Delay aware Reactive Routing Protocols for QoS in MANETs: a Review

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ABSTRACT
Mobile Ad Hoc Networks (MANETs) are wireless networks, which do not require any infrastructure support for transferring data packets between mobile nodes. These nodes communicate in a multi-hop mode; each mobile node acting both as a host and router. The main function of Quality of Service (QoS) routing in MANETs is to establish routes among different mobile nodes that satisfy QoS requirements such as bandwidth, end-to-end delay and to be able operate within the limited energy constraints. Efficient QoS routing protocols are required by most commercial, real-time and multimedia applications. Ad Hoc On-Demand Distance Vector (AODV) and Dynamic Source Routing (DSR) protocols are two of the most on-demand protocols used in MANETs. These protocols use shortest path as a main metric to establish routing between source and destination. However, they are designed primarily as best effort services and as such they do not fully heed QoS requirements as required by MANETs. This paper presents an overview of reactive routing protocols in QoS which use delay as a main metric.

Keywords: MANETs, QoS Routing protocols, Delay.

1. Introduction

MANETs are wireless networks, which do not require any infrastructure support for transferring data packets between mobile nodes, such as an access point or a base station. Each mobile node acts both as a host as well as a router. The difficulties and constraints known in conventional wireless networks are more pronounced in MANETs due to dynamic topological changes, energy constraint, bandwidth limitation and the lack of current network state information. Interference, environment noise, collision, congestion, hidden/exposed problems and security, are some of these difficulties.

A wide range of potential applications exist for Ad Hoc networks of which distributed computing, disaster recovery, mobile access Internet, military applications, vehicles communication, healthcare providers, sensor networks and multimedia applications are some examples.

In recent years, increasing use of MANETs has led to intensive research in the QoS provisions to fully meet QoS guarantees as required by application according to its scenario requirements. However, finding an efficient route while adhering to multiple QoS requirements is typically difficult and in many cases is considered as a NP-complete problem[1].

Delay is an additive metric which belongs to the type of NP-complete problem, although, not much research has been done on the delay problem directly. This paper presents a review of some QoS extensions based on reactive (on-demand) routing protocols which consider delay in the network layer as a main metric. Bandwidth and energy metrics, the other important aspects of QoS, are not considered here being outside the scope of this paper.

The remainder of this article is organized as follows. Section two defines the fundamentals of MANETs routing protocols. Section three explains the QoS routing protocols and the challenges facing them. Section four describes delay aware routing of QoS in MANETs. Section five touches on evaluation and comparison of different reactive routing protocols of QoS. Section six ends with the conclusion and the direction of future work.

2. MANETs Routing

MANETs routing are based on unique addresses in the network. The source mobile node specifies the destination address. The network routing service creates a route path that contain multiple intermediate mobile nodes between the source and destination. Data Packets are routed through intermediate nodes and every node forwards the packets according to destination address.
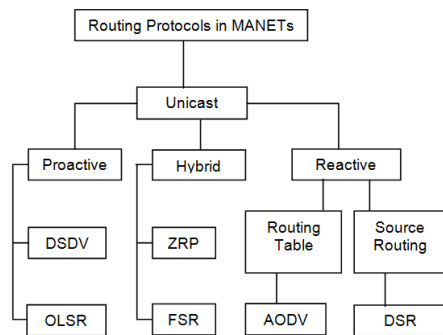

Figure 1. A simple classification of MANET Routing

Routing protocols are classified either as unicast or multicast, depending on the mechanism used in delivering data packets. Unicast transmission is the sending of data packets to a single network destination whereas multicast transmission is the delivery of packets to a group of destinations simultaneously in a single transmission. As outlined in figure 1, MANETs using unicast routing protocols are classified according to the routing discovery schema; Proactive, Reactive, and Hybrid.

Proactive (Table Driven) routing protocols periodically update routing tables at each node without the need for packet discovery. Routes then can be computed from the Routing Tables based on the protocol police. These kinds of protocols have the property of low latency and high routing overhead due to maintenance of up-to-date routing information, especially in high mobility scenarios as exemplified in Optimum Link State Routing (OLSR) [2] and Destination Sequenced Distance Vector Routing protocol (DSDV) [3].

In Reactive (On-Demand) routing Protocols, route discovery is initiated whenever packet forwarding requests arrive. This routing method does not waste channel capacity and energy. This discovery mechanism is characterized by high latency and low routing overhead. Dynamic Source Routing (DSR) [4], and Ad hoc On-demand Distance Vector (AODV) [5] routing are examples.

Hybrid Routing protocols try to combine the advantages of both methods by defining Zones around each node. Inter Zone Routing is performed reactively to reduce the Overhead of frequent messages, while Intra Zone Routing is performed proactively, as in Zone Routing Protocol (ZRP) [6] and Fisheye State Routing (FSR) [7] protocols.

Most of these currently used routing protocols are by design best effort service. The optimum path from source to destination can be found by using the shortest path calculation or the minimum hop count. These protocols do not take into consideration QoS metrics such as bandwidth, total delay, jitter and energy constraints. However, this technique is not always optimal to transmission of data flow as required by QoS. As such, efficient QoS incorporating these matrices in new routing protocols are necessary.

In On-Demand (reactive) protocols, the route discovery process is only activated when a source node needs to broadcast a data packet. They do not need to maintain routing information at all mobile nodes in the network. The basic mechanisms of on-demand routing protocols in DSR and AODV are explained below.

2.1 Dynamic Source Routing (DSR) protocol

In DSR [4] protocol, when a source node (S) wants to send a data packet to a destination node (D), it checks its route cache on availability of route. If a route is not available, then S initiates route discovery mechanism by broadcasting a request message (RREQ) to its neighbors. On receiving RREQ the neighbor of S checks first to see whether it itself is a D or not. If it is D, then it copies the collected information in the RREQ into a RREP and then signals a route reply (RREP) back to S. If it is not D, it checks its route cache for any other existing route to D; if not, it adds its address details in the RREQ packet and rebroadcasts until D receives the RREQ. D then replies to all RREQs. When S receives a RREP packet, it starts transmitting data packets along the path indicated in the RREP packet. If multiple paths are available, it chooses the shortest path.

Route maintenance is activated when a node detects a broken link. It then deletes the link from its route cache and transmits route error (RERR) messages to every node that has used the link.

2.2 Ad Hoc On-Demand Distance Vector (AODV) protocol

In AODV [5] which is quite similar to DSR, when a source node (S) wants to send a data packet to a destination node (D), it checks its route table to see if a route exists. If S is unable to find a route, then S activates the route discovery process by broadcasting a request packet (RREQ) to its neighbors. Each RREQ packet contains information about the destination sequence number (DSN), the source sequence number (SSN), source address (SA) and destination address (DA).

If a neighboring node is not a D, it broadcasts a RREQ to its neighbors. It also maintains track of the RREQ by creating a reverse path as well as a forward path. If the neighboring node happens to be D, then it replies to S by using the reverse path.

Stale routes can be detected by reference to the DSN in the RREQ packet against the sequence number in the route table. If the sequence number is greater the recorded one, it rebroadcasts the RREQ.

When a RREP packet travels back through the reverse path, every intermediate node creates a pointer-indicator to the node from which it receives the reply.

When S receives a RREP, it then starts transmitting data packets to D, using the discovered path. AODV protocol also includes route maintenance. When a link is broken, the involved node signals a route error (RERR) packet to neighboring nodes using the route.

3. QoS routing protocols in MANETs

QoS is defined as a set of service requirements that should be met by the network while transmitting a data packet from source to destination. The burden of QoS routing in MANETs is not only to establish routes between different mobile nodes that satisfy QoS requirements such as bandwidth and delay - but not limited to it - but

also to be able to respond quickly to constantly changing requirements. However, there is no universal QoS routing protocol, which satisfy all possible applications' requirements. Standard QoS routing protocols used in wired networks are unsuitable for MANETs because of node mobility. Routing protocols need to be more dynamic so that they can quickly respond to topological changes [8] while simultaneously meeting QoS requirements.

QoS routing in MANETs is difficult to design in general because of the highly dynamic nature of MANETs due to high node mobility and the required ability to operate efficiently with limited resources such as available bandwidth, memory, processing capacity and limited battery power of the individual nodes in network.

3.1 Challenges to QoS routing mechanisms

Below is a summary of the major challenges in providing QoS routing mechanisms for MANETs [9]

3.1.1 Dynamic topology

Changes in the topology of MANETs are due to constant changes in the position of the mobile nodes, the length of node life and the entry and exit of mobile nodes in the network. However, the frequent exchanges of topology information may lead to considerable transmission overload, congested limited bandwidth wireless links, and possible depletion of the limited battery life of the nodes involved. These complications imposed by mobility in MANETs may severely degrade network quality. The frequent route breakage is a natural consequence of mobility, which complicates routing. The application of topology management [10] could be a possible solution to the overhead arising as a result of continuous changes in the network parameters.

3.1.2 Unreliable wireless channel

Wireless channels may be unreliable due to interference by other transmissions, thermal noise, shadowing and multi-path fading effects, all of which either affect packet delivery ratio or link longevity guarantees or both.

3.1.3 Node mobility

Topology information must be updated frequently to let data packets to be routed to their destinations. Otherwise, packet delivery ratio

and/or link stability guarantees will be affected. As long as the velocity of state information broadcast is greater than the rate in the change of topology information, the network will be able to operate, and the routing information will not be stale.

3.1.4 Channel contention

To realize network topology, nodes in a MANET should communicate on a common channel. However, this leads to problems of interference and channel contention. This problem of channel contention can be avoided by resorting to protocols such as Code Division Multiple Access (CDMA) and Time Division Multiple Access (TDMA) and their improved variants.

3.1.5 Lack of centralized control

The main advantage of MANETs is that they may be created on an ad hoc basis and its members may change dynamically. A lack of centralized control is an inherent condition of a MANET. These imply a greater burden on routing protocols as the integrity of QoS must be maintained.

3.1.6 Heterogeneity

MANETs are usually heterogeneous networks with different types of mobile nodes which use a variety of communication technologies. Its diversity comes in the form of different types of nodes, ranging from sensors, palmtops and laptops all operating within a network or as a result of an ad hoc merging of multi-organized network. Nodes differ in their energy capacities and their computational abilities. Hence, mobile nodes will have different packet generation rates, routing responsibilities, network activities and energy draining rates. Dealing with node heterogeneity is the critical factor for successful operation of MANETs.

3.1.7 Insecure medium

Communication through a wireless channel is open to security issues. Hence, security is a significant issue in MANETs, especially for military and tactical applications. MANETs are vulnerable to attacks such as spoofing, eavesdropping, denial of service, message distortion, and impersonation.

3.1.8 Imprecise state information

Nodes in MANETs maintain both link-specific state information and flow-specific state information. The link-specific state information includes delay, bandwidth, delay jitter, error rate, loss rate, cost, stability, and distance values for each link. The flow specific information includes source address, session ID, destination address and QoS requirements of the flow, such as maximum bandwidth requirement, minimum bandwidth requirement, maximum delay and maximum delay jitter. The network state information is often necessarily inaccurate due to node mobility and channel characteristics.

3.1.9 Hidden terminal problem

A hidden terminal problem occurs when two nodes not within transmission range of each other, transmit data packets which simultaneously arrive at a third common node, causing a collision. Solutions have been proposed to overcome this problem.

4. Delay aware routing protocols in QoS for MANETs

The majority of conventional solutions proposed in the literature focus on providing QoS based primarily on two metrics; throughput and delay. Throughput is considered as the minimum packet delivery rate required by most voice or video applications [11]. Additionally, other constraints affect QoS parameters during the route discovery process.

Delay in MANETs consist of many types such as compression and decompression delay, processing delay, propagation delay, media access delay, acknowledgment and retransmission delay, jitter delay, end-to-end delay and routing delay.

End-to-end delay is a very important performance metric in MANETs especially in real-time or multimedia applications. It refers to the total time experienced by a single packet travelling in a MANET from source node to destination node.

The increase of delay time can be due to congestion and/or collision and also other factors such as the length of the route and interference level along the route path. However, it is important

for MANETs to avoid network congestion and collision, in order to optimize MANETs' throughput and performance in general.

Delay and jitter are considered additive constraints whose overall value is the summation of the values of its constituents. Probability of packet loss and reliability are considered multiplicative constraints whose resulting value is a product of the values of its constituents. Bandwidth is considered a concave constraint which is a minimum of the bandwidths of the links that constitute the path.

The standard QoS guarantees provide minimum standards, such as bandwidth, delay, jitter and packet delivery rate to users or applications. Regrettably, authors in [1] have proved that if QoS contains at least two additive metrics, then the routing is a NP-complete problem. Hence, supporting more than one QoS constraint makes the QoS routing problem a type NP-complete problem.

4.1 Delay aware protocols based on AODV

As stated previously in section 2.2, AODV routing protocol is one of the most widely on-demand (reactive) routing protocols used in table-based theory. It is designed as best effort service and considers minimum number of hops or shortest path between source and destination as the main metric in determining optimum routes, without considering to QoS requirements.

The author in [12] proposed a QoS-AODV routing protocol with some improved extensions to his earlier work in [5]. This enhanced protocol helps in choosing optimal path from source to destination using hop count as a basis along with delay and bandwidth. However, the protocol does not take into account the dynamics of MANETs, such as topology changes due to nodes moving out of range, thereby causing link failure or the occurrence of node failure, which in turn leads to inaccurate delay estimates.

A delay aware routing protocol has been proposed [13] which combines selected and modified components of QoS-AODV [12] and AODV-Multipath [14], in a new protocol, namely, Delay Aware AODV Multi-path (DAAM). This protocol enables the computation of multiple node-disjoint paths without incurring the overhead generated by link-state routing methods. The cumulative delay during the route

discovery process from the source node to destination node is recorded by each node.

In [15], EDAODV which is a modified version of AODV with additional delay and energy extensions, the two parameters of minimum energy and maximum delay are added to the AODV routing table per entry. Nodes with these two new fields transmit a route request (RREQ) packet with the QoS energy and delay extensions. The extension of delay gives the maximum delay permitted between the source and destination.

Ad hoc QoS on-demand routing (AQOR) [16] protocol uses restricted flooding to discover the best route possible in terms of minimum end-to-end delay within the bandwidth guarantee. A route request packet includes both end-to-end delay and bandwidth constraint. Delay is computed during route discovery. The route with least delay is selected by source.

In [17] it was proposed to improve the route discovery process of AODV by the addition of the two parameters of residual battery power and buffer size. This was done via the addition of an Energy and Delay-Constrained (EDC) algorithm. Buffer information is an indicator of a particular node's ability to forward new additional traffic and is incorporated in every energy aware routing protocol. Current size of the queue is controlled to restrict end-to-end delay of the data packets.

4.2 Delay aware protocols based on DSR

As stated previously in section 2.1, DSR is the primary on-demand routing protocol based on source routing theory. It designed as best effort service which considers the minimum number of hops in determining the shortest route. A shortcoming of this approach is the additional generation of delay and network congestion incurred.

In [15] the additional mechanisms proposed for AODV are now to be applied to DSR. Route discovery in DSR uses these energy and delay extensions and the ensuing new protocol is called EDDSR.

In [18] the on-demand routing protocol, named Split Multi-path Routing (SMR), calculates two paths in route discovery. One is calculated using delay as the main metric whereas the other is the maximum disjoint path.

Protocol Name	Based on	QoS Metrics
Energy and Delay with AODV (EDAODV) [15]	AODV	D, E
Energy and Delay-Constrained on AODV (EDC-AODV) [17]	AODV	D, E
Energy and Delay with DSR (EDDSR) [15]	DSR	D, E
Ad Hoc QoS On-demand Routing (AQOR) [16]	AODV	BW, D
QoS - Ad-hoc On demand Distance Vector (QoS- AODV) [12]	AODV	BW, D
Delay Aware AODV Multi-path (DAAM) [13]	AODV	D, MP
Split Multi-path Routing (SMR) [18]	DSR	D, MP

D = Delay, BW = Bandwidth, E = Energy, MP = Multipath.

Table.1 Summary of reactive routing Protocols based on QoS metrics

5. Evaluation and comparison of different reactive routing protocols on QoS

Table 1 summarizes some reactive routing protocols available in the literature. Some of these protocols emphasize QoS in terms of Delay and Bandwidth metrics [12], [16], whereas other focus on Delay and Energy metrics [15], [17]. The strategy of Multipath selection and Delay has been proposed in [13], [18] to improve end-to-end delay and to minimize packet loss.

The attempts to optimize delay have been done at the path discovery stage by adding delay calculations to the route table. Delay calculations include among others, time taken during passage of route request and route reply message. The dynamic behavior of MANETs in terms of topology change and node mobility results in inaccuracy of the delay estimation at path discovery stage. Delay calculated at the route discovery stage is useful as long as MANETs remain stable since delay is calculated at discovery time. The very structure of MANETs allows mobile nodes to freely move in and out of network range. Consequently, the network load is continuously changing and the variable factors of interference and end-to-end delay are also variable.

6. Conclusion and Future Directions

This paper outlines delay aware reactive routing protocols for QoS on DSR and AODV, in addition to presenting a summary of challenges facing routing protocols for QoS in MANETs. Further, the different reactive routing protocols for QoS were briefly explained and a comparison was drawn between them.

More emphasis in future needs to be done on delay aware protocols in QoS as delay is an important metric in QoS routing protocol for MANETs. In addition to the emphasis on delay metric, to future improve QoS work along the lines of Multi-path routing selection technique, multiple access control and cross-layer design would be in the right direction.

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