Low Bandwidth and Computational Capacity of the Nodes in Mobile Ad-Hoc Networks (MANETs)

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Abstract

Ad hoc networks are gaining increasing popularity in recent years because of their ease of deployment. No wired base station or infrastructure is supported, and each host communicates one another via packet radios. In ad hoc networks, routing protocols are challenged with establishing and maintaining multihop routes in the face of mobility, bandwidth limitation and power constraints. In this dissertation, we study the scalable multicast routing, Quality of Service, and secure multicast for Mobile ad hoc networks. On-demand routing protocols and table driven algorithms are analyzed and compared against each other. Our study shows that on-demand protocols are better suited for mobile networks because they generate less control overhead and manage the mobility in a more efficient manner. Simulation experiments also indicate that providing multiple routes is beneficial in increasing the robustness against mobility. The need for supporting real time and multimedia applications for users of Mobile Ad hoc Network (MANET) is becoming essential. Mobile ad hoc networks can provide multimedia users with mobility they demand, if efficient QoS multicast strategies were developed. We propose a cross layer framework and a multicast routing protocol with mechanisms to ensure QOS guarantee to multicast session (call-admission, bandwidth reservation and delay constrain).

Keywords: MANET, QoS

I. INTRODUCTION:

In mobile ad hoc networks (MANETs), all communications are done over wireless media, typically by radio packet through the air, without the help of wired base stations. Direct communication is allowed only between adjacent nodes. So, distant nodes communicate over multiple hops, and nodes must cooperate with each other to provide routing. The QOS routing in MANETs is difficult because the network topology will change dynamically, the available state information for routing changes dynamically, nodes may join, leave, and rejoin an ad hoc network at any time and any location. Additional challenges in ad hoc networks are attributed to mobility of intermediate nodes, absence of routing infrastructure, low bandwidth and computational capacity of the nodes. Another challenge with supporting QOS for real-time applications is associated with the design of the medium access control (MAC) protocol. The dynamic nature of wireless ad hoc networks makes it difficult to dynamically assign a central controller to maintain connection state and reservations. Because of this, best effort distributed MAC controller is widely used in existing wireless ad hoc networks. There are many requirements to provide QOS in MANETs, first, find a route through the network that is capable of supporting a requested level of QOS. Second, ensure that when networks topology changes, new routes that can support existing QOS are available or can be quickly found. Third, respond to changes in available resources, either as the result of a route change or as the result of change link's characteristics with a given route. QOS in MANETS is highly dependent upon routing and medium access control; also there is a strong coupling between routing and MAC layer to improve QOS in MANETs. Delivering end-to-end service quality in MANETs is intrinsically linked to the performance of the routing protocol because new routes or alternative routes between source and destination pairs need to be periodically computed during ongoing session. Protocol layering is an important abstraction that reduces complexity for designing network but it is not well suited to wireless networks because the nature of the wireless medium makes it difficult to decouple the layers. For example, routing protocols can avoid building routes that cannot meet QOS requirements depending on information that come from MAC layer. Several protocols have been developed to perform ad hoc multicast routing, i.e. CAMP, ODMRP, M-AODV, and FGMP. However, these multicast protocols did not address the QOS aspect of ad hoc communication. There are several studies for unicast routing protocols with QOS in MANETs in literature, but QOS support for a multicast protocol should be differently designed from the unicast QOS. For a unicast QOS, the main issue is related to the resource reservation between a source and destination. On the other hand, a multicast QOS should provide QOS paths to all destinations, not only between the source and destination; as a result, QOS multicast should cope with large number of receivers and be able to utilize them. Recently, addresses QOS multicast routing, this protocol uses a lantern-tree as a topology for multicast group and CDMA/TDMA model at MAC layer; lantern-tree takes long time at startup to find all paths and to share time slots between neighbors. It splits flow in to multiple paths which add more complexity when more than one flow are admitted, nodes need to store and process more information about sub flows, multiple paths built and released without sending through them. In addition, CDMA/TDMA is difficult to be implemented in a real network.

II. MULTICAST ROUTING WITH QOS

A. Session initiation and destruction

A node that has data to send starts session by broadcasting a session as a quality of service route request (QRReq) with Time –To-Live (TTL) greater than zero. Intermediate nodes rebroadcast QRReq if they have available bandwidth until arriving at destinations or TTL equal zero. Destination nodes receive QRReq and send route reply (RRep) to the source. Source nodes and destination nodes can leave the session by not sending QRReq and RRep respectively

B. Forward group and member management:

When an intermediate node receives QRReq from source node, it stores the source ID and the sequence number in its message cache to detect any potential duplicates. If the message is not a duplicate, intermediate node has available bandwidth and the TTL is greater than zero, then the node rebroadcast QRReq; routing table is updated with node ID that receives from it. The destination node will receive QRReq from several paths; it selects one path with the best QOS conditions and sends RRep. When an intermediate node receives RRep from destinations, it checks if the node ID in RRep matches its own ID. In this way, each intermediate node propagates the RRep until it reaches the multicast source via the selected path. This whole process constructs or updates the routes from transmitters to receivers. Through this process, all paths to destinations will be defined and source node can start sending data packet.

C. Admission control

We use distributed admission control at every intermediate nodes, when intermediate node receive QRReq packet, it must calculate its available bandwidth and rebroadcast QRReq packet if it has available bandwidth. QRReq forwarded as long as QOS requirements are met. The packet is dropped if QOS requirements cannot be met any more, avoiding flooding the network unnecessarily. Before QRReq packet rebroadcast, each intermediate node temporarily updates its QOS information with the current QOS conditions. With this rule, nodes do not accept more traffic than the bandwidth available. Figure1 shows structure of route request with QOS requirement phase and figure2 shows reply phase and forward group establishment.

In our framework, we propose to compute the available bandwidth based on the channel status of the radio to determine the busy and idle periods of the share wireless media. By examining the channel usage of a node, we are able to take into account the activities of both the node itself and its surrounding neighbors and therefore obtain a good approximation of the bandwidth usage; we will use the standard IEEE 802.11 at MAC layer.

D. Bandwidth reservation

In CDMA/TDMA protocol used at MAC layer, every node in the path needs to share information with all neighbors about free slots. In our scheme, we propose to use a distributed bandwidth reservation, where each intermediate node in the network will calculate its own available bandwidth independently without need to share information free time slots with neighbors. Intermediate node rebroadcast data packet if it is a forward node for the source of data packet, figure3 shows forward data packet phase.

In a non- QOS scheme, intermediate nodes do not check their bandwidth requirements before rebroadcast RReq packet. Because of this, some of forwarding nodes become heavily overloaded. As a number of senders grow, more than one RReq are accepted without considering the available bandwidth.

E. Use multi forward group for Load balancing

The new idea is uses many number of forward groups to apply multicast with QOS and balance the overload. Considering the QOS support, the bandwidth on a single link might not be adequate if there are many sources in the network and consequently, many packets may be discarded, so we propose a practical situation that the data packets from different sources may come from different directions to a local group. When intermediate node drops QRReq, it will arrive at enough available bandwidth. In addition, load balancing appears through updating forward group.

F. Route recovery and prevent congestion.

Most multicast applications belong to category that number of senders is less than number of receivers. In this situation, sender advertising is more efficient than receiver advertising, so in our proposed routing protocol we use sender advertising. Each source periodically sends QRReq that make route recovery by updating forward group.

The problem with the admission control solution in most previous studies is that a one-time procedure performed before the flows start. It does not take into Account the change in the wireless network over the duration of the flow's operation. Capacity of channel may change dramatically and available bandwidth that estimated by individual nodes and due to fading and outside interference .In our approach when source update forward group, paths will update also and nodes estimate the available bandwidth, so all changes that appear as a result of node movement will be taken. Any forward node can detect congestion using periodic traffic measurement. When a node detects such congestion, it starts sending a prop packet to source or destination.

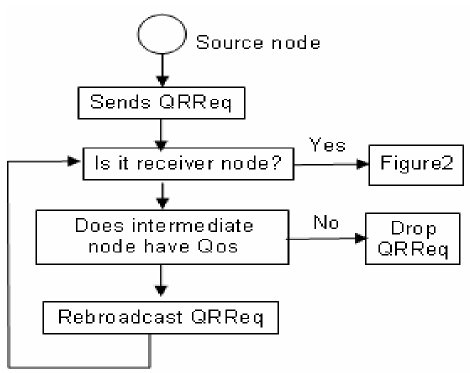

Figure 1: QoS Route Request Phase

Figure 1 shows QOS route request phase from source to destinations and describes how intermediate node behaves when it receives QOS route request. Figure 2. Shows route reply phase from destination to source; describe how intermediate node behaves when it receives route reply and when it sets to be a forward node. Figure 3 shows data packet phase from source to destinations, describes how intermediate node behaves when it receives data packet. Figure 4 gives an overview about cross-layer (interaction between network, routing and MAC layers) and performs at intermediate node. Describes how intermediate node checks QOS requirements and estimates available bandwidth.

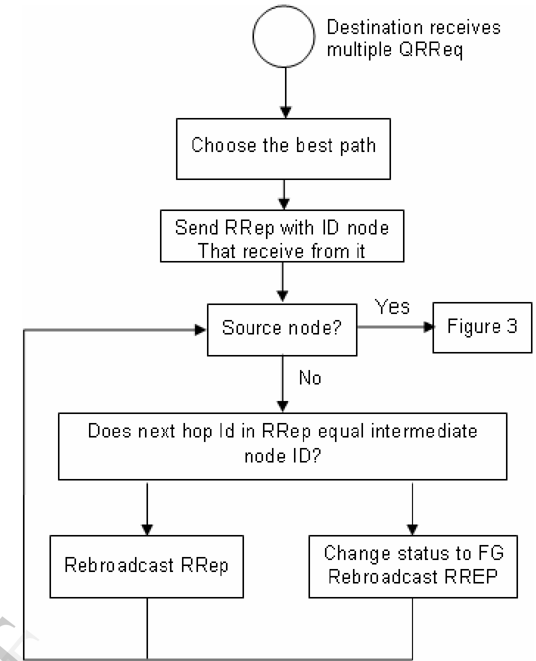

Figure 2 Reply Phase and Forward group establishment

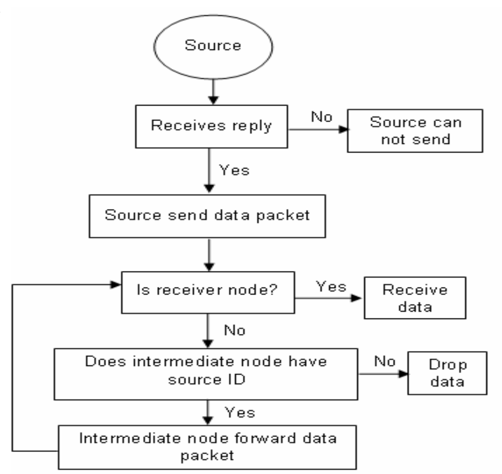

Figure 3 Forward data packet phase after receive RRep

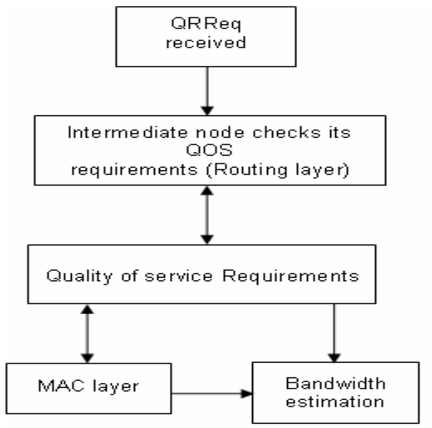

Figure 4 Overview shows action perform at intermediate node

III. CROSS-LAYER DESIGN FOR MULTICAST QOS

The nature of the wireless channel requires that different layers (i.e. network and MAC sub-layer) interact in order to provide QoS; in general, the system performance in wireless networks can be enhanced by taking advantage of the available information across different layers. In our proposed cross-layer enhancement to QMR, admission control at the network layer makes a decision to accept or reject the new request depends on the information that comes from the MAC layer. Figure 5 gives an overview on the cross-layer framework.

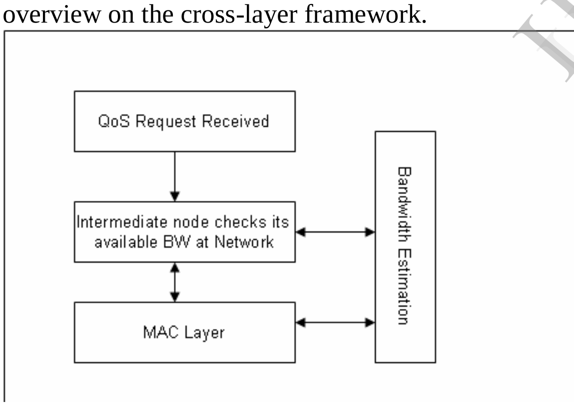

Figure 4.5 Cross-layer QoS framework.

Estimating available bandwidth using the IEEE 802.11 MAC in MANETs is still a challenging problem, because the bandwidth is shared among neighboring hosts. In addition, accurate estimation of a node's bandwidth utilization is difficult in a multi-hop packet radio networks. When we estimate the available bandwidth, we must take into account the activities of the neighbors of nodes since the wireless medium of a node is shared among neighboring nodes.

We estimate the available bandwidth based on the channel status of the radio and compute the idle periods of the shared wireless media. By using this method we consider the activities of neighbors of node; where any send or receive from other nodes will affect the channel status. In this method, for estimating the available bandwidth, each node can listen to the channel to determine the channel status and computes the idle duration for a period of time t; in our approach t = 1 s. The IEEE 802.11 MAC utilizes both a physical carrier sense and a virtual carrier sense. Since multicast transmission does not use virtual carrier sense (RTS/CTS), we rely on physical carrier sense to determine the idle and busy state of the channel to determine channel activity. In this case the IEEE 802.11 wireless radio has two states:

1- Busy s1- Busy state (transmitting, receiving and carrier sensing channel).

2- Idle state.

Each node will constantly monitor when the channel state changes; it starts counting when channel state changes from busy state (transmitting, receiving and carrier sensing channel) to idle state and stops counting when channel state changes from idle state to busy state. The Idle Time (Ti) is composed of several idle periods during an observation interval t; the node adds all the idle periods to compute the total idle time. We calculate the idle ratio (τ) for each period of time t as:2- Idle state. Each node will constantly monitor when the channel state changes; it starts counting when channel state changes from busy state (transmitting, receiving and carrier sensing channel) to idle state and stops counting when channel state changes from idle state to busy state. The Idle Time (Ti) is composed of several idle periods during an observation interval t; the node adds all the idle periods to compute the total idle time. We calculate the idle ratio (τ) for each period of time t as:

$$\tau = Ti / t \quad (1)$$

$$Bw_{avail} = \tau \times BW \quad (2)$$

Where BW is the raw channel bandwidth (2Mbps for standard IEEE 802.11 radio). After the node finishes computing the available bandwidth during a period of time t at the MAC layer, it sends the information of the available bandwidth to the Network layer and starts computing available bandwidth during the next period of time t.

The passive listening method compared with the active hello messages method and concluded that passive methods are straightforward and relatively accurate with no control overhead. However passive method does not consider the impact of mobility. They proposed an active approach using hello messages that account for mobility but has the disadvantage of very high control overheads; this control overhead increases with the number of nodes. In our case, limiting overheads is a higher priority, so the passive listening method is used to estimate available bandwidth. The QMR protocol address the impact of mobility by updating forward nodes (FNs) periodically by freeing the allocated BW for old paths and allocating it for new paths. However, there might be an interval where FNs in the old path might not be aware that the amount of allocated bandwidth was changed since we use 5 second FN update intervals. During this time, QoS requirements of other ongoing flows that use the same or nearby FNs are respected and protected. This is better than using extra overhead to free the allocated bandwidths. This proposed version of bandwidth estimation is what is found in E-QMR.

A. Adhoc QoS Multicasting Protocol

Bandwidth reservation, bounded loss and delay, and the implementation of QoS classes are important for an efficient ad hoc QoS multicasting strategy. Addressing these issues, the structure of AQM is defined in the following sections. The design details include session initiation and destruction, membership management, and neighborhood maintenance.

1) Session Initiation and Destruction

A session can be started by any node (MCN_INIT), which broadcasts a session initiation packet (SES_INIT) consisting of the identity number and the application type of the session. A table of active sessions (TBL_SESSION) is maintained at each node to keep the session definition. Using their session tables, nodes forward initiation packets of new sessions. A membership table (TBL_MEMBER) is used to denote the status of the predecessors (MCN_PRED) having informed the node on the existence of a multicast session, and the QoS level of the path from the session initiator up to that node via this predecessor. If a node receives an initiation packet for a known session which improves the QoS conditions substantially, the tables are updated and the packet is also forwarded. Hop count information in the packets is used to prevent loop formation. The session is closed by its initiator with a session destruction message (SES_DESTROY). Upon receiving it, all nodes clean their tables, whereas nodes forwarding multicast data also free their resources allocated to that session. A node receiving a session destruction packet forwards it if it has forwarded the corresponding initiation packet or is currently forwarding session data. Thus, receivers of a closed session are forced to leave the session.

2) Membership Management

A node directly joins a session if it is already forwarding data to other nodes in that session. Otherwise, it has to issue a join request. When a node broadcasts a join request packet (JOIN_REQ) containing the session information, upstream neighbors which are aware of the session take the request into consideration. The QoS conditions are checked at each node to make sure that the current situation on resource availability allows the acceptance of a new session. Ad hoc networks are highly dynamic, and available resources may change considerably after the arrival of the QoS conditions with the session initiation packet. As explained in the following section, greeting messages are exchanged between neighbors to update nodes on the bandwidth usage in a neighborhood. However, nodes do not send session status update messages to avoid excessive control traffic. Instead, QoS is announced once by the session initiation packet and is updated only on demand. Intermediate nodes maintain a temporary request table (TBL_REQUEST) to keep track of the requests and replies they have forwarded and prevent false or duplicate packet processing.

A forwarded request eventually reaches some nodes which are already members of that session and can directly send a reply (JOIN_REP). Members of a session are the initiator, the forwarders, and the receivers. Downstream nodes, having initiated or forwarded join requests, thus waiting for replies, aggregate the replies they receive and forward only the reply offering the best QoS conditions towards the requester. The originator of the join request selects the one with the best QoS conditions among possibly several replies it receives. It changes its status from predecessor to receiver (MCN_RCV) and sends a reserve message (JOIN_RES) to the selected node which has forwarded the reply.

Eventually, the reserve message reaches the originator of the reply, which can be the session initiator with some or without any members, a forwarder with one or more successors, or a receiver. If the replier is the session initiator and this is its first member, it changes its status from initiator to server (MCN_SRV). If it is a receiver, it becomes a forwarder. In both cases, the replier records its successor in its member table and reserves resources to start sending multicast data. If the node is an active server or forwarder, it must have already reserved resources. It only adds the new member to its member table and continues sending the regular multicast data. At the end of each successful request-reply-reserve process, intermediate nodes have enough routing and membership data available to take part in the multicast data forwarding task.

A node needs to inform its forwarder on the multicast graph upon leaving a session. After receiving a quit notification (SES_LEAVE), the forwarding node deletes the leaving member from its member table. If this has been its only successor in that session, the forwarding node checks its own status regarding the session. If the node itself is also a receiver, it updates its status. Otherwise, it frees resources and notifies its forwarder of its own leave.

3) Neighborhood Maintenance

Each node periodically broadcasts greeting messages (NBR_HELLO), informing its neighbors on its existence and bandwidth usage, which is determined by the QoS classes of the sessions being served or forwarded by that node. Each node keeps the information it receives with these messages in its neighborhood table (TBL_NEIGHBOUR). This table is used to calculate the total bandwidth currently allocated to multicast sessions in the neighborhood, which is the sum of all used capacities of the neighboring nodes for that timeframe. Neighborhood tables also help nodes with their decisions on packet forwarding. If a node does not receive any greeting messages from a neighbor for a while, it considers that neighbor lost. Lost neighbors are deleted from neighborhood, session and membership tables.

Due to the broadcasting nature of the wireless medium, the available bandwidth of a node is the residual capacity in its neighborhood. A node can only use the remaining capacity not used by itself and its immediate neighbors. This approach to residual bandwidth calculation has some flaws since it does not consider bandwidth usage beyond direct neighbors. Thus, it is susceptible to hidden terminal problems and therefore needs further research. Nevertheless, it provides a sufficient method to measure bandwidth availability within a neighborhood.

IV.CONCLUSION

The changing expectations of wireless users towards high quality, group-oriented, mobile multimedia communication forces today's networks to support ad hoc QoS multicasting. AQM and cross layer framework improves multicasting efficiency through resource management on a neighborhood basis. It has a simple and flat structure, avoiding complicated topologies such as hierarchical or clustered networks. However, it is possible to adapt AQM to a clustered network to scale with the network size. Intra-cluster multicast sessions can be handled by AQM, whereas inter-cluster communication can be managed by a higher-layer, hierarchical version of the same protocol, providing the network with QoS features. It is not a realistic assumption that a mobile network can afford a pure on demand scheme if it has to support QoS. AQM proposes a hybrid method in terms of multicast routing with table-driven session management and on demand verification of QoS information upon the initialization of a join process.

AQM is compared to a non-QoS scheme with regard to session efficiency. By applying QoS restrictions to the ad hoc network, AQM achieves better satisfaction grades and improves the multicasting efficiency for sessions. Without a QoS scheme, users experience difficulties in getting the service they demand as the network population grows and bandwidth requirements increase. AQM proves that QoS is essential for and applicable to ad hoc multimedia networks.

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