CHAPTER 2

LITERATURE SURVEY

2.1 INTRODUCTION

Multicast routing in ad hoc networks is entirely different from routing found in traditional infrastructure networks. In order to understand better the importance of multi-constrained multicast routing and QoS issues in wireless ad hoc networks, the various mechanisms of multicast routing and QoS solutions are presented in this chapter. The taxonomy of multicast routing protocols, various QoS architectures and QoS parameters required to support multimedia applications are also discussed. The QoS constrained multicast routing protocols present in the current scenario and various multi-constraint path selection algorithms are also reviewed along with their basic operations. The benefits of software agents in multicast routing are also reviewed in this chapter.

2.1.1 Multicast Routing Techniques

The original techniques for multicasting were developed for wired networks and thus refer to routers, edge-routers and subnets. The same idea can be applied to ad-hoc networks where nodes take the responsibilities of routers. Chen and Wu (2003) classified the multicast methods into three basic categories in MANETs.

Flooding: A basic method is to simply flood the network. Every node receiving a message floods it to a list of neighbours other than the link on which it was received. A node keeps the information regarding the
received packets, thus duplicate packets, if any received by the node are discarded. Flooding is used as the preferred forwarding method in MANETs to increase the chance of a node receiving a packet. Some multicast routing protocols are based on limited flooding to decrease the control overhead.

**Proactive routing:** In the proactive approach paths are pre-computed to all possible destinations and this information is stored in the routing table. To maintain an up-to-date database, routing information is periodically distributed throughout the network. The advantage is that each mobile host has correct and up-to-date data. So, when a path is needed, it can be found directly in the memory and the links can be established quickly. Examples of this type of routing protocols are the Ad-hoc Multicast Routing protocol utilizing increasing ID numbers (AMRIS), Ad-hoc Multicast Routing (AMRoute), Core Assisted Mesh Protocol (CAMP) etc.

**Reactive routing:** In the reactive routing protocol, a path is searched to the destination only when it is needed. The idea is based on a query response phase mechanism or reactive multicast. In the query, a node explores the environment; once the query reaches the destination the response phase starts and establishes the path. The advantage is that routing tables in the memory are not updated continuously. Multicast Ad hoc On-Demand Vector (MAODV) protocol, Lightweight Adaptive Multicast (LAM) algorithm and Location Guided Tree (LGT) algorithm are a few typical reactive multicast routing protocols worth mentioning.
There are various issues on which the multicast routing protocols are classified into different categories.

### 2.1.2 Taxonomy of Multicast Routing Protocols

MANET protocols can be classified into different categories. One of the most popular methods to distinguish MANETs multicast protocols is based on how distribution paths among group members are constructed. In terms of this method, existing multicast routing protocols for MANETs can be divided into tree-based, mesh-based and hybrid multicast routing protocols as shown in Figure 2.1. In tree-based protocols, there exists only one possible path between a source-destination pair, whereas in mesh-based protocols more than one path may exist. Hybrid protocols combine the features of both tree-based and mesh-based multicast protocols (Viswanath, 2006, Jogendra Kumar 2012).

![Figure 2.1 Topology-based Classification of Multicast Routing Protocols](image-url)
Tree-based Multicast Routing Protocols: Tree-based multicast routing protocols can be further divided into source-rooted tree and shared-tree concepts according to the roots of the multicast trees. In a source-rooted tree multicast routing protocol, source nodes are roots of multicast trees and execute algorithm for tree construction and maintenance. This requires a source that must have the topology information and addresses of all its receivers in the multicast group. Therefore, the source-rooted tree protocols suffer from control traffic overhead when used for dynamic networks. Some of the popular source-rooted tree based protocols are Multicast Core-Extraction Distributed Ad hoc Routing (MCEDAR) (Sinha et al 1999), Associativity-Based Ad hoc Multicast (ABAM) (Toh et al 2000), Bandwidth Efficient Multicast Routing Protocol (BEMRP) (Ozaki et al 2001), and Multicast Routing Protocol Based on Zone Routing (MZRP) (Zhang and Jacob et al 2004).

In the shared-tree based approach, only one multicast tree is created for a multicast group which includes all the source nodes. This tree is rooted at a node referred as the core node. Each source uses this tree to initiate a multicast. The shared-tree based approach is less efficient in multicast, since it maintains more routing information. In addition, the traffic is aggregated on the shared tree rather than evenly distributed throughout the network, which results in low throughput. Moreover, multicast protocols using a shared-tree based approach require proper protocol operation to manage network partitions and mergers, since multicast group members may be separated into several disconnected partitions. Some of the popular shared-tree based protocols are MAODV, (Royer and Perkins 1999), AMRIS, (Wu et al 1999) and AMRoute (Xie et al 2002).

Mesh-based Multicast Routing Protocols: In a mesh-based multicast routing protocol, packets are distributed along mesh structures that
are a set of interconnected nodes. Route discovery and mesh building are accomplished in two ways: using broadcast mechanism to discover routes and by using core or central points for mesh building. The mesh-based protocols are robust when compared to the tree-based protocols in the high mobility environment as they provide redundant paths from source to destinations while forwarding data packets. To maintain the mesh topology however, it requires more control messages than the tree-based approach. Since multiple copies of the same packet are disseminated through the mesh, resulting in power inefficiency, network load and control overhead. The On-Demand Multicast Routing Protocol (ODMRP) (Lee et al 2002), CAMP (Garcia-Luna-Aceves and Madruga 1999), Protocol for Unified Multicasting through Announcements (PUMA) (Vaishampayan and Garcia-Luna-Aceves 1999) and Mesh-based Multicast Routing Protocol with Consolidated Query Packets (CQMP) (Dhillon and Ngo 2005) are mesh-based multicast routing protocols proposed for MANETs.

**Hybrid Multicast Routing Protocols:** Hybrid multicast routing protocols combines the advantages of both tree-based and mesh-based approaches. Hence, hybrid protocols address both efficiency and robustness. Using this scheme, it is possible to get multiple routing paths, and duplicate messages can reach a receiver through different paths. However, they may create non-optimal trees with nodes mobility. Adaptive Shared-Tree Multicast (ASTM) Routing (Ching-Chuan Chiang et al 1998), Efficient Hybrid Multicast Routing Protocol (EHMRP) (Biswas et al 2004) and On-demand Global Hosts for mobile Ad hoc Multicast services (OGHAM) (Hu et al 2006) are the instances for hybrid multicast routing protocols.

### 2.2 REVIEW OF MULTICAST ROUTING PROTOCOLS

A number of multicast routing protocols that have been designed specifically to address the characteristics of a MANET are examined in this
section. MAODV, AMRoute and AMRIS are examples of shared-tree protocols. The mesh based protocols such as CAMP and ODMRP are designed to increase the protocols’ robustness and to provide redundant paths.

2.2.1 Multicast Ad-hoc On-Demand Distance Vector Routing Protocol

Royer and Perkins (1999) proposed a Multicast operation of the Ad-hoc On demand Distance Vector Routing (MAODV) protocol. It is based on unicast Ad-hoc On demand Distance Vector (AODV) Routing protocol. The MAODV routing protocol discovers multicast routes on demand using a broadcast route-discovery mechanism. MAODV protocol is a classical example of minimum hop-based multicast routing protocols for MANETs.

Tree Formation Phase: In MAODV, a receiver node joins the multicast tree through a member node that lies on the minimum hop path to the source. A potential receiver wishing to join the multicast group broadcasts a Route-Request (RREQ) message as shown in Figure 2.2.

![MAODV Path Discovery](image)

Figure 2.2 MAODV Path Discovery
If a node receives the RREQ message and is not part of the multicast tree, the node broadcasts the message to its neighbours and also establishes the reverse path by storing the state information consisting of group address, requesting node-id and sender node-id in a temporary cache. If a node receiving the RREQ message is a member of the multicast tree and has not received the RREQ message earlier, the node waits to receive several RREQ messages and sends back a Route-Reply (RREP) message on the shortest path to the source. The member node also informs in the RREP message, the number of hops from itself to the source. The prospective receiver receives several RREP messages and selects the member node which lies on the shortest path to the source. The receiver node sends a Multicast Activation (MACT) message to the selected member node along the chosen route. The route from the source to receiver is set up when the member node and all the intermediate nodes in the chosen path update their multicast table with state information from the temporary cache.

**Tree Maintenance Phase:** Tree maintenance in MAODV is based on the Expanding Ring Search (ERS) approach, using the RREQ, RREP and MACT messages. The downstream node of a broken link is responsible for initiating ERS to issue a fresh RREQ for the group. This RREQ contains the hop count of the requesting node from the multicast source node and the last known sequence number for that group. It can be replied only by the member nodes whose recorded sequence number is greater than that indicated in the RREQ and whose hop distance to the source is smaller than the value indicated in the RREQ.

2.2.2 Ad hoc Multicast Routing Protocol utilizing Increasing ID-number

Wu et al (1999) has proposed Ad hoc Multicast Routing Protocol utilizing Increasing ID-numbers (AMRIS) protocol. It is a proactive shared
tree and is geared towards long-lived multicasting sessions so that route reconstruction is emphasized over route discovery. Each node is assigned an ID number that increases with the number of hops from the core. In order to reduce the number of join requests that propagate through the network, nodes only forward requests to lower numbered nodes. Each node on the tree periodically sends a one-hop broadcast containing its ID number as well as the ID numbers of its parent and children. When a link breaks, the higher numbered node is responsible for recovery actions. If it knows a neighbouring node that is a potential parent, it will send a join request to that potential parent node; otherwise it will broadcast a join request using an ERS technique. If the upstream node of the broken link has no other downstream children on the tree then it will request to be pruned from the tree.

### 2.2.3 Ad-hoc Multicast Routing

Xie et al (2002) proposed an Ad-hoc Multicasting Routing (AMRoute) and it is a shared-tree protocol. The senders and receivers are nodes of the tree and there are no relay nodes. If a tree contains a virtual link between node A and node B, AMRoute uses a unicast route between the two nodes. If the path from A to B changes, the multicast tree is not affected as long as some path between the two nodes exists. Dynamically chosen core nodes detect new members and manage the tree, but they are not central data distribution points as in other shared-tree protocols.

Tree creation is a two-step process. Each core node sends out a join request message to discover a close member node using an ERS. Initially each node is a core of its own single node tree. When another member node is discovered, the meshes are merged and one core is designated as the unique core of the new structure. Once the mesh has been formed, the core sends out a tree creation message to each of the group members that are adjacent to the core by a virtual link. Group members that receive the message remember the
incoming link and forward the tree creation message to other virtually adjacent group members. Transient loops can be formed in the tree as a result of node mobility, but are eliminated once the network becomes less dynamic.

### 2.2.4 Core Assisted Mesh Protocol

Garcia-Luna-Aceves and Madruga (1999) proposed a Core Assisted Mesh protocol (CAMP) which is a proactive or table driven multicast routing protocol based on shared meshes. It relies on a distance vector unicast routing protocol such as Wireless Routing Protocol (WRP) to determine paths to cores and to source nodes. Core nodes may be designated at the time the multicast group is set up or they may be dynamically chosen. The former assumes that a node can find out initial group information from a service similar to a Domain Name Server (DNS). The latter requires the core to periodically broadcast its own advertisement messages.

A node that wishes to join a group sends a join message towards its nearest core node. If a node that is a group member receives the join message on its way to the core, the member node returns an acknowledgement to the new member. If the join message gets all the way to the core, then the core returns the acknowledgement. Once a node can be attached to the mesh, it announces this fact to its neighbours. A neighbour to a node on the mesh records which neighbours are on the mesh in case it needs to attach itself later. This method reduces the number of join/acknowledge message pairs in the network. Another technique to reduce traffic is to allow nodes to join the group as a sender-only node in which data packets from other sources are not forwarded to the node.

Intermediate and destination nodes accept a data packet from any incoming link; receipt of a packet is not restricted to a particular incoming
link as in other multicast tree schemes. This feature allows a node to receive the data from different paths and increasing the robustness of the multicast.

2.2.5 On-Demand Multicast Routing Protocol

Lee et al (2002) proposed an On-Demand Multicast Routing Protocol (ODMRP), which is a reactive mesh-based multicast routing protocol and uses a forwarding group concept for multicast packet transmission. The source manages the group membership, establishes and updates the multicast routes on demand. There are two main phases of ODMRP; the request phase and the reply phase. When a multicast source has a packet to send but it has no routing and group membership information, it floods a Join Request packet to the entire network. Join Request packets are member-advertising packets with piggybacked data payload adapt to node movements by utilizing mobility prediction method; the protocol becomes more resilient to topology changes. Mobile nodes forward non-duplicated data packets if they are forwarding nodes. Since all forwarding nodes relay data, redundant paths are available for data packets delivery even if the primary path is disconnected. ODMRP also operates as an efficient unicast routing protocol, and does not need support from another underlying unicast routing protocol.

A quick comparison of multicast routing protocols in MANETs is presented in Table 2.1. On analyzing the existing popular multicast routing protocols, it is found that QoS is one of the main issues to be explored as it is not analyzed extensively. Moreover, control packet flooding is an important issue. Most of the existing multicast routing protocols do not take effort in reducing the flooding of control packets. Another important issue is routing metric. Most of the multicast routing protocols find the shortest path in terms of minimum number of hops, which is not sufficient to support multimedia communication.
Table 2.1 Comparison of Different Multicast Routing Protocols in MANETs

<table>
<thead>
<tr>
<th>Protocol / Parameter</th>
<th>MAODV</th>
<th>AMRoute</th>
<th>AMRIS</th>
<th>ODMRP</th>
<th>CAMP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multicast Topology</td>
<td>Shared-tree</td>
<td>Shared-tree</td>
<td>Shared-tree</td>
<td>Mesh</td>
<td>Mesh</td>
</tr>
<tr>
<td>Routing scheme</td>
<td>Reactive</td>
<td>Pro-active</td>
<td>Pro-active</td>
<td>Reactive</td>
<td>Reactive</td>
</tr>
<tr>
<td>Dependency on Unicast routing</td>
<td>Unicast-AODV</td>
<td>Dependent</td>
<td>Autonomous</td>
<td>Autonomous</td>
<td>Dependent</td>
</tr>
<tr>
<td>Initialization of multicast connectivity</td>
<td>Receiver initiated</td>
<td>Hybrid</td>
<td>Source initiated</td>
<td>Source initiated</td>
<td>Hybrid</td>
</tr>
<tr>
<td>Route acquisition latency</td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>QoS Support</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Control packet flooding</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Primary multicast routing metric</td>
<td>Minimum hop</td>
<td>Minimum hop</td>
<td>Minimum hop</td>
<td>Minimum hop</td>
<td>Link affinity</td>
</tr>
</tbody>
</table>

2.3 QoS IN MULTICAST ROUTING

Multicast routing with QoS constraints has become an important research issue in ad hoc networks due to the necessity of providing multimedia applications in such networks. These applications are typically delay-sensitive and have high bandwidth requirements. In addition to the common design goals of ordinary multicast routing protocols a QoS multicast routing protocol discusses the routing problem with one or more of the QoS constraints such as delay, jitter, bandwidth and packet loss (Mina Masoudifar, 2009). Traditional QoS protocols developed for wired networks cannot be easily adapted to wireless scenario due to the dynamic topology and error-prone nature of the wireless links. QoS multicast routing protocols include the issues of QoS architectures and mechanisms, QoS resource reservation mechanism and MAC sublayer supporting QoS guarantees.
2.3.1 QoS Architectures and Mechanisms

Considering the significance of QoS in Internet, the IETF has proposed many service models to meet the demand for QoS. Among them Integrated Services (IntServ), Differentiated Service (DiffServ) and Flexible QoS Model for MANETs (FQMM) are important to meet QoS guarantee. These architectures try to meet high service requirements but do not include QoS aware routing mechanisms.

Integrated Services: Braden et al (1994) developed the IntServ QoS model that offer guaranteed service and controlled load service in addition to best effort service. Guaranteed and controlled services meant specifically for applications requiring fixed delay bound and requiring reliable and enhanced best effort service respectively. The basic idea of IntServ model is to provide special QoS for the packet streams by reserving resources along the path in the network using Resource reSerVation Protocol (RSVP) (Braden et al 1997).

RSVP reserves the resources by sending a path message to the receiver specifying the characteristics of the traffic. The message is taken along the route identified by the routing protocol. The receiver responds with a reservation message along the same path. If the resources are available in the return path they will be reserved according to the QoS requirements. Otherwise the QoS cannot be met in the path due to non-availability of resources. Most of the protocols use this kind of reservation. QoS-ODMRP (Darehshoorzadeh et al 2007) and Cluster-based QoS Multicast Routing Protocol (CQMRP) (Nargunam et al 2008) are some such protocols.

The IntServ architecture has certain limitations such as the QoS is provided on perflow basis and hence the flow specific state information in the routers increases proportionally to the number of flows. As a result, the
storage and processing overhead in routers are more. The IntServ architecture is not scalable because of huge overhead in the routers.

**Differentiated Services**: Weiss (1998) proposed the Differential Service (DiffServ) architecture which avoids the problem of scalability by defining a small number of PerHop Behaviors (PHBs) at the boundary routers and associating a different DiffServ Code Point (DSCP) in the Internet Protocol header of packets belonging to each class of PHBs. The interior routers along the forwarding path use DSCP to differentiate between different QoS classes on per-hop basis. Thus, DiffServ is scalable but it does not guarantee services on end-to-end basis. This hinders DiffServ deployment in the Internet as well as in MANETs. The Diffserv model is used by the protocols like QoS service for Multicast in MANETs (QAMNet) (Tebbe et al 2006) and QoS Constrained Multicast Routing for Mobile Ad Hoc Networks (QoS-MAODV-2Lqos) (Latha et al 2009).

**Flexible QoS Model for MANETs**: Xiao et al (2009) designed a Flexible QoS Model for MANETs (FQMM), which tries to take the advantage of both the per-flow service granularity in IntServ and the service differentiation in DiffServ. This model defines three types of nodes: an ingress node which sends data, an interior node which forwards data to other nodes, and an egress node which is the destination. Obviously, each node may have multiple roles. FQMM selectively uses the per-flow QoS guarantees of IntServ for applications with high priority, and the service differentiation of DiffServ for applications with lower priorities. Some of the protocols based on FQMM are Cross-layer QoS Multicast Routing Protocol (E-QMR) (Saghir et al 2006) and Framework for QoS Multicast (FQM) (Saghir et al 2006).
2.3.2 QoS Resource Reservation Mechanisms

QoS resource reservation is one of the very important components of any QoS framework. A QoS framework is a complete system that provides required/promised services to each user or application. It is responsible for reserving resources at all intermediate nodes along the path from the source to the destination as requested by the QoS session. Reddy et al (2006) has classified the QoS resource reservation mechanisms into two categories, hard state and soft state reservation mechanisms.

**Hard State Reservation** scheme, reserve the resources at all intermediate nodes along the path from the source to the destination throughout the duration of the QoS session. If such a path is broken due to network dynamics, these reserved resources have to be explicitly released by a deallocation mechanism. Such a mechanism not only introduces additional control overhead, but may also fail to release resources completely in case a node previously belonging to the session becomes unreachable. Due to these problems soft state resource reservation mechanisms, which maintain reservations only for small time intervals are used.

The hard state schemes reserve resources explicitly and hence at high network loads, the call-blocking ratio will be high. CQMRP and Ad hoc QoS Multicasting (AQM) (Bur and Ersoy 2005) protocols use hard state for reserving resources.

**Soft State Reservation:** Most of the protocols in MANETs use soft state, since this is well suited for the dynamic topology and the dynamic membership of multicast groups. Soft state QoS is maintained with explicit and periodic set up and timer based tear down. These reservations get refreshed if packets belonging to the same flow are received before the timeout period. The soft state reservation timeout period can be equal to
packet inter-arrival time or a multiple of the packet inter-arrival time. If no data packets are received for the specified time interval, the resources are deallocated in a decentralized manner without incurring any additional control overhead. Thus no explicit tear down is required for a flow. The soft state schemes provide high call acceptance at a gracefully degraded fashion. Some of the protocols that follow the soft state reservation scheme are E-QMR, QoS-MAODV and FQM.

2.3.3 MAC Layer Supporting QoS Guarantees

The Media Access Control (MAC) protocol determines which node should transmit next on the broadcast channel when several nodes are competing for transmission on that channel (William Stallings 2009). Based on the interaction between the routing protocol and the MAC protocol, Reddy et al (2006) classified the QoS protocols into two categories, independent and dependent QoS protocols. In the independent QoS protocol, the network layer is not dependent on the MAC layer for QoS provisioning. The dependent QoS protocol requires the MAC layer to assist the routing protocol for QoS provisioning.

The dependent MAC protocol is divided into two categories, contention free and contended. In contention free MAC protocol, resources are identified first and then it reserves the resources. It basically uses the Time Division Multiple Access (TDMA) for slot allocations. These kinds of protocols can provide pseudo-hard QoS guarantee in MANET. The QoS guarantees provided are essentially hard, except for when channel fluctuations or node failures or movements occur, and hence the term “pseudo-hard”. Due to these unpredictable conditions, a MANET is not a suitable environment for providing truly hard QoS guarantees. The protocols like Hierarchical QoS Multicast Routing Protocol (HQMRP) proposed by Wei Wang et al (2006)
and On Demand QoS Multicast for MANETs (ODQMM) proposed by Ng et al (2004) belong to this category.

Contended MAC protocols estimates the statistical data of the available resources. Such protocols typically use these estimations to provide statistical or soft guarantees. This maintains the implicit reservation mechanism so that session admission cannot be overlapped.

The last category is independent and it does not have any interaction with MAC protocols. They estimate node state and attempt to route using those nodes for more favorable conditions.

2.3.4 QoS Constrained Multicast Routing Protocols

There are numerous QoS constrained multicast routing protocols found in the literature (Reevas and Salama 2000, Brahim et al 2005, Korkmaz and Krunz, 2003, Younis and Fahmy, 2003). While the number of hops is usually used for selecting routes in non-QoS routing, various metrics reflecting different application requirements are used for QoS routing. Bandwidth and delay are the key parameters to support multimedia applications.

2.3.4.1 Bandwidth-constrained Multicast Routing Protocols

The objective of the bandwidth based multicast routing mechanism is to deliver the packets to multicast destinations by estimating required bandwidth. The minimum guaranteed bandwidth in each node is required for doing admission control in QoS routing mechanism. However, each node needs the information of channel bandwidth as consumed or available. Using this information, each node decides about the admission or rejection of a flow in the route. For the discovered routes which provide QoS requirements, the
admission control policy guarantees the requested minimum bandwidth. Estimating available bandwidth in IEEE 802.11 MAC in MANETs is still a challenging problem.

Chen and Ko (2004) developed a Lantern-Tree topology (LTM) which provides QoS multicast routing in terms of guarantee bandwidth. This protocol shares time slots at the MAC layer and uses a Code Division Multiple Access (CDMA) over TDMA channel model. In this model, available bandwidth is measured in terms of the amount of free slots. At startup, it shares time slots among all neighbour nodes and finds a suitable scheduling of the free slots. Its main disadvantage is the need for a centralized MAC scheme in ad hoc mobile networks with dynamic wireless environments.

Saghir et al (2005) proposed a QoS Multicast Routing (QMR) protocol by integrating bandwidth reservation function into a multicast routing protocol. It assumes that available bandwidth is constant and equal to the raw channel bandwidth.

Saghir et al (2006) proposed a Cross-layer QoS Multicast Routing Protocol (E-QMR) which uses the estimation of available bandwidth for admission control. This admission control at the network layer makes a decision to accept or reject the new request depends on the information that comes from MAC layer. Most of these protocols have some problems, because they estimate the available bandwidth based on the channel status. Each node can listen to the channel to determine the channel status and computes the idle duration only for a period of time. All these protocols support QoS multicasting by estimating the available bandwidth and providing admission control policy.
2.3.4.2 Delay-guaranteed Multicast Routing Protocols

The objective of delay-guaranteed routing protocols is to deliver the packets to multicast destinations within an end-to-end delay constraint.

Brahim et al (2005) proposed Ad hoc On-Demand Distance Vector with QoS (QoS-AODV) protocol, in which the delay is taken into account as QoS constraint in addition to the multicast consideration. The creation time of a packet is included in RREQ messages of each node during the neighbour discovery performed by the QoS-AODV. When a neighbour node receives this message, it calculates the difference between the creation time and the current time, which represents the measured delay. Such one-way measured delay includes the queuing time, the transmission time, the collision avoidance time and the control overhead time. Otherwise, the measurement of the one-way delay avoids the increase of traffic load at adding acknowledgment messages to the QoS-AODV protocol.

Chen et al (2009) proposed a Delay-guaranteed multicast routing in multi-rate MANET over ODMRP (DG-ODMRP), in which one-hop delay along with end-to-end delay are considered to construct routes from source to destinations using the IEEE 802.11 MAC. To estimate one-hop delay, each node has to sense the shared channel for its busy/idle time ratio which helps to predict the network load. Estimation of end-to-end delay helps in making decision to admit the requested flow. The delay-guaranteed multicast routing operates as per ODMRP except that routing of packets takes place with end-to-end delay constraint. This protocol maintains QoS support with the bounded end-to-end delay guarantees.

The above protocols though offer QoS services in terms of reserving bandwidth and delay-guarantee in multicast routing, they can be
further improved to accommodate multiple QoS constraints to support real-time applications.

2.4 MULTI-CONSTRAINED QoS IN MULTICAST ROUTING

A problem that is considered to be a part of the QoS provisioning in a network is the way to identify paths that satisfy two or more constraints. In order to meet constraints of applications, routing protocols must use QoS metrics to find QoS satisfied paths. Most of the existing multicast routing protocols try to either maximize the throughput or minimize the end-to-end delay (Lee et al 1995, Younis and Fahmy 2003). But this is not sufficient to support real-time multimedia communications. It requires not only finding a route from a source to a destination, but to satisfy the end-to-end QoS requirement, often given in terms of bandwidth, delay, packet loss, jitter and bandwidth-delay product (Vogel 1996, Orda 1999). It is proved to be a NP-complete problem, and heuristic approaches are usually used to solve the problem (Wang and Crowcroft 1996).

2.4.1 Multi-constraint Path Selection Algorithms

Some works focus on the algorithmic aspect of multi-constrained QoS routing with application to wired networks. Multi-constraint path problem can be defined as a routing problem, trying to find a path that satisfies a number of QoS constraints and it is proved to be NP-complete problem.

Korkmaz et al (2001) proposed a heuristic algorithm that pre-computes a post-path using the reachability information from each node to other nodes at the first step of the routing procedure. The algorithm then uses the post paths to update a set of pre-paths from the source to the current node.
The objective is to combine these pre-paths to post-paths resulting in a set of suboptimal routes.

Shin et al (2002) modified the approach used by Korkmaz et al (2001) by proposing another heuristic algorithm that uses a minimum normalized margin metric based on severity of constraints. The algorithm strives to find a feasible path from a set of pre-paths and post-paths that has the best margin over the severity of all constraints. This algorithm runs in polynomial time.

Xin Yuan (2002) developed two heuristic algorithms namely limited path and limited granularity heuristics which provide efficient approximate solutions to the problem. Both algorithms run in polynomial time.

Yang Cui et al (2003) proposed an algorithm that used a weighted coefficient approach to combine multiple constraints to a single energy cost function. It creates vectors of such coefficients and for each vector creates a least energy cost spanning tree and incorporates this to its routing table. Depending on the constraints required by the incoming QoS flow, it chooses the corresponding tree that satisfies the constraints and computes a route for that flow.

Khadivi et al (2008) proposed a technique to solve the multi-constraint QoS routing using a new single mixed metric. The proposed method takes into account variations of the link weights in performing path selection. It uses a number of constant parameters that help to control the region over which searching is performed. In this algorithm, it is possible to use the single mixed metric function as either a path indicator or for computing a single weight for each link.
All the above algorithms works well in wired networks and it cannot be directly applied to MANETs due to the dynamic topology of multicast tree.

2.4.2 Mechanisms for Providing Multiple QoS Constraints

Viet Thi Minh Do et al (2010) has classified the mechanisms for dealing with multiple QoS constraints into two categories, the constructed metric technique and independent metric technique.

**Constructed Metric Technique** is a function of other metrics such as delay and cost. When an intermediate node receives a probe packet, it calculates the value of constructed metric of this probe packet. If the value of constructed metric of the new probe is better than that of the previous probe, the node changes its predecessor to the node that forwarded the new probe packet. When a better path is found, the probe will be forwarded; otherwise, the probe packet is discarded. Location-based multicast routing for mobile ad hoc networks (LACMQR) protocol proposed by Shih et al (2008) is an example for this category.

**Independent Metric Technique** considers multiple QoS metrics independently and only the path segments satisfying all requirements are considered. Generally, all paths satisfying the QoS constraints are selected first. The next step is to apply an evaluation function, based on the other metrics, to select the best path for building the multicast tree/mesh. The evaluation function is usually the function of some parameters such as cost of tree, tree stability etc. The protocols, QoS Multicast Routing Protocol for Clustering Mobile Ad Hoc Network (QMRPCAH), Hierarchical QoS Multicast routing using GA (HQMGA), CQMRP, QoS-MAODV and Genetic Algorithm for Energy-efficient based multicast routing (EGA) make use this type of technique.
2.4.3 Multi-constrained QoS aware Multicast Protocols

The multi-constrained QoS aware routing protocols are application dependent and are designed for special applications.

Chunlin and Layuan (2007) proposed a QoS Multicast Routing Protocol for Clustering Mobile Ad Hoc Network (QMRPCAH) which uses delay, bandwidth, jitter, and packet loss metrics. However, the authors mainly considered the delay and bandwidth QoS constraints and mobility issues were not considered. In this protocol, the links that violate the bandwidth constraint will first be deleted. Then routing process uses a cost function of link delay to decide the multicast routes.

Takashima et al (2007) proposed a Hierarchical QoS Multicast routing using GA in MANET (HQMGA) which finds a multicast tree satisfying the bandwidth and delay constraints and maximizes the value of an evaluation function. The evaluation function is a function of tree stability, latency, and the number of nodes that can receive the data stream.

Yen et al (2008) proposed a Genetic Algorithm for Energy-efficient based multicast routing in MANETs (EGA) protocol which considers two QoS constraints: propagation delay and residual battery energy. The propagation delay is used for building the multicast tree. The maximum lifetime of the multicast tree is defined based on a function of the total residual battery energy in the multicast tree.

Wang et al (2008) proposed an Ant Colony algorithm based on Orientation factor for QoS multicast (MACO) which uses a modified biology inspired algorithm for multicast routing. Multiple multicast trees, where the
links satisfying bandwidth, delay, and jitter constraints, are found; then the best multicast tree is selected based on the value of cost function of these trees.

Nargunam et al (2008) proposed a Cluster based QoS Multicast Routing Protocol (CQMRP), in which the QoS parameters considered are bandwidth, delay, jitter, and buffer capacity. An intermediate node will forward a request packet if all QoS parameters are satisfied; otherwise it is discarded. This protocol does not use an evaluation function.

Latha and Ramachandran (2009) proposed QoS constrained Multicast Routing for Mobile Ad Hoc Networks (QoS-MAODV-2Lqos) with the QoS constraints delay, throughput and cost. This protocol provides services for three classes of applications: the delay sensitive application, throughput constraint application, and best effort application. When receiving the request from source, the receiver selects the path based on QoS class and QoS state, which are included in the request, and sends a reply packet to the source. When the source receives the reply packet, the stability metric followed by power level is used to select the path.

Multi-constrained QoS routing protocols have been compared for various performance parameters and are tabulated in Table 2.2. These protocols though offers QoS services with multiple constraints, the efficiency of multi-constrained QoS routing can be further improved to reduce the control overhead and route setup latency. It can be achieved by flooding-limited and mobility prediction mechanisms. The mobile agent technology can be used to reduce the route setup latency.
Table 2.2  Comparison of Multi-constrained QoS Multicast Routing Protocols

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Routing scheme</th>
<th>Multicast Topology</th>
<th>QoS constraints</th>
<th>MAC sublayer</th>
<th>Resource reservation state</th>
<th>Mobility prediction</th>
</tr>
</thead>
<tbody>
<tr>
<td>CQMRP</td>
<td>Hybrid</td>
<td>Source specific Tree</td>
<td>Bandwidth, Delay, Buffer capacity</td>
<td>802.11, TDMA</td>
<td>Hard</td>
<td>No</td>
</tr>
<tr>
<td>QMRPCA</td>
<td>Hybrid</td>
<td>Source specific Tree</td>
<td>Bandwidth, Delay</td>
<td>802.11, TDMA</td>
<td>Soft</td>
<td>No</td>
</tr>
<tr>
<td>HQMGA</td>
<td>Proactive</td>
<td>Source specific Tree</td>
<td>Bandwidth, Delay</td>
<td>802.11</td>
<td>Soft</td>
<td>No</td>
</tr>
<tr>
<td>EGA</td>
<td>Proactive</td>
<td>Source specific Tree</td>
<td>Delay, Cost</td>
<td>802.11, TDMA</td>
<td>Soft</td>
<td>No</td>
</tr>
<tr>
<td>MACO</td>
<td>Proactive</td>
<td>Source specific Tree</td>
<td>Bandwidth, Delay, Jitter</td>
<td>802.11, TDMA over CDMA</td>
<td>Hard</td>
<td>No</td>
</tr>
<tr>
<td>QoS-MAODV-2Lqos</td>
<td>Reactive</td>
<td>Shared Tree</td>
<td>Bandwidth, Delay, Buffer capacity, Stability</td>
<td>802.11</td>
<td>Soft</td>
<td>Yes</td>
</tr>
</tbody>
</table>

2.5  SOFTWARE AGENTS IN MULTICAST ROUTING

For the past several years, researchers and developers have put substantial efforts in the development of the basic technology for mobile agents. This has resulted in emergence of several robust and efficient platforms that implement the mobile agents since the 1990. The traditional programming paradigm uses functions, procedures, structures and objects to develop software for performing a given task. This paradigm does not support development of flexible, intelligent and adaptable software and also does not facilitate all the requirements of Component Based Software Engineering (CBSE) (Griss and Pour 2001, Castelfranchi et al 2003). In recent developments, agent technology is making its way as a new paradigm in the
areas of artificial intelligence and computing which facilitates sophisticated software development with features like flexibility, scalability and CBSE requirements.

2.5.1 Benefits of Agents

Griss et al (2001) stated that agents are the autonomous programs that can migrate from one node to another node in a heterogeneous environment and complete a task specified by its owner without disturbing the activities of the host. In this way, a mobile node requires less communication connectivity than the conventional routing approaches. The following are the distinctive features of the mobile agents that demonstrate the great feasibility of incorporating mobile agents in the MANETs routing design (Vu Anh Pham 1998, Lange and Oshima 1999).

i) Mobile agents reduce network load: The main motivation behind using mobile agents is to move the communication to the data rather than the data to the computations. In the mobile agent paradigm, the mobile agents allow us to package a conversation and send it to a destination host. The agents migrate to interact locally, at the same host as the resources. The result is an enormous reduction of network traffic.

ii) Mobile agents conserve bandwidth: Mobile agents limit intermediate messages between the nodes, and hence reasonably reduce the amount of bandwidth needed. This is very important in MANETs due to the strict bandwidth constraints they have.

iii) Mobile agents encapsulate protocols: Due to the continuous evolution of existing protocols in a distributed system, it is very cumbersome to upgrade protocol code property in each
host. Mobile agents are able to move to remote hosts in order to establish channels based on proprietary protocols.

iv) *Mobile agents overcome network latency* by moving the executing code to the system where computation and output is to be produced. Again this helps with battery constraints in mobile nodes.

v) *Mobile agents execute asynchronously and autonomously:* In this case the task of the mobile node can be embedded into mobile agents, which can then be dispatched at the destination and can operate asynchronously and autonomously to accomplish the task. At a later stage the mobile node can reconnect and collect the agent with the results.

vi) *Mobile agents advance mobile computing* by handling the nodes’ join-and-leave issues. This is achieved by the ability of a mobile agent to continue its task even if one of its links goes off due to a disconnected node. The dynamic topology of MANETs requires such a feature.

vii) *Mobile agents are naturally heterogeneous:* Mobile agents are generally independent of the transport layer and depend only on their execution environment. Hence they can perform efficiently in any type of heterogeneous networks.

viii) *Mobile agents are robust and fault-tolerant:* The dynamic reactivity of mobile agents to unfavorable situations makes it easier to build robust and fault-tolerant systems. Fault tolerance is one of the main features required for MANETs due to the frequent joining and leaving of nodes in the network.
ix) *Mobile agents adapt dynamically*: Mobile agents are capable of sensing their execution environment and take decisions based on that dynamically.

By inheriting the above merits of mobile agents, some of the protocols have been developed for QoS routing using mobile agents.

### 2.5.2 Agent based QoS Routing Protocols

The main advantage of using mobile agents is to make all the nodes in the network to be topology-aware and reduces the control overhead.

Romit Roy Choudhury et al. (2004) have designed Multi-Agent Routing Protocol (MARP), where the agents are responsible for updating the node routing information. The mobile agents are broadcasted to all neighbor nodes and are only accepted by the next destination node, so all the neighbor nodes will know about the sender node as their neighbor. This methodology consumes considerable part of the network bandwidth due to mobile agent traffic. Also, agent loss is not considered.

Manvi et al. (2007) developed a mobile agent based on-demand QoS unicast routing scheme for supporting multimedia applications that considers bandwidth, delay and packet loss rate as QoS metrics for feasible path computation. A mobile agent is employed to find multiple QoS paths and select a best path among them to preserve resources. This protocol increases call success ratio and network bandwidth utilization as well as adapt to network dynamics. However, in this protocol the agent overheads and agent response time is high when the QoS arrival rate is high.

Chen Wei and Zhang Yi (2009) has proposed a routing algorithm with multiple QoS constraints based on mobile agent for ad hoc network. In
their work, the authors use mobile agents to collect information of all mobile nodes in order to reduce the network delay and the overhead of control messages for routing. They claimed that their algorithm has lower probability of link failure because it selects links with large link expiration time during route creating phase.

Manal Abdhullah and Hellen Bakhsh (2009) designed an Agent-based Routing Protocol (ARPM) for unicast routing in MANET. The objective of this protocol is to make all working nodes in MANET, to be topology-aware using a number of mobile agents that take the responsibility of exchanging and updating data for nodes in the network.

Budhyal et al (2011) developed a QoS routing model in MANETs using software agents that employ fuzzy logic and neural networks for intelligent routing, in which, mobile agents are used to maintain and repair the paths.

**Agent aided QoS Multicast Routing Protocols:** Very few algorithms have been developed for multicast routing based on mobile agents. Wang et al (2001) developed a Mobile Multicast Agent (MMA) protocol which uses mobile agents to form the virtual backbone of an ad hoc network. The MMA multicast algorithm is based on AODV and provides multicast tree discovery and multicast tree maintenance. MMAs are also used as relay nodes, so that the multicast tree is composed of a sender node, MMAs, and multicast group members. When a mobile node wants to send a packet to a multicast group, it sends a route request packet to its MMA. If there is valid information for routing to the multicast group stored in the MMA, the MMA will reply with a route reply packet. If not, the sender should initiate a route request process. To limit the number of route request packets propagated, an MMA processes a route request packet only if it has not already seen this packet.
In MMA, only mobile agents are used to transfer control information and retransmission packets, which means that the control overhead and battery power are reduced and the throughput of the network is increased. Route information is only stored in MMAs, which reduces the time it takes to find the multicast tree and the time required for a sender node to obtain routing information. As the fulfillment of many responsibilities relies on MMAs, these nodes must have a large buffer memory compared to other nodes.

Shekhar et al (2004) proposed a Mobile Agents aided Multicast Routing (MAMR) protocol. It is a reactive QoS-based hybrid multicast routing protocol where intelligent Mobile Agents (MAs) can be used for topology discovery. MAMR can be integrated with other exiting multicast routing protocols, such as MAODV and ODMRP in order to overcome the limitation of these protocols. In MAMR, MAs are simple packets, which roam around the network and provide the current topology information and other QoS values such as link delay, congestion etc, which help nodes for taking efficient routing decisions as they visit different nodes. The information carried by the MAs helps to find a route for a given destination, when no route exists in the multicast table to the destination. By this way, the protocol overcomes the additional delay which would have been required, in finding a new route to the destination and also reduces the control traffic generated. Although this method requires extra cost for processing MAs, the benefits would be gained in terms of better end-to-end latency and packet delivery ratio.

Baburaj and Vasudevan (2007) developed a Hierarchical Differential Destination Multicast (HDDM) protocol to enhance the scalability and reliability of multicast routing. This protocol is implemented within Reusable Task-based Systems of Intelligent Networks Agents.
(RETSINA) agents. The RETSINA architecture improves the performance of HDDM by continuously monitoring the network topology changes and provides intelligent access to a heterogeneous collection of information sources.

Manvi and Kakkasageri (2008) proposed an Agent Based Multicast Routing Scheme (ABMRS) which employs a set of static and mobile agents in order to find the multicast routes and to create the backbone for reliable multicasting. The steps of the ABMRS are the following: reliable node identification, reliable node interconnection, reliable backbone construction, multicast group creation, and network and multicast group management.

ABMRS computes multicast routes in a distributed manner, which provides good scalability. ABMRS is more reliable, as it has a higher packet delivery ratio, than MAODV. This is because ABMRS constructs the multicast tree based on reliable nodes. However, ABMRS incurs a significant control overhead compared to MAODV, especially when mobility and the multicast group size are increased.

Rajashekar Biradar and Manvi (2011) developed an agent-based multicast routing mechanism in MANET that builds a backbone in the form of a reliable ring and finds multicast routes. The reliability of such a backbone is modelled by using reliable links based on the probabilistic measure of link failures. Later, a mesh of multicast routes is found by connecting the source and its nearest ring node and destination and its nearest ring node. The mechanism consists of a set of static and mobile agents which coordinate through a knowledge base and identify the stable links to form a reliable ring at an arbitrary distance from the centre of MANET area. Agents are also used to recover routes against link failures, node failures and mobility with local patching of failed links/nodes.
Krishna Deshpande (2012) developed an agent based QoS multicast routing based on fuzzy priority scheduler. The fuzzy scheduler finds the priority index of the queued packets. The performance of the fuzzy-based priority scheduler for data traffic is analyzed with mesh based multicast routing protocol ODMRP. Here the software agents are used for both in routing and fuzzy priority scheduling stages.

The above mobile agent assisted protocols confirm that the mobile agents can be used to collect all topology-related information from each node in the network and distribute them periodically to other nodes. This makes all mobile nodes in the network to be topology-aware and effectively reduces the route setup latency and control overhead in the network.

### 2.6 FLOODING SCHEMES IN MULTICAST ROUTING

Flooding is one of the most fundamental operations in MANETs. Efficient flooding schemes are different from the broadcast mechanisms used in the networks. The broadcast mechanism is used in transmission of a large amount of data or stream media data. These applications require an efficient broadcast route before the actual transmission of data, so that data can be transmitted efficiently along the pre-found route (Hai Liu et al 2007, Jiao et al 2007). In contrast, flooding is usually used in dissemination of control packets, which is a one-off operation and it does not need routing beforehand (Obraczka et al 2001). Most of the major routing protocols like MAODV, ODMRP, AMRoute, AMRIS etc. rely on flooding for disseminating route discovery, route maintenance, and topology update packets.

The existing flooding mechanisms are of three categories based on the information each node keeps. They are pure flooding, Flooding with Self Pruning (FSP) and Selecting the Multipoint Relaying (MPRs).
**Pure Flooding:** Pure flooding also called blind flooding, is the simplest flooding technique. In pure flooding, each node in the network re-transmits the message without the need of other nodes information. The basic idea of this approach is every node in the network retransmits the message when it is the first time to receive it (Ho et al 1999, Jetcheva et al 2001). However, this algorithm will generate an excessive amount of redundant network traffic when all nodes in the network are re-transmitted the flooding message. This will consume a lot of energy of the mobile nodes and also cause congestion in the network.

**Flooding with Self Pruning:** Lim and Kim (2002) proposed a Flooding with Self Pruning (FSP) scheme. FSP is a receiver-based scheme and it assumes that each node keeps the information of 1-hop neighbours. The 1-hop neighbour information can be obtained by exchanging the HELLO message in MAC layer protocols. A sender forwards a flooding message by attaching all of its 1-hop neighbours to the message. A receiver compares its own 1-hop neighbours with the node list in the message; it will not forward the message if all its 1-hop neighbours are already included in the list, otherwise it forwards the message as a sender.

**Selecting the Multipoint Relaying:** Amir Qayyum et al (2002) proposed an efficient flooding technique, selecting the Multipoint Relays (MPRs). MPRs assume that each node keeps the information of 2-hop neighbours, i.e. the neighbours of the 1-hop neighbours. To obtain the information of 2-hop neighbours, one solution may be that each node attaches the list of its own neighbours, while sending its HELLO messages. With this information, each node can independently calculate its 1-hop and 2-hop neighbour set. Once a node has its 1-hop and 2-hop neighbour sets, it can select a minimum number of 1-hop neighbours which covers all its 2-hop neighbours.
The performance gain of MPRs is greater than that of self pruning, because MPRs uses 2-hop neighbourhood information while self pruning uses 1-hop neighbour information only. On the other hand, MPRs has larger overhead than self pruning and the overhead increases as the node mobility increases. Therefore, MPRs is more appropriated in a network with moderate size and little mobility.

FSP and MPRs though reduce the excessive redundancy of messages; it could not reduce resource contention and signal collision. Therefore, an efficient implementation of the flooding-limited scheme is necessary in order to reduce the overhead of routing protocols and to improve the throughput of networks.

**Flooding-limited QoS Routing Protocols:** Yen et al (2008) have devised a Flooding-limited for Multi-constrained QoS Routing Protocol (FLMQRP). FLMQRP uses a flooding-limited mechanism to broadcast QoS route request packets with a built-in quick-pruning mechanism to find a suitable routing path. However, this protocol works on unicast routing and the established connections are guaranteed for bandwidth, end-to-end delay and battery energy metrics.

Yen et al (2011) proposed a multi-constrained QoS multicast routing method using the genetic algorithm. It is a flooding-limited scheme using the available resources with minimum computation time in a dynamic environment. By selecting the appropriate values for parameters such as crossover, mutation, and population size, the genetic algorithm improves and tries to optimize the routes. However, this algorithm guarantees the minimum bandwidth and maximum end-to-end delay requirements.
2.7 LINK STABILITY BASED MULTICAST ROUTING PROTOCOLS

In MANETs all the nodes are free to move anywhere at any time. As mobility increases, link failures trigger the reconfiguration of the entire tree. When there are many sources, one either has to maintain a shared tree or maintain multiple trees resulting in increase of storage space and control overhead. In pursuit of this, at the time of joining the tree, each receiver node selects the most stable path to the source node. This would minimize the number of tree reconfigurations. In order to determine the stable paths and trees, routing protocols use metrics such as predicted Link Expiration Time (LET) link affinity and associativity ticks (Oh et al 2008).

Moustafa and Laboid (2003) proposed an on demand multicast routing protocol named as Source Routing-based Multicast Protocol (SRMP). This protocol constructs a mesh of paths to connect group members, providing robustness against mobility. It also provides stable paths based on link availability according to future prediction of links state, and higher battery life paths tending to power conservation. Thus, it reduces the overhead needed to reconstruct the paths compared to ODMRP protocol.

Bo Rong et al (2005) have proposed a Mobility Prediction Aided Dynamic Multicast Routing (MPADMR) protocol. In order to attain good routing performance in MANET, MPADMR mainly has two objectives. First, the multicast tree should remain relatively stable during the whole multicast session despite the frequent join/leave events. Secondly, the tree’s hop-count should stay approximately minimal without the need to reconstruct the entire multicast tree from the beginning. To reach these two goals, MPADMR consists of two steps. In the first step, with the aid of mobility prediction a link lifetime constrained minimum hop-count multicast tree is constructed at the beginning of a multicast session. In the second step, a
dynamic multicast tree maintenance procedure is employed to rearrange the existing multicast tree when a group member joins/leaves the multicast session. This approach reduces the route reconstruction process and hence the control overhead is very much reduced.

Hao Xu and Dejun Mu (2008) proposed a Cluster Based Stable Multicast Routing Protocol (CBSRP) in ad hoc networks. The protocol uses flooding algorithm under extended range of some network conditions like higher mobility and enhanced traffic conditions. It constructs a new metric of node stability and selects a stable path with the help of entropy metric to reduce the number of route reconstruction. It selects the nodes which have the most weight and stability to be the cluster heads. Though the stable node selection increases the stability, this selection is made possible using clusters and the proactive maintenance of cluster heads is a major overhead and the overhead increases with number of nodes.

MohammadReza EffatParvar et al (2009) proposed a Cluster-based On Demand Multicast Routing Protocol (SC-ODMRP) as an extension to the ODMRP to improve network performance in terms of end-to-end delay and control packets using clustering concept. It proposes a link stability approach to design a stable multicast algorithm. This approach increases data delivery and decreases overhead.

Rajashekar Biradar et al (2010) have proposed a Link Stability based Multicast Routing scheme in MANET (LSMRM). It is a mesh-based multicast routing scheme that finds stable multicast path from source to receivers by the selection of stable forwarding nodes that have high stability of link connectivity. However, this method does not include any QoS constraints.
Link stability based routing protocols assure better quality of links and minimizes the possibility of link failures and the overhead needed to construct the paths.

2.8 COST ADAPTIVE MECHANISM AND GENETIC ALGORITHM OPTIMIZATION IN MULTICAST ROUTING

It is important for a multicast connection to select a routing tree whose network cost is minimal. The mobile nodes in MANETs potentially have fewer resources than fixed networks in terms of limited battery capacity, less computational power and limited buffer space. These factors have a major impact on the provision of QoS assurances. Mobile nodes operating on a battery supply have strong power constraints and network life depends on the management of this resource. Since, low buffer space limits the amount of packets buffered at each node, the accumulation of more packets resulting in collisions and retransmission attempts can cause congestion. Hence, it is necessary to take routing decisions by considering multiple metrics. Some of the attempts have been made to provide a level of network diversity by considering various QoS metrics and choose a route among a number of alternatives and according to the dynamic nature of the network.

Nicolas Roux et al (2000) proposed a Cost Adaptive Mechanism (CAM) to provide network diversity among the available routes. CAM calculates a cost for each route using a weighted summation of individual metrics such as transmit power, wireless activity and traffic load. CAM does not provide any standard method to calculate the weights and arbitrarily sets these weights using trial and error.

Shivanajay et al (2004) proposed an Evolutionary Ad hoc On-demand Fuzzy Routing (E-AOFR) which makes use of link stability between two neighbours, remaining battery capacity and buffer length at a node for
route selection and converts them into a single fuzzy cost metric. The destination node chooses the least cost one as the routing path from all possible routes between the source and destination. In E-AOFR, every node needs to compute its fuzzy cost as long as it receives RREQ packets between any two pair nodes. The frequency of this computation is very high, placing a heavy burden on the node.

Abu Md. Zafor Alam (2005) proposed a Cost-effective Lifetime Prediction (CELP) based routing protocol to consider both the routing cost and network lifetime issue in route selection. Therefore the network remains stable and data are routed through cost-effective path. CELP considers the remaining battery energy for route life time prediction and do not consider about the network traffic rate.

The above protocols concentrate on minimizing the energy consumption of mobile nodes only and they do not take effort on other metrics. Hence it is necessary to devise a routing decision based on multiple performance metrics to achieve optimal overall network resource utilization.

Regarding QoS algorithms, the researchers show an increasing interest around solutions based on Genetic Algorithms (GA) which can solve NP problems (Chang Wook Ahn and R.S. Ramakrishna 2002). GA routing algorithms, given the network topology and QoS costs of network components, implement genetic operations to search the best route subject to multiple QoS constraints. Basically, a genetic algorithm is a search technique used to find approximate solutions for optimization. They are robust and efficient for global optimization search in complex space.

Baolin sun et al (2008), Li Zhang et al (2009) developed a new multicast routing optimization algorithm based on GAs, which find the low-cost multicasting tree with multiple QoS constraints. The simulation results
show that GA is able to find a better solution, fast convergence speed and high reliability. It can meet the real-time requirement in multimedia communication networks. Hence it is necessary to develop an algorithm to find out multicast routes with QoS constraints by simultaneously optimizing various QoS requirements.

2.9 EXTRACT OF THE LITERATURE SURVEY

In this chapter, the fundamental concepts of multicast routing, QoS constrained multicast routing protocols, multi-constrained QoS issues in multicast routing and mobile agents aided multicast routing protocols that are related to this research have been presented.

Compared to tree-based protocols, mesh-based multicast routing protocols are more resilient to link failures due to the availability of redundant paths between the source and destination pairs. The existing multicast protocols react to a link failure after it occurs. No attempts have been made to predict link availability and provide reliability using data redundancy based on the prediction before the link fails. Hence it is imperative to devise a stable path mechanism using mobility prediction method in a large scale MANETs.

The existing QoS protocols provide the QoS on per-flow basis only. They do not consider packet level differentiation and class of service for providing QoS. MAC sublayer has the components to support QoS. Most of the QoS aware protocols work on TDMA based MACs and provide soft QoS guarantees and it is very difficult to provide hard QoS guarantees in MANETs due to the nature of its dynamic topology.

Most of the existing multicast routing protocols provide an assured throughput and delay-guaranteed service. They do not concentrate on other QoS parameters such as jitter and packet loss rate. These parameters play an
important role in supporting real-time multimedia communication and hence it is necessary to develop a multicast protocol which satisfies all QoS constraints.

Traditional multicast routing protocols have become inefficient in a large scale network when the group size and number of groups are increased. This is due to node mobility and the corresponding control packets to reestablish the failed links. Therefore it is necessary to devise a flooding-limited and admission control mechanism at each node to reduce the control overhead.

The mobile nodes in MANETs potentially have fewer resources than fixed networks in terms of limited battery capacity, less computational power and less memory. Hence, it is imperative to consider the effective resource utilization of the mobile nodes while satisfying the various requirements of the application. The solution to this problem can be provided by integrating multiple performance metrics into a routing decision to achieve an optimal overall performance.

Most of the multicast routing protocols establish routes on demand where a considerable amount of time is spent in finding the routes from source to all the group members. This introduces additional delay to the overall end-to-end delay. To reduce the route set up latency and control overhead, the performance benefits of intelligent mobile agents can be integrated with the existing multicast routing protocols.

The above issues form the foundation and motivation for this research work. In particular, QoS aware protocol with multiple constraints, flooding-limited and mobility prediction mechanism, agent assisted framework to support multi-constrained QoS routing and cost adaptive mechanism in multicast routing protocols have been explored in this research.
Based on these issues the objectives are derived and certain protocols are developed to satisfy the objectives. The newly developed protocols are adapting to the current multi-constrained QoS network conditions. The implementation of the proposed protocols and performance analysis with the existing protocols are presented in the subsequent chapters of the thesis.