Performance Optimization in Ad-hoc Networks

Swati Jaiswal, Satya Prakash, Neeraj Gupta, Devendra Rewadikar

Abstract — A mobile ad-hoc network (MANET) is a collection of mobile nodes which communicate over radio. Mobile ad hoc networks are infrastructure-free, pervasive, ubiquitous and without any centralized authority. These kind of networks are very flexible, thus they do not require any existing infrastructure or central administration. Therefore, mobile ad-hoc networks are suitable for temporary communication links. The biggest challenge in this kind of networks is to fulfill Quality of service parameters. Quality of services for a network is measured in terms of guaranteed amount of data which a network transfers from one place to another in a given time slot. In this paper, I will focus on quality of service issues in mobile ad-hoc networks, for this we use Qos routing protocol to sort out the problem of dynamically varying network topology. This paper also provides you the information about the real time traffic support in ad-hoc networks. Quality of Service support for Mobile Ad-hoc Networks is a challenging task due to dynamic topology &limited resource. The main purpose of QoS routing is to find a feasible path that has sufficient resources to satisfy the constraints. This paper surveys the prevailing mobile ad hoc network QoS parameters with its recent solutions.

Index Terms — MANET, QoS , Topology, Ad hoc

I. INTRODUCTION

A mobile ad-hoc network is an autonomous system of mobile nodes connected by wireless links forming a short, live, on-the-fly network. The ad hoc wireless network is a special case of wireless network where there is no fixed Backbone infrastructure. Due to this property, wireless ad hoc networks can be flexible and rapidly deployed, but also poses significant technical challenges [1]. Numerous challenges include effective routing, medium access, power management, security and quality of service (QoS) issues [2]. As the nodes communicate over wireless links, each node should fight against the highly erratic nature of wireless channels as well as interference from other transmitting nodes. These factors make it a challenging problem to maximize data throughput while meeting user-required QoS in wireless ad hoc networks. Recently, power control has been studied as a useful means to improve wireless link quality and increase data throughput [3].

Nodes in mobile ad-hoc networks generally operate on low power battery devices. Due to the limited transmission range of wireless interfaces, the communication traffic has to be relayed over several intermediate nodes to enable the communication between two nodes. Therefore, this kind of networks is also called mobile multi-hop ad-hoc networks. These nodes can function both as hosts and as routers. As a host, nodes function as a source and as a destination in the network. On the other hand, as a router, nodes act as intermediate bridges between the source and the destination giving store-and-forward services to all the neighbouring nodes in the network. In a mobile ad-hoc network, nodes are free to move randomly and can organize themselves in arbitrary fashions, resulting in frequent and unpredictable changes in the network topology.

In a mobile ad-hoc network, a number of different routes with various levels of node capacity and power may be available for a source to transmit data to the destination. As a result, not all routes are capable of providing the same level of quality of service that can meet the requirements of mobile users. Quality of Service (QoS) is usually defined as a set of service requirements that need to be met by the network while transporting a packet stream from source to destination. Quality of service is more difficult to achieve in ad hoc networks than in their wired counterparts, because the wireless bandwidth is shared among adjacent nodes and the network topology changes unpredictably as the nodes move. This requires extensive collaboration between the nodes, both to establish the route and to secure the resources necessary to provide the QoS. The network is expected to guarantee a set of measurable specified service attributes to the user in terms of end-to-end delay, bandwidth, probability of packet loss, energy and delay variance (jitter).

The goal of Qos provisioning is to achieve more deterministic network behaviour, so that information carried out by the network can be better delivered and network resources can be better utilized. A network can offer numbers of services to the users. The QoS metrics can be classified as additive, concave, and multiplicative. The discovered routes can only be considered if they provide guarantees of the QoS parameters, such as bandwidth required by the application. Let m(u, v) be the performance metric for the link (u, v) connecting node u to node v, and path (u, u1 , u2 ,..., uk , v) a sequence of links for the path from u to v. Three types of constraints on the path can be identified [3]:

A. Additive constraints:

A constraint is additive if

\[ m(u, v) = m(u, u1 ) + m(u1 , u2 ) + ... + m(uk , v). \]

For example, the end-to-end delay (u, v) is an additive constraint because it consists of the summation of delays for each link along the path.

B. Multiplicative constraint:

A constraint is multiplicative if

\[ m(u, v) = m(u, u1 ) \times m(u1 , u2 ) \times ... \times m(uk , v). \]

The probability of a packet prob (u, v), sent from a node u to reach a node v, is multiplicative, because it is the product of individual probabilities along the path.
C. Concave constraint:
A constraint is concave if
\[ m(u, v) = \min \{ m(u, u_1), m(u_1, u_2), ..., m(u_k, v) \}. \]
The bandwidth \( bw(u, v) \) requirement for a path between node \( u \) and \( v \) is concave. This is due to the fact that it consists of the minimum bandwidth between the links along the path.

Bandwidth and energy are concave metric, while cost, delay, and jitter are additive metrics. The information flow is carried out through request response procedures. The user sends request for the services, after receiving a service request, the first task is to find out a suitable loop-free path from the source to the destination that will have the necessary resources available to meet the requirements of QoS. This process is known as QoS routing. This paper contains some issues and challenges occurred in ad-hoc network during transmission like dynamic changes of network topology, limited resource availability and imprecise state information etc. Some solutions to the problem are given which helps in efficient communication. The paper is organized as follows: In section I we briefly describe the dynamic changes of network topology with their solution, section II covers the problem of limited resource availability, and section III solves the problem of imprecise state information.

II. DYNAMICALLY VARYING TOPOLOGY

As we all know that the nodes in ad-hoc networks do not have any restrictions on mobility, the network topology changes dynamically. The topology of the network changes dynamically as mobile nodes join or depart the network or radio links between nodes become unusable. This is a complex and difficult issue because of the dynamic nature of the network topology and generally imprecise network state information. The QoS requirements arise at the application layer in the form of restrictions on values of certain QoS metrics. The most commonly studied QoS metrics are bandwidth, delay and jitter. Bandwidth is the QoS metric that has received the most attention in the QoS literature. The QoS requirements are typically met by soft assurances rather than hard guarantees from the network. Most mechanisms are designed for providing relative assurances rather than absolute assurances.

The nodes in wireless network are free to move anywhere, and in area. Due to this the QoS sessions suffers frequent path breaks, thereby requiring such sessions to be re-established over the new path [10][11]. The delay incurred in re-establishing a session may cause maximum delay, minimum bandwidth and message loss which is not acceptable for applications that have strict QoS requirements. Such kind of problems degrades the performance of wireless ad-hoc network. The maximum delay time spread is the total time interval during which the signal reaches destination.

We propose to use UDP for communication. Hence, it is important to handle message losses as they can lead to duplicate IP address assignments. In this protocol, message losses are handled using timers and confirmation messages. Timers are used to ensure that the protocol is deadlock-free and works correctly in the event of message losses or node mobility. Confirmation messages are provided by the use of acknowledgement procedure that ensures that data has been received successfully. In MANETs, node mobility often results in frequent topology changes, which presents a significant challenge when designing QoS routing protocols. High node mobility can make satisfying QoS requirements unachievable. Consequently, it is required that the network be combinatorial stable in order to achieve QoS support [2]. This means that the changes in network topology must be slow enough within a particular time window to allow the topology updates to propagate successfully as required in the network.

QoS support of MANETs requires availability of network state. However, due to mobility and constant topology changes, the cost of maintenance of the network state is expensive especially in large networks. In [4] the imprecise network state model is introduced. It provides a cost-effective method for providing QoS support based on imprecise network information. The majority of QoS routing protocols are reservation-based. Probe messages are sent through the network from the source to the destination in order to discover and reserve paths which satisfy a given QoS requirement. Due to the dynamic nature of the network, reserved QoS paths must be reaffirmed periodically by sending special control packets, called refreshers, along the path.

On the other hand, QoS adaptation introduces [11] the concept of dynamic QoS, where a range of QoS values, rather than a single point, is allowed to be specified by the application. This must be done through appropriate, flexible, and simple user interface which effectively maps the perceptual parameters into QoS constraints. The use of dynamic QoS provides more flexibility to the system and gives the network the ability to adjust the allocation according to the current availability of the required resources. The higher networking layers can then adapt to these changes. This adaptation can be achieved in different ways at the different layers of the architecture. The physical layer, for example, can adjust the transmission power to react to more frequent bit errors. The link layer can incorporate more error control (detection and correction) codes as well as automatic repeat requests (ARQ) in reaction to changes in link error rates.

At the other end of the OSI stack, namely the application layer (multimedia video conferencing for example), different compression techniques with varying compression ratios can be employed to adapt the application to the changes in bandwidth, delay, and error rates without drastically compromising the perceived audio and video quality. As more resources become available, the quality of the presentation can then be adjusted to take advantage of the added resources. In addition to compression algorithms, other techniques are being investigated at this level including layered encoding, rate shaping, adaptive error control, and bandwidth smoothing.
It is important at this point to state that the QoS model defines the general approach, goals, and framework for providing QoS support in a network. So, as to improve the performance of ad-hoc network we use a QoS protocol that is ad-hoc on-demand distance vector (AODV) routing protocol [2] [10] which is reactive routing to provide support in ad-hoc wireless networks. AODV performance is depends on certain measures. QoS parameter reservation is more difficult in proactive than reactive protocols. In the proactive case, the routing protocol periodically updates the reach ability information in the nodes routing tables. Thereby a route is immediately available when needed. Proactive protocols use an adaptive system of routing based on periodic exchange of control messages. Measures which define the actual transmission of data through networks. AODV protocol maintains a routing table which contains no. Of entries i.e. it stores information about the maximum delay incurred during transmission, minimum bandwidth available, list of different sources which are requested for delay guarantees and list of sources requesting bandwidth. These fields help in routing the packet at correct destination at minimum time.

The maximum delay extension field is interpreted differently for Route Request and Route Reply messages. The Route Request message indicates the maximum time required for the transmission of packet from source to destination node. Where Route Reply message indicates the time required for reaching a Route Reply message from destination to source node. Using this concept the source node finds a path from source node to the destination node. Before forwarding the Route Request, an intermediate node compares its traversal time with the delay indicated in the maximum delay field. If the delay is less than the traversal time than discard that Route Request message otherwise subtracts traversal time with the delay value of the extension field. On the other hand the destination node returns the Route Reply message with the maximum extension field set to zero. When the message traverse from different intermediate nodes each node record the delay value in the routing table of its own.

The second field of AODV protocol [10] is the minimum bandwidth which is required for the transmission of the message from source to destination. In this field the Route Request message requires the minimum bandwidth for transfer the message from source to destination and Route Reply indicates the minimum bandwidth required from destination to source. Using this field the source node finds out the path from source node to destination node which requires minimum bandwidth for the transmission. Before forwarding the Route Request message an intermediate node compares its bandwidth with the bandwidth available in the bandwidth field. If the requested amount of bandwidth is not available, the node discard the Route Request [10] message otherwise the node processes the Route Request message. The Route Reply message in response to the Route Request with the bandwidth field set to a large value returns by a destination to source node. This value is also stored in the routing table for the corresponding destination with its minimum bandwidth. These entries help the AODV protocol to improve the QoS performance.

The goal of QoS provisioning is to achieve more deterministic network behaviour, so that information carried out by the network can be better delivered and network resources can be efficiently utilized. Consider a scenario in which user sends a service request for the transmission. After accepting a service request, the network has to ensure that the service requirements of the user have met throughout the duration of the flow. After receiving the request from the user, the first step is to find out a suitable loop-free path from the source to the destination that will have the necessary resource available to meet the requirements of the desired service. This process of providing the best effort network facility is called as QoS routing. After finding a suitable path, a resource reservation protocol is employed to reserve the necessary resources along that particular path. For example, consider the attributes of the link that may be denoted as (bw, d), where bw denotes the available bandwidth and d denotes the delay in the transmission of the packets. Now the QoS routing searches for a path that has sufficient bandwidth to meet the requirement of the flow. Here seven paths are available between 1 to 7 nodes. The end-to-end bandwidth of a path is equal to the minimum bandwidth among all the links of a path. And the end-to-end delay is equal to the sum of the delays in all the links of a path. The given table specifies the available bandwidth, delay incurred and no. of hop count from source to destination.

Table 1: Path reservation table

<table>
<thead>
<tr>
<th>S. no.</th>
<th>Path available</th>
<th>End-to-end bw</th>
<th>Hop count</th>
<th>End-to-end delay introduces</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1→5→7</td>
<td>3</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>2</td>
<td>1→4→5→7</td>
<td>3</td>
<td>3</td>
<td>14</td>
</tr>
<tr>
<td>3</td>
<td>1→2→5→7</td>
<td>4</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>1→2→5→6→7</td>
<td>3</td>
<td>4</td>
<td>22</td>
</tr>
<tr>
<td>5</td>
<td>1→4→5→6→7</td>
<td>2</td>
<td>4</td>
<td>21</td>
</tr>
<tr>
<td>6</td>
<td>1→2→3→6→7</td>
<td>3</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td>7</td>
<td>1→2→3→6→5→7</td>
<td>3</td>
<td>5</td>
<td>23</td>
</tr>
</tbody>
</table>

Table 1: Path reservation table
This table indicates different paths from source to destination out of which path 1-2-5-7 will be selected by QoS routing because this path satisfy the condition of 4 mbps bandwidth for the flow of requested service. The number of hop count to this path is 3 which is again an efficient path for the packet flow.

One more important concern to maintain efficient quality of service parameters are the lost messages due to the increase in node traversal time or decrease in the link capacity. These measures affect the performance of the network. To solve such problems, we use to forward the lost messages to all the sources which are potentially affected by the change in the QoS parameter.

### III. IMPRECISE STATE INFORMATION HANDLED THROUGH GLOBAL APPROACH

The state information is inherently imprecise due to dynamic network topology and channel characteristics. Hence routing decisions may not be accurate, resulting in some of the real-time problems. The following end-to-end state information is required to be maintained [2][11] at every node for every possible destination. The information is updated periodically by a distance-vector protocol for mobile computers. Readers are referred to [1] for a detailed description of such a protocol.

A. **Delay:**

\[ D_i(t) \] keeps the minimum end-to-end delay from i to t, i.e., the delay of the least-delay path.

B. **Cost:**

\[ C_i(t) \] keeps the least end-to-end cost from i to t, i.e., the cost of the least-cost path.

C. **Bandwidth:**

\[ B_i(t) \] keeps the maximum end-to-end bandwidth from i to t, i.e., the bandwidth of the largest bandwidth path.

The previous information is inherently imprecise in an ad-hoc network because the network state and topology may change at any time. The imprecision model proposed by Guerin and Orda for wire line networks is based on probability distribution functions. For instance, every node maintains, for every link, of link having a delay of units. This the probability model is not suitable for an ad hoc network where links may be short-lived [7] and do not give enough time for collecting the Probability distribution. In contrast, we propose a simple imprecision model that does not rely on the topology and can be easily implemented. Two additional state variables are required

A. **Delay variation:**

\[ dD_i(t) \] keeps the estimated maximum before the next update. That is, based change of on the recent state history, the actual minimum end-to-end delay from to is expected to be between and in the next update period.

B. **Bandwidth variation:**

\[ dB_i(t) \] keeps the estimated maximum Bi(t) before the next update.

So from the given metrics we can calculate the new metric from the previous given values

\[ \text{New} = a \times \text{derivative old value} + (1-a) \times \text{new-old} \]

It should also be noted that our imprecision model and routing algorithms do not intend to cover every possible situation, which is impractical in an ad hoc network.
Some stateless and stateful approaches are used for defining imprecise state information. First we talk about stateful approach; in this approach each node maintains either local state information or global state information. The state information contains the information about the topology used and the flow specific information. Another approach is used called as stateless approach which does not contain any flow specific and link specific information. Through this stateless approach we cannot avoid this imprecise state information. To avoid this problem global or local state information is maintained. For global or local state two types of cases are there, if global state information is available the source node uses a centralized routing algorithm to route packets to the destination. The overall performance of the routing algorithm depends solely on the accuracy of data stored in global state information. On the other hand if the source node or the mobile node maintains local state information the distributed routing algorithms are used which are more accurate. Hence the imprecise state information can be easily handled through these global or local states.

IV. LIMITED RESOURCE AVAILABILITY MANAGED BY SOFT-STATE RESERVATION

To cope with the unpredictable nature of this highly dynamic environment, wireless ad hoc networks need to be able to adapt to changes in resource availability (i.e., energy, bandwidth, processing power, network density, and topology changes) and overcome any unanticipated networking problems [2] while satisfying a wide range of application requirements. Meeting these requirements in such an environment is very challenging because the performance observed by users, devices, and routing paths selected through the network will continuously change in response to the time-varying network dynamics.

Maintaining the QOS of adaptive flows in mobile ad hoc networks is one of the most challenging aspects of the QOS framework. In wire line networks that support quality of service and state management, the route and the reservation between source-destination pairs remain fixed for the duration of a session.

This style of hard-state connection oriented communications (e.g., virtual circuit) guarantees quality of service for the duration of the session holding time. However, these techniques are not flexible enough in mobile ad hoc networks, where the path and reservation need to dynamically respond to topology changes in a timely manner. We believe that a soft-state approach to state management at intermediate routing nodes is suitable for the management of reservations in mobile ad hoc networks. Such an approach models the transient nature of network reservations, which have to be responsive to fast time-scale wireless dynamics, moderate time-scale mobility changes and longer time scale session “holding times.”

Based on the work by Clark, soft-state relies on the fact that a source sends data packets along an existing path. If a data packet arrives at a mobile router and no reservation exists then admission control and resource reservations attempt to establish soft-state.

Subsequent reception of data packets (associated with a reservation) at that router are used to refresh the existing soft-state reservation. This is called a “soft-connection” when considered on an end-to-end basis and in relation to the virtual circuit hard-state model. When an intermediate node receives a data packet that has an existing reservation it reconfirms the reservation over the next interval. Therefore the holding time for a soft connection is based on the soft-state timer interval and not based on session duration holding time. If a new packet is not received within the soft-state timer interval then resources are released and flow states removed in a fully decentralized manner. Due to the problems of hard state i.e. Control overhead the soft state reservation can be implemented successfully.

Based on the work of Seoung-Bum Lee [7], Soft-state resource management is used to maintain reservations. The duration of soft-state timer has a major impact on the utilization of the network. Figure 2-15 shows the impact of soft-state times on network performance in terms of the number of reserved mode packets delivered. Reception of a reserved mode packet at the destination indicates that the packet is delivered with max-reserved or min-reserved assurance. Reception of a packet degraded implies that the packet has been delivered without such guarantees. Therefore the percentages of reserved and degraded packets received by destination nodes as a whole indicate the degree of service assurance that an network can support for different values of soft-state timers. As shown in Figure 2-15, the mobile soft-state timer value has an impact on the overall network performance. The ability to support adaptive services decreases as the soft-state timer [7] value increases. The percentage of delivered reserved packets decreases as mobile soft-state timer increases. The percentage of degraded packets increases as the soft-state timer value increases, as shown in Figure 2-15. Worst performance is observed when the soft-state timer value is set to 30 seconds. In contrast, the best performance is observed when mobile soft-state timer is set to 2 seconds.
We observed that 69% of the packets are delivered as reserved packets and 31% as best effort packets when the soft-state timer is set at 30 seconds. Support for QoS substantially improves with 88% of reserved packets being delivered to the receivers with a soft-state timer value of 2 seconds.

As the value of the soft-state timer gets smaller fewer resource lockups are observed and utilization increases. However, when the timer is set to a value smaller than 2 seconds the network experiences what we describe as “false restoration”. This occurs when a reservation is prematurely removed because of a small soft-state timer. False restorations occur when the timeout value is smaller than the inter-arrival time between two consecutive packets associated with a flow.

V. CONCLUSION

QoS in mobile ad-hoc network is a rapidly growing area of interest. This is due to the interest in rising popularity and necessity in multimedia applications and efficient data transfer. In this paper we tried to analyze and overcome the problems that arise in ad-hoc network to maintain QoS parameters. For overcoming the problem of dynamically changing network topology we use UDP protocol of OSI model and AODV routing protocol. AODV performance depends on certain measures. Measures which define the actual transmission of data through networks. AODV protocol maintains a routing table which contains no. Of entries i.e. it stores information about the maximum delay incurred during transmission, minimum bandwidth available, list of different sources which are requested for delay guarantees and list of sources requesting bandwidth. These fields help in routing the packet at correct destination at minimum time. For providing resources to the nodes we use soft-state reservation system. Soft-state reservation system allows the efficient allocation of resources to the nodes in the network. One of the most important point about the network i.e. imprecise state information can be easily handled through global state information system. Much more work has to be done in future before providing this form into public areas.

REFERENCES

[1] Zenalipour- Yazti Demetrios,”A Glance of Quality of services in Mobile Ad-hoc Networks,” in proc of University of California-Riverside CA 92507, USA.


[3] Imad Jawhar and Jie Wu,”Quality of Service Routing in Mobile Ad Hoc Networks,” Department of Computer Science and Engineering Florida Atlantic University, Boca Raton, FL 33431
