾ w4(p2)) then P1 dominates p2. If given two paths p1 and p2, we call p1 dominates p2. If we cannot find a path dominating p1, call p1 a non dominated path.

3) Compute Path Weight(CAB)

Composite Available Bandwidth(CAB) of path p is w(p) = (W 1(p1), W 2(p2) ,W 3(p3), w4(p4)) W 1(p) = W B(p) is bandwidth of whole path W2(p)=HB(p)is bandwidth of sub path composed of first three link. W3(p)=TB(p) is bandwidth of sub path composed of first two link and W4(p)=FB(p) is bandwidth of first link. (w1(p1) w2(p2)), iff W 1(p1) ⩾ W 1(p2), W 2(p1) ⩾ w2(p2), W 3(p1) ⩾ w3(p2), W 4(p1) ⩾ w4(p2)).

V.C Packet Forwarding

1) Route Packet Construction

The isotonicity property of the proposed path weight allows us to develop a routing protocol that can identify the maximum bandwidth path from each node to each destination. In particular, whether a path is worthwhile to be advertised, meaning whether a path is a potential sub path of a widest path. In the routing protocol, if a node finds a new non dominated path, it will advertise this path information to its neighbours. We call the packet carrying the path information the route packet. For each non dominated path p from s to d, s advertises the tuple (s; d; N F (p); N S(p); N T (p); w(p)) to its neighbours in a route packet. NF(p),NS(p), and NT(p) are the next hop, the second next hop, and the third next hop on p from s , respectively. Based on the information contained in a route packet, each node knows the information about the first four hops of a path identified. This information is necessary for consistent routing.

2) Table Construction

Each node keeps two tables: distance table and routing table. Node s puts all the non dominated paths advertised by its neighbours in its distance table. It keeps all the non dominated paths found by s itself in its routing table. When s receives an advertisement (s; d; N F (p); N S(p); N T (p); w(p)) from u which represents a non dominated path p from u to d, s removes all the locally recorded paths from u to d which are dominated by p. Denote p' as the path from s to d which is one-hop extended from p.

3) Node Update

After the network accepts a new flow or releases an existing connection, the local available bandwidth of each node will change, and thus the widest path from a source to a destination may be different. When the change of the local available bandwidth of a node is larger than a threshold, the node will advertise the new information to its neighbours. After receiving the new bandwidth information, the available bandwidth of a path to a destination may be changed. Although the node is static, the network state information changes very often. Therefore, our routing protocol applies the route update mechanism in DSDV . Based on DSDV, each routing entry is tagged with a sequence number which is originated by the destination, so that nodes can quickly distinguish stale routes from the new ones. Each node periodically transmits updates and transmits updates immediately when significant new route information is available. Given two route entries from a source to a destination, the source always selects the one the larger sequence number, which is newer, to be kept in the routing table. Only if two entries have the same sequence number, the path comparison is used to determine which path should be kept.

VI. PROBLEM DEFINITION

The hop by hop packet forwarding mechanism in CAB is the method that provides bandwidth guarantee. Only the CAB routes through the maximum available bandwidth path from source to destination with the satisfaction of optimality and consistency requirements of routing protocols. But this method does not consider traffic load on each link. An efficient load aware bandwidth guaranteed routing method, which provide maximum available bandwidth guarantee from source to destination is yet to be formulated.

VII. PROPOSED SYSTEM

Different channels can be used for packet transmission. First, transmit packets through the low bandwidth channel. Here the packets send through the maximum available bandwidth path from source to destination. If the load increases and the transmission overhead occurs in that channel change the channel and transmit through high bandwidth path.

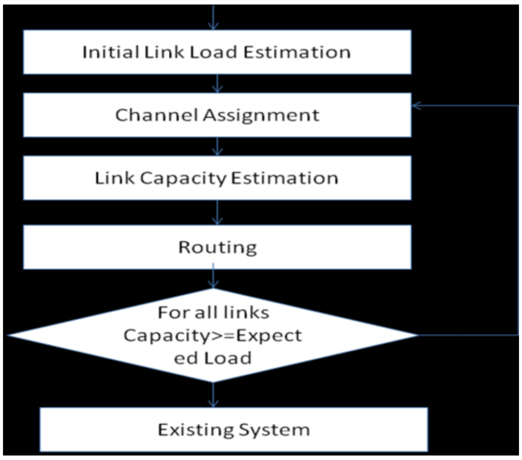

Figure 5: Flow diagram of proposed system .

VIII. OBSERVATION AND ANALYSIS

Table I describes different routing metrics and their path characteristics, Table 2 describes the different components of metrics.

TABLE I

METRIC COMPONENTS

Metrics	Metric Components				
	Number of hops	Link Capacity	Link quality	Channel diversity	Number of hops
ETX	Yes	No	Yes	No	Yes
AVAIL	Yes	Yes	Yes	No	Yes
EED	Yes	Yes	Yes	Yes	Yes
CAB	Yes	Yes	Yes	Yes	Yes
Proposed CAB	Yes	Yes	Yes	Yes	Yes

ETX does not perform well in multi rate and multi radio networks due to its lack of knowledge of cochannel interference and its insensitivity to different link rates or capacities. As a consequence, ETX tends to select links with lower rate. Links with lower transmission rates take up more medium time to transmit data and forces neighbouring nodes to back off from their own transmissions and ETX does not consider the load of a link and will therefore route through heavily loaded nodes without due consideration, leading to balanced resource usage. ETX does not discriminate between node types and makes no attempt to minimize intra flow interference by choosing channel-diverse paths. However, ETX does deal with inter-flow interference indirectly, through the measurements of link-layer losses. Links with a high level of interference will have a higher packet loss rate and therefore a higher ETX value. ETX is isotonic, and therefore allows efficient calculation of minimum weight and loop-free paths metric is able to find routes with considerably higher throughput than the routes chosen by ETX or IRU.

AVAIL typically selects longer routes than those chosen by IRU or ETX. This is because AVAIL does a better job at finding longer routes with higher available bandwidth than shorter routes. The throughput gain of AVAIL increases when the offered load in the network is increased. More importantly, under loss-based metrics almost half the flows receive close to zero throughput while AVAIL is able to identify non-starving paths.

EED metric can result in much better end-to-end delay performance than ETX and ETT. Regarding the network throughout, ETT and EED has the similar performance, while outperforming the ETX. The reason that ETT and EED have similar throughput performance is that both of them exploit the transmission failure probability for computing the link metric, while the transmission failure probability is directly related to the MAC throughput. In most of the cases, ETT has slightly higher throughput, which is due to the larger computation overhead with EED and implementation overhead due to path change incurred by the random queue length behaviour. An inappropriate large update interval will not timely respond to a congested link and result in unnecessary packet loss due to a full buffer. If the buffer size is small, in most of the cases all the buffers are full, where the EED could not exploit more benefit com- pared to the ETT. The extra computation overhead and route updating overhead, however, will lead to a smaller network throughput. When the buffer is large, EED can select a path with more buffer space, which will lead to less tail-dropping of the packets and thus a higher throughput.

The path ETX or IRU is simply computed by summing the ETXs or IRUs of all the links on a path. Such calculation method causes ETX and IRU prefer the short path to the long path, such that ETX or IRU may select a low available bandwidth path. Although the practical throughput of the existing metric is higher than that of CAB metric for some particular flows, the difference is small. Therefore, CAB metric is relatively more efficient for finding the high throughput path. CAB provides high bandwidth guarantee and satisfies optimality and consistency requirement.

IX. EXPERIMENTAL RESULTS

Completed the hop by hop routing protocol[6] implementation in NS 2.31 and the method is simulated. Plotted the graph for different parameters such as through put, packet delivery ratio and delay. Graphs shows the improvement of throughput, and reduction of delay than the method ETX[2].

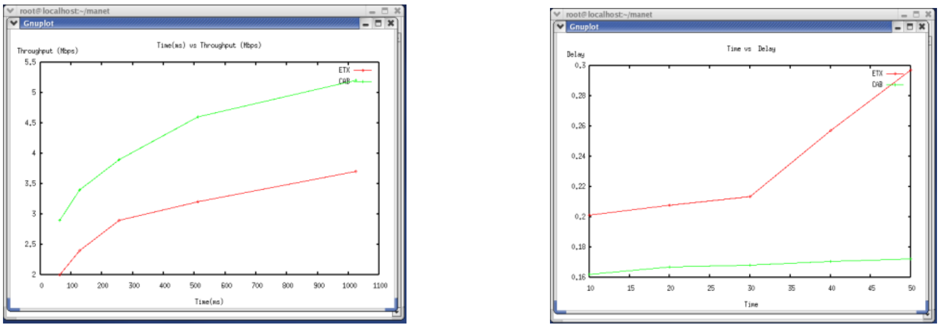

Figure 6 Graph of throughput and delay

X. CONCLUSION AND FUTURE SCOPE

Bandwidth guaranteed routing is one of the most emerging areas of research in wireless mesh networks. This paper analyses different routing techniques which provides bandwidth guarantee and high throughput. The maximum available bandwidth path problem, is the fundamental issue to support quality of-service in wireless mesh networks. The hop by hop packet forwarding mechanism in CAB is the only bandwidth guaranteed routing method that can route through the maximum available bandwidth path from source to destination. Load balanced bandwidth guaranteed routing protocol that can route through the maximum available bandwidth path from source to destination which is suitable for highly dynamic situation may be designed and developed.

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