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Routing in Ad-hoc Network with Quality of service

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Abstract: An Adhoc network is formed by mobile nodes with wireless interfaces that communicate with each other without a centralized control or infrastructure. Sometimes, Adhoc network's performance degrades due to the presence of malicious nodes. In Conventional routing, protocols use minimum hop count or shortest path as the main metric for path selection. However, networks that require high Quality of Service (QoS) needs to consider several criteria that could affect the quality of the chosen path in packet forwarding process. Quality of service is more difficult to guarantee in ad hoc networks than in most other type of networks, mainly due to node mobility, multihop communications, contention for channel access and a lack of central coordination. This requires extensive collaboration between the nodes, both to establish the route and to secure the resources necessary to provide the QoS. In this paper, we present an overview of concept of QoS and its related issues. Also how QoS is considered at various layers. We include an overview of QoS routing and also its metrics found in the literature. Various characteristics of existing QoS routing protocols are also studied and compared. Also, we present a comparative analysis of various quality of service routing protocols of mobile ad hoc network.

Keywords: MAC***, QoS, MRP, CEDAR, OLSR***

I. Introduction

Mobile Ad hoc networks [MANETs] are rapidly evolving as an important area of wireless technology. These networks are infrastructure less and wireless in which there are several routers which are free to move arbitrarily and perform management of routes [1].

MANETs have characteristics that network topology changes very rapidly and unpredictably in which many mobile nodes moves to and from a wireless network without any fixed access point where routers and hosts move. If mobile nodes are within the communication range of each other, then source node can send message to the destination node, otherwise it can send through intermediate node. With the popularity of ad hoc networks, many routing protocols have been designed for route discovery and route maintenance. They are mostly designed for best effort transmission without any guarantee of quality of transmissions.

MANETs have three distinct characteristics [2]: dynamic topologies, bandwidth constraints, energy-constraints. The first characteristic allows the nodes to move arbitrarily and unpredictably causing possible failures in links or routes. The second concerns the wireless links typically having a significantly lower capacity than their wired counterparts. Moreover due to contention from multiple users, fading, noise and interference, the capacity is highly time variable. Third, the nodes are usually battery-operated; therefore, management of the power is needed.

Quality of Service (QoS) in ad hoc networks is more required because most of real time applications are implemented on the network. Quality of service is more difficult to achieve in ad hoc networks rather than in wired networks.QOS is defined as a set of service requirements to be met by the network while transmitting a packet from source to destination. Intrinsic to the notion of QOS is an agreement or a guarantee by the network to provide a set of measurable pre-specified service attributes to the user.

By considering QoS, in terms of data rate and delay, it will help to ensure the quality of the transmission of real time applications. The resource limitations and variability further add to the need for QoS provisioning in such networks. So the purpose of the study is to manage an adhoc network topology that always change and answer the problem of disconnected route caused by the level of mobility of the adhoc node that cannot be predicted.

II. Routing In Adhoc Networks

Adhoc network's routing protocols are divided into three main categories i.e. proactive, reactive and hybrid routing protocols. Each category has a number of protocols.

Proactive routing protocol maintains regular and up to date routing information about each node in the network by propagating route updation at fixed time intervals throughout the network, when there is a change in network topology. As the routing information is usually maintained in tables, so these protocols are also called table-driven protocols e.g. QOLSR.

Reactive routing protocols establish the route to a destination only when there is a demand for it, so these protocols are also called on demand protocols e.g. MRP, GAMAN. When a source wants to send message to a destination, it uses the route discovery mechanisms to find the path to the destinations by initiating route request. When a route is established, it

remains valid till the destination is reachable or when it is expired. Hybrid routing protocols are the combination of both proactive and reactive routing protocols e.g. PLBQR, CEDAR.
Proactive and reactive algorithms are used to route packets. The route is established with proactive routes and uses reactive flooding for new mobile nodes. These routing protocols are designed either to minimize the data traffic in the network or to minimize the average hops for delivering a packet. They are designed without considering QoS. When QoS is considered, some protocols may be unsatisfactory or impractical due to the lack of resources and the excessive computation overhead.

III. QoS and Associated Issues

Some of factors that influence QoS of the network include:

1. Throughput of Network: Represents the total number of bits (in bits/sec) forwarded from network layers to higher layers in all nodes of the network.

2. Retransmission Attempts: Total number of retransmission attempts by all MACs in the network until either packet is successfully transmitted or it is discarded as a result of searching short or long retry limit.

3. Data Dropped: Data dropped due to unavailability of access to medium.

4. Medium Access Delay: It includes total of queuing and contention delays of the data.

When we provide QoS in adhoc networks, computational and communicational cost will be increased. It means, more time to setup a connection and maintains information per connection is needed. QoS support in adhoc network includes issues at the application layer, transport layer, network layer, MAC layer and physical layer of the network infrastructure [3].
In Mobile adhoc networks, there are several unique issues and difficulties that do not apply to the traditionally wired infrastructure. These issues include features and consequences. Examples of features include unpredictable link properties, dynamic nature, and limited battery life, whereas hidden and exposed terminal problems, route maintenance, and security can be categorized as consequences.
These are itemized as follows.

1. Unpredictable link properties: Wireless media is very unpredictable. Packet collision is intrinsic to wireless network. Signal propagation faces difficulties such as signal fading, interference, and multipath cancellation. All these properties make measures such as bandwidth and delay of a wireless link unpredictable.

2. Dynamic nature: Mobility of the nodes creates a dynamic network topology. Links will be dynamically formed when two nodes come into the transmission range of each other and are torn down when they move out of range.

3. Limited battery life: Mobile devices generally depend on finite battery sources. Resource allocation for QoS provisioning must consider residual battery power and rate of battery consumption corresponding to resource utilization. Thus, all the techniques for QoS provisioning should be power-aware and power-efficient.

4. Hidden and Exposed Terminal Problems: In a MAC layer with the traditional carrier sense multiple access (CSMA) protocol, multihop packet relaying introduces the “hidden terminal" and “exposed terminal" problems. The hidden terminal problem happens when signals of two nodes, say X and Y, that are out of each other's transmission ranges collide at a common receiver, say node Z. With the same nodal configuration, an exposed terminal problem will result from a scenario where node Y attempts to transmit data (to someone other than X or Z) while node Z is transmitting to node X. In such a case, node Y is exposed to the transmission range of node Z and thus defers its transmission even though it would not interfere with the reception at node X.

5. Route maintenance: The dynamic nature of the network topology and the changing behaviour of the communication medium make the precise maintenance of network state information very difficult. Thus, the routing algorithms in adhoc networks have to operate with inherently imprecise information. Furthermore, in ad hoc networking environments, nodes can join or leave at any time. The established routing paths may be broken even during the process of data transfer. Thus, the need arises for maintenance and reconstruction of routing paths with minimal overhead and delay. QoS routing would require reservation of resources at the routers i.e. intermediate nodes. However, with the changes in topology the intermediate nodes also change, and new paths are created. Thus, reservation maintenance with updates in the routing path becomes cumbersome.

6. Security: Security can be considered a QoS attribute. Without adequate security, unauthorized access and usage may violate QoS negotiations. The nature of broadcasts in adhoc networks potentially results in more security exposure. The physical medium of communication is inherently insecure; so, there is a need to design security-aware routing algorithms.

IV. QoS in Different Layers

QoS of a network can be considered different in different layers.

QoS considered in physical layer means the quality in terms of transmission performance. For example, through transmission power control both the stations that are near the sender or far away from the sender could hear the signal clearly with different transmission power. Power control is used both to ensure the quality of reception and to optimize the capacity.

QoS considered in MAC layer is also important. It could provide high probability of access with low delay when stations with higher user priority want to access the wireless medium. QoS considered in the routing layer aims to find a route which provides the required quality [4]. The metric which helps to choose the route is not only the number of needed hops along the route but also some other metrics like maximum delay and minimum data rate are also needed.

V. QoS Routing and Its Metrics

In Ad hoc networks, due to the interactions with the MAC layer, the performance in terms of throughput and end-to-end delay often degrades significantly, which can be attributed to hidden node, exposed node and control packet overhead. These problems cause throughput instability, unfairness, and dependence on the number of nodes, size of the area, and the length of the packets. These in turn affect the quality of service at the application layer level.

This is achieved by using some mechanism such as QoS routing to find the best route which satisfies these requirements in the best way. QoS routing requires not only finding a route from a source to a destination, but a route that satisfies the end-to-end QoS requirement, often given in terms of bandwidth, delay or loss probability.

QoS routing usually involves two tasks: collecting and maintaining up-to-date state information about the network and finding feasible paths for a connection based on its QoS requirements [5]. To support QoS, a service can be characterized by a set of measurable pre-specified service requirements such as minimum bandwidth, maximum delay, maximum delay variance and maximum packet loss rate.

QoS routing could have two added cost factors .One is computational cost and other is protocol overhead [6]. Computational cost comes from the more frequent path selection computations, as besides maintaining the source-destination connection, computations are also needed to satisfy the QoS request. Additional protocol overhead comes from the need to distribute the updated link state information. The trade-off between the QoS performance the QoS routing protocol achieves and the additional cost it introduces should be carefully observed.

QoS routing metrics are base parameters of quality for a network. QoS parameters include bandwidth, delay, jitter, security, network availability, and battery life and packet loss. End-to-end delay is the time between the arrival of a packet and its successful delivery to the receiver. Another metric, access delay, is the time between packet arrival and packet transmission by the sender. Jitter is the variation of delay and is an important metric for multimedia applications. Bandwidth is the measure of data transmission capacity and influences throughput, which is the amount of data successfully transmitted and received in unit time.

The QoS metrics could be concave or additive. Bandwidth is concave in the sense that end-to-end bandwidth is the minimum of all the links along the path. Delay and delay jitter are additive. The end-to-end delay (jitter) is the accumulation of all delays (jitters) of the links along the path. As different applications have different requirements, the services required by them and the associated QoS parameters differ from application to application. For example, in case of multimedia applications, bandwidth, delay and delay-jitter are the key QoS parameters, whereas military applications have stringent security requirements. The following is a sample of the metrics commonly used by applications to specify QoS requirement to the routing protocol.

1. Minimum Throughput– the desired application data throughput [7].
2. Maximum Delay – maximum tolerable end-to-end delay for data packets [8].
3. Maximum Delay jitter – difference between the upper bound on end-to-end delay and the absolute minimum delay [9].
4. Maximum Packet loss ratio - the acceptable percentage of total packets sent, which are not received by the final destination node [10].

VI. QoS Routing Protocols

The primary goal of the QoS routing is to determine a path from a source to the destination that satisfies the needs of the desired QoS. The QoS-aware path is determined within the constraints of band width, minimal search, distance, and traffic conditions. Since path selection is based on the desired QoS, the routing protocols can be termed QoS-aware. Numerous routing protocols have been proposed for finding QoS paths. In the following sections some of these QoS routing protocols [11] are described.

1. CEDAR: The Core Extraction Distributed Ad Hoc Routing (CEDAR) routing protocol for small to medium-sized ad hoc networks consisting of tens to hundreds of nodes. It dynamically establishes the core of the network, and then incrementally propagates the link states of stable high-bandwidth links to the core nodes. Route computation is on demand, and is performed by the core nodes using only local state.

2. Multipath Routing Protocol (MRP): MRP is a reactive on-demand routing protocol which extends DSR protocol to find multipath routing [17] coupled with bandwidth and reliability constraint. It consists of three phases: routing discovery, routing maintenance and traffic allocation. In routing discovery phase, the technique selects several multiple alternate paths which meet the QoS requirements and the ideal number of multipath routing is achieved to compromise between load balancing and network overhead. In routing maintenance phase, it can effectively deal with route failures similar to DSR.

3. Genetic Algorithm-Based QoS Routing Protocol for MANETS (GAMAN): A Genetic Algorithm-based source-routing Protocol [14] for adhoc networks uses end-to-end delay and transmission success rate for QoS metrics. Genetic Algorithms (GAs) may be employed for heuristically approximating an optimal solution to a problem.

4. Predictive Location-Based QoS Routing in Mobile Ad Hoc Networks (PLBQR): It is a location aware QoS [13] routing protocol in which a location-delay prediction scheme, based on a location-resource update technique has been performed. The location updates contain resource information pertaining to the node sending the update. This resource information for all nodes in the network and the location prediction mechanism are together used in the QoS routing decisions [18]. There are dynamic changes in topology and resource availability due to the high degree of mobility of nodes in the ad hoc network. Due to these changes, the topological and routing information used by current network techniques is rendered obsolete very quickly.

5. QoS Multicast Routing Protocol with Dynamic group topology (QMRPD): The QMRPD is a hybrid technique which attempts to significantly reduce the overhead of constructing a multicast tree with multiple QoS constraints. In QMRPD, a multicast group member can join or leave a multicast session dynamically, which should not disrupt the multicast tree. It satisfies the multiple QoS constraints and least cost's requirements. Its main objective is a multicast tree that optimizes a certain objective function (e.g., making effective use of network resources) with respect to performance-related constraints and design a multicast routing protocol with dynamic group topology. It attempts to minimize the overall cost of the tree. The dynamic group membership has been handled by this technique with less message processing overhead.

6. QoS Optimized Link State Routing (QOLSR): The Optimized Link State Routing (OLSR) protocol [15] is a proactive link state routing protocol for MANETs. One key idea is to reduce control overhead by reducing the number of broadcasts as compared with pure flooding mechanisms. The basic concept to support this idea in OLSR is the use of multipoint relays (MPRs) [15, 16]. MPRs refer to selected routers that can forward broadcast messages during the flooding process. To reduce the size of broadcast messages, every router declares only a small subset of all of its neighbours. This protocol is suitable for large and dense networks [15]. MPRs act as intermediate routers in route discovery procedures. Hence, the path discovered by OLSR may not be the shortest path. This is a potential disadvantage of OLSR. OLSR has three functions: packet forwarding, neighbour sensing, and topology discovery. Packet forwarding and neighbour sensing mechanisms provide routers with information about neighbours and offer an optimized way to flood messages in the OLSR network using MPRs. The neighbour sensing operation allows routers to diffuse local information to the whole network. Topology discovery is used to determine the topology of the entire network and calculate routing tables.

7. Ad hoc QoS on-demand routing (AQOR): This protocol uses limited flooding to discover the best route available in terms of smallest end-to-end delay with bandwidth guarantee. A route request packet includes both bandwidth and end-to-end delay constraints. Let Tm denote the delay constraint. If a node can satisfy both constraints, it will rebroadcast the request to the next hop and switch to explore status for a short period of 2Tm. If multiple request packets arrive at the destination, it will send back a reply packet along each of these routes. Intermediate nodes will only forward the reply, if they are still in explored state. However, the bandwidth reservation for each flow is only activated by the arrival of the first data packet from the source node. Delay is measured during route discovery. The route with the least delay is chosen by the source. No mechanism for connection tear-down is needed or integrated, since all reservations are only temporary. Timers are reset every time a route is used. So there is an upper time bound after which broken routes are detected.

Table 1: Comparative analysis of QoS routing protocols

Routing technique	Network architecture	Route discovery	Resource Reservation	Type of QoS guarantee	QoS metrics
CEDAR	Hierarchical	Proactive/ Reactive	Yes	Soft	Bandwidth
MRP	-do-	Reactive	-do-	-do-	Bandwidth
GAMAN	-do-	Reactive	-do-	-do-	Bounded delay, packet loss rate
PLBQR	Location prediction	Proactive/ Reactive	No	-do-	Delay, and Bandwidth

QMRPD	Hierarchical	Reactive	Yes	Pseudo-hard	Bandwidth,Delay, Delay-jitter and cost
QOLSR	-do-	Proactive	-do-	Soft	Throughput and Delay
AQOR	Flat	Reactive	-do-	-do-	Bandwidth, Delay

VII. Conclusion

In this paper we reviewed the basic concepts of routing in adhoc networks. Also we reviewed the concept of QoS and its associated issues. Then we found how QoS is considered in different layers of networks. After that we have given an overview of QoS routing and various metrics used to evaluate the performance of protocols. In end, we have explored existing QoS routing protocols and their comparative analysis table in order to expose the current trends of progress in this field and to identify the topics for further research. A lot of research has been done in this field. Still QoS will be proved as an important research area in adhoc networks in future communications. Several important research issues and open questions need to be addressed to make possible QoS support in adhoc networks. Route discovery, route maintenance and finding path having optimized cost are key issues of QoS routing that need to be explored in future.

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