CHAPTER 3

LITERATURE SURVEY

3.1 INTRODUCTION

This chapter deals with the review of various aspects of multicasting. The papers reviewed are sectioned as follows:

- Multicasting in Wired Network
- Multicasting in Wireless Network
- Multicasting in Heterogeneous Network
- Multicast Routing Algorithm
- Multicast routing QoS
- Optimization using Genetic Algorithm
- Multicast Routing Algorithm for Multimedia Applications

3.2 MULTICASTING IN WIRED NETWORK

A scheme meant for wired networks, Distance Vector Multicast Routing Protocol (DVMRP) was developed by Deering et al (1990) can also be used by wireless networks like MANETs. DVMRP uses data packets source flooding to discover group members. Non-member nodes prune themselves form neighbours, thereby creating a shortest path between source and multicast group members based on Reverse Shortest Path Forwarding.
mechanism (RPF). When set up, data is forwarded by nodes to the tree. As DVMRP is a soft state protocol, regular flooding/pruning is normal to locate new members. New members also join the tree through forwarding o graft message. Though widely used in Internet multicast routing, DVMRP does not suit MANETs due to potentially high data flooding.

PIM-DM (Deering 1994) has been designed for networks that are densely populated with members of a multicast group. PIM-DM builds the multicast tree using “flood-and-prune” RPF, as in DVMRP. Periodic flooding is carried out in the dense-mode networks by the multicast sources with multicast traffic and then prune messages inactivate routers without clients. The prune messages are generated by the routers that do not have any interested multicast receiver for that multicast group under its subnet.

The primary difference between DVMRP and PIM-DM is that PIM-DM is independent of the unicast routing protocol; it simply requires that a unicast routing protocol exists to construct the unicast routing tables; PIM-DM uses the unicast routing tables to build the multicast tree. The PIM-DM assumes that the unicast routes are symmetric. The packet forwarding on outgoing interfaces is also slightly different between PIM-DM and DVMRP. PIM-DM accepts additional overhead to simplify the RPF check. Else, the two protocols are very similar, and the arguments for and against DVMRP apply to PIM-DM also.

PIM-SIM, sparse-mode protocols, set up distribution trees through the use of explicit messages. Such trees are set up on only on distribution tree routers with data packets being sent to LANs which have hosts joining the groups. So Sparse-mode protocols suit big internet works in which dense-mode protocols are likely to waste bandwidth through packet flooding in the entire internetwork prior to pruning unwanted connections. Sparse-mode protocols construct both shared trees or source trees or both types of trees.
Sparse-mode protocols might suit a magazine subscription as a distribution tree is built only if a receiver joins the group.

The Protocol Independent Multicast (PIM) has been used for multicast routing in an attempt to remove the deficiencies in other multicast routing protocols like DVMRP or CBT while incorporating their positive features. As the name suggests, PIM is independent of the underlying unicast routing protocol. The PIM was mainly designed to overcome the limitations of dense mode protocols such as DVMRP, which was not scalable for large and sparse multicast network groups. Core based approaches were introduced at that time to support sparse mode, but these approaches have their own limitations. The core-based approaches sometimes result in a bottleneck at cores in applications, and placement of core(s) is critical. Hence, PIM was designed to overcome the problem of scaling in dense mode as well as core based algorithms. The PIM introduced several collections of algorithms like PIM-SSM (Bhattacharyya 2003), PIM-DM (Adams et al 2005), PIM-SM (Fenner et al 2006), and PIM-BIDIR (Handley 2007).

Noguchi et al in (2003) pointed out that achieving max-flow using network coding can create congestion and used a technique for load balancing. Sanguankotcbakorn and Thanb Son (2003) used an extension of Distributed Routing Algorithm (DRA) for supporting multicast routing. The algorithm is called Multicast Distributed Routing Algorithm (MDRA). With a reasonable delay for the connection (500 ms), the successful ratio of MDRA (delay) was acceptable with a value of 92.09% for selective probing and 99.84% for QoS flooding. The Performance of the new algorithm was investigated and compared to the one of QOS routing using flooding mechanism and broadcast routing (non-QOS) and the performance of MDRA was better than the flooding mechanisms.
Zhu et al (2004) established distributed algorithms to construct two redundant multicast graph as the multicast topology over which network coding is applied while minimizing cost of link stretch and stress. Their algorithm doubles end-to-end throughput in most cases with a small increase in delay, stress and resource usage compared to conventional multicast on overlay networks. Li and Li (2004) showed that throughput improvement due to network coding in directed network is \( \Theta(|V|) \) and therefore, unbounded for multiple independent unicast transmissions. For undirected networks with integral routing, there still exist configurations that are feasible with network coding but infeasible with routing only.

Li Lao et al (2005) designed a two-tier overlay multicast architecture (TOMA) to provide scalable and efficient multicast support for a variety of group communication applications. The two-tier architecture provided efficient resource utilization with less control overhead, especially for large-scale applications. It also alleviated the forwarding state scalability problem and simplified multicast tree construction and maintenance when there were many groups on-going in the networks. Extensive simulation study results demonstrated that TOMA performed well in several common scenarios, provided efficient multicast transmission comparable to IP multicast, and was scalable to group size as well as to the number of co-existing groups. The experiments showed that the dimensioning algorithms could efficiently plan the network resources with little penalty and that the invention of this practical, comprehensive, and profitable multicast service model would greatly facilitate wide multicast deployment.

Li and Li in (2006) proposed a necessary and sufficient condition for multicast rate feasibility and an efficient distributed sub-gradient algorithm for computing the maximum multicast rate. They concluded that network coding may not be instrumental in achieving better maximum
multicast rates in most cases. Rather, it facilitates the design of significantly more efficient algorithms to achieve such optimality.

Network coding based routing algorithms for multicast was presented by Chi et al (2006) as multicast rate is smaller than multicast capacity revealing that when average node degree was high, network throughput achievability and coding based multicast was higher than shortest path tree distributing algorithm and only slightly bigger than the maximum rate distribution tree routing algorithm.

While the DST and the Narada exhibit similar delay characteristic, delay of Coded Multicast is significantly greater than network coding protocol in (Lun et al 2006). It is because Coded Multicast uses only sub-optimal 2-redundant multicast graph while network coding protocol in (Lun et al 2006) uses optimal multicast subgraph.

Wang Ji-Lu and Dai Wan-Zhou (2009) incorporated an Adaptive Distributed Multicast Routing protocol (ADMRP), whose node could compute forward list dynamically and distributed. These mechanics could save limited bandwidth, decrease channel collision and reduce the total overhead of MANETs. The proposed method combines the merits between the mesh-based and the tree-based MANET multicast protocol. In experiments, ADMRP packet delivery ratio achieved a better performance in more than 20 members network; ADMRP control overhead remained below that of MAODV and ODMRP. Compared to ODMRP and MAODV, there was a clear improvement and advantage with using ADMRP which also proved that ADMRP could adapt itself to the dynamic changes of network topology, improve forward efficiency, and reduce channel collisions and the control overhead.
Eli Brosh investigated (2009) the problem of finding minimum delay application layer multicast trees, similar to those constructed in overlay networks. The model enabled evaluation of multicast performance using a single delay cost. In this model, the problem was shown to be NP-hard. Hence the study presented a logarithmic approximation algorithm and a heuristic solution with a \( -(pn) \) approximation ratio where \( n \) was the size of the multicast group.

Both algorithms generated minimum delay trees that intrinsically balanced short latency with a small degree, and thus avoided an external trial-and-error type of balancing between the two as the study solutions do not impose a maximum degree on the multicast trees.

The heuristic scheme achieved an optimal solution for grid graphs, and provided performance bounds for multicasting in the grid and tree topologies. A simulation study evaluated the average performance of the said algorithms. The results showed that the study was scalable for a large group sizes, and produced results that were very close to optimal.

The works incorporated in the literature are ideal for wired nodes where frequent tree reorganization is not required. The traditional routing protocols can cause significant overheads which may not be acceptable in the wireless side of the network where bandwidth constraint is common.

### 3.3 MULTICASTING IN WIRELESS NETWORK

Multicasting involves datagram transmission to a group of zero or more hosts identified through a single destination address. It is meant for group oriented computing. A multicast datagram is delivered to the destination host group members through “best effort” reliability similar to regular unicast IP datagrams. In other words, there is no guarantee that this
datagram will arrive intact at group member’s destinations or in an order similar to other datagrams (Deering 1989). Wired networks multicast protocols cannot be ported to MANETs as they will be unable to handle frequent link breaks and route changes or two networks deferring characteristics Chiang et al designed mechanisms to make wired multicast protocols compatible to MANETs (Chiang et al 1997).

MANET Multicasting is more complex and challenging than in wired networks. Multicast group members movement precludes fixed infrastructure multicast topology use as wireless channel characteristics do vary with time in addition to there being restrictions on node energy/capacity (Chiang 1998). Multicast in MANETs reduces communication cost, improves wireless channel efficiency when forwarding multiple data copies using wireless transmission’s broadcasting properties., Multicasting minimizes channel capacity consumption instead of sending data through multiple unicasts, lowers sender/router processing, energy consumption, and delivery delay, important MANET factors. Multicasting is also a simple yet robust communication method through which receiver’s individual address is not known to the transmitter or transparently changeable by it (Paul 1998; Stojmenovic 2002).

ODMRP (Lee et al 1999), is an on-demand mesh based, besides it is a multicast routing protocol, which also uses unicast technique to send multicast data packet from the sender nodes toward the receivers in the multicast group. To start sending multicast data packets, ODMRP uses two kinds of control messages: join-query and join-replay, if there are nodes which want to join to the multicast group, it uses join-query. Using of join-reply will be activated when the receiver node accept to receive the multicast data packet. In ODMRP protocol, each source floods a join request (i.e Join-Req,) message periodically in the multicast group. A node receives the Join-
Req. message uses store the greatest node ID in a Routing Table, then it will rebroadcasts the massage. The process continues until reaching the multicast receiver node. Once the receiver node received the Join-Req. message, it will declare its joining by broadcasting Join-Reply message to the multicasting group.

The MAODV (Royer 1999) is a multicast extension for AODV protocol. The MAODV based on shared trees on-demand to connect multicast group members. The MAODV has the capability of unicast, broadcast, and multicast. The MAODV protocol can be route information obtained when searching for multicast; it can also increase unicast routing knowledge and vice-versa.

MANETs have static or mobile nodes connected wirelessly and without infrastructure/central administration. If within transmission range, two nodes can communicate easily; or else intermediate nodes relay (routers) the communication when out of range (multihop routing). Their advantages include rapid deployment, robustness, flexibility, inherent mobility support, highly dynamic network topology, mobile devices limited battery power, limited capacity, and asymmetric/unidirectional links. MANETs support military operations and civil applications like audio/video conferencing, sport events, telematics applications, disaster situations, and integration with cellular systems (Perkins 2000; Toh 2002).

Simulations reveal increased control packet overhead and immediate lowering of throughput with increased node mobility. Simulation results also show by such approaches that alternative multicast strategies should be explored.

Several MANET multicast routing protocols were evaluated (Wu et al 2000; Park et al 2004; Shen et al 2005). Such protocols have different
design principles and operational features when applied to multicasting issues. Favoured properties are protocol dependent. Some common wireless network multicast Protocols are the following.

Tseng and Chen (2001) introduced a distributed candidate’s selection protocol, named DSDMR, which is self-adapting based on group density. An adaptive two-direction join mechanism technique which addresses the problem of poor scalability resulting from high control overhead is proposed by the author. The mechanism performed well both in densely populated and sparsely populated networks. Extensive simulation results show that DSDMR can create low cost tree close to optimal greedy strategy with very low control overhead and join latency.

ADMR (Jorjeta et al 2001) is an on-demand source-based protocol. By using the shortest-delay path from the sender node to the receivers, ADMR uses packet forwarding techniques by using a sequence number to uniquely identify the packets and is generated as a count of all flooded ADMR packets.

Bettahar and Bouabdallah (2002) incorporated a new approach for delay-constrained routing which captured the trade-off between cost minimization and the risk level regarding to the delay constraint. The work incorporated a protocol called Parameterized Delay-Constrained Routing (PDCR) protocol that implemented a simple and efficient parameterized selection function. Simulations revealed that the protocols produced paths and trees which were stable, less risky and suitable for various network conditions.

Gupta and Srimani (2003) presented a distributed core selection and migration protocols for mobile ad hoc networks. Core selection in ad hoc network is expensive due to the dynamic topology. The core location method
is based on median node of the multicast tree instead of the median node of the entire network. Adaptive distributed core selection and migration method uses the median of the tree as the centroid of that tree. The cost of multicast tree is computed as the sum of weights of all the links in the tree, which gives the total bandwidth required for multicasting a packet and the cost of shortest-path tree rooted at the tree median, CostTM, is compared with the cost of shortest-path tree rooted at the median of the graph, CostGM. The simulation results show that the ratio CostTM/CostGM lies between 0.8 to 1.2 for different multicast groups.

Wu et al in (2005) showed that mutual exchange of independent information between two nodes can be efficiently performed by exploiting network coding and physical-layer broadcast property of the wireless medium which improves upon conventional solutions that separate the processing of the two unicast sessions. The authors proposed a distributed scheme along with packet formats that eliminates the need for synchronization and is robust to random packet loss and delay etc. Lun et al in (2006) showed how network coding, combined with distributed flow optimization, gives a practical approach for unicasting that promises to significantly outperform the present approach of end-to-end or link-by-link re-transmission combined with route optimization for any performance measure which increases with the number of transmissions made by each node.

Katti et al in (2006) implemented COPE, architecture for wireless mesh networks. They addressed the common case of unicast traffic, dynamic and potentially bursty flows, and practical issues facing the integration of network coding in the current network stack. The test bed deployment results showed that COPE largely increased in the network throughput. The gains vary from a few percent to several folds depending on the traffic pattern, congestion level, and transport protocol. Due to coding, COPE has to send
less number of packets and as a result, load on the bottleneck link reduces, giving it double advantage.

Hua Chen et al (2006) presented an Entropy-based long-life multicast routing protocol in MAODV (EMAODV). The key idea of EMAODV algorithm was to construct a new metric-entropy and select long-life multicast routing with the help of entropy metric to reduce the number of route reconstructions in MANET. Simulation results provided an accurate and efficient method to estimate and evaluate route stability in dynamic mobile networks.

Xi and Yeh (2006) used network coding to achieve minimum-cost multicast in interference-limited wireless networks where link capacities are functions of the Signal to-Interference-plus-Noise Ratio (SINR). They considered joint optimization of network coding subgraphs with power control and congestion control without excessive control overhead and designed set of distributed node-based scaled gradient projection algorithms and derived scaling matrices for fast, guaranteed global convergence. Ho et al (2006) compared multicast network coding for a time-varying wireless network model with the interference-determined link capacities instead of collision based wireless model with fixed link capacities and showed that the gap in multicast capacity between network coding and routing decreases relatively to a collision-based wireless model with fixed link capacities and the main advantage of network coding is a reduction in complexity of optimization and operation as network coding significantly reduces complexity of dynamic back pressure algorithms used for optimization.

According to Fragouli et al (2006) benefits of the wireless environment network coding could be seen in situations where topology changes and operations are limited to distributed algorithms that fail to use
network environment knowledge thereby proving that network coding offers benefits of a factor of log n regarding energy efficiency.

Park et al (2006) presented CodeCast, which achieves controlled loss and bounded delay multicast with the help of network coding. They showed that the protocol yields a nearly 100% delivery ratio, as compared to a 94% delivery ratio by traditional multicast and the overhead is reduced by as much as 50%.

Zhang and Fan (2007) investigated methods to find nodes that need encoding instead of doing coding at all nodes in order to reduce cost and complexity of coding. A modified Ford Fulkerson algorithm was established to obtain the maximum flow and encoding nodes in an undirected graph instead of getting encoding nodes by subtree decomposition.

A general modelling/solution framework for wireless networks throughput optimization issues, instead of cost optimization was established by Yuan et al (2007) where data routing, wireless medium contention and network coding are taken into account jointly for achieving optimal network performance. Cross-layer optimization divides the main issue into the network layer, data routing sub-problems and power allocation sub-problems at a physical layer considering physical layer interference.

Sengupta et al in (2007) discovered a theoretical formulation to compute network throughput coding on a wireless network topology and concurrent unicast traffic sessions of any pattern. He wanted routing to be aware of network coding opportunities instead of, being oblivious to it, as in COPE. Trade-off between routing flows “close to each other” to use coding chances and “away from each other” to ensure that wireless interference was avoided revealed a computing source-destination routes method, using the best coding opportunities available to maximize throughput.
Jipeng Zhou and Jianheng Lu (2009) implemented a location-based reliable multicast algorithm for mobile ad hoc networks. A grid network with geographical locational information was divided into a high-channel sub-network and a low-channel sub-network according to labels of grids. Then destination nodes were partitioned into groups by using location information, and a multicast routing was done in label order for each group. The algorithm does not require the maintenance of a distribution structure including a tree or a mesh or a planar graph, which introduced extra cost. The algorithm was well suited for highly dynamic networks.

The gateway connecting the wireless and wired network may experience congestion as the packet loss on the wireless side will be higher than the wired side. Similarly, the end to end delay will be different for wired and wireless side leading to QoS issues for multimedia traffic.

### 3.4 MULTICASTING IN HETEROGENEOUS NETWORK

The recent past saw the Internet evolving from wired infrastructure to a hybrid of wired/wireless domains ensuring microwave access (WiMAX), Wi-Fi, and cellular networks interoperability globally ensuring an increasing need to facilitate reliable content delivery over heterogeneous networks. But, Application Layer Multicast (ALM) is a promising approach to stream media content from a server to many interested nodes. ALM nodes construct a multicast tree through which they deliver the data stream.

Aurrecoechea et al (1998) examined the state-of-the-art in the development of QoS architectures and presented QoS terminology and a generalised QoS framework for understanding and discussing quality of service in the context of distributed multimedia systems. The study incorporated a generalised QoS framework that was motivated by five design principles including integration, separation, transparency, multiple timescales
and performance. The elements of the generalized framework included QoS specification along with static and dynamic QoS management. These were summarized and evaluated key research in QoS architecture for distributed systems while presenting a discussion of some issues that emerged during comparison of existing QoS architectures. While the area of QoS research in multimedia networking was mature, work on QoS architecture remained in early developmental stages with no performance results validating this approach.

Xiaohua Jia et al presented (2001) i) a delay analysis model for admission control of real-time multicast ATM network connections; ii) a distributed multicast routing algorithm generating suboptimal routing trees in real-time constraints; and iii) a connection setup procedure integrating multicast routing and admission control. Simulation revealed that group size was always made up of less than 30% of the total nodes, because multicast applications running in a wide area network usually involved only minimum network nodes.

Border Gateway Protocol (BGP) was extended to advertise available bandwidth and delay route information by Li Xiao et al (2002). Instead of traditional deterministic metrics, statistical metrics like Available Bandwidth Index (ABI), Delay Index (DI), Available Bandwidth Histogram (ABH) and Delay Histogram (DH), were defined and applied to QoS information advertising/routing. Statistical metrics major contributions include: i) QoS information being abstracted into one/several probability intervals, resulting in heterogeneous/dynamic QoS information being represented more flexibly and precisely; ii) Capture of QoS information detailed distribution, statistical property, the new metrics proved efficient and could lower routing message overhead thereby ensuring that QoS advertising was routing scalable. Simulations confirmed QoS extension contributions to
BGP well. Also besides BGP, such statistical metrics were applicable to other networks and protocols in addition to BGP, to represent QoS information precisely and scalable.

A load sensitive routing (LSR) algorithm attempting to route packet through an alternate route due to link congestion was tried out by Shao (2002). Increase in real-time applications like Voice over IP, audio and video streaming in the internet ensured QoS based routing. The study believed that a better way of implementing QoS routing was to localize the QoS routing changes in the region where QoS had deteriorated, instead of flooding the entire network. LSR routing was contained locally. Only neighboring nodes of a congested node performed LSR routing and so it had much less overhead than other QoS routing protocols reported. The LSR algorithm was designed to avoid any looping. Simulation results of LSR algorithm showed that its average performance was better than OSPF algorithm with regard to delay and jitter.

Striegel and Manimaran (2002) presented a method for providing heterogeneous QoS to multicast groups via dynamic DiffServ Code Point (DSCPs) without per-group state information in the DiffServ core. The study detailed its approach as well as examined implications for an adaptive method for both multicast and unicast connections. To evaluate the effects of heterogeneous DSCP marking in the DSM Cast architecture, the study conducted extensive simulation studies using the ns simulator. The simulation studies compared performances of two previously discussed models, including the non-dynamic DSCP tree and the dynamic DSCP tree. For the non-dynamic DSCP tree, multiple DSCPs were forwarded by creating separate trees for each DSCP. The studies revealed that using dynamic DSCPs in a multicast tree could offer significant bandwidth savings. Although these savings were reduced under non-uniform loads, they were
significant enough to justify the additional per-packet cost of DSCP information. This approach had a merit for not only QoS multicasting but also for adaptive unicast services.

An overview of QoS concept, its importance and specification issues in communication networks and QoS routing algorithms and their classifications was presented by Abdullah et al (2003). Two main issues to support QoS in communication networks were QoS specifications and QoS routing. QoS specifications investigated and specified QoS requirements and quantified them.

QoS routing selected a data transmission path from source to destination in a way to satisfy constraints or optimise requirements. Routing Algorithms have usually one or more goals including correctness, Optimality, simplicity, low overhead, stability and robustness, rapid convergence and flexibility. Routing algorithms could be classified different criteria like information source, number of destinations, decision place, number of considered QoS metrics, required QoS guarantee levels, wired or wireless and Connection mode. Though most of these categories were overlapped or dependent on each other, they still were able to clarify routing algorithm classification.

Jang et al (2008) implemented a heuristic algorithm to construct a shared-route in multicast routing networks that provided communications between multi-users like IPTV, remote education/health, and internet broadcasting. The performance of algorithm was compared with the optimal solution in which enumeration method was used to find the shared route with minimum delay. The results showed that the minimum of maximum delay (MMD) had the largest cost, and the Minimum Estimated Delay (MED) outperformed Minimum Average Delay (MAD) and MMD. From the cost deviation analysis cost deviation with the optimal solution was evaluated as
the 29.1% (MMD), 19.1% (MAD), and 17.3% (MED) thereby showing that MED performed the best among the three. The results revealed that the total delay increased when the number of sources increased. The cost deviation with the optimal solution is calculated as 11.3% (MMD), 3.05% (MAD), and 3.05% (MED). Under the routing network with the uniformly distributed delay between nodes, the simulation results showed that the algorithm using the estimated delay outperformed other algorithms.

Most techniques in the literature were able to improve the QOS in the heterogeneous network, however they do not address the NP-Hard problem faced by protocols used to improve QOS. Further work needs to be done to address the QOS issues.

3.5 MULTICAST ROUTING ALGORITHM

Sun et al (1998) proposed a distributed delay constrained dynamic multicast routing algorithm DCDMR. The proposed algorithm DCDMR scales well as the source of the multicast tree needed only limited computation or might not even be involved in the route computation. Many new distributed multimedia applications involved dynamic multiple participants have stringent end-to-end delay requirements and consume large amount of network resources. When group membership changed, the existing multicast tree was perturbed as little as possible and the average resulting tree cost was very satisfactory. DCDMR had very good cost performance. Simulation results showed that DCDMR in the fast mode was at least better than NAIVE and DCDMR in the slow mode was at least better than DCDMR in the FAST mode. When DCDMR worked in the FAST mode the route computation was very fast and when it works in the slow mode very low cost trees could be computed.
Karaman et al (2007) analyzed the problem of constrained cost minimization and proposed a new solution, SPAN. The proposed model executed on multiple metrics for constrained multipoint communication, and spanned the entire range of solutions in its search. Constrained cost minimization in QoS routing for multipoint communication groups was the problem of path construction to achieve efficiency. Generally, the source-or core-based approaches are used, solely searched a sub-domain of the solution space. The study’s analysis of the space solution for this range of problems indicated the need for a broader range which was not explored by existing models. But SPAN met this need through a distributed asymmetric framework for constrained, multi-source, multipoint communication groups searching for solutions in an extended space for improved cost-efficiency. Simulation results demonstrated the significance of the findings indicating the potential contribution of the range of models processing in the extended space. SPAN operated on local distance-vector information on the routers, and its functionality was not restricted due to the characteristics of autonomous systems. Its core-based architecture could be extended further for inter-domain groups with participants cutting across routing domains through the construction and management of intra-domain routes coordinated by the core placed in the domain.

Pavarangkoon et al (2004) proposed the late version of MG algorithm that yielded good performance in a situation that the inaccuracy of information given by user might have happened as revealed through simulation. Resewing resources for requested applications was one of the most effective schemes that were offered for the time-critical multimedia applications recently. Because the resource was limited, the ability to provide resource reservation in advance was essential in multi-party applications with dynamic accessing and leaving of users like modern integrated (voice, video and data) collaboration systems. Modified Greedy (MG) algorithm 141 was
proposed for multicast routing in advance reservation environment (time of joining in and leaving from multicast group needed to be informed of source node). However, MG algorithm had an assumption that members of multicast groups join in and leave from multicast sessions punctually. The proposed method modified the dynamic multicast routing problem with advance resource reservation to be more realistic as the original version of MG algorithm wasted more network resources to cope with errors. The new version of MG algorithm was biased toward existing routes with significantly higher departure time which meant that the source node attempted to make a reservation for more resources, just in case member nodes consumed more network resources than reserved. But the proposed algorithm was centralized and so required many query/reply messages between member nodes. The performance of network nodes would be degraded when network grew up to be large-scale and the central server might be overloaded.

Tran et al (2003) proposed a new multicast routing algorithm that aimed to reduce evolving tree cost over time, yet did not require any rearrangement to the existing tree. This study was based on dynamic multicast routing problem where nodes were allowed to join and leave a multicast group at any time. Many algorithms were proposed for this problem and their performance was always evaluated on the tree cost at the time of a join or a leave event. However, it was believed that the multicast tree cost over time should be used as a performance metric in evaluating the effectiveness of a dynamic multicast routing algorithm. A proposed new multicast routing algorithm PDM, made use of the probability of a node being pruned off from an existing multicast tree to make a good decision on where and how to connect a node to the multicast tree so that the quality of the tree did not deteriorate over time due to join and leave activities. Simulation results proved that as long as pruned-off probabilities of on-tree nodes were computed properly, the multicast tree constructed by PDM consistently used
less network resources than shortest path, Greedy, W-Greedy, VTDM, and Wang-Chen’s algorithms for all test cases.

Xiongfei Li et al (2004) presented a dynamic multicast routing algorithm called CRMR. An initial multicast tree was constructed by the KPP algorithm and a virtual trunk (VT) was built simultaneously in the algorithm. The Trigger Function (TF) that associated the QoS affected by members update in this region was used in CRMR. The study also introduced a bandwidth indication function to alter CRMR algorithm to fit multiple QoS guaranteed, which could deal with the constraints of bandwidth and delay. The performances of CRMR algorithm and others was compared through simulation. The performance of CRMR was analyzed through the following metrics including cost competitiveness, average tree change, average CPU time and random request generation. The simulation results indicated that CRMR algorithm provided better balance between cost performance and changes in the multicast tree after each update. Reasonable values of the parameters were given in this study. The study also introduced a bandwidth indication function to alter CRMR algorithm to multiple QoS guaranteed algorithm that could deal with the constraints of bandwidth and delay.

Chen and Shavitt (2004) presented a new scalable QoS multicast routing protocol (SoMR) that had very small communication overhead and required no state outside the multicast tree. The study was the result of many Internet multicast applications like teleconferencing have QoS requirements. The proposed SoMR achieved a trade-off between routing performance and overhead by careful selection of the network sub-graph in which it conducted the search for a path that could support the QoS requirement, and by auto-tuning the selection according to current network conditions. Its early warning mechanism helped to detect and route around the real bottlenecks in the network, which increased chance of finding feasible paths for additive
QoS requirements. SoMR minimized the system requirements and relied only on the local state stored at each router and completely decentralized routing operations were achieved. Remarkably, SoMR achieved better success ratio at much lower message overhead. When the delay requirement was small like 100, the spanning joins protocol had a very large overhead of more than 600 messages per join request. That was because the multicast tree was always small and most join requests resulted in large scale flooding. Although the overhead of SoMR was higher than that of SPR, it was worth mentioning that for join requests SPR was able to find feasible paths, but as SoMR behaved just like SPR it too had the same overhead. Only for join requests was SPR unable to find feasible paths. SoMR also sent more control messages.

Sahoo (2002) presented an algorithm based on Open Shortest Path First (OSPF) called Load Sensitive Routing (LSR) algorithm, in which congestion notification was limited to neighbors of the congested node with neighbors trying to use alternate next hops to route packets. The study came about due to the fact that real-time applications like Voice over IP, audio and video streaming required QoS as they were being executed over the Internet. Some QoS routing used source routing and others used flooding of some QoS node attributes. There were also some variants of shortest path algorithm reported in literature, but they required changes to packet forwarding engine and logic for loop detection. This study believed that a better way of implementing QoS routing was to localize QoS routing changes in the region where QoS had deteriorated and choose loop-free alternate paths. Alternate LSR next hop is chosen in such a way that it preserves the next hop property of OSPF routing which enabled LSR algorithm to avoid loop. Three methods were presented for choosing an alternate LSR next hop. All these methods provide loop free routing. The simulation results based on the three methods
showed that on an average LSR algorithm performed better than OSPF algorithm with regard to delay and jitter.

Huang and Lee (2006) proposed a group computation based distributed algorithm for solving the problem of multi-constraint multicast routing. The main objective of the algorithm lay in how to reduce network cost of the multicast tree while considering the connectivity of the network and the routing overhead. This algorithm was fully distributed and could generate within acceptable time and message complexities a multicast routing tree, which not only satisfied the required multiple QoS constraints but also had a sub-optimal network cost. In experiments when the group size was small, the extent of the influence was not apparent. But as the group size increased, the impact was more apparent. The study also showed the improvement-ratio but from a different view of point; from the variation of the delay constraints. When the delay constraint was stringent, the number of candidate nodes including fork nodes that the algorithm can choose did not increase, so the extent of the improvement was not very apparent. But as the delay constraint was loosened, the number of candidate nodes increased and proportionately the extent of the improvement would also increase. The study made use of an underlying Multi-Constraint Unicast Routing Protocol/Algorithm (MCURA) and iteratively selected possible candidate fork nodes in the current multicast routing tree to construct feasible QoS paths to destinations in the multicast group, while optimizing the total network cost to the extent possible. Compared to the existing well-known algorithms/protocols this algorithm was more efficient in terms of communication cost, the overhead of the message and performance of the resource sharing. The results of the simulations showed that the multicast routing tree generated by the proposed algorithm had better performance than previous well-known results.
Younis and Sonia (2003) discussed several constraint-based routing approaches and explained their requirements, complexity, and recent research proposals. In addition, the study illustrated how these approaches could be integrated with Internet label switching and QoS architectures. Constraint-based routing algorithms selected a routing path satisfying constraints which were either administrative oriented (policy routing), or service-oriented (QoS routing). The routes, in addition to satisfying constraints, were selected to reduce costs, balance network load, or increase security. Constraint-based routing comprised both policy and QoS routing. Policy routing was important to provide better and more flexible services. The study discussed the general policy framework, policy routing problems in BGP, and some of the recent work at the Internet Engineering Task Force (IETF) working groups. QoS routing was studied in literature more extensively than policy routing. Recent studies revealed the possibility of performing QoS routing with inaccurate information without suffering significant performance losses. In addition, applying aggregation techniques for scalability did not always negatively impact performance and it was found that intelligent tuning of QoS routing algorithm parameters used in state updates could improve performance with regard to stability and load balancing.

Yang and Yang (2005) designed a heuristic algorithm which could construct a delay constrained minimum cost multicast tree dynamically and add or remove group members without rerouting the path between the source and other group members. This study came about due to the fact that multicast was an efficient way for group communication over the Internet. The performance of multicast relied greatly on the multicast tree constructed among group members. Constructing a multicast tree spanning group members with minimum cost was called Steiner tree problem which was a well-known NP-hard problem. Existing heuristic algorithms could build such a Steiner tree statically when the group members were known in advance. But
in many multicast applications, group members changed frequently requiring the algorithm to adjust the multicast tree dynamically. Additionally QoS was becoming a more important issue in multicast applications, and many applications posed a tight bound on end-to-end delay. The proposed algorithm not only avoided packet loss but also saved network bandwidth. The proposed algorithm guaranteed that the end-to-end delay between source and a group member was bounded with a threshold. Simulation results revealed that the algorithm achieved a balance between cost of a multicast tree and time of tree construction. Simulation results showed that the proposed algorithm achieved much lower tree cost than SPT and had only 10-20% higher tree cost than KMB.

Alrabiah et al (2001) focused on developing low-cost, delay-bounded multicast trees to support the QoS requirements of multimedia applications. The study was necessitated by the fact that support for multimedia applications was a major objective of future high speed networks. Multimedia applications were usually resource intensive, with stringent QoS requirements, and in many cases involved large multicast groups. Multicasting enabled these applications to scale to a large number of users without overloading network and server resources. The approach taken in development of multicast trees was to decouple cost optimization from bounding the delay by first building a low-cost tree and then handling any delay violations that might occur in the tree. Three new heuristics were proposed. The first two delay-constrained low-cost inexpensive multicasting (SLIM) and SLIM+, used the least-cost path between the multicast nodes to incrementally build a multicast tree that satisfied delay requirements of multicast nodes. Their complexity was \( O(n^3) \), where \( n \) was the number of network nodes. The third heuristic, K-SLIM, built a set of \( k \) shortest paths and used them to further reduce the cost of the multicast tree without violating delay requirements of multicast nodes. Its time complexity was \( O(kn^3) \).
log(n)), where \( k \), a user-defined parameter, denoted the number of shortest paths under consideration. Simulation results showed that K-SLIM on average outperformed well-known heuristics. The results proved that SLIM+ produced low-cost, delay-bounded trees with an average cost close to the average cost of trees produced by K-SLIM but with reduced processing overhead.

Carzaniga et al (2012) et al proposed a routing scheme for multicast communication in wireless networks. The proposed method is compact, and fully decentralized. The proposed routing is built on top of a geographical routing layer. A geometric minimum spanning tree connecting the source and all the destinations is used to transmit each message. The system routes message through a random intermediate node for each edge in this tree. The congestion is reduced by choosing an intermediate node in the vicinity of the corresponding edge. The proposed method was analytically evaluated and it was proved to achieve optimal level of congestion. Simulation results demonstrate that the proposed routing performs well.

Kamboj et al (2010) with minimum control overhead proposed an energy efficient multicast routing protocol for MANET. Implementing the node’s physical location, shared multicast tree are formed for the multicast sessions in the proposed protocol. For the purpose of attaining the node’s physical location information that efficiently minimizes the overheads for searching route and maintaining shared multicast tree is achieved by implementing a distributed location service in the protocol. For sustaining proactive topology within the zone around every node, the protocol employs the small overlapped zones concept. The constrained directional forwarding is utilized to ensure superior decrease in overhead compared to network wide flooding for the purpose of searching multicast tree outside the zone. The local connectivity method and preventive route reconfiguration based on the
existing node’s status are proposed in this work and in terms of minimized power, overhead and bandwidth necessitates the efforts to advance the performance. These proposed approaches in the link breakages and in prevention of network prevention guarantees superior minimization in latency.

Nguyen et al (2006) proposed a multirate-aware multicast routing in MANETs called Rate-Adaptive Multicast (RAM) routing protocol. In path discovery process, the evaluation of quality of wireless links is performed to provide the rate of optimal transmission that are then implemented for evaluating total transmission time acquired by the path of the mobile nodes. Many paths occurring from the source to destination are considered and then the path with less total transmission time is chosen by RAM. By performing simulations in terms of packet end-to-end delay, packet delivery ratio, and high-throughput of the multicast group the performance of RAM is revealed over single-rate multicast. RAM functions well in any multirate standards and it is the first routing protocol to find the ability of multirate mobile devices.

3.6 MULTICAST ROUTING QUALITY OF SERVICE (QoS)

Chakraborty et al (2003) proposed a QoS based routing algorithm for dynamic multicasting. A Weighted Fair Queuing (WFQ) service discipline was applied to reduce the complexity of the problem to a simple shortest path problem. A modified Bellman–Ford algorithm was used and the proposed routing built a multicast tree, where a node was added to the existing multicast tree without re-routing and satisfying QoS constraints. With user defined life-time of connection this heuristic algorithm built multicast tree which was near optimum over the whole session duration. While finding routes from source to destination was important, it was also important to ensure that use of network resources was optimized. This dual goal was achieved through the MQ-DMR algorithm, which used a unique way to
calculate cost for links constituting an existing MC tree. The links that remain connected to the MC tree for long periods would have lesser cost. Hence it will connect newer destinations and minimize overall bandwidth use of the network. Resource reservation needed to be supported for multimedia communication. If WFQ strategy was used upper bound hop length for delay jitter constraint and loss-free communication becomes known. Different simulations showed that though MQ-DMR searched QoS satisfied routes, it was almost as efficient as other algorithms.

Biradar et al (2010) proposed a new method called mesh based multicast routing approach which detects the constant multicast path from the source to the receivers. The route request and route reply packets including the support of link stability database and multicast routing information cache sustained in all nodes are implemented to build the multicast mesh. On the basis of choosing the stable forwarding nodes which has extreme stability of link connectivity is the stable path identification performed. Parameters such as distance between neighboring nodes, received power and link quality assessed by the bit errors present in a packet are utilized to compute the link stability. The evaluation of the proposed approach is performed by simulation on several MANET nodes with differing mobility. When compared to On-Demand Multicast Routing Protocol (ODMRP), the proposed approach gives packet delivery ratio, reduced packet delay, less control overheads in an efficient and better way.

Calle et al (2003) defined new protection strategies for building reliable MPLS networks, based on what is now called the Network Protection Degree (NPD). NPD based networks still lacked the required degree of reliability needed by new multimedia services. Achieving such reliability would be crucial for the success of the new Internet generation. Most of existing schemes for QoS routing do not consider parameters concerning the
quality of the protection, like packet loss or restoration on time. NPD consists of an a priori evaluation, the Failure Sensibility Degree (FSD), which provided failure probability and an a posteriori evaluation and the Failure Impact Degree (FID), to determine the impact on the network in case of failure. Experiments demonstrated the benefits of NPD application when used to improve the well-known routing algorithm WSP, which had enhanced becoming a protected wide shortest path (WSP) (PWSP) in the study. This lead to a reduction in the FSD and FID, with regard to a reduction in the number of protected links (NPL) and the probability of failure. Besides reducing NPL, resource consumption when using local backups was reduced. PWSP algorithms also reduced the impact in case of failure by decreasing the number of LSPs with critical (large) distances $D(i, a)$ and failure probabilities.

Shin et al (2002) proposed a multiconstraint QoS routing scheme, MPMP (multi-prepaths multipostpaths), which achieved low EDR and polynomial worst-case time complexity using a modified Dijkstra's algorithm with a metric, called the minimum normalized margin. MPMP performance for QoS routing problem was evaluated through two QoS attributes, where 10,000 simulation runs were performed with each of the runs being executed through the following steps. To begin with two kinds of random network topologies using the Waxman model and the Inet Topology Generator were generated with the former having 400 nodes and 1106 links, while the Inet Topology Generator had 4,000 nodes and 7,741 links. The results reveal that MPMP had low EDR for all the correlation coefficients, and that the EDR decreased as the maximum number of prepaths per node increased. It was also noted that EDR for the Internet like network topologies was lower than for network topologies generated by the Waxman model, inspite of larger network size. MPMP thus provided a promising solution for multiconstraint QoS routing, which would be essential for the provision of high-quality
services in communication/computer systems. Thus, MPMP proved it could achieve low EDR with a smaller amount of memory to store prepaths than either TAMCRA or H MCOP.

Sivasubramanian et al (2001) proposed a multi-destination QoS multicast routing protocol that aimed at alleviating traffic concentration around core. In the proposed protocol, a receiver linking into an existing multicast session created a path by performing a single path search towards multiple members of the multicast tree. The emergence of new multimedia group-based applications underlined the need for efficient network support for QoS multicasting. Traditionally, multicasting used a CBT distribution model where a receiver joining the group tried to establish a path to the core, making the core to be the hot spot node in the network, especially when many groups had the same node as their core. Hence, network resources around the core became the bottleneck, which traditional multicast routing protocols suffered from - the hot spot communication around the core. The effectiveness of the proposed multi-destination routing protocol was demonstrated through extensive simulation studies by evaluating its performance with regard to Average Call Acceptance Rate (ACAR) and Average Call Setup Time (ACST). Studies reveal that the proposed protocol performed better than the existing single-destination multicast routing protocols (in terms of ACAR), especially when the groups were resource intensive like the high bandwidth groups.

Striegel et al (2002) presented a multicast “life cycle” model that identified various issues involved in a typical multicast session. The study first outlined various issues in multicast communication through tracing the life cycle of a multicast session and focused on two key issues: managing group dynamics and failure recovery, which had a profound impact on QoS multicast routing and the QoS experienced by the end user. For these issues,
the following research problems were identified. It included: • _Join/leave QoS routing:_ Although significant work was done on QoS routing, currently proposed schemes did not meet all goals of a good multicast routing protocol, leading to the fact that further research was needed to develop schemes providing better performance on both intra- and interdomain routing scales.

As regards Tree _maintenance_, tree rearrangement received significant attention recently and needed further research. The management of group dynamics in an integrated manner addressing all of the sub problems was fit for further research. With regard to _Core and tree migration_ although there was some work on online core evaluation, there was no work on tree migration taking service disruption aspect into account. Three important events could occur during the life cycle of a multicast session: group dynamics, network dynamics, and traffic dynamics. The first two aspects were concerned with maintaining a good quality multicast tree taking into account member join/leave and changes in the network topology due to link/node failures/additions, respectively. The third aspect was concerned with flow, congestion, and error control. Various issues and solutions were examined for managing group dynamics and failure handling in QoS multicasting, and outlined several future research directions.

There was an obvious need for QoS on the Internet and QoS routing was an important component of the overall QoS framework. The role of QoS routing strategy was to compute paths that were suitable for different kinds of traffic produced by the different applications, while maximizing the utilization of network resources. The fulfilment of these objectives required the development of algorithms that found multi-constrained paths. The state of the network and the traffic requirements (jitter, loss rate and available bandwidth) are taken into consideration. But the problem of finding multi-constrained paths had high computational complexity, and hence there was a need to use algorithms which addressed this difficulty. Curado et al (2004)
presented and discussed the approaches used to reduce QoS routing algorithm complexity and improve overall network performance. The main problem that had to be solved by QoS routing algorithm was the Multi-Constraint Path problem. Algorithms to solve this family of problems were known as heuristics to reduce complexity of the path computation problem but at the expense of not attaining the optimal solution for the problem. A feasible solution was enough. Within this framework, QoS routing algorithms presented were grouped as Bandwidth Restricted Path algorithms, Restricted Shortest Path algorithms and algorithms that used metrics combination.

3.7 OPTIMIZATION USING GENETIC ALGORITHM

Jiang-qing et al (2006) proposed a new dynamic multicast routing model. The node movements and the change of link delay the two possible changes in integrated network were specially studied. To achieve balances between cost, time and extension of changes of the tree, the study adopted the idea of accumulating impact on a tree and triggering a rearrangement based on a threshold. Also, even when it was time to rearrange a multicast tree, there was no need to optimize the whole multicast tree from scratch but only from that part of a tree affected directly by the changes. Due to existing shortcomings in heuristic methods the study utilized an artificial immune algorithm to solve the optimization problem of multicast sub-tree. Based on earlier successful research in static multicast routing domain the clone process is taken advantage of, a popular immune process in Artificial Immune System Gene library as the main component of the optimization algorithm. The gene library is composed of good genes. A new antibody produced from gene library had good quality with much higher possibility than produced randomly. Dijkstra K-th shortest path algorithm was used to construct gene library. From simulation experiments, it could be concluded that the solution
for MDCMR proposed still had acceptable computation overhead. It also balanced three metrics better compared to two other routing algorithms.

de Araújo et al (2002) presented the use of Genetic Algorithm (GA) as a method to get appropriate routes to deal with high computational power required by the QoS routing. This study came about due to the fact that prevalent Internet service model did not permit users to obtain QoS as it did not have a differentiated treatment for data flows. The IETF proposed several solutions for QoS, among them, the Traffic Engineering (TE), which demanded Constraint-Based Routing. In routing a combination of additive and/or multiplicative metrics was an NP-complete problem. Thus, the Constraint-Based Routing was viewed as an intractable implementation problem. Two innovations were incorporated in the GA to attend TE requirements. It included the metric of hops in the route evaluation, and a mechanism for avoiding the generation of repeated individuals creating a number of optimal and sub-optimal routes. These two modifications were important for TE as they enabled fast re-routing, load balancing and an improvement in the general performance of the network, by reducing hops steps. The tests for each network consisted of 4 experiments: 2 different population sizes (15 and 30) and 2 different numbers of generations (20 and 50); 20 GA runs formed each experiment. The result showed that the worst of the 4 experiments converged to the global optimum in 70% of the runs, that is, 14 GA runs reached the optimal route. The GA also found the optimal solution. The results indicated that the GA implemented in this study converged to the global optimal solution, while other implementations also discussed did not reach it.

Hamdan et al (2004) presented a constrained multicast routing scheme based on GA, a Delay and Delay Variation Multicast Routing (GADVM). Two constraints which represented QoS measures that a network
should provide for real-time applications were considered. First, constraints on end-to-end delay from source to each destination, second, a bounded delay variations along the paths from source to each destination. The performance of the proposed algorithm was evaluated through simulations and compared with four known multicast routing algorithms including BSM, CDKS, SPT, and KPP. Two performance metrics - failure rate, and average cost per path – were considered. It was demonstrated that GADVM algorithm compared favorably and gave much lower failure rates, while its cost was also comparable and in some cases better than other algorithms. A detailed study of simulation results indicated that GADVM compared favorably with the other multicast routing algorithms with regard to success rate in finding a feasible tree with constraints. The algorithm performed reasonably well in terms of tree cost although it was not developed to optimize the tree cost. Overall, GADVM was able to strike a balance between network requirements (cost) and user constraints (end-to-end delay and delay variations). This feature became increasingly important with more real time applications being offered by the networks.

Tran et al (2003) developed a number of heuristic algorithms for optimal allocation of delay requirements using GA. Knowing the QoS requirement for each link involved in a multicast connection, so that overall QoS requirement was satisfied, would greatly assist both QoS-based multicast routing and resource reservation processes. In case of delay, the question of what delay requirements should be imposed on each link of a source-based multicast tree, so that overall source-to-destination delay and inter-destination delay variation requirements were satisfied at minimum total tree cost, was the focal point of this study. A major Initial tests, with multicast trees of different sizes (10 and 30-node trees), configurations, and overall delay requirements, showed the ability of the algorithms in providing good solutions within a reasonable amount of time. The experiments led to the
derivation of many lemmas and theorems that was the basis for the development of two GA-based algorithms and a greedy algorithm. Initial test showed that the proposed algorithms were capable of providing good solutions. The test results also revealed that GA-based algorithms consistently provided good solutions, while the greedy algorithm was able to come up with very good solutions only in some cases but provided poor solutions in others.

Olivera et al (2005) discussed combinatorial issues occurring in the implementation of multicast routing, including multicast tree construction, minimization of the total message delay, center-based routing, and multicast message packing. This study came about due to the fact that multicasting was a technique for data routing in networks that allowed multiple destinations to be addressed simultaneously. The implementation of multicasting required, however, the solution of difficult combinatorial optimization problems. The rich combinatorial structure of multicasting made it possible to provide several perspectives of the issues at hand problem, though different and sometimes unrelated objectives must be optimized, as well as the various constraints that should be satisfied by practical systems. Most problems concerning multicast routing were challenging for researchers working in combinatorial optimization. First, the problems in this area were of practical interest, as most network applications would benefit from good algorithms for the problems discussed. Secondly, many problems were not fully explored using tools of optimization. As revealed in this study, most algorithms were only concerned with the generation of feasible solutions, with some additional requirements used to maintain a minimum quality of service. It remained an open question as to how the solutions returned by the discussed algorithms could be improved by the application of optimization techniques.
Khreishah et al (2012) investigated the network coding-based opportunistic routing problem for multicast. The factors that affect the performance of the multicast protocols was presented. The problem was formulated into an optimization problem. It was demonstrated that a distributed solution based on duality approach can be utilized to achieve the optimal solution. The proposed distributed solution is applied in two steps. In the first step, a reliable broadcasting tree is created based on the ETX metric. A credit assignment algorithm is run in the second step to decide the number of coded packets that the node has to send. Network coding on the feedback messages is performed to reduce the number of feedback messages. Simulations conducted demonstrate that the proposed algorithm doubled or tripled the throughput achieved in some realistic cases.

Tropea et al (2013) compared between two meta-heuristic algorithms to find sub-optimal solutions for the steiner tree problem. The meta-heuristics are based on GA and Simulated Annealing (SA) mechanism. The goodness of the GA and SA is verified using several simulations. The simulation results demonstrate that the proposed SA achieves good performance for limited network size. The GA outperforms the proposed SA algorithm in finding solutions because it is closer to the optimum solution than the solution found by the SA.

3.8 REAL-TIME MULTICAST APPLICATION

Chen and Nahrstedt (1998) gave an overview of the QoS routing problems and existing solutions. The strengths and weaknesses of different routing strategies and their challenges were highlighted. The study also discussed the basic algorithms in each class, classifying and comparing them, while at the same time pointing out directions for the future in the QoS routing area. The study was the result of the fact that the up and coming Gbps high-speed networks were expected to support a wide range of
communication-intensive, real-time multimedia applications. The requirement for timely delivery of digitized audio-visual information raised new challenges for the next generation integrated-service broadband networks. One of the key issues was QoS routing. It selected network routes with sufficient resources for the requested QoS parameters. The goal of routing solutions was two-fold and included satisfying the QoS requirements for every admitted connection and achieving the global efficiency in resource utilization. Many unicast/multicast QoS routing algorithms were published recently which worked with a variety of QoS requirements and resource constraints. Overall, they could be classified into three classes: (1) source routing, (2) distributed routing and (3) hierarchical routing algorithms. Source routing algorithms simplified path selection problem by locally computing a feasible path based on a global state maintained at every node. The responsibility of path selection was shared by intermediate nodes in distributed routing. Most existing distributed routing algorithms required maintenance of a global state. Hierarchical routing provided a scalable solution as path selection was based on aggregated state information whose size was reduced. But, information imprecision was an issue of concern due to state aggregation. Also it was an unsolved problem to aggregate the state of a subnet with multiple QoS metrics.

Salama et al (1998) compared the performance of all important multicast (MC) routing algorithms when applied to networks with asymmetric link loads. The study came about due to the fact that multicast (MC) routing algorithms capable of satisfying QoS requirements of real-time applications would be essential for future high-speed networks. Each algorithm in the study was judged on the basis of the quality of the MC trees it generated and its efficiency in managing network resources. Simulation results over random networks showed that unconstrained algorithms were not capable of fulfilling the QoS requirements of real-time applications in wide-area networks. They
also revealed that one of the unconstrained algorithms, reverse path multicasting (RPM), was inefficient when applied to asymmetric networks. The study pondered over how combining routing with resource reservation and admission control improved RPM’s efficiency in handling network resources. The performance of a semi-constrained heuristic, MSC, three Constrained Steiner Tree (CST) heuristics, KPP, CAO, and BSMA, and one constrained Shortest Path Tree (CSPT) heuristic, CDKS were also studied and simulations revealed that the semi-constrained and constrained heuristics were capable of successfully constructing MC trees that satisfied QoS requirements of real-time traffic. But cost performance of the heuristics varied. BSMA’s MC trees were lower in cost than all other constrained heuristics. Finally, execution times of, un-constrained, semi-constrained, and constrained algorithms were compared.

3.9 MULTICAST ROUTING ALGORITHM FOR MULTIMEDIA APPLICATIONS

Kang (1997) proposed a source-based optimal dynamic multicast routing algorithm that satisfied network conditions of delay constraints, cost minimization and adapted dynamic network events. A source-based Optimal Dynamic Multicast Routing (ODMR) algorithm was proposed that satisfied network conditions of delay constraints, cost minimization and adaptability to a dynamically changing network condition of adding and deleting a node from the group. The study also views the following network requirements: efficient dynamic group support, high-quality data distribution, and adaptability to dynamically changing events. It constructed a dynamic delay-bounded optimal multicast tree using partial multicast routing and evaluated the performance of the proposed algorithm by running simulations, written in C++ with randomly generated test networks on a Sun Sparc 20 workstation. As a result the study understood that by choosing the appropriate values for
delay bound, the proposed a source based dynamic multicasting routing algorithm satisfied the network conditions of delay constraints, cost minimization and can adapt to a dynamically changing network condition of adding and deleting a node from the group. By choosing the appropriate values for delay bound, the study was able to obtain an optimal solution that was bound between the minimum cost solution and minimum delay.

Gu et al (2004) presented a distributed voice-over-IP (VoIP) conferencing system called Venus that was implemented as a composable application level service overlay network. The study came about because of the fact that while the ubiquitous IP telephony had become a feasible Internet service, it was expected to meet the quality standards for traditional telephone services. Compared to the traditional centralized approach, Venus achieved better scalability and resource utilization by efficiently aggregating resources across distributed voice mixers. Also Venus provided multi-constrained QoS provisioning by establishing each conferencing session based on multiple QoS constraints like delay, loss rate and resource requirements like bandwidth and audio channels. For simulation the study used a degree-based Internet topology generator Inet 3.0 to generate a power-law random graph topology with 3200 nodes representing the IP-layer network. Then a number of nodes were selected as Venus nodes and portals randomly. The initial resource capacity and average QoS values of each network link and mixer were uniformly distributed. Each conferencing session lasted 5 to 30 time units with each simulation running 2000 time units. During each time unit, a certain number of VoIP conferencing requests were randomly generated. Each VoIP conferencing request included 10 to 200 participants whose locations were uniformly distributed. It was observed that Venus could achieve much higher success rates than the other two algorithms by efficiently aggregating resources of distributed mixers and finding best mixing service path under delay and loss rate constraints.
Boulogne et al (2005) considered competitive routing in multicast networks from a non-cooperative game theoretical perspective. Users shared a network, each had to send an amount of packets to a different set of addressees and each address had to receive the same packets. To do this it had only to send one copy of a packet, with the network making duplications of the packets at appropriate nodes again depending on the chosen trees. The routing choice of a user was how to split the flow between different multicast trees. The study presented different criteria of optimization for this type of games. It treated two specific networks, established the uniqueness of the Nash equilibrium in several networks, as well as the uniqueness of links’ utilization at Nash equilibria for specific cost functions in networks with general topology. An interesting expansion of the proposed model arose in the case of multi-rate transmission which could be attained by hierarchial encoding real time signals. In this approach, a signal was encoded into a number of layers that could be incrementally combined to provide progressive refinements. Every layer was transmitted as a separate multicast group and receivers might choose to which group they wished to subscribe, according to the capacity available or the congestion state. Internet protocols for adding and dropping layers can be found. Multi-rate transmission had applications both in video and audio.

Markus Albrecht et al (2000) proposed a QoS management system for multimedia servers that benefited from scaling properties of layered media streams. This study came about due to the fact that the migration of the Internet from classic computer communication to a platform for multimedia applications with real-time communication required end-to-end improvement of network-level service. A proposal known as Differentiated Services was a very promising approach for implementing quality of service in the Internet and was discussed and developed. The challenge was to deliver end-to-end QoS on top of Differentiated Services considering multiple concurrent
application level data streams. This enabled the system to map application QoS demands to available network resources and to adapt the quality of individual streams according to inter-stream QoS dependencies. The proposed approach integrated application-level end-to-end quality requirements and a differentiated services network architecture. Media streams which were subdivided into sub-streams according to their scaling properties were mapped to QoS classes provided by the network. The goals of the QoS distribution algorithm was to achieve a maximum average relative QoS among all streams and realize a fair bandwidth distribution across all streams considering their relative QoS. This algorithm was implemented in a prototype system and evaluated in a laboratory DiffServ environment. The measurements with layered audio streams revealed that the QoS system was able to react properly on end-to-end delay and loss rate variations. It was shown that packet loss rates exceeding certain bounds resulted in the reassignment of the affected layers to higher service classes according to the QoS requirements of the stream. The end-to-end delay measurements show that QoS management attempted to allocate resources in the lowest possible service class and did not waste higher service class resources and hence this approach could be applied to an end-to-end QoS management system in DiffServ networks.

Michel Diaz et al (2001) argued that at the network layer, single-source multicasting (PIM-SSM) should be chosen to overcome shortcomings in multimedia applications. Consequently, the study developed Monomedia Multicast protocol provided, along with reliability and QoS monitoring functionality, an ALM based multicast solution referred to as TBCP (Tree Building Control Protocol), to be used as back channel for SSM like retransmission requests. Despite its obvious suitability for distributed multimedia applications, multicasting was yet to find widespread application. Having analyzed shortcomings of today's approaches, the study devised in the
**GCAP project** a new end-to-end transport architecture for multimedia multicasting that supported partial order and partial reliability. On top of PIM-SSM at the network layer, the monomedia multicast protocol provided a multicast feedback channel through the TBCP control tree. The special requirements of multimedia applications, namely partial order and partial reliability, were supported in the new FPTP that offered a powerful multimedia multicast API to applications, and overcame the limitations of current application layer multicasting approaches. Also group integrity was discussed in a multimedia multicasting context. The study felt that GCAP was setting the stage for multimedia multicast research. On top of the Monomedia protocol, the *Multimedia Multicast* protocol handled multimedia *sessions* composed of multiple monomedia connections: The FPTP (*Fully Programmable Transport Protocol*) allowed applications to specify, through its API, the (global) synchronization and (individual) reliability requirements within a multimedia session.

Banik et al (2004) provided an efficient heuristic algorithm to obtain a multicast network for multimedia applications, given a source and a set of destinations that was within a specified maximum delay and a specified maximum variation in the delays from a source to the destinations. The time-complexity of the proposed algorithm is $O(|E| + nk \log (|E|/n) + m^2k)$, where $n$ and $|E|$ were the number of nodes and edges respectively in the network and $k$ was the number of shortest paths computed and $m$ was the number of destinations. For evaluation the study implemented DVMA, DDVCA, DPDV and the proposed heuristic titled Chains and compared them in terms of the tightest delay variation and execution time. The nodes in the graph were placed in a grid of dimension 4900×4900 km and delay for each link was set to the propagation delay of electrical signal along that link. The average node degree for each graph was kept in the range of 3.5 and 4. Each heuristic was tested on various graphs with nodes varying from 20 to 100 and
percentage of nodes in the multicast group varying from 5% to 15%. Each point in the plots represented average value taken over 30 graphs. It was observed that Chains along with DPDVB achieved the tightest delay variation for all cases and that Chains outperformed DVMA and DPDVB for all cases with regard to execution time. Only DDVCA showed better performance but it was observed that DDVCA did not achieve the tightest delay variation. The study showed that the proposed algorithm had significant improvement with regard to time-complexity compared to existing algorithms. Extensive empirical studies indicated that the proposed heuristic used significantly less run-time when compared to the best-known heuristics and yet was able to achieve the tightest delay variation for a given end-to-end delay bound.

Tu et al (2012) studied video multicasting for wireless mesh networks. The objective of the study was to avoid lengthy and low capacity route using internet access gateways which allow for choice of alternate routes. A set of heuristic-based algorithms was proposed to maximize reliable network capacity. The proposed is a two-tier integrated architecture algorithm. It consists of the weighted gateway uploading algorithm, the link-controlled routing tree algorithm, and the dynamic group management algorithm. The nodes involved in video multicasting are arranged in a clustered and two tiered architecture. This allows the network protocols to make use of multiple gateways to improve system throughput. Experimental results showed that the proposed multicasting algorithms perform better and achieve up to 40% more throughput when compared to other approaches available in the literature.