Review of Multicast QoS Routing Protocols for Mobile Ad Hoc Networks

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Abstract

A Mobile Ad hoc NETwork (MANET) is consisting of a collection of wireless mobile nodes, which form a temporary network without relying on any existing infrastructure or centralized administration. Since the bandwidth of MANETs is limited and shared between the participating nodes in the network, it is important to efficiently utilize the network bandwidth. Multicasting can minimize the link bandwidth consumption and reduce the communication cost by sending the same data to multiple participants. Multicast service is critical for applications that need collaboration of team of users. Multicasting in MANETs becomes a hot research area due to the increasing popularity of group communication applications such as video conferencing and interactive television. Recently, multimedia and group-oriented computing gains more popularity for users of ad hoc networks. So, effective Quality of Service (QoS) multicasting protocol plays significant role in MANETs. In this paper, we are presenting an overview of set of the most recent QoS multicast routing protocols that have been proposed in order to provide the researchers with a clear view of what has been done in this field.

Key words:
MANETs, QoS, Multicast and Routing

1. Introduction

With the rapid advancement in wireless communication and availability of mobile computing devices a conceptual shift happen in mobile computing and a lot of applications that can work any where and any time is emerged. There are to variations of wireless mobile communication. The first one is known as infrastructure wireless networks, where the mobile node communicates with a base station that is located within its transmission range (one hop away from the base station). The second one is infrastructureless wireless network which is known as mobile Ad hoc networks.

Mobile Ad hoc NETworks (MANETs) are collections of mobile nodes that communicate with each other over wireless links in the absence of any infrastructure or centralized administration. Each mobile node acts as a host generating flow, being the receiver of a flows from other mobile nodes, or as a router and responsible for forwarding flows to other mobile nodes [1]. Mobile nodes in Ad hoc networks have a limited transmission range, nodes that relies with the transmission range can communicate directly with each other, while intermediate nodes is needed to forward flow between nodes that are unable to communicate directly. The function of a routing protocol in Ad hoc network is to establish routes between different nodes. Mobile nodes are free-to-move without predefined mobility pattern which makes classical routing protocols used in wired networks are not suitable for MANETs. The routing protocols are classified according to the way of route information collection into proactive and reactive protocols.

Group communication becomes increasingly important in MANETs because a lot of applications relay on cooperation between a team (one-to-many and many-to-many). Video conferencing or class room settings, interactive television, temporary offices and multi-partiy gaming are common examples of these application [2] [3]. As a consequence, multicast routing has received significant attention over the recent days.

Multicast communication is emerged to support applications that facilitate effective and collaborative communication among groups of users with the same interest. Multicast is a scheme for sending the same data from a source to a group of destinations. This is efficient in saving the bandwidth and improving the scalability, which is essential in MANETs [2] [4].

Multicast routing protocol can be classified into four categories based on how routes are created to the members of the group [5]. The first is known as tree-based approaches, there is only one path between a source-receiver pair and the union of the paths from the source to the receivers forms the multicast tree. This is done using either source-base trees or shared trees. In source-based trees, single multicast tree is maintained per source, while in shared trees a single tree is shared by all the sources in the multicast group. Tree-based protocols provide high data forwarding efficiency and low overhead but it is not robust in high mobile environments [6] [7]. The second approach is mesh-based, where may be multiple paths between senders and destinations. This redundancy

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provides robustness against topological changes better than tree-based protocols [5] [6]. The third one is the hybrid approaches which try to achieve better performance by combining the robustness of mesh-based approaches and low overhead of tree-based approaches [1] [5]. The fourth approach is Stateless multicasting, tree and mesh based approaches have an overhead of creating and maintaining the delivery tree /mesh with time. In MANETs environment, frequently movement of mobile nodes considerably increases the overhead in maintaining the delivery tree /mesh. To minimize this overhead stateless approach is proposed where a source explicitly mention the list of destinations in the packet header. This approach focuses on small and medium multicast groups. Assuming that the protocol takes care of forwarding the packet to represent destinations based on the address in the packet header [5] [8].

The increasing popularity of using multimedia and real time in different potential commercial applications in MANETs makes it a logical step to support Quality of Service (QoS) over wireless network. QoS is defined as a guarantee given by the network to give a performance level to satisfy a set of predefined service parameters requested by the network user, these parameters including bandwidth, end-to-end delay, delay-jitter and packet to loss ratio. QoS support is tightly related to resource allocation and reservation to satisfy the application requirement [4] [9]. The role of QoS routing protocol is to find a suitable loop-free paths that have enough resources available from the source to the destination to satisfy the desired QoS requirements.

There are two QoS strategies used to search for routes and maintain the information state in QoS multicast routing. The first is source routing, where a feasible route is computed locally at the source node, which is not scalable for large area networks. The second one is distributed routing, the path computation is distributed over the intermediate nodes which makes it more scalable than source routing [10].

It is not easy task to combine QoS to multicast ad hoc networks. So, supporting QoS for multicast protocols has to be designed in a way different from unicast protocols. The difference is that in unicast QoS protocols the resource reservation is done between a source and a destination. While multicast QoS routing protocols should provide suitable QoS paths to all destinations of the multicast group. Also, the heterogeneous nature of paths to the destinations adds extra challenges to the design of QoS multicasting protocols [11].

The remainder of this paper is organized as follows: in section 2 several QoS multicast routing protocols for MANETs are discussed. In section 3 we give a summary for the paper.

2. QoS Multicast Routing Protocols

In the previous section, we reviewed the special properties of mobile ad hoc networks, challenges of QoS in MANETs and the classifications of multicasting. In this section, we present several multicasting protocols proposed specifically for supporting QoS over the mobile ad hoc networks.

2.1 Lantern-Tree-based QoS On-Demand Multicast Protocol (LTM)

The Lantern-Tree-based QoS On-Demand Multicast Protocol (LTM) in [12] first searches for lantern paths from a source to a set of destination nodes and then merges them together to construct the lantern tree. The QoS path is a path which satisfies end-to-end bandwidth requirement under CDMA-over-TDMA channel model at the MAC layer based on [13] [14]. Available bandwidth in this model is measured in terms of the number of free time slots.

LTM defined a lantern as a path or more sub-paths that exists between two nodes to satisfy the required bandwidth as shown in figure (1).

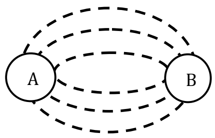

Figure (1): Lantern between two nodes

The path from S to D is considered as a lantern path because a lantern exists in the path. When the bandwidth is limited, multi-path is constructed as the route between nodes B and C in the graph. While, a uni-path is constructed if the bandwidth is sufficient as the link between node A and B in figure (2). The worst case is found when no uni-path found from the source to the destination as shown in figure (3).

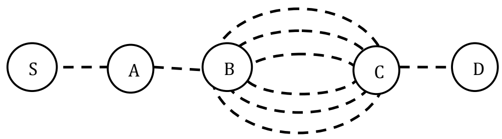

Figure (2): uni-path between (A-B), Lantern between (B-C)

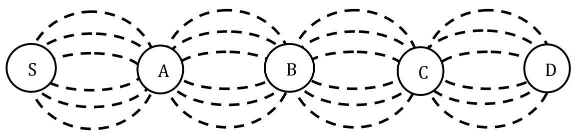

Figure (3): Worst case (no uni-path found)

To identify a lantern, each node periodically maintains information about all one hop and two hop neighboring nodes with the free time slots of these nodes. After collecting the link state of all the nodes, the lantern is

identified. Lantern tree construction is started after time slot reservation is finished.
The source node floods the network with lantern-path request packet to check if one or more lantern exists in the source. If a lantern exists, the lantern path is constructed. This process repeated until a possible lantern path arrives at a destination node. An Ack message is sent to acknowledge the two parties of the lantern about the successful transmission. The construction of the multicast tree is done by replacing all the spiral-fat-tree paths of the spiral-fat-tree protocol [15] into lantern-path to provide QoS capability.

Advantages

1- Using multiple paths provide high aggregate of the network bandwidth.
2- High access rates and high stability due to using multiple path lantern trees.
3- Efficient utilization of the network bandwidth especially when the bandwidth is limited.

Disadvantages

1- Increasing the number of links increase the contention at the MAC layer.
2- It takes a long time to find all the paths and shares the time slots between the neighboring nodes.
3- Nodes have to process and store more information about sub-paths which wastes the resources.

2.2 QAMNet: Providing Quality of Service to Ad hoc Multicast Enabled Networks

In QAMNET [16], the idea is to extends existing approaches of mesh based multicasting like ODMRP [17] and unicast provisioning like SWAN [18] by introducing service differentiation (real-time (RT) and best-effort (BE) traffic class), distributed resource probing and admission control mechanisms as well as adaptive control of non-real-time traffic based on MAC layer feedback. When a node has real-time traffic to send for multicast group, it floods the network with the first data packet (*Join-Probe*) piggybacked with bottleneck bandwidth (BB) and required bandwidth (RB). When the intermediate node receives the request, it sets a pointer toward their upstream nodes and updates the BB field if its local available bandwidth is less than BB in the request. Bandwidth availability at the local node is calculated similar to SWAN [18]. When the request arrives to a multicast receiver, it waits to collect all the requests and it evaluates the available bandwidth. If the largest value of BB is greater than BR, it creates Join-Reply packet piggybacked with the largest BB and RB. Also, it sets RTF-Flag and becomes multicast forwarder for the group to construct the mesh similar to ODMRP. Intermediate forwarder node updates BB field with the maximum of all received replies and sets RTF-Flag if BB is larger than RB for the given multicast group and rebroadcast the reply.
When the reply reaches the source, it starts sending RT traffic with the help of real-time forwarder nodes and it sets a Type of Service (ToS) bit in the packet header and broadcast it via MAC layer. At the intermediate node, the classifier checks the RTF-Flag for the given flow. If it is set, the packet passes to MAC layer for rebroadcasting. Otherwise, ToS is set to zero and the packet is put into the node shaper for BE traffic.
QAMNET uses MAC layer back-off delay of 802.1lb to regulate BE traffic (BB less than BR, RTF-Flag not set). If back-off increases, the rate is decreased to enable BE traffic to enter the MAC layer and reject RT traffic at each intermediate node. Otherwise, Additive Increase Multiplicative Decrease (AIMD) control is used to control the BE effort at each node.
When violation in RT traffic is detected, each node selects randomly one of its real-time flows and sets Congestion Experience (CE) bit in all packets belong to the given flow and RTF-Flag set to zero to enforce the nest real-time packet to enter the shaper.

Advantages

1- Routing stability and reduction of control messages by integrating probing with multicast routing.
2- Performing admission control at intermediate nodes is effective than performing at the destination nodes.
3- Controlling the average delay for RT packets due to regulating the BE traffic at the shaper.
4- Maintaining low delay and required throughput for real-time multicast flow.

Disadvantages

1- Periodic gathering of information about the resource availability and executing the SWAN algorithm consumes the bandwidth and introduce extra delay.
2- The request is accepted or rejected only at the destination. The forward node will continue to forward requests even when there is not enough available bandwidth and this wastes bandwidth.
3- Best Effort traffic suffers from additional delay for the packets because they are regulated by the shaper.
4- SWAN suffers from difficulty in determining the threshold rate accurately based on the traffic pattern which directly affects the performance of QAMNET.

2.3 QoS multicasting routing protocol (QMR)

A QoS multicasting routing protocol (QMR) is presented in [11] [19]. It's a mesh-based on demanded protocol to connect a group of members and provide QoS paths to the multicast group. Bandwidth estimation is done at MAC layer using CDMA/TDMA channel model using passive listening method [20]. The estimation of the bandwidth at each node is based on the status of the radio channel; they rely on the physical carrier sense to determine the idle and busy state of the channel. Each node monitors the channel and start counting the channel state from idle to busy states. They uses forward group as a subset of the network topology that provides at least one path from each source to each destination in the multicast group like On-demand Multicast Routing Protocol (ODMRP) [17]. The session is initiated by the node that has data to send by broadcasting a QREQ packet with the required bandwidth and maximum hop (MH) greater than zero. Intermediate nodes calculate its available bandwidth, update its available bandwidth with current QoS condition and if the node satisfies the requested bandwidth it rebroadcast the packet until MH equal zero or QREQ arriving at a destination. Otherwise, the packet is dropped. The bandwidth is computed at intermediate nodes independently without the need to share information with all neighbors. The destination receive QREQ from several paths, it choose the route with best QoS conditions and send a reply back to the source to start data transfer. In replay phase, the intermediate node compares the ID with the ID from the reply if it is match then it set the *ack* flag to indicate that its part of the forwarding group. Also, it reserves the bandwidth to be used in forwarding data packets.

QMR provides a load balancing and contention prevention scheme by updating the forwarding nodes and use intermediate nodes with enough bandwidth to forward the data. This scheme is used when multiple sources sending to the multicast group simultaneously which causes nodes in a single path to be overloaded and the probability of packet discarding increase.

In QMR Source nodes and destination nodes can leave the session by not sending route request and route reply respectively.

Advantages

1. The data packets reach the destinations through more than one path increase the data packet transmission.

2. The interactions between MAC layer and network layer provide provides efficient routing mechanism and utilize the bandwidth.
3. Rejecting the requests that does not satisfy required bandwidth utilize the usage of the residual bandwidth.
4. The mesh structure guarantee good delivery ratio.

Disadvantages

1. Route recovery is not dynamic to allow new members to join the held session and keep the bandwidth requirement satisfied.
2. The mesh-based methodology and the large amount of forwarding nodes introduce more control packets.
3. Data packet flooding in the forwarding group will generate duplicate packets and the probability of collision will increase.

2.4 QoS aware multicast routing protocol (QMRP)

QoS aware multicast routing protocol (QMRP) in [1] is a mesh based protocol offers bandwidth guarantee for applications in MANETs. The multicast mesh is created by broadcasting a RouteRequest packet from the source. The intermediate node rebroadcasts the packet after it updates its cache and increases the hop count. When the receiver receives the request, it caches the route and broadcast a RoutReply packet. If the upstream node is the node that sends the request to the receiver, it will set the Forwarding Flag and Forwarding Timeout fields and rebroadcast the reply packet. Otherwise, it will set the Neighbor Flag and Neighbor Timeout and does not rebroadcast the request packet. The receiver use QMRP-nw to respond for the first request without waiting for other requests. And it us QMRP-w to respond for the request after waiting for a period of time and choose the best route based on the Forwarding count and non-Forwarding count and gives preference for the route with the highest value of Forwarding count. In both cases the RouteRequest is rebroadcasted because the receiver node may be a forwarding node for other receivers.

Each node periodically sends Hello message to transfer the bandwidth knowledge in the network. The node that receives the message knows the bandwidth information of its first and second neighbor, and then it can estimate the residual bandwidth as follows:

$$\text{Residual BW} = \frac{(\text{Raw Channel Bandwidth} - \text{Total Bandwidth Consumed})}{\text{Weight Factor}}$$

The receiver calculates the maximum bandwidth and adds it to the RouteReply packet. When the upstream nodes receive this reply packet, it updates the maximum bandwidth in its memory.

On-demand maintenance is triggered when a forwarding node cannot send data to any forwarding node on the route (maintenance from a node that link failure occurs). The node broadcast a packet to find new route that satisfy the required bandwidth from this node to a receiver node. The node that receive this message updates the routing information, increase hop count and rebroadcast the packet if it is a neighbor node. The receiver set new route to the node when he receive the on-demand maintenance packet.

While, periodic maintenance is triggered by the source involving only mesh nodes and neighbor nodes periodically in the same manner as mesh creation. During mesh maintenance, each node compares the residual bandwidth with the maximum value and if the residual value is less than the maximum bandwidth, the maximum value updated with the residual bandwidth.

Advantages

1. Using on-demand maintenance reduces the control overhead by starting from a node that the link failure occurs.
2. The packet delivery ratio is high because of using forwarding nodes as ODMRP.
3. The protocol is loop free.
4. Limiting Periodic maintenance to mesh nodes and neighbor nodes reduce the control overhead.

Disadvantages

1. The network bandwidth is not efficiently utilized because it use only routes that support the require bandwidth.
2. Collecting the bandwidth information of the nodes periodically introduce extra processing overhead and contention on the wireless medium.
3. Flooding the network with control packets consumes the limited network bandwidth especially for non-participating nodes.

2.5 QoS multicast routing by using multiple paths/trees

An On-demand QoS multicast routing protocol is proposed in [21]. This protocol considers bandwidth as the number of free slots by using CDMA over TDMA channel model and delay as the number of hops. When the source node has data to send, it floods a *RREQ* packet in the network, this packet contains the QoS requirements and each node has to record its number of free slot on this message. When a node receives a RREQ packet, it checks if there are common slot between itself and the last-hop sender. If not, it means that there is no bandwidth to receive from the last node in the path and the RREQ packet is dropped. Otherwise, the RREQ packet is updated and TTL is decreased and it rebroadcast the request packet if the maximum hop count is not exceeded. If the RREQ packet was received before, this means that there exists another path from the source to this node, then the RREQ is not rebroadcast but network information is used.

When non-destination node receive the RREQ, it waits for a prespecified time or number of RREQs then is sends back a RREP packet to informing about paths that goes through this node. When any destination receives the RREQ packet, it will send back a RREP packet to the source. The source waits for a prespecified time or number of RREPs to obtain partial network topology information in order to uses this partial information to construct paths/trees.

When route discovery and reply are completed, the next step is to construct multiple paths/tree multicast routing by choosing one of the three construction strategies to select the suitable paths. In SPTM - shortest path/tree based multiple-paths, the delay from the source to each destination is chosen to be minimum in terms of number of hops. Multiple parallel path segments can be used to aggregate the required bandwidth to admit the call.

The Least cost tree based multiple-paths (LCTM) algorithm found a delay-bound least cost tree using Jia algorithm [22] then it adds multiple paths to the tree.

In multiple least cost trees (MLCT), first a LCT is found using Jia algorithm [22] , then if the bandwidth is not enough, the bandwidth of the LCT is reserved and deducted from the available bandwidth of all the links. The source still searched for LCT until the aggregate bandwidth of all LCTs can satisfy the requirement or no LCT can be found.

The flooding of the request packet in the network maintains extra overhead especially in large scale networks. Also, the extra over head on the source consume more power and capacity because it has to compute the optimal route for all destinations, which is increased when the multicast group is large.

Advantages

1. Reduce looping and allow reception of multiple requests.
2. The effective use of the bandwidth by using multiple paths in parallel.
3. Reducing the percentage of blocking and utilization of the network resources.
4. The protocol can be integrated with unicast protocols in a unified framework because route discovery and reply are similar to on-demand protocols.

Disadvantages

1. New joining node need to join the session need a lot of control messages to contact the source specially if it is located far away from the source
2. Flooding the network with request packets introduce extra overhead for non-multicast nodes.
3. The overhead applied for the source node is large specially when the number of multicast group members increase, because he is responsible for checking the QoS paths to all destinations, management of the membership of multicast group and reply to new joining nodes.

2.6 Quality of Service Support for ODMRP

ODMRP approach is extended to support QoS in [9] by using admission control based on [23]. To calculate the bandwidth of a flow, the available and consumed bandwidth has to be known and the available bandwidth at node *i* given by:

$B_{available}(i) = B - \sum_{j \in N(I)} B_{self}(i)$, where B is the row data of node *i* and $B_{self}(i)$ is the total traffic between node *j* and its neighbors. If the required bandwidth is B_{min}, then the bandwidth to be reserved for flow *j* at node *i* is B_{min} if the node is sender or receiver, and $2B_{min}$ if it is an intermediate node because it need to receive and forward the flow traffic. The consumed bandwidth for flow j on node i's channel is calculated as:

$$B_{consumed}(i,j) = B_{uplink(i)}(j) + B_{downlink(i)}(j)$$

The value of B_{uplink} and $B_{downlink}$ are the reserved bandwidth for the flow j on upstream and downstream neighbor and can either equal to B_{min} or $2B_{min}$. This computation works when the node has one downstream node, and if the node has more than one downstream forwarder as ODMRP multicasting, then the consumed bandwidth calculated as:

$$B_{consumed}(i,j) = B_{consumed}(i,j) + B_{min}$$

The admission control can accept or reject the flow based on comparing the value of $B_{available}(i)$ and $B_{consumed}(i,j)$. To enable each node to compute the available bandwidth, each node needs to maintain the neighborhood information. Each node sends HELLO message periodically to its neighbors. This message includes the traffic of the node with TTL=1. When a node receives this message, it updates its neighbor list information.

The multicast session is initiated by broadcasting a JOIN-REQUEST with the required bandwidth from the source node, the source check its ability to provide the required bandwidth before broadcasting the join request. When a node receives the request, it compares $B_{available}$ and $B_{consumed}$ and if it satisfies the required bandwidth it, store the last hop node, add new entry to its reservation table and updates it status to "explored", then it rebroadcast the request. The node stays at this status for a period of time. Since the node that propagates the JOIN-REQUEST does not aware of the downstream nodes to the destination, it uses B_{uplink} as estimation of $B_{consumed}$. The destination broadcasts Join-Reply via the select route with Join-Request if it has enough bandwidth and updates its status to "registered". When a node receives the Join-Reply, if it realizes that it is on the path to the source and it has enough bandwidth, then it sets the forwarding flag and rebroadcast the reply request and changes its status to "registered". When the nodes handle the Join-Reply it is aware of downstream and uplink bandwidth, then it recomputed the $B_{consumed}$ to give precise estimation. When the source receives a certain number of JOIN-REPLY packets, it constructs the routes to the destinations. When a node receives a data packet it changes their status from "registered" to "reserved" until receiving the next Join-Request.

Advantages

1- The admission control drops the routes that do not satisfy the bandwidth requirement which utilizes the network bandwidth and provide high delivery ratio.
2- Precise estimation of the bandwidth by considering uplink and downstream nodes.

Disadvantages

1- The periodic messages to collect the neighbor bandwidth consume the bandwidth due to the large number of control packets.
2- Keeping the nodes that participate in the flow in "reserved" state reduce the transmission traffic but in the same time wastes the bandwidth.

2.7 Ad hoc Quality of Service Multicast Routing Protocol (AQM)

Ad hoc Quality of Service Multicast Routing Protocol (AQM) [3] tracks resource availability within a node neighborhood based on previous reservation, and announce the QoS conditions at session initiation. In AQM, any node can start the session by broadcast a message (SIS-INIT) with QoS requirement, number of users and the application type. Its predecessors (MCN_PRED) propagate the packet upstream as long as QoS can be satisfied and within the number of hops limit. The node that receive SIS-INIT message updates QoS information field with the current QoS conditions. New nodes can join the session by sending JOIN-REQ toward any member of the session, only nodes that aware of the session consider this request. Downstream nodes aggregate the replies from the session members and

forward the reply within the QoS conditions, to enable the requester to choose the best of them. And then, a reservation message is sent to the node which is the forwarder of the reply. If the intermediate node among the intended forwarder on the path, they change their state to be forward nodes, reserve resources and update membership table, until the reserve message reaches the reply originator. The replier may be a forwarder or server initiator, it have already reserved resources and it added the new joining node to its member table and continue send multicast data.
Periodically, a session update message is broadcasted by the network nodes to keep themselves and their neighbors aware of the changes in the QoS conditions.
Each node periodically sends broadcast a HELLO message to inform its neighbors on its existence as well as its maximum available bandwidth. Upon receiving this message, nodes record neighbor information in a neighborhood table which is used to calculate the total bandwidth allocation to the held multicast session.
The node can leave the session by sending SES-LEAVE message to its forwarder, the forwarder then deletes the leaving member from its member tables. The session is closed by its initiator. Upon receiving it, all nodes clean their tables and free the reserved resources.

Advantages

1. The QoS conditions are checked at each node to insure the availability of resources for the new session which reduce the processing at nodes the does not satisfy the QoS conditions.
2. Bandwidth aggregation messages are piggybacked with control packets which reduces the control overhead.
3. Support running different multimedia applications simultaneously with varying QoS requirements.
4. Limiting over flooding the network with more broadcast messages by checking the QoS conditions at each node to insure the availability of resources and dropping the packets if QoS requirements are not satisfied.

Disadvantages

1. The periodic messages (Hello messages) introduce considerable overhead in mobile network which directly affect QoS support.
2. Using long network lifetime is good realistic impression, but it is better to reduce the simulation time and repeat the process several times with different environments will give more realist results.
3. Using broadcasting to start the multicast session may waste the resources and introduce loops.

2.8 Hierarchical QoS Multicast Routing Protocol (HQMRP)

A protocol called Hierarchical QoS Multicast Routing Protocol (HQMRP) is presented in [24]. It organizes the network into multiple domains, the 0-level represents the nodes, and several nodes form the first-level which contains at least one node and does not overlap with any first-level cluster. The upper levels are forming from grouping the down levels into domains. The clusters with the same level are connected using bridge nodes as shown in figure (4).

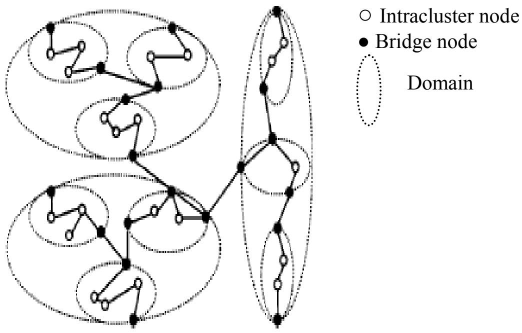

Figure (4): Network Topology

This protocol consider the bandwidth and delay as QoS metrics and assume that each node measure periodically the delay of outgoing links and broadcast it to cluster members. Similarly, the bridge nodes measure the delay of the outgoing links and broadcast this information to bridge nodes in the same level.
The multicast tree is constructed by sending a *JOINReq mes* with QoS metrics by the first member to its parent bridge node, and the first entry in the array is set to the address of this node. If the bridge node does not aware of the multicast tree, it adds itself to the array and forwards the request to its parent bridge node. If the multicast tree not found, the request will arrive to the bridge node at top-level domain. The top bridge node sends multicast generation (MT *generation*) message towards the node. When the new member receives this message it reply by sending MT *update msg* to its parent bridge node to generate the tree. Each bridge node maintains the address of all on-tree nodes within the domain and bridge addresses of the lower level domains containing on-tree nodes.
When a new node wants to join a multicast group, it sends a JOINReq *msg* to its parent bridge node. If the message arrives at a bridge node that is aware of the multicast tree, it forwards it to all on-tree nodes or bridge nodes of the sub-domains having on-tree nodes. Otherwise, the bridge node forwards the message to its parent bridge node.

When the JOINReq arrives at an on-tree node, the node initiates a *SF* message. This message is flooded towards the new node by sending it to some neighbors which in turn forward the message to their neighbors.

Advantages

1. HQMRP is scalable for large area networks due to it hierarchy of domains.
2. Reducing the message overhead by selecting fewer on-tree routers to flood towards the host router.
3. Local nodes maintain local multicast routing information instead of global network states.

Disadvantage

1. Using periodic messages to construct the Neighbor table introduce considerable control overhead.
2. Using subscribing to handle changing the domain will requires excessive communication and message processing specially in high mobility networks.

2.9 On-Demand QoS Multicast Routing and Reservation for MANETs (ODQMM)

On-Demand QoS Multicast for MANETs (ODQMM) [25] is a protocol built based on MAODV protocol. It provides resource reservation when the protocol attempts to find a path that satisfies the requested bandwidth. When a node wishes to join a initiate a multicast group, it broadcasts *RREQ* packet and if it does not receive *RREP* after a number of attempts, it assumes that it is the first node in the group and becomes the group leader, and then it announces this for the network.

The requested bandwidth is included in the RREQ, on-tree nodes respond to this request if all the group members have enough bandwidth. Off-tree nodes reply to the request only if it has the required bandwidth.

A node can join the group as a receiver to receive the data from the group using best effort. And if it wants to send data to the group, it needs to specify the reservation style. ODQMM used two reservation styles, fixed-filter (FF) use distinct reservation for data from each source (senders can't share resources). While, shared-filter (SB) use single reservation from all senders in the session. The joining node check if it has enough BW to receive data from the multicast group in addition to the bandwidth needed by data streams generated by the node. If yes, *RREQ* is sent with the corresponding flag set. Otherwise, it set the *N* flag to indicate that the node does not have information on the reserved BW of the multicast group.

When a node receives *RREQ,* it checks its Group Leader Table. If it does not have information about the multicast group or its group sequence number is less than the number included in RREQ, it rebroadcast the *RREQ* with *N* flag set. Otherwise, it retrieves reserve bandwidth information and handles the *RREQ* based on the attached flag. If the request is *RREQ-J* and the received node is off-tree node, it checks if the available bandwidth equal to the reserved bandwidth of the multicast group then it rebroadcast *RREQ-J*, and if not it discard the packet. When on-tree node receives *RREQ-J* and the bandwidth is enough, it will send *RREP* with the bandwidth reservation. In case that the request is *RREQ-F*, the off-tree node rebroadcast the request if the available bandwidth equal the bandwidth reserved for the multicast group and it is discarded if the bandwidth is not met. While, on-tree node sends *QoS-Error* and the node is not admitted if the bandwidth is not as requested. While, if the requested bandwidth available, the node then check if all other nodes in the group have the available bandwidth to support the new request by sending *RREQ-QF* to the group. If any node on the multicast tree does not have the available bandwidth, it will send *QoS-Error* and the admission of the new node is rejected. If no error messages received within certain time, the BW is assumed to be available and *RREP* is sent to the joining node. *RREQ-S* is handled as *RREQ-F* except that a node has to determine if extra BW is needed.

When an on-tree node reply with *RREP*, all nodes in the reverse path reserve the required BW temporarily for a period of time until receiving Multicast Activation message (MACT) from the joining node after the best route is chosen. A long the path, off-tree nodes become on-tree nodes and forward the packet to the next hop on the tree. The on-tree nodes forward MACT message to the group leader, which update its table and broadcast the new BW reservation information on the network.

Advantages

1. Integrating the reservation service into the routing protocol.
2. The protocol is free from loops.
3. Utilization of the network bandwidth, by only reserve the required bandwidth when the path is found.

Disadvantages

1. The failure of the group leader might affect all multicast sessions.
2. Each node maintains multiple tables about the network topology and the bandwidth reservation which need large storage and communication.
3. The increased contention on the shared wireless medium because each node in the multicast group has to reserve the same amount of bandwidth.

3. Conclusion

Ad hoc networks are held in the fly between a collection of mobile devices in a multi-hop fashion without rely on any infrastructure which makes supporting QoS over MANETs is a challenging task. Also, the properties of the wireless medium and the limitations of the resources add extra constraints to QoS provision. Multicast routing can efficiently utilize the resources by sending the same information to all destinations simultaneously. The design of QoS multicast routing protocols are varies according to the goal and the requirement and based on the assumptions and properties of the network and application area. QoS multicasting routing protocols different from each others in the way to maintain the network state, constructing the links to the multicast group, how to join and leave the group and the QoS constrains supported. Also, the design of the protocol is influenced by the wishes of the multicast members which have to balance between supporting QoS and utilization of the resources.

In this paper we have offered a survey of the most recent contributions in QoS multicast routing. We have stated the advantages and disadvantages of each protocol to provide and identify new areas to be covered in future research.

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