Quality of Service Routing in Ad hoc Wireless Networks

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Abstract. Quality of service is the collective effort of service performance which determines the degree of satisfaction of a user to the service. This paper focuses upon the several techniques proposed in the literature for providing QoS support in Mobile Ad hoc Networks. Initially, this paper discusses the relevant QoS issues and challenges in ad hoc wireless networks. Classifications of the existing QoS approaches under several criteria have been discussed with their merits and demerits. These categories cover almost all the aspects of the QoS requirement for designing an efficient QoS based routing protocol in MANETs. The detailed survey of this paper for QoS routing support in ad hoc wireless networks may pave the path for designing an efficient QoS routing protocol as per the QoS measures required for an end user application.

Keywords: Mobile Ad hoc Networks, Routing, Quality of Service

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1 Introduction

Quality of service is the collective effort of service performance which determines the degree of satisfaction of a user to the service [1]. It is usually defined as a set of service requirement that need to be met by the network while transferring a packet stream from source to destination .The goal of the QoS service is twofold: satisfying the QoS requirement for every admitted connection and achieving overall efficiency in resource utilization [2]. A network or a service provider can offer different kind of services to the users. A service can be characterized by a set of measurable pre-specified service requirements such as minimum bandwidth, maximum delay, and maximum packet loss rate etc. After accepting a service request from the user, the first task of the protocol is to find a suitable loop free path from the source to the destination that meets the desired QoS requirements of the desired service [3]. The need for QoS in MANETs is essential for wide ranging applications [4]. A lot of work has been done to provide QoS in the Internet, but none of them can be directly used in MANETs because of bandwidth constraints, multihop communication, channel contention, lack of central coordination, limited energy, limited computation power, limited memory and dynamic topology of MANETs [5]. QoS provisioning in MANETS requires knowledge of parameters like link delays, bandwidth, loss rates, error rates etc. The basic Problem is the difficulty in obtaining this information due to constantly changing links, node mobility, and environmental affects, etc.

2 QoS ROUTING ISSUES AND CHALLENGES

Major problems in the development of a QoS routing protocol are providing complex functionality with limited available resources in a dynamic environment. One of the key issues in providing end to end QoS guarantees in MANETs is how to determine a feasible path that satisfies a set of QoS constraints. In general finding a path subject to multiple additive constraints is an NP-complete problem. A simple solution with predictable performance and adjustable overheads for the NP-complete multi-constrained problem is not available. Moreover all applications do not need the same QoS, hence developing a generalized QoS protocols is again intractable. It is very difficult to obtain hard QoS guarantees in case of MANETs due to imprecise state information and dynamic topology. Assumption of precise state information provides approximation in data delivery. Nodes are battery powered which can not be replenished; therefore energy efficiency is also a critical issue to deal. It is also a challenge to manage smooth transition when traffic passes between wired and wireless network and to manage the coexistence of QoS sensitive and best effort traffic flows. A brief description of the above on QoS routing in MANETs is given below.

2.1 Internetworking Mechanisms

The mobility mode of an Ad hoc network is quite different from that of infrastructure networks. In infrastructure networks only the nodes at the very edges (the last hop) of fixed cellular networks are moving, whereas an ad hoc network can be completely mobile, since a device can serve both as router and host at the same time. Consequently, in an ad hoc network mobility is handled directly by the routing algorithm. In many cases, device accesses both within the ad hoc network and to public networks (e.g. The Internet) can be expected to form a universal communication scenario. In other words, a terminal in an ad hoc wireless network is able to connect to nodes outside the MANET while being itself also accessible by external nodes. The coexistence and cooperation with the public IP based wireless networks is necessary to be able to access internet based services.

2.2 Unpredictable Link Properties due to Node Mobility

Maintaining link state information is very difficult task in case of MANETs due to dynamic topology. It is a significant challenge to monitor and maintain the link information. In MANETs, changes in network topology are random and frequent and nodes in the network are inherently mobile. It means the lifetime of the information regarding nodes status is very short. This information must be updated in a timely manner to prevent packet loss and to provide the routes to the packets to their destination. High node mobility can make QoS provisioning impossible.

2.3 Hidden Terminal Problem

The hidden terminal problem is inherent in ad hoc wireless networks. This problem occurs when packets originating from two or more sender nodes, which are not with in the direct transmission range of each other collide at a common receiver node. A routing protocol must be able to avoid hidden terminal interference and maximize the channel reuse.

2.4 Security

Security, reliability, and availability are three crucial aspect of MANET, especially in security-sensitive applications. Since ad hoc relies on wireless communication medium, it is important to deploy a security protocol to protect the privacy of transmissions. The requirements regarding confidentiality, integrity, and availability are the same as for any other public communication networks. However, the implementation schemes of key management, authentication, and authorization are quite different because there is no aid of a trusted third-party certification authority to create trusted relationships by exchanging private/public keys.

2.5 Limited Resources

Nodes in MANETs are battery based and have limited computational power and memory as compare to the nodes used in wired networks. These limited factors certainly affect the QoS guarantees in MANETs. Precise information about link and network status can not be efficiently maintained with limited memory capacity. Somehow if u can enhance the memory capacity of the light weighted terminal of MANETS, even though you are required to have a great power backup (again a scarce resource in MANETs) to perform all the computations required to maintain state information. Therefore a protocol has to be developed with maintaining a tradeoff of these two important resources to achieve the QoS support in MANETs.

2.6 Route Maintenance

Wireless communication is subject to interference and poor signal quality. Frequent link failures at the time of routing either due to the paucity of energy at the nodes or due to the mobility of the nodes disrupt message delivery. However, there exists an inherent attribute of redundant routing paths between nodes. It is, therefore, possible to provide a robust route maintenance scheme to increase the fault-tolerance capacity of the routing discovery scheme, for increasing the stability, reliability and availability.

2.7 No Central Coordination

In MANETs there is no central coordination among the nodes as wired networks, because MANETs are self organizing networks. Nodes can leave and join the network at any time anywhere in the network. This distributed feature is quite advantageous as to deploy a network instantly but creates overheads and complexity in the routing algorithm.

2.8 Unreliable Wireless Channel

The wireless channel is always prone to bit errors due to interference from other transmissions, thermal noise, shadowing and multi-path fading effects [6]. This makes it impossible to provide hard packet delivery ratio or link longetivity guarantees.

2.9 Imprecise State Information

Nodes in an ad hoc wireless network maintain the link specific and flow specific information. This information contains bandwidth, delay, cost, source address, destination address, and other QoS requirements. The state information is inherently imprecise due to dynamic changes in network topology and channel characteristics. Hence, routing decisions may not be accurate, resulting in packet loss or real time packet missing their deadlines.

3 QoS ROUTING DESIGN ISSUES

Three basic design choices for providing QoS support has been mentioned very clearly in [5], which are discussed below.

3.1 Hard State Vs Soft State

Hard resource reservation schemes reserve resources at all intermediate nodes for a path requested to provide QoS between a specific source-destination pair. If this path is broken, all the resources must be released explicitly. It is not always possible to release all the resources properly due to unreachability of previously involved node. Moreover, this scheme introduces extra overheads at the time of resource de-allocation.

3.2 Stateful Vs Stateless Approach

In stateless approach routing nodes need not maintain either any information related to associated links or required flows. This ensures scalability but providing QoS becomes tedious. In stateful approach, each node maintains the information of the associated links or flows either globally or locally. In both the cases QoS depends on the accuracy of the state information. These calculations for state information increase the significant control overheads, especially in global approach.

3.3 Hard Vs Soft QoS

If the QoS requirement of a request is guaranteed to be met then it is referred as hard QoS otherwise soft QoS. Due to the dynamic topology and limited resources of the mobile ad hoc networks, it is very difficult to ensure or guarantee the QoS as per the required request. So in MANETs there is always a restriction on the guaranteed QoS thereby most of the existing proposal in MANETs provide soft QoS.

4 QoS ROUTING CLASSIFICATION

QoS routing protocols can be classified in to a variety of ways. Most of which have been covered in the previous surveys done [5] [7]. In [7], protocols have been classified on the MAC layer dependence and divided into three categories: Contention free (CCBR [8], NSR [9] etc.), Contended (CAAODV [10], CACP [11] etc.), and Independent (AAQR [12], EBR [13] etc.). In [7] almost twenty MAC concerned routing protocols have been discussed in detail. A variety of routing protocols based on MAC, and network layer have been discussed in detail in [5]. Few proposals related to cross layer optimization have been also discussed in [5]. Therefore in our classification for QoS routing protocols, we are not including layer wise categorization of the QoS routing protocols. Interested authors can have a detailed summary of these protocols in [5] [7]. In our classification scheme, protocols have been divided into five categories: Single and multi-path Routing, Information based routing, Application based routing, location based routing and some specific proposals related to genetic engineering and fuzzy logic have been discussed with their merit and demerits. These categories cover almost all the aspects of the QoS requirement for designing an efficient QoS based routing protocol in MANETs. It is an acceptable fact that all the aspects of the QoS requirement can not be fulfilled with a single routing protocol, therefore the detailed study of various QoS routing protocols may pave the path for designing an efficient QoS routing protocol as per the QoS measures required for an application of the end user. Figure 1 represents the classification of the QoS routing protocols based on different categories.

4.1 Genetic Algorithm (GA) Based QoS Routing

A genetic algorithm based routing method for mobile ad hoc networks (GAMAN) has been proposed in [14]. The primary concern of the protocol is robustness rather than optimality. It is a source routing protocol developed to provide soft QoS. It makes an assumption that topologies are not very fast changing. GAMAN

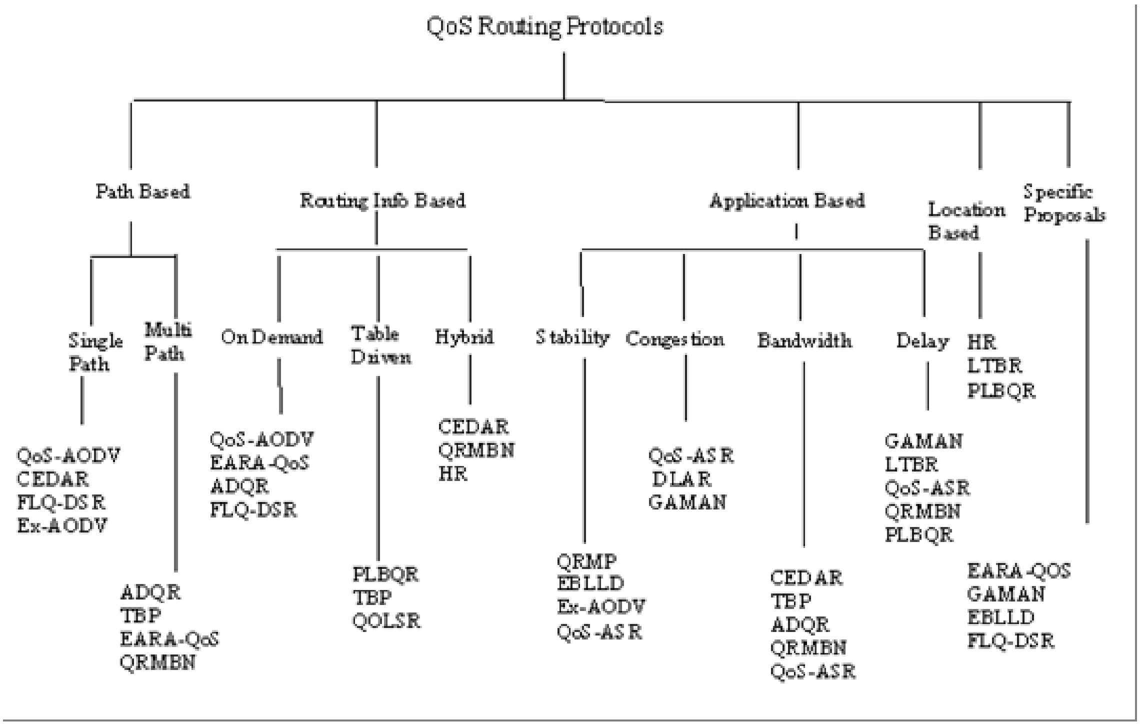

Figure 1: Classification of QoS Routing Protocol

uses two parameters delay and transmission success rate to decide the QoS paths. GAMAN discovers the path on demand basis and then makes a tree structure of the network topology view. Tree reductions are done to avoid duplicate sub trees. Each tree junction represents a gene and these genes combined represent a path referred as chromosome. This complete process is known as gene encoding. The fitness T of each path is calculated as:

$$T = \frac{\sum_{i=1}^{n} D_i}{\sum_{i=1}^{n} R_i} \qquad (1)$$

Here D_i and R_i are the delay and reliability of the link i respectively. The value of D_i and R_i is collected locally at the time of route discovery. A path with the minimum value of T is announced as the fittest path. This path and offspring from the genetic operation are carried forward into the next generation. This way GAMAN provides a strong platform to GAs in MANETs and shows the way to apply heuristics to solve the multi-constrained QoS routing problems through GAs. Although the computations involved for collecting and maintaining sufficient routes and state information are costly in terms of control overheads and energy consumption. However with some limitations GAMAN is a good example to show the application of GAs in MANETs as it achieves good response time and can support two QoS parameters at the same time.

4.2 Biologically Inspired QoS Routing (EARA-QoS)

A biologically inspired QoS routing algorithm (EARA-QoS) has been proposed in [15], which is an improved QoS version of the self organized Emergent Ad hoc Routing Protocol (EARA) [16], which was inspired by the foraging behavior of biological ants. EARA-QoS is an on demand multi-path routing protocol which incorporates positive feedback, negative feedback and randomness into routing computations. Each node using this protocol maintains a probabilistic table and a pheromone table. Pheromone table track the amount of pheromone on each neighbor link. In probabilistic table, each route entry for the destination d is associated with a list of neighbor nodes j. A probability value Pi, j, d in the list expresses the goodness of node j as the next hop to the destination d. The routing probability value Pi,j,d is computed by the composition of the pheromone values , the local heuristic values and the link delays as follows:

$$\frac{[\tau_{i,j,d}]^{\alpha}[\eta_{i,j}]^{\beta}[D_{i,j}]^{\gamma}}{\sum_{l \in N_i}[\tau_{i,l,d}]^{\alpha}[\eta_{i,l}]^{\beta}[D_{i,l}]^{\gamma}} (\tau_{i,j,d} > L) \qquad (2)$$

Where α ,β and γ are tunable parameters that control the relative weight of pheromone trail $\tau_{i,j,d}$, heuristic value $\eta_{i,j}$ and the link delay $D_{i,j}$. N_i is the neighbors of node i. With $\tau_{i,j,d}$ > L, data traffic can only be forwarded following a valid route. L is the lower pheromone value below which data traffic can not be forwarded. The heuristic value $\eta_{i,j}$ is calculated with the network interface queue length in node i as:

$$\eta_{i,j} = 1 - \frac{q_{i,j}}{\sum_{l \in N_i} q_{i,j}} \quad (3)$$

Where $q_{i,j}$ is the length (in bits waiting to be sent) of the outgoing queue of the link $l_{i,j}$, N_i are the neighbors of node i. Making routing computation using the heuristic value and link delay makes this algorithm more efficient to possess the load balancing behavior. A light weight DiffServ model has been introduced to deal with different type of data traffic by scheduling the queues in the token bucket scheme.

4.3 Distributed Entropy Based Long Life QoS Routing (EBLLD)

A new Entropy Based Long Life Distributed QoS routing protocol for MANETs has been proposed in [17]. The protocol is aimed to select the long-life path along with the entropy metric (decides the stability of the path) to provide QoS support in ad hoc networks. In this protocol, authors have assumed that the position of a node can be easily acquired with the help of any GPS based positioning service. In EB-LLD, a link relation from node i to j is considered as a function of location vector, velocity vector and the transmission range. Entropy metric at a mobile node i during the time interval is defined as:

$$H_i(t, \triangle) = \frac{-\sum_{k \in F(i)} P_k(t,\triangle) \log P_k(t,\triangle)}{\log C(F(i))} \quad (4)$$

where

$$P_k(t, \triangle) = \frac{a_{i,k}}{\sum_{l \in F(i)} a_{i,l}}$$

and F (i) represents the set (or any subset) of neighboring nodes of node i, and C (F (i)) represents the cardinality (degree) of the set F (i). If the local network stability has to be calculated then F(i) represents the set that includes all the neighboring nodes of the mobile node i, and if stability of a part of a specific route is computed then F(i) represents the two neighboring nodes of the mobile node i over that route. Similarly to the path P from node i to j, entropy is defined as:

$$H_p(i, j) = \prod_{k=1}^{N_r} H_k(t, \triangle) \quad (5)$$

Where N_r represents number of nodes in the path from node i to node j. The path P is more stable, as high its entropy value from i to j is. EBLLD uses two special operators (order operator and filter operator) along with a heuristic function, h, which can have many options for computations. At the time of route discovery source node sends a route request in the form of discovery message which has the special fields like delay_so_far, path_so_far and entropy_so_far. Now the source calculates set of receivers of node i with the help of order and filter operators and the heuristic function. When an intermediate node j receives discovery message from a node i then node j check whether it has received the same message before or not. If it has received the similar message before, it straight forward discard the message, otherwise it checks for path_so_far field, if it appears in the field again, it discards the message, otherwise it add the delay (i,j) to delay_so_far and update the discovery message. After updating it a local multicast is done again by receiving the further set of receivers from j. This process is repeatedly applied until the route message reaches the ultimate destination node (D). D waits for multiple messages from the same source by different paths and ultimately selects a path with the least entropy value among all the received messages. After selecting the final path a route reply is sent back to the source and path is established to transfer the data upon it. This protocol involves a lot of calculations which are used to select the appropriate set of receivers for a particular node. Excessive calculations can not be a good solution in an energy constrained environment like ad hoc networks. The protocol does not reserve the resources at any phase hence it is not capable of providing hard QoS.

4.4 QoS Based Ad hoc Distance Vector Routing

A QoS extension to traditional AODV protocol (QoS-AODV) has been proposed in [18], to provide soft-QoS. This protocol has two promising features for the QoS support, first is maximum tolerable delay and second is minimum available bandwidth requirement. In this protocol route request (RREQ) and route reply (RREP) packets of the AODV has been modified by appending the new fields of minimum bandwidth and maximum delay to their existing format. The newly added field maximum delay is treated differently for route request and route reply phase of the protocol. In the route request phase delay field represents the maximum time allowed for transmission from source to destination. While in route reply phase it represents the cumulative delay from the intermediate node forwarding the route reply to the actual destination. The route request is forwarded by an intermediate node only if the value of Node_Traversal_Time ( ) is less than the maximum delay extension. While in case of route reply each intermediate node adds the Node_Traversal_Time to the delay field and forwards the route reply to the source node. In the similar way minimum bandwidth extension has been treated separately for routé request and route reply phases. Protocols search for a QoS path in terms of minimum bandwidth required by the new connection request at a source. If in either case (for delay or bandwidth) the required QoS support path can not be established, maintained or not available in the network then QoS_LOST message is being send to all the relevant sources. In this protocol only link traversal time has been considered as delay while there may be several more reasons involved to cause delay (queuing, propagation, transmission, contention etc.).

4.5 Core Extraction Distributed Ad hoc Routing (CEDAR)

A Core Extraction Distributed Ad hoc Routing to support QoS for small and medium size MANETs has been proposed in [19].The core of a network is defined as Minimum Dominating Set (MDS), that is, all nodes are either part of this set or have a neighbor that is part of the set. The core of the network is established dynamically and then core incrementally propagates the link status of stable high bandwidth links to the core nodes. RTS-CTS handshaking is used to avoid the hidden and exposed node problem. CEDAR has three major phases to work. First phase is core extraction, in this a set of nodes are elected to form the core to maintain the local topology of the nodes in its range and also perform route computation. The selection of core nodes is done by approximating the MDS. Second phase of CEDAR is link state propagation; in this the bandwidth availability of stable links is propagated to all core nodes. Third phase of the CEDAR is route computation, in this phase CEDAR iteratively tries to find a partial route from the source to the domain of the furthest possible node in the core path satisfying the bandwidth requirement. Now this node becomes the source of the next iteration. CEDAR ensures the efficient use of network resources and relatively accurate and up to date knowledge of the QoS state where it is required. CEDAR incurred low overheads by ensuring the availability of the link state information at the core nodes.

4.6 Ticket Based QoS Routing

A ticket based QoS routing scheme (TBP) has been proposed by Chen and Nahrstedt in [20]. In this paper two algorithms were proposed, one is for delay constrained routing and other is bandwidth constrained routing. In TBP feasible paths are searched by making use of probes. A probe consists of one or more ticket and a ticket simply represents the permission to search a path. In TBP tickets are of two types, one is green which represents a search for low cost path and yellow represents search for the paths which have least delay. How many tickets at a time must be issued to explore a feasible path is depend upon the cost and the delay requirement of the connection request. In TBP an attempt is made to collect the state information as precise as possible so that more optimized routes can be found upon the request. If a new connection request comes to a source for a great QoS support then TBP increases number of ticket in the probe to find out more number of paths and collect the state information as better as possible. Although in this case little overheads are increased but a higher degree of QoS can be achieved. But if a new connection request does not demand stringent QoS then TBP issues a few tickets to the probe to explore the new paths. This way control overheads can be significantly restricted. So throughout both the algorithms there is always a trade-off between QoS and overheads. TBP always try to find out a least cost path and assume that it has precise state information on the cost of higher overheads. It is a good heuristic which perform the delay and bandwidth constrained routing in turn and is dynamic in nature to react as per the connection request of the user.

4.7 An Adaptive QoS Routing Protocol

An Adaptive QoS Routing Protocol (ADQR) with Dispersity for MANETs has been proposed in [21], which is aimed to provide multiple disjoint paths with network resource information at the time of route discovery. ADQR also proposes a route maintenance algorithm to proactively monitor network topology changes and to perform an action before a path become unavailable. ADQR determines the maximum transmission range R to the neighbor. ADQR define two threshold values Th1 and Th2 in terms of signal strengths (SR) of the associated neighbors. These threshold values have been used for routing decision as per the node set classes which are first, second and third link class. If all the nodes in the network has the same maximum signal strength then if a node has signal strength greater than Th1 then it is in first link class. If a node has a value between

Th1 and Th2 then it is in second link class. If a node is in the range of SR and Th2 then it is in third link class. In the route discovery phase of ADQR, a source node broadcasted a route request packet and search for multiple disjoint paths based on some QoS metric (bandwidth) as per the link class. A route with stronger link class has precedence over another. Route request and route reply algorithm are invoked for setting up a QoS route. Whenever a link break takes place upon a pre-established route; a route maintenance algorithm is run in two phases viz pre-rerouting and rerouting. ADQR makes use of different type of packets for reserving and releasing route. ADQR approach work well even under high mobility scenarios due to its capability to find multiple path and a robust route maintenance scheme.

4.8 Fuzzy logic Based QoS Routing (FLQ-DSR)

In [22], a Fuzzy Logic Based QoS Routing Protocol has been proposed for MANETs. The protocol not only considers bandwidth and end to end delay but it also considers the cost of the path by adding the fuzzy logic module in the route discovery. Route discovery procedure of FLQ-DSR is divided into three phases. First phase is used to discover multiple paths. In the second phase, information collection of link state and route state is done. Third phase computes the most qualified path for application requirement through fuzzy controller. Link state information like delay, bandwidth and cost is achieved by modifying the 802.11. So this work is getting done using the MAC layer protocol. The major contribution of FLQ-DSR is selecting the most appropriate path among multiple available paths. Fuzzy logic has been introduced in the third phase of the FLQ-DSR and a fuzzy controller has been designed to provide the fuzzy logic for route selection. This fuzzy controller has three major components. First one (traffic fuzzy controller) is used to process the application requirements and the second component (Route fuzzy controller) is used to handle the route QoS service parameters. Third component is QoS matching controller which matches the fuzzy output of first and second component of the fuzzy controller. Now after these three components , a route selection module is invoked to select the appropriate route by making use of different continuous function namely triangular tri (x; a, m, b) and trapezoidal trap(x; a, m, n, b) [23], where m and n are the modal values, a, b represents the lower and upper bounds for non zero values of tri(x) and trap(x). The route maintenance phase of FLQ-DSR is as similar to DSR. Requested bandwidth and the delay are the entry variables for the fuzzy controller. For proper computations and fuzzy mapping of entry variables and their membership functions, bandwidth and delay parameters have been formed as a set of different values. Bandwidth has been divided into five classes: lower, low, medium, high and higher. Delay has been divided into short, middle and long fuzzy sets. Although FLQ-DSR is only suitable to a small to medium size MANETs only but yet the adaptability to fuzzy logic paves a new direction to researchers to think in a different way to provide QoS to the application requirement with little control overheads and selection of most feasible routes.

4.9 Predictive Location Based QoS Routing (PLBQR)

Shah and Nahrstedt [24] have proposed a predictive location based QoS routing scheme which has a location resource update protocol for the distribution of geographical location and resource information. This protocol considers resources like power, processor speed, transmission range etc. Two types of updates are possible through PLBQR. First update is done periodically to get the physical location of the nodes. Second update is invoked whenever there is a change in the position of the node. In PLBQR different formulas are used to calculate the location and the delay values for destination and intermediate nodes. As a result each node is supposed to have knowledge of the complete network. Each node maintains two tables: Route Table and Update Table. The update table contains information about every node, updates received from. To make the location-delay prediction a node must have two last updates from other node. The route table of a node contains the information about the all active connections with this node as a source. Whenever an update is received at a node it checks is any of the routes in its route table is broken if so a route re-computation is initiated. Due to the location prediction, based on the updates, PLBQR can predict if neighboring nodes on a route are about to move out of each other's transmission range. In this case route re-computation is being initiated even before the route actually breaks. This way by making use of location and delay prediction PLBQR can efficiently search a feasible path in terms of delay. As well as with the help of update protocol it can recomputed the path whenever a link failure takes place even it can recomputed a path before a route actually breaks. As PLBQR maintains the information of the complete network, it significantly increases the control overheads as the size of the MANETs increases. In this scheme there is no role of resource reservation. Therefore no hard QoS guarantees can be provided with PLBQR.

Protocol	QoS Parameter Used/	Information Utilized	QoS Guarantee	Route Maintenance	Protocol used
GAMAN	Bounded Delay and Packet dropping rate	Packet success ratio and and node traversal delay	Soft	No explicit route Maintenance	No protocol is mentioned, GAMAN 1 algorithm has been used for comparison.
EARA-QoS	Local heuristic value and link delay	Interface queue length, Node mobility, Network density	Soft	Local Repair is done	Pure and congestion routing
EBLLD	entropy	Life of a path (stability and energy in terms of entropy)	No guarantees (attempt to pseudo hard but soft)	No route maintenance	No base protocol is specified but uses 802.11 DCF and On demand routing
QoS-AODV	Maximum tolerable delay and minimum available bandwidth	Node traversal time	Soft	No route maintenance	AODV
CEDAR	Assured throughput	Link residual capacity, core nodes	Soft	No proper route maintenance	No information
TBP	Assured throughput/ bounded delay	Available channel capacity, delay estimates	Soft	Enable	DSDV routing
ADQR	Link bandwidth	Network resource information, signal strength	Soft	Enabled	No information
FLQ-DSR	End-to-end delay, cost of the path, bandwidth	Link state information	No guarantees, but it can achieve soft QoS	Similar to DSR	DSR
PLBQR	Delay	Node location information	Soft	Enabled	No information
QOLSR	Throughput and delay	Link capacity and delay information	Soft	No route maintenance	No information
QRMP	Bandwidth and delay	Mobility and route expiration time	No guarantees	Partial route maintenance	No information
HR	Throughput and latency	Backbone nodes, location info.	Pseudo Hard	Enabled	AODV
QRMBN	Minimum delay and least cost	Backbone nodes	Soft	Enabled	No information
QoS-ASR	Least cost	Link stability, Lifetime of the node	Soft	Enabled	DSR
DLAR	Load	Load of intermediate nodes	Soft	No route maintenance	No information
LTBR	Progress-over-cost	Location information	Soft	No route maintenance	No information
Ex-AODV	Stability	History table, Node stability	Soft	No route maintenance	AODV

Figure 2: Comparison of QoS features of different QoS protocols

4.10 QoS based Optimized Link State Routing (QOLSR)

A proactive QoS routing protocol has been proposed in [25]. This protocol is a QoS extension to the Optimized Link State Routing protocol (OLSR). In QOLSR multipoint relays (MRPs) are build with the help of efficient heuristics in order to introduce QoS routing in the protocol. In QOLSR, the calculation for channel capacity, delay information between a node and its neighbor and the construction of MRPs is given in detail in order to provide the QoS routing. It is also shown that QOLSR selects appropriate MRPs using the link capacity and delay information as compare to OLSR, where each MRP contains the information of its two hop neighbor. Finding two hop neighbors for each MRP is itself a NP complete problem. This problem has been dealt properly in QOLSR by constructing the MRPs in more efficient way as compare to OLSR.

A few more QoS approaches like QRMP [26], HR [27], QRMBN [28], QoS-ASR [29], DLAR [30], LTBR [31], EX-AODV [32] etc can also be analyzed in detail. But due to the page limits in the paper length only their characteristics have been shown in Figure 2. Figure 2 represents a comparative detail of the QoS features of different QoS routing protocols discussed in this paper.

5 CONCLUSION

In this paper several techniques proposed in the literature for providing QoS support for applications in Mobile Ad hoc Networks have been described. First, the issues and challenges in providing QoS in ad hoc wireless networks were discussed. Thereafter the classification of the existing QoS approaches under several criteria such as single and multi-path Routing, information based routing, application based routing, location based routing and some specific proposals related to genetic engineering and fuzzy logic were discussed with their merit and demerits. These categories cover almost all the aspects of the QoS requirement for designing an efficient QoS based routing protocol in MANETs. Two common problems which can be easily extracted from Figure 2 are ;lack of proper route maintenance technique and absence of energy awareness in the available QoS routing protocols. All the aspects of the QoS requirement can not be fulfilled with a single routing protocol, therefore the detailed study of various QoS routing protocols in this paper may pave the path for designing an efficient QoS routing protocol as per the QoS measures required for an end user application.

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