A Review of On-Demand Quality of Service (QoS) Routing Protocols in Mobile Ad hoc Networks

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ABSTRACT

Abstract—Increasing pan globe mobility of human beings always draws attention of researchers of networking community and generates a requirement of infrastructure-less, quick deployable and self organizing network with mobile autonomous terminals. This category of networks is referred as mobile ad hoc network (MANET). As MANETs are gaining popularity it is becoming necessary to have an efficient routing with QoS support. QoS parameters differ from application to application like for military applications security and network availability are important on the other hand for multimedia applications bandwidth, jitter and end to end packet delay are important parameters. QoS provisioning for MANET can be done at each layer of protocol stack. The aim of this paper is to re-present contemporary on-demand QoS routing protocols for MANETs with the help of flowcharts and point out the observations.

***Keywords**: MANET, QoS, AODV, DSR, Routing metrics.*

I. INTRODUCTION

Mobile ad hoc network (MANET) [1] is a collection of mobile nodes which can communicate to each other via multi hop or single hop. The nodes in ad hoc networks operate in self-organized manner. Due to lack of central control, frequent change in network topology, and resource constraints make routing a big challenge in an ad hoc network.

Much work has been done on routing in ad hoc networks: the ad hoc on-demand distance vector (AODV) protocol [2], the dynamic source routing (DSR) protocol [3], etc. Emphasis of these approaches for routing has been on providing the shortest path. However, all the previous routing solutions do not meet quality of service (QoS) criteria, such as delay jitter, bandwidth constraint, end-to-end packet delay, etc. QoS provisioning [4] mechanism can be applied at network layer for connecting routing approaches with QoS requirements in ad hoc networks.

QoS routing protocols [5] [6] consider QoS parameters as routing metrics for providing QoS feasible path. As shown in Figure 1 contemporary work in QoS routing is divided in three major categories: In proactive QoS routing protocols routing table is maintained at each node before routing starts, In reactive or on-demand QoS routing protocols identify the routes that are required to carry data in the network and does not maintain route information, the hybrid QoS routing protocols are the combination of proactive and reactive QoS routing protocols. This paper focuses only in the on-demand QoS routing protocols, incorporating some of the QoS parameters.

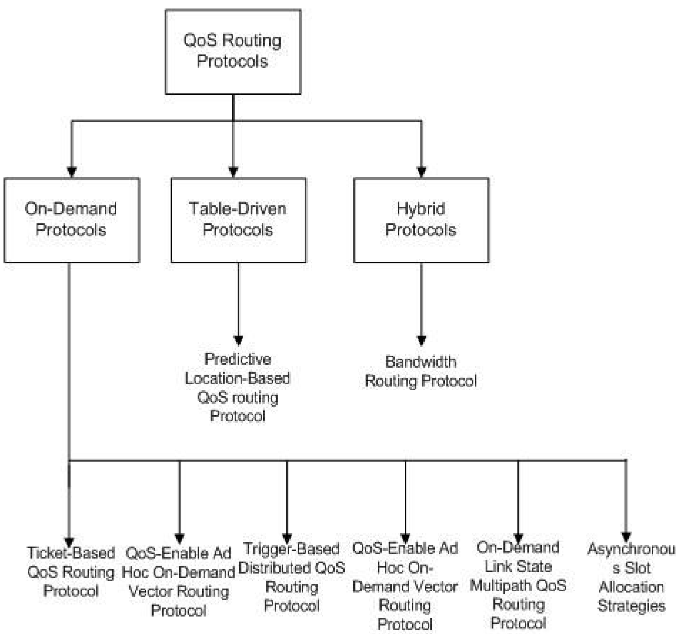

Fig. 1. Classification of QoS routing protocols

The rest of the paper is organised as follows. Section two gives on-demand QoS routing protocols and their shortcomings. Section three gives a comprehensive comparison of reactive QoS routing protocols. Section four concludes review.

II. ON-DEMAND QOS ROUTING PROTOCOLS

In on-demand routing protocols, dissemination of link state information is performed only when a route is required by a node to communicate with destination. QoS provisioning mechanism can be applied to reactive routing protocols for improve routing in real time scenario in ad hoc networks.

This section explains some of existing on-demand QoS routing protocols with the help of flowchart.

A. Ticket-Based QoS Routing Protocol (TBR)

Ticket-Based routing protocol (TBR) [7] is distributed QoS routing protocol. It explores multiple path parallelly for finding QoS feasible path. Explored multiple paths are limited by number of ticket issued by source node. Generated no. of tickets are based on the state information about intermediate node present at source node or QoS requirement for specific application. The state information consist evaluation of end-to-end delay and present path bandwidth for each node available in the network. If QoS requirements are strict or state information is not precise, then more tickets are issued, this upgrades the chance of finding feasible path, but this increases control overhead. There is a trade off between control overhead and QoS provisioning. Issued tickets are attached to probe packet by source node.When a probe packet is received by intermediate node, than it explore more than one feasible path or just forward the packet to next node based on the state information present at intermediate node. State information maintained at intermediate nodes are used as key component for finding accurate QoS feasible route probing.

Two algorithms are discussed which are based on idea of ticket based searching: Delay-constrained QoS routing, Bandwidth-constrained QoS routing. In delay constraint QoS routing protocol, delay of route which is traversed by probe packet is calculated. Similarly in bandwidth constraint QoS routing protocol, bandwidth is calculated by probe packet. For example, if an intermediate node X receives probe packet (PKT) from node Y (Y is neighbour of X), node X modifies the delay field or bandwidth field in probe packet (PKT) by putting delay value or bandwidth value of link between node X and Y. Now node X has full information about it's neighbours to which it has to forward probe packet. Node X splits tickets available in the PKT among new probe packet to neighbor nodes. If multiple probe packets are received by destination node (these probe packets consist the list of intermediate node present in it's route), then least cost path is selected for data transfer and other paths are used as backup when link is broken due to mobility of nodes. The flowchart of Ticket-Based QoS routing protocol is shown in Figure 2.

1) Observations: Performance of this protocol is based on number of tickets issued at source node and splitting of tickets at intermediate node. In this algorithm, each node does not keep global state information, may fail in some scenarios where topology changes very frequently. This algorithm is not acceptable for hard QoS requirement applications.

B. QoS-Enable Ad Hoc On-Demand Vector Routing Protocol(QoS AODV)

In QoS AODV [8] authors have done some modification in basic ad hoc on-demand distance vector(AODV) routing protocol to provide QoS. Route discovery in basic AODV routing protocol is divided into two phases: Route Request (RREQ), and Route Reply (RREP). Some fields are extended to each routing table entry: maximum delay, maximum available bandwidth, list of sources requesting QoS. This algorithm focuses on two QoS parameter, such as delay and bandwidth. Flow chart of this protocol is shown in Figure 3.

Meaning of maximum delay extension field is different for RREQ and RREP. In RREQ packet, it indicates the maximum time allowed from current node to destination. Minimum bandwidth extension field is also interpreted differently for RREQ and RREP. In RREQ, it indicates, minimum bandwidth required from source to destination. IN RREP, it indicates minimum bandwidth available in Path between source and destination.

1) Observations: In this algorithm, resource reservation along path between source and destination does not exist, so it does not support hard QoS applications. Node traversal at each node consider only processing time for packet, it does not consider time taken in packet queuing, this may lead wrong estimation of delay in the network.

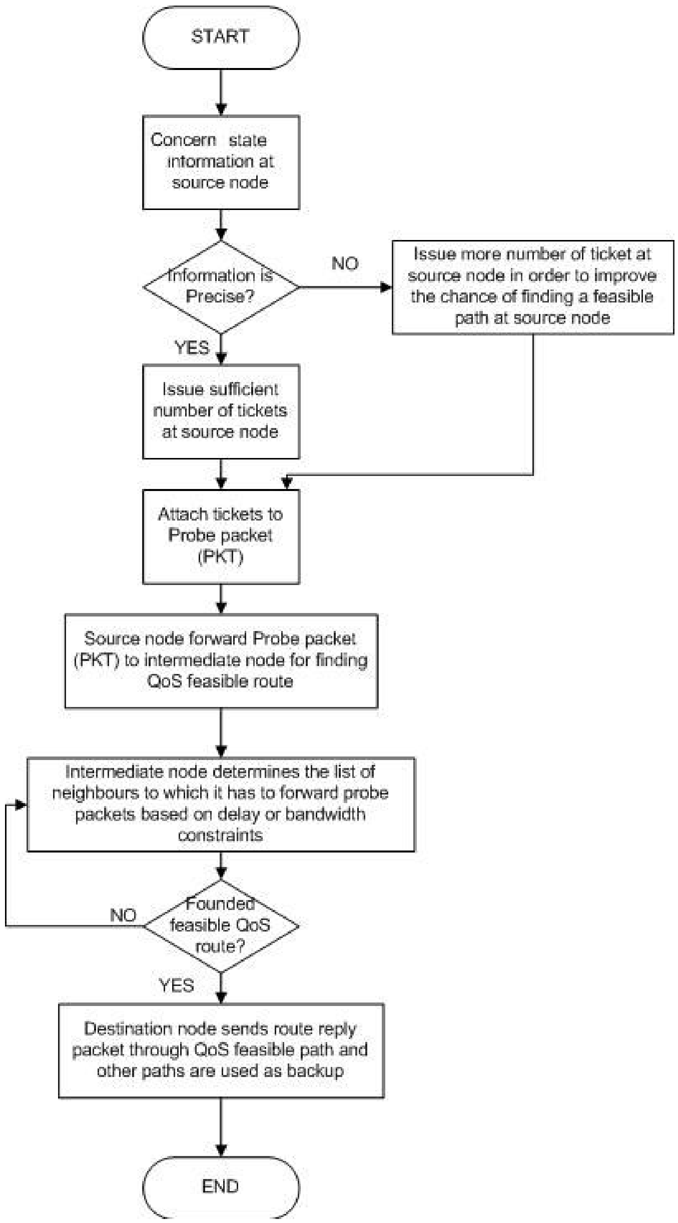

Fig.2. Flow chart of Ticket-Based QoS Routing Protocol

C. Trigger-Based Distributed QoS Routing Protocol (TDR)

Trigger-based distributed QoS routing (TDR) protocol [9] is discussed by authors for real time applications in MANET. Computational overhead and storage overhead can be reduced by maintaining local neighbourhood information (Source table ST_N, Destination table DT_N, Intermediate table IT_N) at each node. The following fields of source table, destination table and Intermediate table are given below

Source table: Session ID, Source ID, Destination ID, Maximum bandwidth required (MaxBW), Maximum accepted delay, destination location(DLoc), Next-node ID(NID) and activity flag(NodActv)

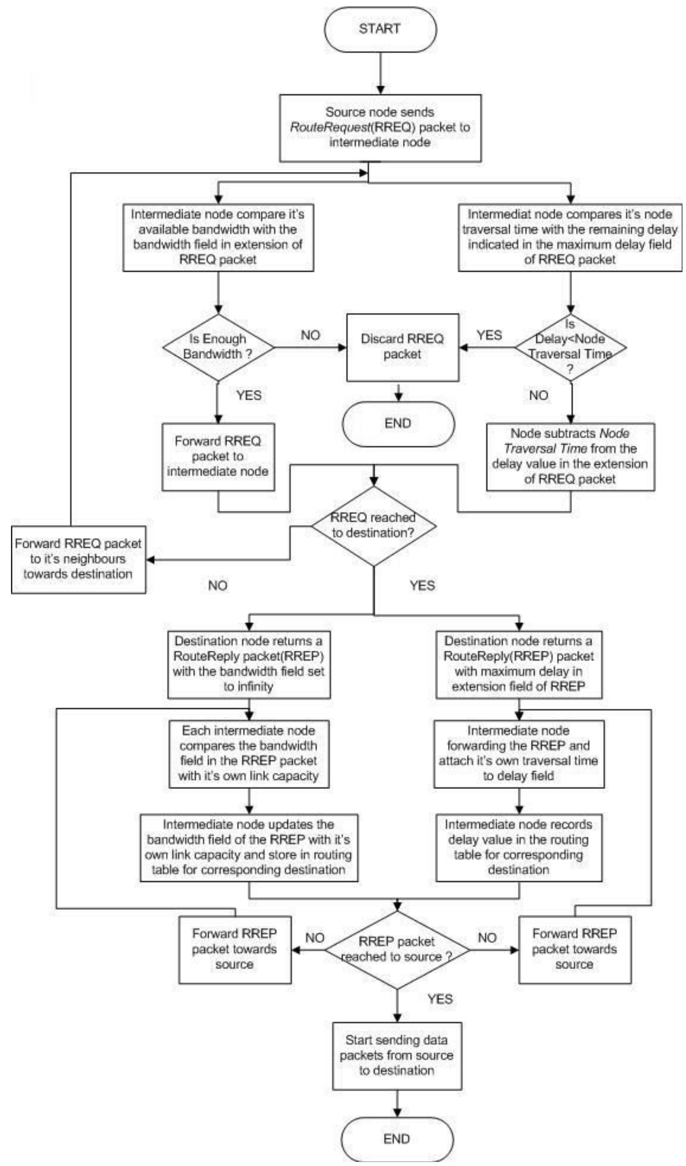

Fig. 3. Flow chart of QoS-Enable Ad Hoc On-Demand Routing Protocol

Destination table: Session ID, Source ID, Destination ID, SLOC, MaxBW, MaxDelay, Previous node ID(PID), Hop count and NodActv.

Intermediate table: Session ID, Source ID, Destination ID, Source location(SLoc), MaxBW, MaxDelay, DLoc, NID, previous node ID(PID)

TDR protocol is discussed in three phases: Route discovery, Route maintenance and Route termination.

a) Route Discovery: Initiate route discovery process between source(S) and destination(D). Source(S) checks for enough residual bandwidth(ResiBW) to meet required MaxBW for the session. If it has enough ResiBW then S starts route discovery process, otherwise terminate the route discovery process. This protocol uses global positioning system based (GPS) for getting location information of destination. If S has location information of D then selective forwarding method is used for route discovery, otherwise flooding mechanism is used. In selective forwarding method, route discovery packet is forwarded to selective neighbour node which are near toward destination. Before forwarding route discovery packet, S updates NodAct flag to zero in source table (ST_S) for this session, in order to ensure route stability and for reducing the control overhead, signal strength of packets received from selected neighbours should be greater than the threshold power (Pth) during route establishment process. When an intermediate node(IN) receives route discovery packet, it checks in it's intermediate table(IT) in order to avoid duplicate discovery packet and increments the hop count field by one. Then it checks for ResiBW and hop count for satisfying MaxBW and MaxDelay requirements. If requirements are satisfied, then NodAct flag is set to zero for the session in intermediate table and forward route discovery packet to neighbour node with updated network ID (NID).

When destination node receives first discovery packet, it has to satisfy both ResiBW and Maxdelay requirement for accepting route discovery packet and discovered route. After selecting the discovered route, destination table is created by destination node (D) with NoAct flag value is 1 and start sending ACK packet to source node along accepted route. When source node(S) and intermediate nodes receives ACK packet, then NodAct flag is set to 1 in their respective tables and updates the ResiBW status. Now data transfer takes place. The flow chart of route discovery is shown in Figure 4.

b) Route maintenance: This paper discussed two approaches for alternate route discovery before link failure: Intermediate node-initiated re-routing (INIR), source-initiated re-routing (SIRR). In SIRR approach, when an intermediate node receives data packet with low signal strength(less than Pth), then intermediate node sends re-routing message to source node and re-routing is done from source. In INIR approach, when an intermediate node receives data packet with low signal strength, then intermediate node sends query packet to S with Route reapir status(RR_{Stat}) set to zero. If any intermediate node involves in re-routing process those node sets the flag value of RR_{Stat} with 1 and send reply to generator of query packet (RR_{Stat}). If generator of query packet does not receive reply packet before its received packet power level from predecessor node goes below threshold power, it starts discovering an alternate path (ex. SIRR).

c) Route termination: For route termination source node sends termination message to destination and remove it's source table. Intermediate nodes which are part of route for that session have to remove their tables and ResiBW should be updated.

1) Observations: This algorithm uses INRR and SIRR schemes for quick re-routing with less control overhead during link failure. In both schemes received power level of packet is analysed for detecting link failure. If received power level falls below a threshold, according to this algorithm path is going to fail. But due to fading also the received power level may fall below the threshold value. This increases overhead because of initiation of re-routing.

D. On-Demand QoS Routing Protocol(OQR)

In On-Demand QoS Routing Protocol(OQR) [10] algorithm, bandwidth is the key QoS parameter. This uses admission control scheme over on-demand routing protocol. The path bandwidth calculation technique in routing is discussed, in order to measure end-to-end bandwidth. The flow chart of ondemand QoS routing protocol in shown in Figure 5.

This protocol is discussed below in different phases.

a) Route Discovery: Source node initiates route discovery process by flooding QoS route request packet(QRREQ). QRREQ packet consist: sourceID, destinationID, sequence no., route list, slot array list, data and TTL(time to live).

Each QRREQ packet is determined by sourceID, sequence no.. When intermediate node N receives QRREQ packet, it checks for duplicate packet with the help of sourceID, sequence no., if same sourceID, sequence no. fields in QRREQ packet is present then packet is discarded. Otherwise, node N checks, it's own address in route list field of received QRREQ packet, if address is present then it discards QRREQ packet. Otherwise, node N decrements TTL field by one, if TTL became zero then QRREQ packet is discarded. Otherwise node N starts calculating bandwidth from source by recording the free slots in slot array list of QRREQ packet and then attach it's address to route list of QRREQ, rebroadcast this QRREQ packet toward destination.

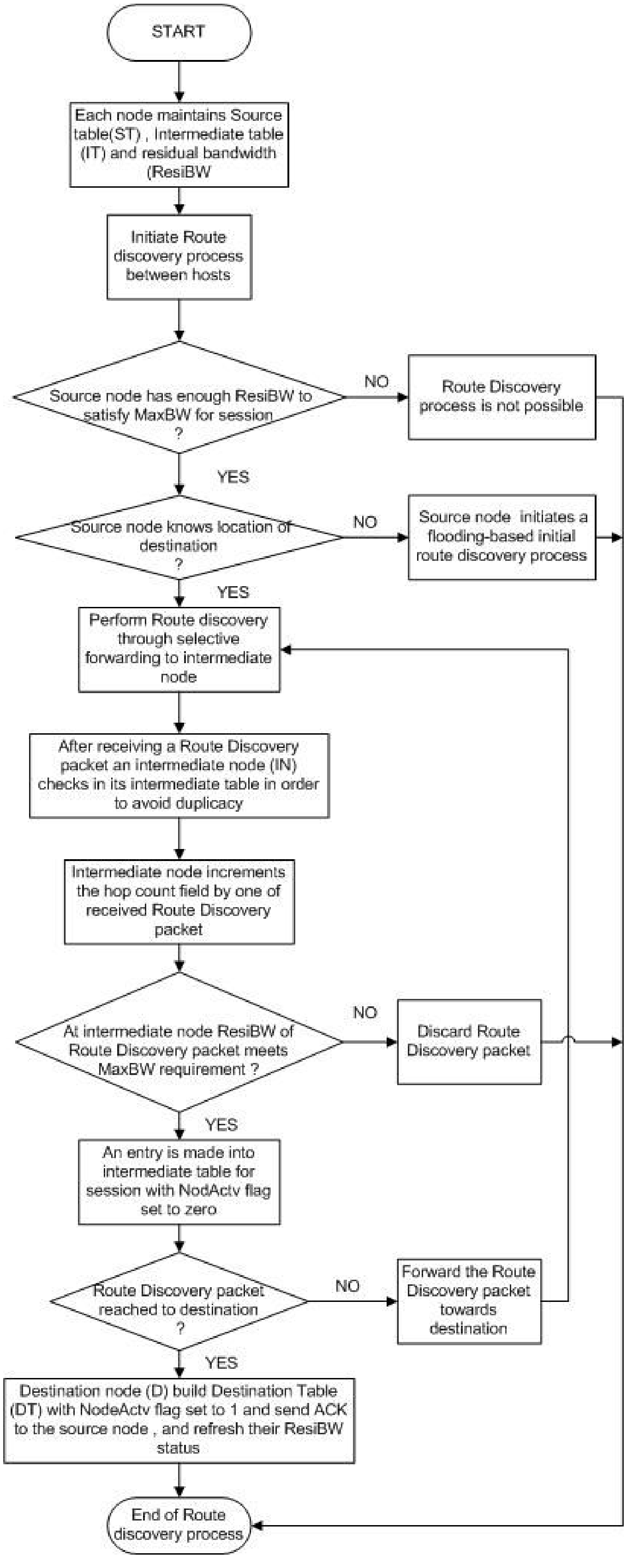

Fig. 4. Flow chart of Route discovery in Trigger-Based Distributed QoS Routing Protocol

b) Bandwidth reservation: The destination node(D) may receive multiple copies of QRREQ packet, then it selects least-cost path among all discovered path by QRREQ packet and send back QRREP packet to source along that selected path. When QRREP packet traverse back to the source, nodes which are present in array list reserve free slots. When source node receives QRREP packet bandwidth reservation process is completed.

c) Reservation failure: When reservation failure occurs in selected least-cost path, the node at which reservation is failed, sends a Reserve Fail packet to destination. Destination node(D) again starts bandwidth reservation process along another least-cost path.

d) Route maintenance: When link failure occurs, the node who detects link failure sends Route Broken packet to source node and destination node. Source node rediscovers a path and destination node releases all reserved resources along that previously using route.

1) Observations: This algorithm uses the code division multiple access (CDMA) over time division multiple access (TDMA), so fully synchronized network is required. Ondemand nature of route discovery process may consume more connection set-up time.

E. On-Demand Link-State Multipath QoS Routing Protocol (OLMQR)

On-Demand Link-State Multipath QoS Routing Protocol (OLMQR) [11] finds multiple path which collectively fulfil the QoS requirements. It is very difficult to satisfy all QoS requirement in a single path. OLMQR uses multiple path concept which satisfy all QoS requirements. This protocol uses CDMA-over-TDMA channel mode.

This protocol is divided into three phases: phase 1 is ondemand link-state discovery, phase 2 is uni path discovery, and phase 3 is multipath and reply.

a) Route discovery phase: In phase 1 source node floods a QRREQ (QoS Route Request) packet toward the destination. Each QRREQ packet consist history of nodes which are present in its route. QRREQ has following fields: source ID, Destination ID, node history, bandwidth requirement, TTL, free time slot list. When an intermediate node N receives QRREQ packet, it checks this packet for it's address. If address is present then QRREQ packet is discarded, otherwise node N inserts its address in node history field of QRREQ and rebroadcast.

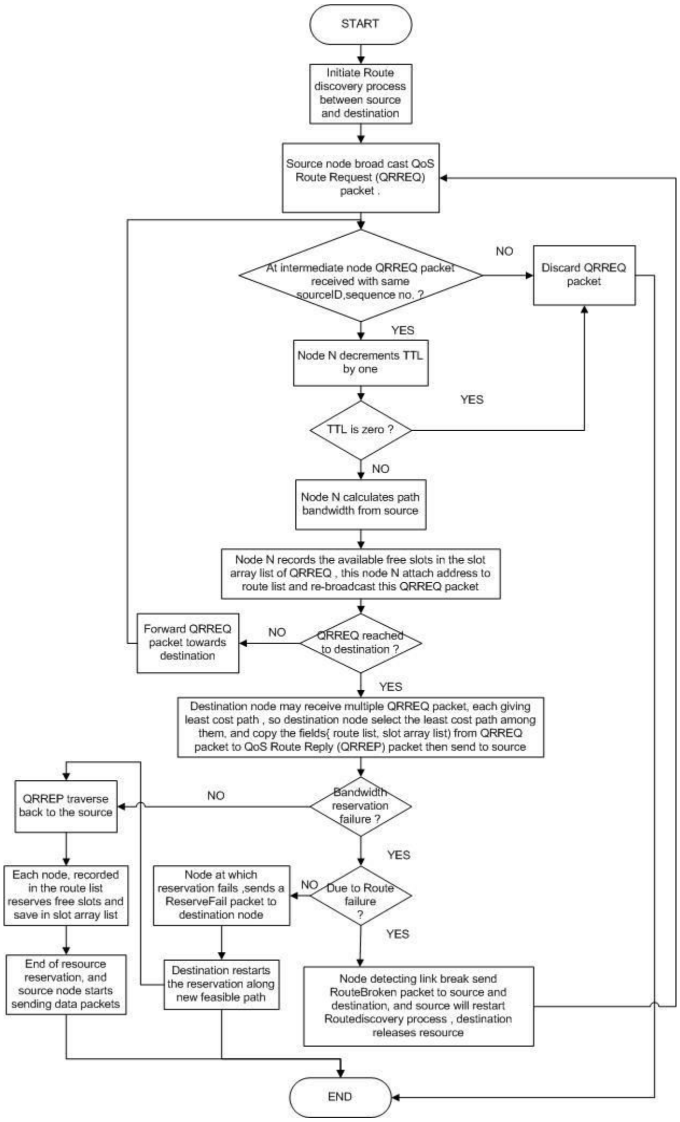

Fig. 5. Flow chart of On-Demand QoS Routing Protocol

b) Uni path discovery phase: Phase 2 is applied by destination node in order to determine maximum bandwidth required by each path with the help of constructing least cost first time-slot reservation tree(T_{LCF}) and a time slot reservation tree T. Time slots are reserved for a particular uni path with the help of T_{LCF} and T. T is constructed using breath-first- search (bfs) and T_{LCF} is constructed by T. Depth-first-search (DFS) is performed by unipath time slot reservation algorithm on the T_{LCF} tree for determining a pattern of time slot reservation with maximum path bandwidth.

c) Multipath and reply phase: Phase 3 is also applied by destination, after calculation of bandwidth requirement destination node sends reply packet along these founded paths for reserving resources on corresponding path toward source. The flow chart of on-demand link-state multipath QoS routing protocol in shown in Figure 6.

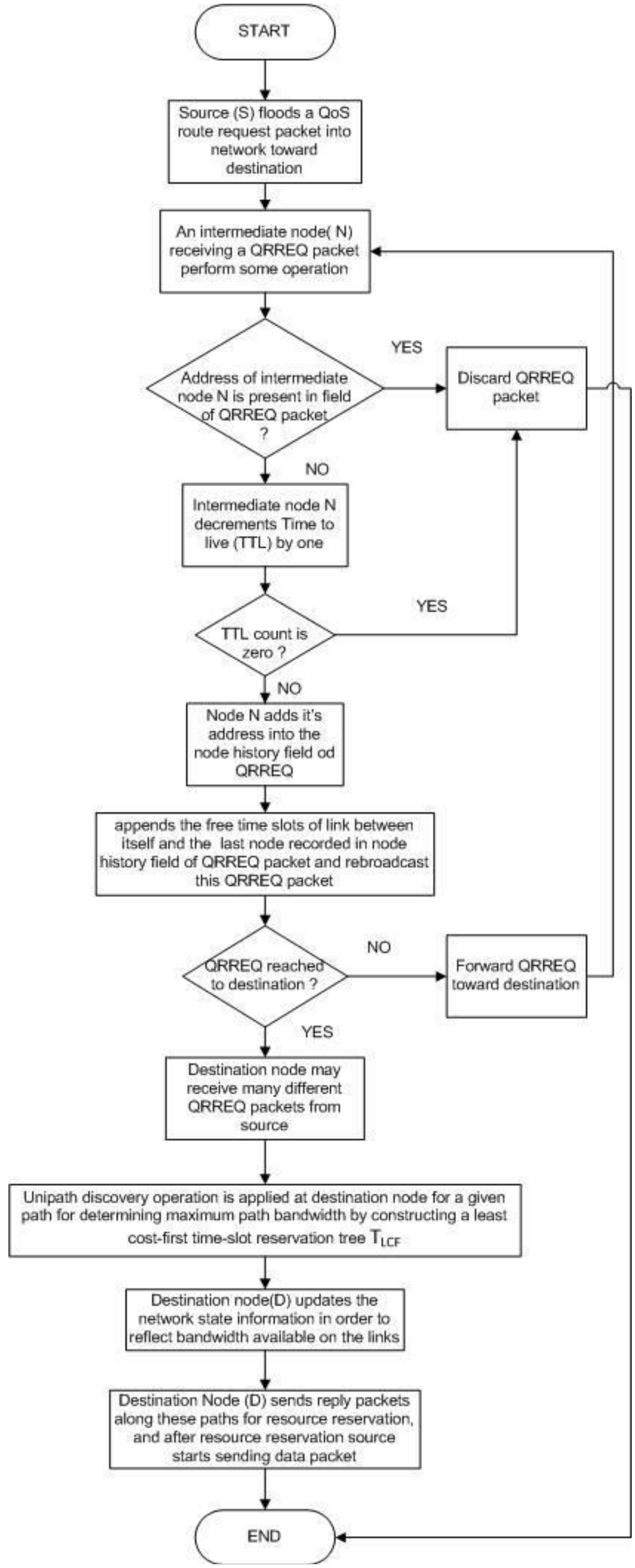

Fig. 6. Flow chart of On-Demand Link-State Multipath QoS Routing Protocol

TABLE I
COMPARISON OF ON-DEMAND QOS ROUTING PROTOCOLS

On-Demand QoS Routing Protocols	QoS Parameter	Resource Reservation	Coupled	Dependent	Route break prediction
TBP	Bandwidth,Delay	Yes	Yes	No	No
TDR	Bandwidth,Delay	Yes	Yes	No	Yes
QoSAODV	Bandwidth,Delay	No	Yes	No	No
OQR	Bandwidth	Yes	Yes	Yes	No
OLMQR	Bandwidth,Delay	Yes	Yes	Yes	No
AQR	Bandwidth,Delay	Yes	Yes	Yes	No

1) Observations: OLMQR has high overhead of maintaining and repairing paths, because multiple paths are used to fulfil QoS requirement.

F. Asynchronous Slot Allocation Strategies (AQR)
In above discussed protocols a CDMA-over-TDMA model has been taken for network. This type of network needs time synchronization across all nodes. Due to dynamic topology in MANET synchronization problem arises.

Asynchronous QoS routing scheme [12] and slot allocation [13] gives a unique procedure to reserve resources in asynchronous network. AQR is a extension of dynamic source routing (DSR). There are three phases in AQR: bandwidth feasibility test phase, bandwidth allocation phase, bandwidth reservation phase.

The objective of bandwidth feasibility test phase is the selection of paths with needed bandwidth using Route Request (RREQ) packets. Bandwidth allocation phase is applied at destination node that assign free slots to each intermediate link in the selected path. In bandwidth reservation phase, reservation of bandwidth is done using Route Reply packet.

1) Observations: On-demand nature of routing in AQR takes high setup time and reconfiguration time. AQR is unique mechanism for providing end-to-end bandwidth reservation in asynchronous network.

III. PERFORMANCE EVALUATION OF ON-DEMAND ROUTING PROTOCOLS

This section of paper compares different on-demand QoS routing protocols for MANET. Some of the performance metrics as given in [14] [15] are used for comparison. These are summarized as follows:

1) QoS Parameter: QoS parameters differ from application to application, because each application has different requirements. For example, in multimedia application bandwidth, delay, and delay jitter are key parameters.

2) Resource Reservation: Resources are reserved at all intermediate node along the path from source to destination.

3) Coupled: There is a closely interaction between routing protocol and QoS provisioning mechanism.

4) Dependent: Some on-demand QoS routing protocols are dependent on MAC layer for QoS provisioning.

5) Route Break Prediction: Link may break due to mobility, resource constraints, etc., this causes packet loss. Packet loss can be reduced by predicting route failure.

Table 1 shows a comparison of the on-demand QoS routing protocols discussed in this paper as per above parameters.

IV. CONCLUSION

In this paper, we have analysed on-demand QoS routing protocols in terms of resource reservation mechanism, QoS parameters, dependency on MAC layer for QoS provisioning, and route break prediction. All these discussed protocols support soft QoS applications. OQR protocol only deals with bandwidth QoS parameter. Some of above discussed protocols like TDR, OQR, OLMQR, and AQR are dependent on MAC layer for QoS provisioning. Resource reservation mechanism is not available in QoS AODV protocol. The relative advantages and their shortcoming are summarized to help researchers and practitioner in selection of right on demand QoS routing protocol for their purpose.

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