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AN EFFICIENT BANDWIDTH UTILIZATION MECHANISM FOR CONSISTENT ROUTING IN WIRELESS MESH NETWORKS

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Abstract

A wireless mesh network has a more planned configuration, and may be deployed to provide dynamic and cost effective connectivity over a certain geographic area. In this paper, we use the existing methods for calculating the bandwidth of a path for wireless networks and using it we provide an efficient path selection and packet forwarding mechanisms. The main objective of the paper is to provide a quality of service and at the same time utilise the bandwidth efficiently. The interference problem makes it difficult for computation of the available bandwidth for a particular route. In this paper the concept of composite available bandwidth is used along with clique based bandwidth computation. In this paper we will be using AODV routing protocol along with a distributed packet forwarding scheme and we will also find the no of hops to be stored in a packet for the distributed packet forwarding scheme based on expected transmission hops.

***Keywords*-- Distributed Forwarding; Clique Based Bandwidth Computation; Quality of Service (QoS).**

I. INTRODUCTION

Wireless mesh network is a topology where all nodes/routers are connected to each other i.e. full mesh or, almost connected to each other i.e. partial mesh. The main features of mesh topology are high scalability, adaptability and reliability. Wireless Mesh Networks have nodes comprised of mesh routers and mesh clients. Each node operates not only as a host but also as a router, forwarding packets on behalf of other nodes that may not be within direct wireless transmission range of their destinations. It is gaining significant attention as a possible way for cash strapped Internet service providers (ISPs), carriers, and others to roll out robust and reliable wireless broadband service access in a way that needs minimal up-front investments.

A WMN is dynamically self-organized and self configured, with the nodes in the network automatically establishing and maintaining mesh connectivity among themselves creating an adhoc like network. There are two main properties in WMNs that differentiate WMNs from MANETs. First, in WMNs, most of the traffic originates or terminates at the gateways (nodes connected to the wired infrastructure/Internet). Second, in most applications, WMN nodes tend to be neatly differentiated as either stationary nodes (providing connectivity and coverage) or mobile nodes.

Wireless mesh networks have the potential to play a critical role as an alternative technology for broadband Internet access. WMNs are a special case of mobile ad-hoc networks where the nodes have relatively fixed positions and communicate to the Internet through one or more gateways. Some of the important problems in wireless networks are Unreliable and unpredictable wireless channel conditions, Contention due to shared nature of the wireless medium, Hidden terminal problem, Node mobility and route maintenance, Limited battery power life and no centralized control. Providing a routing protocol that overcomes all these problems is very difficult.

1.1. Quality Of Service

QoS routing in multihop wireless networks is very challenging due to interference among different transmissions. Even in a multi channel wireless network, interference still exists since two transmissions may interfere with each other if they are using the same channel. A QoS connection request usually comes with a bandwidth requirement and QoS routing seeks a source to destination route with requested bandwidth.

The notion of QoS, is a guarantee by the network to satisfy a set of predetermined service performance constraints for the user in terms of the end-to-end delay statistics, available bandwidth, probability of packet loss, and so on.

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The cost of transport and total network throughput may be included as parameters. Obviously, enough network resources must be available during the service invocation to honor the guarantee. The first essential task is to find a suitable path through the network, or route, between the source and destination(s) that will have the necessary resources available to meet the QoS constraints for the desired service.

1.2 Bandwidth Estimation

Bandwidth sometimes defines the net bit rate, channel capacity, or the maximum throughput of a logical or physical communication path in a digital communication system. The computation of bandwidth in wireless medium is difficult because of interference from other nodes during transmission. There is very few bandwidth calculation mechanisms developed for wireless networks. Some of them are variable packet size probing (VPS), packet pair/packet train dispersion probing (PPTD) and so on. These are based on the Round trip time based on probe messages.

1.3 Routing Protocols

A routing protocol is composed of two components a path calculation algorithm and a packet forwarding scheme. Different combinations of path calculation algorithms and packet forwarding schemes result in different routing protocols.

1.3.1 Path Calculation Algorithms

Different path calculation algorithms have different costs and are appropriate for different networks. Some of the path calculation algorithms are flooding based route discovery, Dijkstra's algorithm and the Bellman-Ford algorithm, all of which are widely used in wireless routing protocols.

1.3.2 Packet Forwarding Schemes

In wireless networks two packet forwarding schemes, source routing and hop-by-hop routing, are often used in different routing protocols. In source routing, a source node put the entire path of a flow in its packet headers. Intermediate nodes forward packets based on the path information carried in packet headers. In hop-by-hop routing, a source node only puts the destination addresses in its packet headers. The intermediate nodes maintain a routing table that stores the next hops to reach other nodes.

Using this routing table, the intermediate node forwards packets based on their destination addresses.

We have to choose an appropriate routing algorithm based on the type of the networks to achieve maximum performance.

II. RELATED WORKS

There have been extensive researches for routing in wireless mesh networks. The routing will normally be based on either finding the shortest path or finding a path with a highest data rates or more formally as path with highest bandwidth. In this paper the routing schemes we propose are based on the bandwidth of the links. There are several methods being developed for the computation of bandwidth. We will be using the Clique Based Bandwidth computation for calculation of the maximum available bandwidth in a path.

2.1 Clique Based Bandwidth Computation

In Clique Based bandwidth computation the bandwidth is calculated taking the interference constraints into consideration. First for a given network we have to calculate the no of cliques. Each node will interfere with a node within its transmission range. All the nodes that get affected because of this interference together are termed as a clique. Similarly we have to calculate for all the nodes in the network and find all the possible cliques. Then we have to calculate the bandwidth of each clique from **Eq. 1** and **Eq. 2**. The minimum of these will give the maximum available bandwidth in a path.

The formulas for the calculation of the bandwidth using Clique Based computation are

$$B(p) = \min_{1 \le k \le h-4} C_k \quad (1)$$

$$C_k = \left(\frac{1}{B(k)} + \frac{1}{B(k+1)} + \frac{1}{B(k+2)} + \frac{1}{B(k+3)}\right)^{-1} \quad (2)$$

Where:

P is the path
B is the bandwidth
C is the Clique

B(p) represent the bandwidth of the particular path. The minimum bandwidth of all the cliques is taken as the available bandwidth. An example for bandwidth computation is shown with **Fig.1**.

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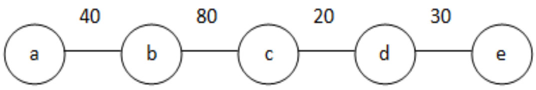

Fig. 1 Example for bandwidth computation.

There are five nodes a, b, c, d and e with data rates of 30, 25, 80 and 40 pkt/sec between the nodes. Now if we see from a to e there are two cliques. Based on **Eq. 2** we will get the value for the first clique as 11.42 pkt/sec and second clique as 10.43 pkt/sec. So the available bandwidth will be taken as minimum of these two which is 10.43 pkt/sec. Hence we can give a guarantee that when transferring data from node a to e we will get a minimum of 10.43 pkt/sec of data rate.

2.3 Feasibility Check

First of all before we actually start transmitting the data we have to make sure the connection request is feasible or not. That there may be high data rates in the beginning but as the data passes through the network the data rates may reduce due to low bandwidth availability or may be some other data is being transmitted in the subpath. So to check weather a connection is feasible or not we send a probe message and wait for an acknowledgment. If the acknowledgement is received within a particular time then the connection will be termed as feasible. This is an important aspect to provide quality of service in the routing methodology.

2.2 Composite Available Bandwidth

The concept of composite available bandwidth was first proposed by Ronghui et al. In a source routing format the path from a source to destination is fixed so there are no intermediate computations required. But in hop by hop routing each node has to make a decision as to which should be the next node the data is to be forwarded to. The complexity in this is if a node checks for a bandwidth efficient path from its own perspective and forwards the data then the next node may not be able to find an efficient path. So the concept of the available bandwidth is used.

According to this concept there are four factors to be considered. They are the whole bandwidth (WB), the bandwidth on the first link (FB), the bandwidth on subpath consisting of first two links (TB) and bandwidth on subpath consisting of first three links (HB).

These four factors are taken into consideration for bandwidth computation. In the composite available bandwidth also the clique based bandwidth computation is used. All the four factors i.e. WB, HB, TB and FB are computed using a modified form of the **Eq. 1** and **Eq. 2**. The advantage of using this concept is that it follows the left isotonic principle.

2.3 Left Isotonicity

This property guarantees the consistency constraints for data transmission in a network. If any protocol that is developed satisfying the property of left isotonicity we can safely say that the protocol will be consistent. The rule is shown below in **Fig 2**.

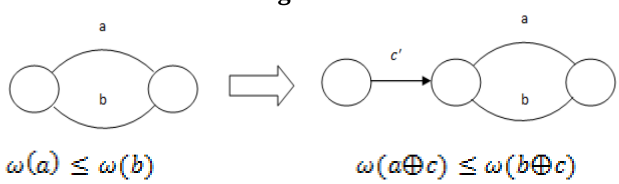

Fig. 2 An example for left isotonicity

In the **Fig. 2** ω denotes the path weight. a⊕c denotes the path a and c together. ω(a) $\leq \omega(b)$ means the path weight of a is less than path weight of b. As per the left isotonicity principle if the path weight of 'a' is less than the path weight of 'b' then the combined path weight of a and c together should also be less than the path weight of b and c together. For all flooding based route discovery with hop by hop routing right isotonicity with strict left isotonicity is mandatory in networks.

III. Proposed System

In the existing systems the network is not utilized properly and there are problems in consistency and loop freeness that are not addressed. In our paper we will develop a routing mechanism that will utilize the network much more efficiently and provide a quality of service in data transmission.

3.1 Overall Description

In the proposed system the routing mechanism we will utilize the distributed packet forwarding scheme. The protocol will be based on a modified form of AODV algorithm i.e. the routing is based on 'on demand'. The basic block diagram is shown in **Fig 3**.

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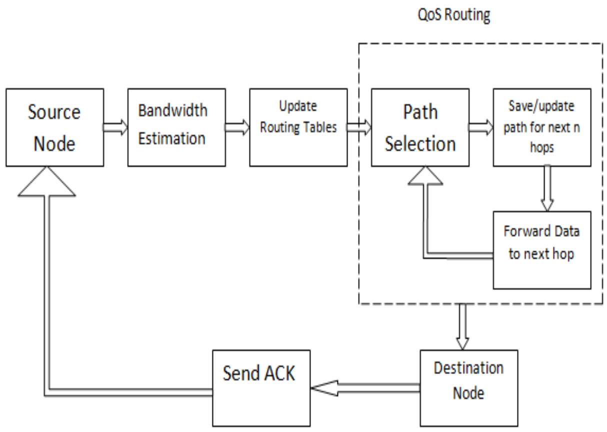

Fig. 3 Block Diagram of overall mechanism

When a data is to be transmitted first we calculate the bandwidth of the subpaths and check if the connection is feasible or not. Then we update the routing tables and go for path selection. After an appropriate path is selected the data is transmitted for the n hops. When the data reaches the destination node an acknowledgement message is sent back. The main concepts and enhancements in the paper i.e. the path selection, packet forwarding, updating routing tables and distributed algorithms are explained in the forthcoming sections.

3.2 Path Selection

The path selection is the first step in a routing algorithm. In the existing systems the path with highest bandwidth was chosen by each node in a hop by hop manner. The problem in this is we are choosing the path with highest data rate that is far above our requirement and is unnecessary. If we leave this path idle then at least some other nodes that are transmitting the data at that time can make use of it. An example is for path selection shown in **Fig 4**.

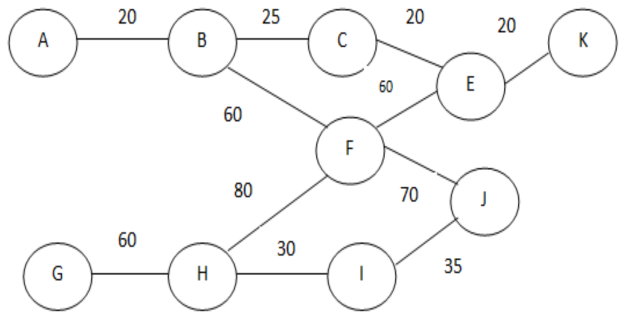

Fig. 4 An example to show proper network utilization

Now say we are sending data from node A to K and at the same time data is being transmitted from G to J. First we forward the data from A in a Hop by Hop packet forwarding scheme. So each node decides the next node that the data is to be forwarded to. Based on the previously existing schemes the node will select the path with the highest data rate and forward it.

In the above example when data is being transmitted from A to K say the node B chooses F as next hop based on highest bandwidth then the data from G to J cannot utilize the node F. As per the existing system the path chosen will be A, B, F, E, K and G, H, I, J. Instead we can utilize the network more efficiently by choosing the paths A, B, C, E, K and G, H, I, J. Since the incoming data rate for node B is only 20 pkt/sec choosing a path with a data rate of 60 pkt/sec is not necessary. So we can choose the path with a data rate of 25 pkt/sec. This is more than the incoming data rates and we can leave the node F free. So the data being transmitted from node G to J can utilize it.

To implement this mechanism we must first set a threshold value for path selection. Due to interference problems we will not be able to use the specified bandwidth as well. The complexity of the above model increases as we are not using the bandwidth obtained directly by clique based computation but we are making use of the concept of Composite Available Bandwidth.

The next enhancement we are adding to our project is to choose a path that crosses over a least number of nodes in case the bandwidth of both the paths is same to an extent. First a node has to look for a path with a higher data rate than the incoming data rate. At the same time it has to be somewhat close to the incoming data rate. If no such path is found then a path with a lower data rate will be chosen. In case an intermediate path has a very low data rate it will automatically be found by the probe message already explained. So it will automatically be reported as connection request is not feasible.

3.3 Packet Forwarding

In this section the distributed packet forwarding scheme is discussed. This scheme makes use of a combination of the source routing and hop by hop routing. Normally in a hop by hop routing the packet does not contain any specified path that it is supposed to follow. Each node is free to choose its own path based on the algorithms used. In the distributed packet forwarding scheme the n four hops that the data has to traverse is also stored in the header of the packet and each time the data packet moves to the next hop this header is updated and the packet is forwarded based on this information. When a node chooses a path on its own perspective we cannot obtain an efficient path. That is why we go for the concept of composite available bandwidth as well.

In the existing system this n hops is taken as four and this composite available bandwidth is obtained. But this will not be suitable for all kinds of networks. Even in the same network if the data has to be transmitted over a short distance or a very long distance, using the composite available bandwidth with four hops will not be an optimal solution. So we have to choose the value of n depending on the type of data transmission and the number of nodes in the network. The number of nodes that the data has to traverse can be calculated using probe messages and the number of transmission attempts is calculated based on the expected transmission time and expected transmission count. These parameters can be found from **Eq. 3** and **Eq. 4**.

$$ETX = \frac{1}{1-P_l} \qquad (3)$$

$$ETT = ETX \times \frac{S_l}{B_l} \qquad (4)$$

Where:

ETX is the expected transmission count
ETT is the expected transmission time.
p_l is the packet loss probability.
S_l is the packet size.
B_l is the data rate.

The **Fig 5** shows an example for the importance of a distributed packet forwarding mechanism. Consider a data is to be transmitted from node a to h.

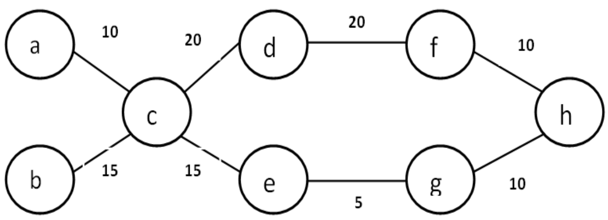

Fig 5 Example to show need for distributed packet forwarding

The data packet will first be forwarded from a to c and then the node c will have to decide the next hop. In case where distributed packet forwarding is not used e will be selected as the next hop because the data rate of 15 is close to and higher than incoming data rate. Now the problem arises when the data is forwarded from e to g. The data rate is only 5 pkt/sec and much lower than incoming data rates and will lead to unnecessary queuing of packets. To avoid this we go for a distributed packet forwarding scheme. In this we take into consideration the data rates of the next n hops as well before choosing a path. We will be including the data rates of next n hops in the routing tables and all these will be compared for choosing the best path. So clearly the node c will choose d as the next hop and the packet will be forwarded.

3.4 Updating Routing Tables and Consistency

In the existing systems there were problems of consistency and loop formation. Since it was developed based on DSDV routing protocol the routing tables needed to be updated frequently. So if the routing tables are not up to date during data transmission it will cause inconsistencies and lead to loop formation. This can be avoided by using different routing strategies.

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In the proposed system we use an on demand routing protocol so that the routing tables are updated only at the time of data transmission. This will provide a consistent packet forwarding scheme. Since the routing table is updated only at the time of data transmission there will be a delay in the transmission. But since our main objective is to provide a Quality of Service and since the delay is also very small this will not be a matter of concern.

The overall sequence diagram is shown in **Fig 6**.

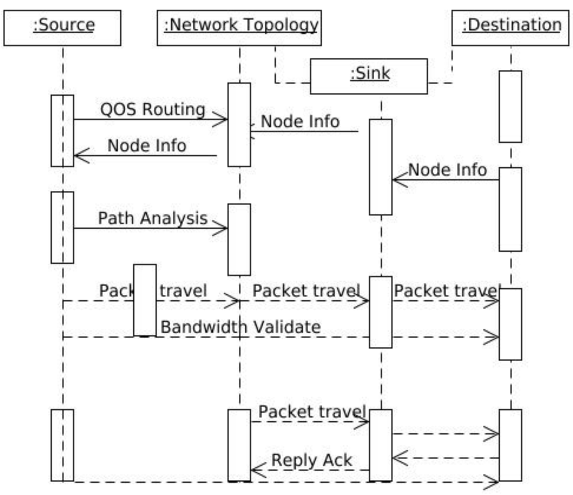

Fig. 6 Sequence Diagram

IV. Conclusion

The proposed routing algorithm is implemented for wireless mesh network. The implementation is carried using network simulator tool. The proposed model can satisfy the consistency and optimality requirements thus providing a Quality of Service for data transmission in a mesh network. This mechanism can make use of the bandwidth more efficiently than the previously existing systems and the possibilities of loop formation are considerably reduced.

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