Quality of Service Issues in Wireless Mesh Networks

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Abstract- In this paper the Quality of Service Issues in Wireless Mesh Networks has been described. Several access points may be put into wireless Ad Hoc networks for people connecting to WWW or other Internet services. This kind of wireless network is called wireless mesh networks (WMNs). Quality of service is largely lacking. For improving the performance of QoS in face of unreliable wireless medium, a new cross layer routing metric called expected transmission efficiency (ETE), which aims to find high throughput and low delay paths. Access points are placed in an wireless mesh network for maximizing cell coverage. However, larger coverage of an AP leads to lower throughput and longer delay in the access link as well as in the relay link. To find the optimal tradeoffs among delay, capacity, and coverage, Routing protocol design is critical to the performance and reliability of wireless mesh networks. Consequently, the overall performance of the network are poor even the total traffic load is far below the system capacity. Packet losses and delay due to interference in a multiple-hop mesh network with limited capacity .The wireless routers in the mesh network implemented. For improving performance of QoS. We can use traffic balancing.

I. INTRODUCTION

The wireless mesh network (WMN) is a new broadband Internet access technology. The competition with other broadband technologies, including cable, digital subscriber line, broadband wireless local loop and satellite Internet access, is stiff, but WMNs have significant advantages, making them a viable alternative. For accessing Internet we need a better quality of service in WMN. Despite the recent startup surge in WMNs, much research remains to be done before WMNs realize their full potential. That is good QoS for wireless mesh network. Parameter issues of QoS are minimum delay, minimum cost, maximum reliability and maximum throughput. We can implement a Backbone wireless mesh networks (BWMNs), those are highly adaptable, scalable, reliable and cost effective, which can be deployed easily in areas. Wireless mesh network (WMN) is this type of wireless network that allow mobile nodes to relay information between access points and end users to increase the coverage. WMNs have several significant advantages [12] such as very high coverage levels with very low initial investments, excellent spectral efficiency and complete flexibility in service delivery.

Despite the recent startup surge in WMNs, much research remains to be done before WMNs realize their full potential. Unlike wireless Ad Hoc networks, traffic in WMNs concentrates on the area around the access points and the throughput of each node decreases as O(1/n), where n is the total number of nodes in the network Traffic Balancing proposed to explore the wasted and unused bandwidth in wireless Ad Hoc networks provides a solution to the problem by forcing some traffic load away the congested access points. Traffic Balancing solves the problem of traffic load and increase the throughput and decrease the delay. Adding more gateways will increase not only the capacity of the network but also its reliability. The mesh structure ensures the availability of multiple paths for each node In the network. if one gateway fails, the others will take over its traffic. Wireless mesh networks are becoming a new attractive communication paradigm owing to their low cost and rapid deployment. Routing is critical to the performance and reliability of mesh networks. We can use a novel routing protocol, called Simple Opportunistic Adaptive Routing (SOAR), for wireless mesh networks.

Backbone wireless mesh networks (BWMNs) are highly adaptable, scalable, reliable and cost effective, which can be deployed easily in areas where the deployment of wired backbone is difficult or cost-prohibitive. Fig. 1 depicts an example of BWMN, where dash lines represent wireless links and solid lines represent wireline links. A BWMN consists of mesh routers and is responsible for providing Internet accesses for clients. Mesh routers are equipped with multiple network interfaces, and can cooperate to forward packets to the respective destinations. Some mesh routers are equipped with wireline network interfaces to connect to the Internet backbone and act as gateways. Clients may present a variety of patterns, e.g., an individual user or a network and can connect to a mesh router via a wireline or wireless link in a single hop or multi-hop manner. Note that in a BWMN, traffic flows to or from the gateways [8]. In this study, we focus on the problem that given the locations of mesh routers and their traffic demands, determine which routers play the roles of gateways and the connectivity among them, i.e., the network topology, subject to the number of antennas can be installed in a mesh router, the capacity of wireless links and the maximum tolerable delay, such that the construction cost is minimal.

I. INTRODUCTION

Fig. 1. Backbone wireless mesh network

Client • Gateway 0 Mesh router ---- Wired link ----- Wireless backbone link
The construction cost includes the cost on setting up gateways and the number of antennas used. The number of gateways deployed dominates the construction cost because wiring may be difficult and disruptive, which costs large budget and takes time. Note that, in general, employing more gateways results in less required antennas in the network, i.e., there is a tradeoff between them. We aim to investigate the optimal network configuration, including the topology, the number of antennas and gateways, such that the network construction cost is minimal.

Mesh topology is commonly considered in wide area networks (WANs) [9]. In WANs, each node has certain traffic demands to each other. However, in BWMNs, traffics flow to or from gateways. Besides, in WANs, network construction cost is proportional to the total distance of wiring and the level of channel bit rate used. In BWMNs, however, network construction cost is proportional to the number of gateways and antennas used. Distance degrades the available bit rate while the construction cost is not affected at all. For the design of access networks, existing solutions are mainly based on the minimum spanning tree. Kershenbaum et al. [10] investigated the optimal topology with the assumption that any two nodes in the network can have a direct link if desired, which is not the case in BWMNs because two mesh routers can have a direct link if and only if they are within the radio coverage. Yen and Lin [5] investigated the tree-based minimum cost topology for wireless access network to serve certain multicast groups. Filho and Galvao [6] searched the optimal locations of bridges to interconnect local area networks (LANs). Ersoy and Panwar [7] investigated the minimum average delay topology that interconnects a set of LANs to MAN. Note that less number of links implies less number of available paths that can share the traffics.

In BWMNs, where link capacity may be tight to satisfy the traffic demands, if the topology is restricted to a tree, more number of gateways may be needed and thus the construction cost increases. Topologies such as ring, star and bus [11] are also possible for BWMNs. Note that these topologies also have the potential drawback of high construction cost as tree topology does. Finding the optimal topology for a BWMN is a complicated task. The problem of designing the optimal network topology using spanning tree is known as an NP-hard problem [10][5]. Since spanning tree is one candidate topology of the BWMN, the complexity of the BWMN design problem is hence NP hard. It is therefore reasonable to employee heuristic algorithms to obtain a near-optimal solution rather than attempt to find the global optimal one for a large network. We model the BWMN design problem in a combinatorial optimization problem and propose the Predefined Gateway Set Algorithm (PGSA) to solve it. Although nodes in a BWMN can operate in either TDD or FDD mode, TDD is chosen here as it simplifies the frequency assignment problem, results in less number of antennas required, and has higher spectrum efficiency in the face of asymmetric traffics such as HTTP and FTP. Each mesh router has certain upstream and downstream traffic demands. A mesh network is modeled as a graph, where vertices represent mesh routers and arcs represent wireless links. Notations adopted in the problem formulation are listed below.

$$R$$ The set of all mesh routers.
$$N$$ Number of mesh routers.
$$K$$ The maximum number of antennas that can be installed in a wireless router.
$$a_{uv}$$ The indicator function which is 1 if a direct wireless link is formed between mesh routers $$u$$ and $$v$$, and 0 otherwise. $$a_{uv}=0$$.
$$\lambda_u$$ The traffic demand of mesh router $$u$$.
$$t_{uv}$$ The traffic load offered by mesh routers $$u$$ to $$v$$.
$$c_{uv}$$ Link capacity of the wireless link between mesh routers $$u$$ and $$v$$. $$c_{uv}=0$$.
$$\delta_u$$ The indicator function which is 1 if mesh router $$u$$ is a gateway and 0 otherwise.
$$\sigma_u$$ The cost on setting up mesh router $$u$$ as a gateway.
$$D$$ The maximum tolerable delay.

II. TRAFFIC LOAD

When more than one access point is put into the WMN, uneven traffic load problem appears time to time. The major reason for this problem is the routing algorithm. In most of routing protocols, control information and routing packets have higher priority than data packets and are inserted to the head of queue regardless of when they arrive. If on-demand routing protocol is used, the first reply for rout request usually goes through the shortest or closer paths. Without other weights to evaluate each hop, the shortest path or closer one is chosen as the default path. In certain period, most end users close to one access points then most traffic load concentrates on this access point. High packet loss rate and long delay caused by the overloaded access point lead to a poor system performance. For an instance, in Figure 2 due to the traffic pattern and routing protocol most traffic load goes to access point G1 even some of them can be routed to the nearby access point G2. Some researchers give weight to each hop and let the sender choose the path by looking at the sum of the weights.

![Figure 2: Traffic Load to access points](image-url)
III. TRAFFIC BALANCING

Figure 3 gives a basic idea of Traffic Balancing. Nodes A, C, and F communicate with nodes B, D, and G respectively. According to the routing algorithm the selected paths are likely to be the ones shown in the bold lines. All of them will pass through node E in order to achieve the shortest distance. When the traffic load is high, the middle area of the network (the area around node E) will be congested (more collisions may happen and packets have to be retransmitted) while other areas (such as the area around the dotted line in Figure 2) are still in a less loaded state. Then the overall system utilization is far below the theoretical limit even if the packet loss rate becomes very high. Because the queue length of each node is fixed, when the queue is full, new incoming packets have to be dropped. Also frequent transmission collisions lead to large numbers of retransmissions and longer backoff time that causes packets to wait longer in the queues. Some packets are dropped because they exceed their allowed lifetime. Traffic balancing is a routing approach that tries to exploit these unused resources around lightly loaded areas. For example, instead of selecting the path 1 indicated by the solid line between nodes A and B in Figure 3, path2 indicated by the dotted line is used for packet delivery for node A and B and gives node E more chance to support communication between nodes C and D & nodes F and G. This can either expand the network ability to support more communications under the same performance level or to improve the performance of the network. The solution is based on a reactive routing protocol and it can be implemented with any reactive routing protocol.

![Figure 3: The selected routing paths](image)

Before giving the description of Traffic Balancing, several issues should be explained. First of all, each node should have the ability to record the usage of medium around itself. The measured results will help the node to decide if the medium around its area is overloaded or not. In our protocol each node records the medium state in the past n milliseconds. If a node senses that the received power is bigger than the interference threshold for a certain period (equal to or longer than the time to transmit the smallest MAC frame), the medium is recognized as being used by other nodes. The duration of the state that the medium is occupied is recorded and accumulated. Then the node can verify the percentage of medium usage in this n millisecond time period. The choice of the value of n depends on the types of traffic in the network. If the traffic is bursty, n should be small. Otherwise, n should be large.

The second issue is the introduction of an additional byte in the header of the route request. This adds some overhead to the system. Another parameter has to be defined before the implementation: the medium usage threshold. The medium usage threshold is used to verify if the medium is busy or not. As mentioned in [6], at different mobility rates the best performance is achieved with different threshold values. One of the reasons is in the 802.11 MAC sublayer protocol, congestion and collision will lead to a longer backoff period, and the medium idle time may become large that leads to a low measured medium usage. Then Traffic Balancing may think the medium usage decreases and accepts more traffic through this busy area. As collision is caused by the node movement, number of collisions that can be seen by a node over a certain period to indicate the medium usage condition. In this solution one byte, the over Threshold Counter, is added in the packet header to indicate the number of nodes in the path that are over-loaded (assuming maximum number of nodes < 28).

When a node receives a route request, it looks at the medium usage and number of collisions around it. Based on the number of collisions, a suitable threshold is set and compared with the measured medium usage. If the medium usage is over the medium usage threshold, the node increases the over Threshold Counter by one. Otherwise, it does nothing but follows the regular routing protocol procedures. Upon receiving the route replies, the sender chooses the route with the smallest over Threshold Counter which is set by the routers and recorded by the sender. If more than one path has the same smallest over Threshold Counter, the one with fewer hops is chosen. If more than one path has the same overt threshold Counter and the same number of hops, the sender randomly chooses one. Traffic Balancing gives an effective solution to solve the uneven traffic load problems. For example, the node nl in Figure 4 has two paths to reach the access points (path (n1, n3, G1) leads to the access point G1 and path (n1, n4, n5, G4) leads to the access point G4). If nodes n1, n2, n3, n15 and n14 all use G1 as access point, traffic around G1 is high and the throughput for each user has to be very low. Based on Traffic Balancing, nl will choose path (nl, n4, n5, G4) because of less traffic aroundG4. Then the throughput of all nodes can be improved.

The Traffic Balancing shows that some of traffic can be routed from busy access point to idle access point and the overall performance can be much better. With Traffic Balancing the throughput of WMNs can be much better.
Upfront investments are minimal, because the technology can be installed incrementally, one node at a time, just as needed. As more nodes are installed, the reliability and network coverage increase. In WMNs, each user node operates not only as a host but also as a wireless router, forwarding packets on behalf of other nodes that may not be within direct wireless transmission range of a gateway. The gateways are connected to the Internet (the backhaul connection itself may also be wireless). The network is dynamically self-organizing and self configuring with the nodes in the network automatically establish. In WMNs, each user node operates not only as a host but also as a wireless router, forwarding packets on behalf of other nodes that may not be within direct wireless transmission range of a gateway. The gateways are connected to the Internet. The network is dynamically self organizing and self configuring with the nodes in the network automatically establishing and maintaining routes among themselves.

The gateways in WMNs are added one at a time as needed. Adding more gateways will increase not only the capacity of the network but also its reliability. The mesh structure ensures the availability of multiple paths for each node in the network. If one gateway fails, the others will take over its traffic, while the network as a whole will continue to function with (slightly) reduced performance. This provides a very appealing “graceful degradation” feature. Mobile users can connect to the WMN and have untethered connectivity as they roam within the coverage area of the WMN. It is conceivable and in fact quite desirable that quality of service (QoS) guarantees can be offered to customers. If the network is designed carefully and enough Internet gateways are placed at key points, each customer can enjoy guaranteed bandwidth. WMNs have several significant advantages such as very high coverage levels with very low initial investments, excellent spectral efficiency and complete flexibility in service delivery. If desired, repeater nodes (pure wireless routers) may be added to extend the coverage or improve the performance of the network. The access points in WMNs can be added one at a time as needed. Adding more access points will increase not only the capacity of the network but also its reliability. There may be a serious problem that some access points are overloaded during particular periods while rest of access points have very low traffic load. Some packets may be dropped by these overloaded access points or experience a very long delay waiting in the queue. However, if there is a possibility that some of traffic load going through heavily-loaded access points could be routed to light-loaded access points even more hops are required between access points and end users, the overall performance can be improved. Traffic Balancing proposed to explore the wasted and unused bandwidth.

To find the global optimal one for a large network. The model BWMN design problem in a combinatorial optimization problem and can use the Predefined Gateway Set Algorithm (PGSA) to solve it mesh routers may select the optimal paths for their traffic demands with respect to the specific metric, quality of service (QoS) requirement and current traffic load at runtime. Note that the channel bit rate degrades with increased distance. Using minimum hop count, the mean path length tends to be small, which implies longer distance per hop and thus lower path capacity. Therefore a non-gateway mesh router would need more number of paths to route its traffic demand. Furthermore, because the channel bit rate tends to be small, consider the number of antennas that can be installed in a gateway (four, in this case), the traffic demands that a gateway can serve tends to be small. Hence more number of gateways and antennas are required to satisfy all traffic demands and thus the network cost increases. This also reveals why the network cost difference between using minimum hop count and minimum packet delay increases as the gateway cost becomes higher. Recently, Wireless Mesh Network (WMN) [2], as a promising newcomer in wireless access technology, has caught the attention of networking industries. Constructing wireless backbone that provides access to Internet (or any database) is probably the most prominent application of WMNs. Large capacity and low delay as the two essential requirements in WMNs.
provides good reliability, market coverage, and scalability. The bottleneck collision domain, defined as the geographical area of the network that bounds the amount of data that can be transmitted in the network. In WMNs the throughput of each node decreases as \( O(1/n) \), where \( n \) is the total number of nodes in the network. The calculation of throughput of any node, to ensure quality of service Excess load drives throughput down, Wireless mesh network is a promising new direction resulting from the recent rapid progress made in wireless communication technologies. While multiple radio, multiple channel technologies have offered a great potential for increasing network throughput. We can use Ring Mesh, a token ring-based protocol for multi-channel routing. And only multi-radio multi-channel systems can offer the parallelism necessary to reduce the delay. A natural approach to routing traffic in wireless mesh networks is to adopt shortest path routing schemes as in wire line networks. These schemes select a shortest path (according to some metric) for each source-destination pair and send traffic along the predetermined path. Recently, researchers have proposed opportunistic routing for mesh networks.

Opportunistic routing differs from traditional routing in that it exploits the broadcast nature of wireless medium and defers route selection after packet transmissions. This can cope well with unreliable and unpredictable wireless links. There are two major benefits in opportunistic routing. First, opportunistic routing can combine multiple weak links into one strong link. For example, consider a source that has 20% delivery rate to each of its five neighbors, and each of these neighbors have 100% delivery rate to the destination. Under a traditional routing protocol, we have to pick one of the five intermediate nodes as the relay node, and cannot take advantage of a transmission that reaches the nodes other than the selected relay node. So altogether we need 5 transmissions on average to send a packet from the source to the relay node, and 1 transmission from the relay node to the destination. In comparison, under opportunistic routing, we can treat the five intermediate nodes as one unit that cooperatively forwards the packet to the destination. The combined link has a success rate of \( 1 - (1 - 0.2)^5 = 0.672 \). Therefore, on average only \( 1/0.67=1.487 \) transmissions are required to deliver 1 packet to at least one of the five intermediate nodes and another transmission is required for an intermediate node to forward. Altogether it takes only 2.487 transmissions to deliver the packet end-to-end, thereby achieving 2.4 times the throughput of traditional routing. Second, a traditional routing protocol has to trade off between link quality and the amount of progress each transmission makes.

For example, considered a linear topology where A sends data to D along the path \( A \rightarrow B \rightarrow C \rightarrow D \) and loss rate increases with distance. If B is used as the next hop, then the quality of link \( A \rightarrow B \) is good, and no retransmission is required to deliver the packet to B. But the progress made is small. Alternatively, if C is chosen as the next hop, a large progress is made if the packet reaches C. However since the quality of link \( A \rightarrow C \) is poor, multiple transmissions are required to deliver the packet to C. In comparison, opportunistic routing does not commit to \( B \) or \( C \) before transmissions. Among the nodes that receive the packet, we choose the one closest to the destination to forward. In this way, we can opportunistically leverage transmissions that are either unexpectedly short or unexpectedly long, thereby achieving high throughput.

B. Challenges for Opportunistic Routing

The major challenge in opportunistic routing is to maximize the progress of each transmission without causing duplicate transmissions or incurring significant coordination overhead. In order to realize the potential benefits of opportunistic transmissions in real networks, a practical opportunistic routing protocol should achieve the following design goals:

- Efficient: It should achieve significant performance improvement over traditional routing.
- Flexible: The protocol should support diverse traffic patterns, including multiple simultaneous flows.

Example

For 100 nodes for traffic balancing in ns2 simulation. 100 nodes are randomly distributed in a 2000x2000 m² area with two access points locating at (500, 1000) and (1500, 1000). Every sender generates a 5.3 Kbps CBR (constant bit rate) traffic to a wired node and receive a 5.3 Kbps CBR traffic from a wired node through one of two access points. Scenarios with different node mobility (20, 5, and 0 m/s maximum node speed) are simulated respectively to verify the improvement achieved by Traffic Balancing, simulations are run in NS2 (Network Simulator Version 2) [9]. Traffic Balancing uses a simple way to adjust the medium threshold in the simulations as follows: Each time a route request is received by a relay node, the node checks the number of collisions in the past 2 seconds. If this number is less than 10, the medium usage threshold is set to 0.9, assuming that this indicates the node mobility in the network is low. If this number is between 10 and 50.

![Figure 5](image-url)
After setting the medium usage threshold, the node compares the measured medium usage with the threshold and decides whether to increase the over Threshold Counter. Figure 6 compares the performance in packet deliver rate between Traffic Balancing and DSR. The results show that the faster nodes moves, the better performance Traffic Balancing provides. When traffic load is at intermediate level, Traffic Balancing support over 50% more traffic than DSR at maximum moving speed of 20 m/s. The improvement in static scenario is negligible because Traffic Balancing requires more bandwidth for its control packets than DSR that consumes the explored bandwidth. Also a CBR connection is closed when simulation stops so that connection set up early has advantage in taking the shortest path and give less chance to traffic balancing to find an alternative path for upcoming connections. Table I shows one results from the simulations that indicates the access points have different incoming traffic when the performance reaches a critical points (packet loss rate reach 5%). Meanwhile, the Traffic Balancing shows that some of traffic can be routed from busy access point to idle access point and the overall performance can be much better. With Traffic Balancing the throughput of WMNs also relates to the position of access points when the number of access points is more than one. Obviously, less number of hops for each connection leads to a better throughput in Wireless Ad Hoc network. The best place for access points will be the place where the overall average number of hops of all connections is smallest.

<table>
<thead>
<tr>
<th></th>
<th>Number of Access Point</th>
<th>Packet Loss Rate</th>
<th>Number of Packet Transferred in Access Point 1</th>
<th>Number of Packet Transferred in Access Point 2</th>
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<td>DSR</td>
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<td>7.26%</td>
<td>3993</td>
<td>1104</td>
</tr>
<tr>
<td>Traffic Balancing</td>
<td>2</td>
<td>1.32%</td>
<td>4347</td>
<td>2552</td>
</tr>
</tbody>
</table>

Table 1: Uneven traffic load at access points

Figure 7 plots the relationship between the position and the network performance on packet delivery rate when the number of communications keeps constant. The network size is 2000x2000 m² and maximum moving speed for each node is 0 m/s (static). There are 4 access points in the network as shown in Figure 8 and x-axis in Figure 7 is distance from each access point to the middle point of the network in horizon direction. Similar property can be found from the network with 2, 3, or more access points.
The performance by DSR has not much difference when access points locate from the range 100 to 600 m. When access-points moves far away, the performance decreases relevantly. The reason for this phenomenon is at the corner of the network traffic comes from ¼h of direction (90 degree) while in the middle of network traffic comes from all directions (360 degree). Then interference at the corner is higher and all traffic in each subnetwork may go through same nodes before reaching access points. On the other side, the performance also degrades when all access points moves closely (<100 m). In this case, as all access points are very close they just looks like one access point then no addition capacity adds to the network.

CONCLUSION

In this paper, Literature Survey of Quality of Service issues of wireless mesh network using Traffic Balancing. Despite the recent availability of WMN products, much research is still needed before the technology is ripe. This Literature survey shows how Gateways are helpful for improving the QoS of WMNs. We can use the Pre-defined Gateway Set Algorithm (PGSA) to determine the optimal BWMN configuration, including the gateways and the topology, such that the network construction cost is minimal. The survey have shown that the PGSA can compute the optimal network configuration in a relative very short time and how Traffic Balancing solves the uneven traffic load problem appearing in wireless mesh networks.

Uneven traffic load is caused by the traditional routing protocols and may degrade system performance even the overall traffic load is light. Traffic load concentrating on one access point temporarily leads to packet loss and extremely long delay. Traffic Balancing provides a way to force part of traffic load from busy area to light-loaded access points and improve the network efficiency. A novel opportunistic routing protocol, called SOAR. It uses priority-based forwarding and judicious forwarding node selection to maximize the progress of each transmission with little coordination among the nodes. It protects against packet losses using local recovery based on selective ACKs, which are sent using either piggyback or ACK compression.

REFERENCES