QoS-Aware routing protocol for improving accuracy of bandwidth estimation in mobile Ad-Hoc Networks

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Abstract- In mobile ad-hoc networks (MANETs), the provision of quality of service (QoS) guarantee is much more challenging compared to wired networks mainly due to node mobility, multi-hop communications, contention for channel access, and a lack of central coordination. QoS-aware routing protocol is significant in context to the approximate bandwidth estimation to react to network traffic. The approach pointed out in this paper deals with the implementation of these schemes by using two bandwidth estimation methods to find the residual bandwidth available at each node to support new streams. QoS-aware routing protocol is simulated for nodes running the IEEE 802.11 medium access control. The experimental results are evident enough to state that the packet delivery ratio increases greatly, and packet delay decrease significantly, while the overall end-to-end throughput is not impacted, compared with routing protocols that do not provide QoS support.

Keywords – Bandwidth estimation, mobile ad hoc networks (MANETs), quality-of-service (QoS)

I. INTRODUCTION

Bandwidth estimation is a basic function that is required to provide QoS in MANETs. It is a way to determine the data rate available on a network route. It is of interest to users wishing to optimize end-to-end transport performance, overlay network routing, and peer-to-peer file distribution. Techniques for accurate bandwidth estimation are also necessary for traffic engineering and capacity planning support. Bandwidth estimation can help to develop better methods for gateway selection, channel selection, routing etc.

In MANETs, the wireless mobile nodes may dynamically enter in the network as well as leave the network. Because of the limited transmission range of wireless network nodes, multiple hops are generally required for a node to exchange information with any other node in the network. Multipath routing permits the formation of multiple paths between one source node and one destination node. Many routing protocols [1-5] have been proposed to provide quality of service provisioning. Broadly these protocols can be classified as: proactive routing protocols and reactive routing protocols. In proactive routing protocols, routing information is periodically exchanged between network nodes. While in reactive protocols, the routing information is obtained only on demand. The basic reactive protocols such as Ad-hoc On Demand Distance Vector (AODV) [6] and Dynamic Source Routing (DSR) [7], flooding is used as the basic mechanism to propagate control packets. These control packets generates a large number of redundant packets that consumes network resources inefficiently. Due to this, more contention and overheads are there in the network.

Available bandwidth estimation techniques can be divided in two major approaches: Intrusive Bandwidth Estimation Techniques which are based on end-to-end probe packets to estimate the available bandwidth along a path. Another is Passive Bandwidth Estimation Techniques uses local information about bandwidth utilization of individual nodes and this information is exchanged between the nodes via local broadcasts**.**

This work presents a QoS-aware routing protocol that incorporates a feedback scheme and an admission control scheme to meet the QoS requirements (provides better than best-effort service) of real-time applications using IEEE 802.11. The highlight of this QoS-aware routing protocol is the use of the bandwidth estimation to respond to the network traffic.

II. RELATED WORKS

Chen and Heinzelman [3] modified the hello messages in the AODV routing protocol so that it carried bandwidth information of each node and its immediate neighbors. This information was then used to calculate the residual bandwidth due to second hop neighborhood interference. Filali [4] proposed a technique implemented using a sniffing based tool (called Wimeter) which captures and analyzes in real-time the frames sent in a preconfigured WLAN. The analysis of captured frames consists of determining the portion of time when the channel is free and then estimating the available bandwidth as a function of the packet size of expected frames to be transmitted and the link-layer rate of the sender and the receiver stations. They went ahead to implement a Call Admission Control Framework that uses the wimeter as a basis for band- width estimation. M Liu *et al.* [5] used average value of history data to calculate the available bandwidth for each period in the past, and used this data to predict the available bandwidth in future. Chakers and Belding-Royer [6] *et al*. proposed an admission control method they called Perceptive Admission Control (PAC). In the method the used a band width estimation method based on listening for the idle time for channel and calculated the available bandwidth as a ratio of idle time to total time multiplied by the channel capacity. Lin *et al.* [7] have proposed an available bandwidth calculation algorithm for ad hoc networks with TDMA. By exchanging routing tables, the bandwidth in the shortest path can be determined. Sinha *et al.* [9] have proposed a core-extraction distributed algorithm (CEDAR). In the CEDAR routing protocol, it is assumed that the available bandwidth is known. The available bandwidth is disseminated among the cores. In this way, the overhead used to propagate the link state information can be minimized. However, if the core is moving out of the selected route, rerouting is very costly.Chen *et al.* [11] have proposed a ticket-based probing algorithm with imprecise state. The bandwidth and delay information were assumed to be available. This algorithm tries to limit flooding by issuing limited tickets. Both CEDAR and ticket-based probing emphasize minimizing overhead used in setting up the route. Ge *et al.* [15] have proposed a proactive QoS routing, which is based on OLSR for static networks. They use monitoring of the channel's idle time to measure available bandwidth. Their work focuses on correctly finding the maximum bandwidth path, without considering route breaks and mobile topologies.
A. Abdrabou *et al*. [18] proposed a MAC layer based estimation method. It is based on the bandwidth of a link in discrete time intervals by averaging the throughputs of the recent packets in the past time window and uses it to estimate the bandwidth in the current time window. Obviously, this estimation may not be accurate because the channel condition is dynamic.

III. METHODOLOGY

QoS is an agreement to provide guaranteed services such as bandwidth, delay, delay jitter, and packet delivery rate to users. Supporting more than one QoS constraint makes the QoS routing problem NP-complete. Therefore the bandwidth constraint is considered when studying QoS-aware routing for supporting real-time video or audio transmission. QoS-aware routing protocol is done by either providing feedback about the available bandwidth to the application (feedback scheme) or by admitting a flow with the requested bandwidth (admission scheme). Both the feedback scheme and the admission scheme require knowledge of the end-to-end bandwidth available along the route from the source to the destination. Thus, bandwidth estimation is the key to supporting QoS.

A. Bandwidth Estimation Methods –

Accurately estimating the available bandwidth allows a node to make optimal decision before transmitting a packet in the network. It is therefore clear that the available bandwidth estimation enhances the QoS in both wired and wireless Networks. Measuring available bandwidth in ad-hoc networks is challenging issue in MANETs and calculating the residual bandwidth using the IEEE 802.11 MAC is a even more challenging problem because the bandwidth is shared among neighboring hosts and an individual host has no knowledge about other neighboring hosts' traffic status. Two methods for estimating bandwidth are used below:

1. *“Listen” bandwidth estimation*: Hosts listen to the channel and estimate the available bandwidth every second based on the ratio of free and busy times. The IEEE 802.11 MAC utilizes both physical carrier sense and virtual carrier sense [via the network allocation vector (NAV)], which can be used to find out the free and busy times. The MAC detects that the channel is free when the three requirements are met: NAV’s value is less than the current time, Receive state is idle and Send state is idle.

NAV sets a new value or Receive state changes from idle to any other state or Send state changes from idle to any other state occurs only when MAC declares that the channel is busy.Using the “Listen” method to estimate residual bandwidth is straightforward. However, using this approach, the host cannot release the bandwidth immediately when a route breaks because it does not know how much bandwidth each node in the broken route consumes. “Listen” only counts the used bandwidth but does not distinguish the corresponding bandwidth cost for each flow. This greatly affects the accuracy of bandwidth estimation when a route is broken. Therefore another better approach “Hello” is proposed for bandwidth estimation that is able to reallocate available bandwidth when routes break.

2. *“Hello” Bandwidth estimation:* The sender’s current bandwidth consumption as well as the sender’s one-hop neighbor’s (from its two-hop neighbors) current bandwidth consumption is piggybacked onto the standard “Hello” message. Each host estimates its available bandwidth based on the information provided in the “Hello” messages and knowledge of the frequency reuse design.

ID	Consumed Bandwidth	Timestamp
Neighbor ID 1	Consumed Bandwidth	Timestamp
. . . .	. . . .	. . . .
Neighbor ID n	Consumed Bandwidth	Timestamp

Figure1. Hello Structure

Hop relay was introduced to disseminate the second neighboring hosts’ information. AODV uses the “Hello” messages to update the neighbor caches. The “Hello” message used in AODV only keeps the address of the host who initiates this message. The “Hello” message was modified to include two fields. The first field includes< host address, consumed bandwidth, timestamp> and the second field includes < neighbors’ addresses, consumed bandwidth, timestamp> as shown in Figure1. Each host finds out its used bandwidth by monitoring the packets it feeds into the network. This value is recorded in a bandwidth-consumption register at the host and is updated periodically.

B. Incorporating QoS in Route Discovery

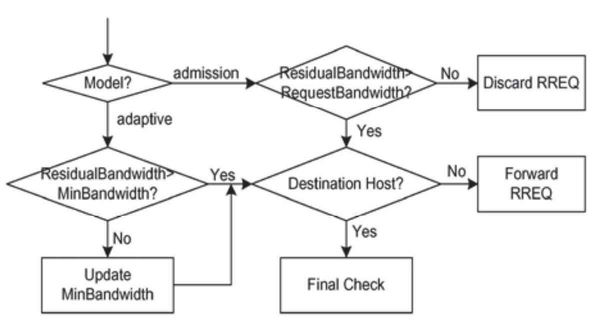

Figure2. Hosts’ working procedure

In QoS-aware routing discovery, the source host sends a RREQ packet whose header is changed to< model-flag, bandwidth request, min-bandwidth, AODV RREQ header>. The model-flag indicates whether the source is using the admission scheme or the adaptive feedback scheme. When an intermediate host receives the RREQ packet, it first calculates its residual bandwidth. If there is model- flag in the admission scheme, the host compares its residual bandwidth with the requested bandwidth. If its residual bandwidth is greater than the requested bandwidth, it forwards this RREQ else it discards this RREQ. If the model-flag is adaptive, the host compares its residual bandwidth with the min-bandwidth field in the RREQ. If its residual bandwidth is greater than the min-bandwidth, it forwards the RREQ. Otherwise, it updates the min-bandwidth value using its residual bandwidth.

C. Route Maintenance

AODV detects a broken route by monitoring the “Hello” messages. If a host does not receive a “Hello” message from a specific neighbor within a predefined interval, it marks the routes using that neighbor host as invalid and sends a corresponding “Error” message to the upstream hosts. Only the source host reinitiates a routing discovery procedure, once receiving the “Error” message. Thus, using caches to respond to a route break in the intermediate host is not utilized.

1. *Listen Method:* QoS-aware routing with “Listen” bandwidth estimation, AODV’s route maintenance scheme is used, because releasing bandwidth from the bandwidth consumption registers is impossible without knowing how much bandwidth is consumed by each host in the route. Therefore, no change in AODV’s route maintenance scheme is needed to address the bandwidth releasing issue.
2. *Hello Method:* It cannot directly use AODV’s route maintenance scheme in the QoS-aware routing protocol with “Hello” bandwidth estimation. We should incorporate a forced cache update in the route maintenance scheme. The QoS-aware routing with “Hello” bandwidth estimation uses the first neighbors’ relay to get the second neighbors’ information. Therefore, once the neighbors get the forced updates, they should disseminate the update information immediately to their neighbors. We use an “Immediate Hello” message to address this concern. This special message’s content is exactly the same as the “Hello message”, except the packet type is marked as “Immediate Hello” in order to differentiate with the regular “Hello” message. When a host receives an “Immediate Hello” message, it sends its regular “Hello” message immediately. The “Error” message is also adopted to trigger an update of bandwidth consumption registers and the dissemination of “Immediate Hello” messages. Once a host receives an “Error” message, it will deduct the amount of bandwidth that the broken route consumes from its bandwidth consumption register to reflect the bandwidth allocation changes.

III. EXPERIMENT AND RESULTS

The performance of this QoS-aware routing protocol was evaluated using NS-2.34 simulators. The IEEE 802.11 MAC protocol in RTS/CTS/Data/ACK mode was used with a channel data rate of 2 Mb/s. The packet size used in this simulation was 1400 bytes. The topologies varied according to the different simulation purposes.

A. Weight Factor Comparison

The performance of “Hello” bandwidth estimation and “Listen” bandwidth estimation cannot be compared using the same weight factor, because these two methods define the consumed bandwidth differently.
•“Listen” mode—accounts for RTS, CTS, ACK, retransmission, routing packets, and transmitted packets.
•“Hello” mode—counts the transmitted packets only.
Therefore for achieving the same performance “Hello” weight factor should be larger than the “Listen” weight factor. In addition, if congestion occurs, the listen mode cannot release the bandwidth immediately so a large weight factor is chosen to avoid congestion when we compare these two different estimation methods.
Performance of the “Hello” scheme and the “Listen” scheme are investigated using topologies where 50 static nodes are located randomly in a 1000m X1000 m plane. Five nodes are randomly chosen as sources and five nodes are randomly choose as destinations. All sources feed the same data rate to their destinations and the feeding rate varies from 0.1 to 0.6 Mbps. After every 10 s interval, one source will begin to send data into the network. Twenty different scenarios were randomly chosen and the simulation was done for 500 seconds.

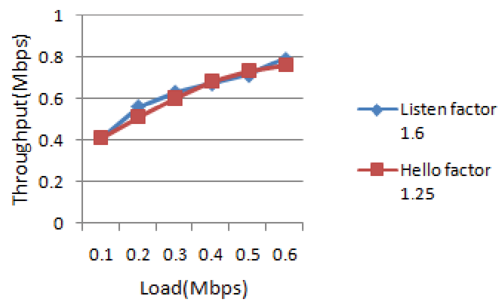

Figure 3: Throughput Comparison ("listen" versus "hello")

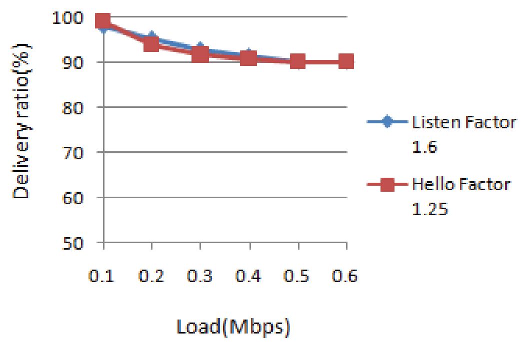

Figure 4: Delivery ratio comparison ("listen" versus "hello")

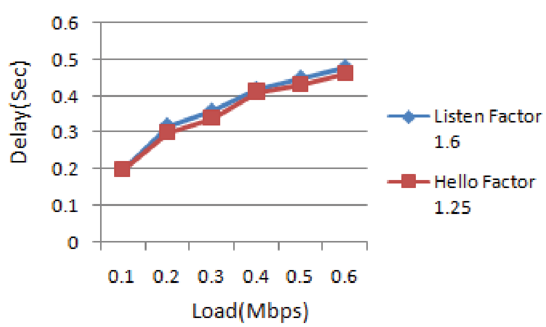

Figure 5: Delay comparison ("listen" versus "hello")

B. Static Topology using admission scheme and feedback scheme

Both the feedback scheme and the admission scheme require knowledge of the end-to-end bandwidth Available along the route from the source to the destination. In the admission scheme, flows are denied if there is not enough bandwidth available to support their request. The total capacity of the admitted flows are being less than that of the feedback scheme, so packet collisions occur less frequently. Correspondingly, the packet delay should be decreased significantly due to fewer collisions. We compare QoS-aware routing with "Hello" bandwidth estimation, QoS-aware routing with "Listen" bandwidth estimation, and conventional AODV, which has no QoS support. The metrics used in measuring the protocols' performance are delay, packet delivery ratio, and overall end-to end throughput.

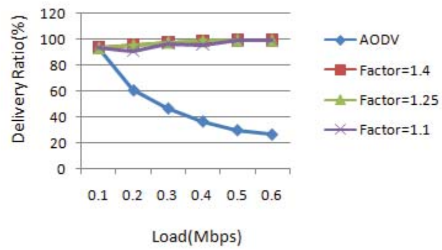

Figure 6: Delivery ratio using Listen

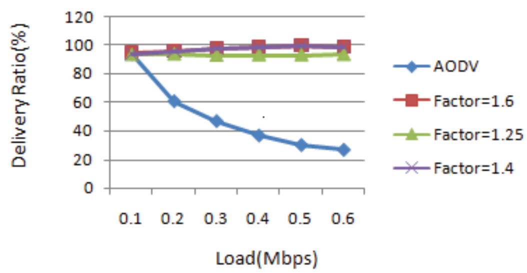

Figure 7: Delivery ratio using Hello

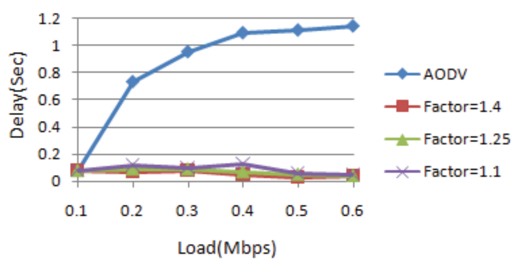

Figure 8: Delay using Listen

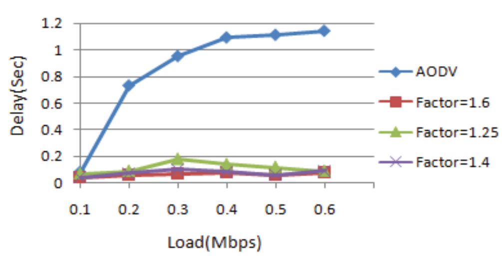

Figure 9: Delay using Hello

C. Mobile Topology

Our routing protocol is designed with the restriction of combinatorial stability. Therefore, if the network changes too fast, we do not expect the QoS-aware routing protocol to perform well. Thus, we choose low mobility scenarios that mimic pedestrian speeds to test our protocol. In the scenarios we choose, each node moves toward a random destination using a speed randomly chosen between 0–2 m/s. Five random source-destination pairs send packets using a requested rate between 0.1 and 0.6 Mb/s. The simulation time is 500 s.

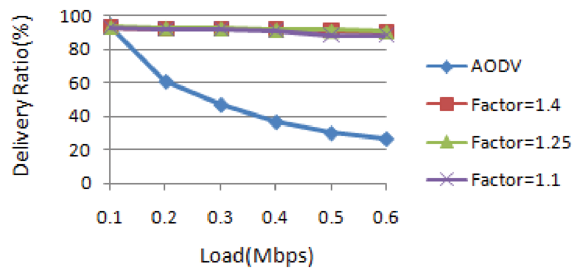

Figure 10: Delivery ratio using Listen

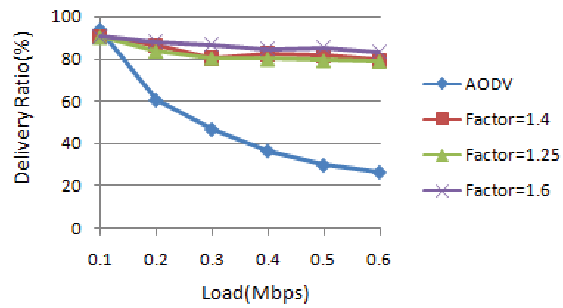

Figure 11: Delivery ratio using Hello

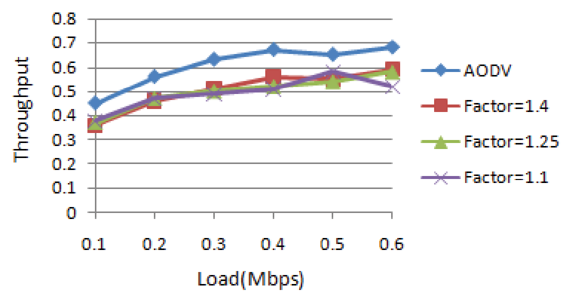

Figure 12: End to End throughput using Listen

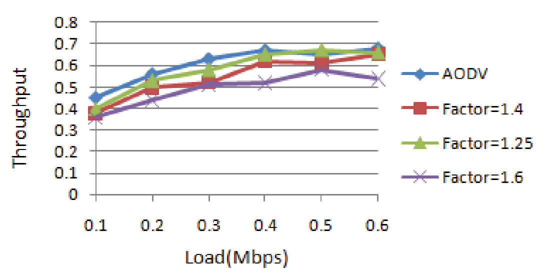

Figure 13: End to End throughput using Hello

The packet delivery ratio is between 88%–92% using the QoS-aware routing protocol with “Listen” bandwidth estimation, and the packet delivery ratio is between 78%–90% using the QoS-aware routing protocol with “Hello” bandwidth estimation. QoS-aware routing shows great improvement over using AODV, which achieves very low packet delivery ratio for high requested loads. As there is a tradeoff between packet delivery ratio and throughput that we discussed previously,the higher the packet delivery ratio, the lower the achievable throughput. Therefore, using the “Listen” scheme, the end-to-end throughput is slightly decreased compared with using the “Hello” scheme, as shown in Fig. 10 to 13.QoS-aware routing protocol's performance will degrade as the moving speed increases, because we designed the QoS-aware routing protocol with a model of low mobility.

IV.CONCLUSION

Two different methods of estimating bandwidth have been compared. The "Hello" bandwidth estimation method performs better than the "Listen" bandwidth estimation method when releasing bandwidth immediately is important. The "Hello"and "Listen" schemes work equally well in static topologies by using large weight factors to reduce the congestion and minimize the chance of lost "Hello" messages incorrectly signaling a broken route. In a mobile topology, "Hello" performs better in term of end-to-end throughput, and "Listen" performs better in term of packet delivery ratio. From the perspective of overhead,"Listen" does not add extra overhead, but "Hello" does add overhead by attaching neighbors' bandwidth consumption information in the "Hello" messages. The accurate measurement of the capacity of a multihop mobile network is an open issue right now.

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