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QoS Routing By Ad-Hoc on Demand Vector Routing Protocol for MANET

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Abstract. A mobile ad-hoc network (MANET) is a collection of mobile nodes that form a wireless network without the use of a fixed infrastructure or centralized administration, and every node acts as a host as well as a router. The topology of an ad hoc network changes frequently and unpredictably. Considering the limited bandwidth and battery power, finding routes that satisfy the bandwidth constraint of applications is a significant challenge. Ad hoc on-demand distance vector routing (AODV) is an on-demand routing protocol that only provides best-effort routes. In this paper, we propose the QS-AODV protocol which is based on AODV and creates routes according to the QoS requirements of the applications. The simulation results (NS2) presented here indicate that QS-AODV provides performance comparable to AODV under light traffic. Under heavy traffic, QS-AODV provides higher packet delivery ratios and lower routing overheads at the expense of slightly longer end-to-end delays as the routes in QS-AODV are not always the shortest. The effects of network size and mobility on the performance of QS-AODV are also presented.

Keywords: MANET, wireless ad-hoc networks, ad-hoc on demand distance vector, QoS over AODV.

1. Introduction

A Mobile Ad hoc Network (MANET) also called mobile packet radio network or mobile multi hop wireless network is an innovative approach to provide services under these situations. Ad hoc generally means constructed from whatever is immediately available but in this context, it means no infrastructure. Physically, a mobile ad hoc network consists of a number of geographically distributed mobile hosts (here referred to as "mobile nodes"), sharing a common radio channel and a network is created "on the fly" as these nodes transmit information to each other [1] [2]. The network does not depend on a particular centralized administrator and dynamically adjusts itself as some nodes join or leave the network. Thus, such a network is both flexible and robust. A mobile ad hoc network can be quickly deployed and to provide limited but much needed communications [3]. In a MANET, each mobile node is equipped with a wireless transmitter and a receiver using antennas. Nodes can communicate directly with other nodes within their wireless transmission range. Thus, each node must be capable of acting as a host and as a router. Packet forwarding, routing and other network operations are distributed and carried out by individual nodes. In general, mobile nodes in ad hoc networks are free to move randomly and organize themselves arbitrarily. The network topology may change with time as the nodes move or adjust their transmission power, so Quality-of-Service (QoS) is a desired parameter to provide the required service differentiation for the demanding connections. Different applications have different QoS requirements, such as bandwidth, delay or delay jitter. However, providing QoS assurance in MANETs is a very complex problem due to their characteristics, such as the mobile nature of the nodes resulting in an unpredictable topology, scarce wireless bandwidth which varies with the changing environmental conditions, limited mobile device power and the requirement of node cooperation to relay packets through the network [4].

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2. QS-AODV Routing Protocol

2.1 Ad hoc On-demand Distance Vector (AODV) Routing Protocol

Ad-hoc On-Demand Distance Vector Routing (AODV) is a distance vector routing protocol based on the Destination-Sequenced Distance Vector Algorithm (DSDV) and DSR, which was first proposed in 1999 [5]. It is the most popular routing protocol for ad hoc networks, and has been investigated widely by many researchers for a large number of network topologies and environments. In July 2003, the latest version of AODV [6] was recommended as an experimental routing protocol for ad hoc networks by IETE.

AODV is a pure on demand routing protocol, so that a route is only discovered when required by a source node. A node does not need to keep route or reserve bandwidth that is not needed. Therefore, AODV is very suitable for bandwidth constrained routing. Based on AODV, in this paper we propose a QoS routing protocol to provide QoS assurance in ad hoc networks. With this protocol, local state information is propagated through the network, and precise network information is not required to create a path that satisfies the QoS requirements of each session.

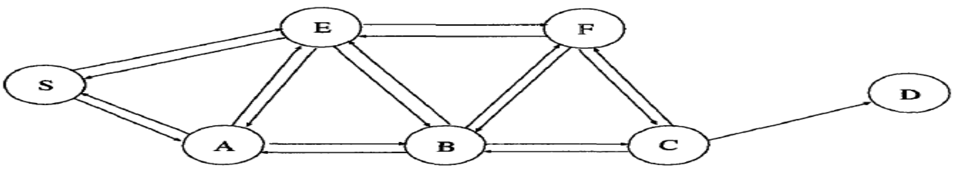

Fig. 1: An example of AODV route discovery

Fig. 1 shows an example of AODV route discovery, where 'S' is the source node and 'D' is the destination node. Links in this figure represent RREQ packet broadcasting.

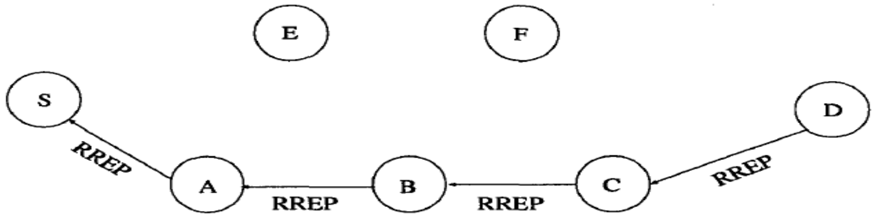

Fig. 2: An example of AODV route reply

Fig. 2 shows an example of AODV route reply. Each node records the RREQ packets that it has received. When it receives duplicate RREQs (with the same RREQ ID and source address) from neighbor nodes, they are discarded and not rebroadcast, which reduces the routing overhead caused by "flooding" broadcasts. The RREQ information recorded in each node must be kept a certain amount of time to ensure that no other node in the network is still processing request packets resulting from the same route discovery.

2.2 Proposed QS-AODV Protocol

QS-AODV is proposed here to provide QoS assurance for the AODV routing protocol. This QoS object extension includes the bandwidth or delay parameters of each application, and is also having a "session ID" which is used to identify each QoS flow that is established according to the application. The extension is added to RREQ and RREP packets to discover and create routes. The session ID and required QoS parameters are recorded in the routing tables to identify different QoS flows. QS-AODV modifies the route discovery and maintenance mechanisms of AODV to provide QoS assurance, a detailed description is given in the following sections.

2.2.1 Route Discovery

For route discovery, when the source node requires a route to a destination node with specified bandwidth requirements, it broadcasts a RREQ packet with the QoS extension to its neighbor nodes. When a node receives a RREQ packet, it first checks if it has enough available bandwidth for the request. A node which does not satisfy the bandwidth constraint will discard the RREQ packet. If required bandwidth is available, a reverse route entry is created with the specified session ID and used to forward the RREP to the source node, and then it rebroadcasts the RREQ packet as in the original AODV until the RREQ packet reaches the destination node. Once the route discovery packet arrives at the destination, a route reply is generated.

2.2.2 Route Maintenance

The other significant part of QS-AODV is route maintenance. Those applications using a QoS route will require a route to be rebuilt more quickly than for other applications. For this reason, a different local repair mechanism is used in QS-AODV. We first assume that when a link breaks, it means that the next node along the route is unreachable but the following node along the route will most likely to be available. Therefore, unlike local repair in AODV, the upstream node of a broken link sends a local repair request to find the node following the next node along the route to the destination node. This request packet includes the session ID and required bandwidth of the QoS flow, with the TTL (Time to Live) value set to 3, which limits the broadcast area of the local repair request. To allow this mechanism, the following node of the next hop along the route is also recorded in each routing table entry. An example of this local repair mechanism is shown in Fig. 3.

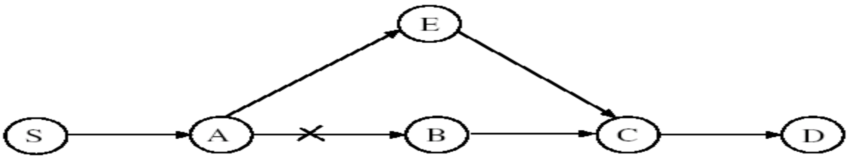

Fig. 3: An example of local repair in QS-AODV.

3. Simulation and Performance Evaluations

The conclusions are based on the results gathered by extensive simulation of the network model which implements the protocol proposed in the thesis. We use the NS-2.34 which can simulate all the layers in the network. It is a popular simulator used for ad hoc networks. NS-2.34 has been used with similar mobility and traffic models in many recent performance studies on ad hoc networks, for example [7]. The latest version of the AODV protocol [6] is used for performance comparison. The simulation is trace-driven. A mobility trace for the nodes and session-level traffic trace are inputs to the simulator. The mobility trace provides complete trajectories of all nodes in the network.

3.1 Traffic and Mobility Model

In our simulations, 50 nodes move in a rectangular area of 550m X 550m, respectively according to a mobility model called random waypoint, as described in [8].

Table 1. Simulation parameters.

Maximum Node Speed (m/s)	In between 1 and 10m/s
Pause Time (s)	5, 10, 15, 20 ,25, and 50,150,250, 350,450
Total Simulation Time (s)	600se
Data Packet Rate (packets/s)	20
Packet Size (byte)	512
MAC Protocol	IEEE 802.11
Data rate	2Mb

In this mobility model each node is randomly distributed in the simulation area initially, then it moves towards a random destination and pauses for a certain time after reaching this destination before moving again. When the node reaches the boundary of the simulation area, it reflects back with the same angle of incidence (similar to reflection of light from a mirror). The nodes move at a speed uniformly distributed between 0 m/s and a maximum speed. Higher pause times reflect lower mobility. 0s indicates a high mobility scenario, while the scenario with 450s pause time is considered as a stable network. We use

Constant-Bit-Rate (CBR) data in the traffic model. Sources generate 512 byte packets at rates of 20 packets/s, so the application bandwidth requirements are 80kb/s. For 35 nodes network simulation, the number of traffic sources is 5, 10, 15, 20, or 30 sources for each of the packet rates. The simulation parameters are shown in Table 1.

3.2 Parameters Monitored

We evaluated the performance of QS-AODV by measuring three parameters: data packet delivery ratio, normalized routing overhead and end-to-end delay of data packet.

3.2.1 Data Packet Delivery Ratio (PDR)

The data packet delivery ratio is obtained by comparing the number of packets received by the sources to the number of packets sent by the destinations. This is the efficiency of delivering data within the network. This metric is important because it reflects the maximum throughput that the network can support. It also a measure of the completeness and correctness of the routing protocol. The PDR is expressed as given in eq^n.

$$PDR = \frac{No.\,of Packets Received by Destination}{No.\,of Packets Originated by Source Node}$$

3.2.2 Normalized Routing Overhead

This ratio is calculated by comparing the total number of routing packets transmitted during the simulation time to the number of data packets delivered. For packets sent over multiple hops, each transmission of the packet over a hop counts as one transmission. This measure indicates the efficiency of the protocol in expending control overhead to deliver data. The normalized routing overhead ratio is a very important metric for comparing routing protocols, as it measures how a protocol functions in congested or low-bandwidth environments, and the efficiency of consuming network resources (e.g., bandwidth and battery power). Protocols that send large amounts of routing overhead increase the probability of packet collisions, and data packets may have longer delay in the network interface queues. We only measure and compare the performance of routing protocols, therefore, we do not include IEEE 802.11 MAC packets or ARP (Address Resolution Protocol) packets. Because the routing protocols could use a variety of different medium access or address resolution protocols, each of which would have a different overhead.

$$Routing Overhead = \frac{No. of Packets Transmitted}{No. of Data Packets Delivered}$$

3.3 Varying the Number of Sessions and Traffic Loads

From the simulations, we observe that traffic load has a significant impact on QS-AODV and AODV performance. When the traffic is light and application bandwidth requirements are low, sufficient bandwidth can be guaranteed for applications in the network to provide a high packet delivery ratio. When traffic load increases the required bandwidth for the applications grows AODV performance drops quickly, and QS-AODV outperforms AODV in this case.

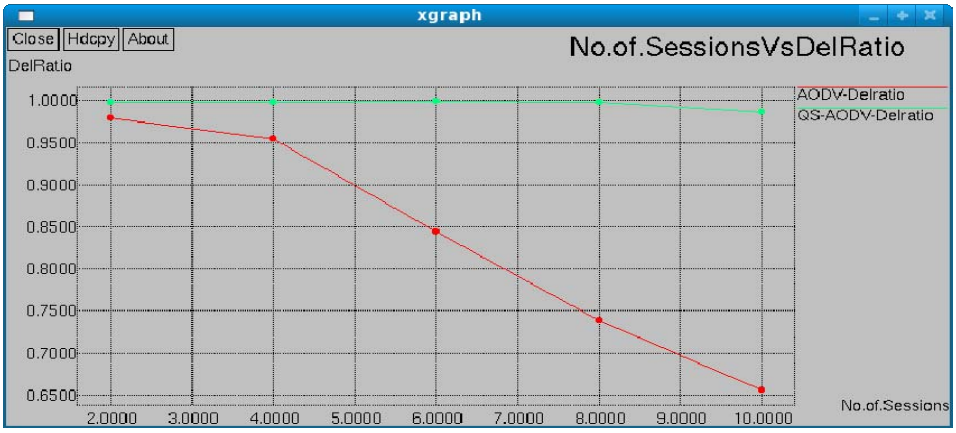

Fig. 4 Packet delivery ratio of AODV, QS-AODV with 20 packets/s.

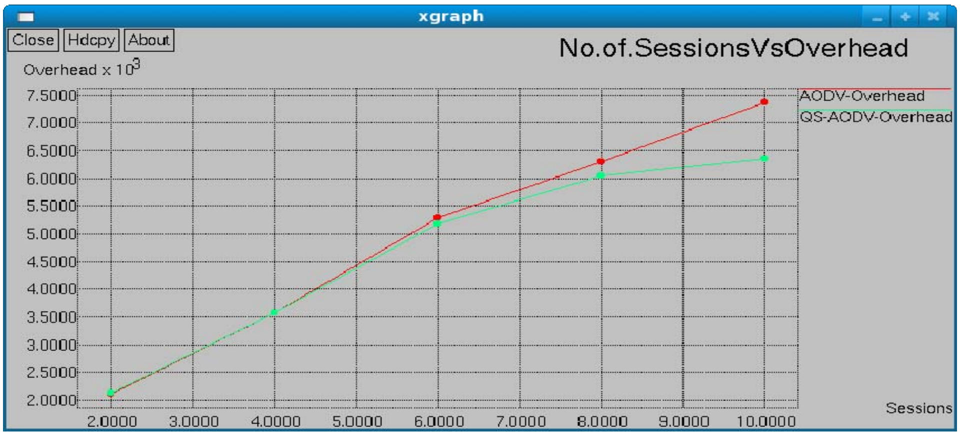

Fig. 5Routing overhead of AODV, QS-AODV with 20 packets/s.

In Figs. 4 and 5, we measure performance metrics with different CBR sources and pause time of 300 seconds at a packet rate of 20 packets/s and at two different speed 5m/se and 15m/se. when the number of sessions increases, the packet delivery ratios of both QS-AODV and AODV decrease. When the traffic is light (number of sessions less than 10), sufficient bandwidth can be guaranteed to provide a high packet delivery ratio, small normalized routing overhead. As the traffic increases normalized routing overhead for AODV also increases. The reason is that AODV has the advantage of using routing information in the intermediate nodes, if the intermediate nodes have "fresh enough" routes to the destination, RREPs can be generated. On the other hand, a RREP packet can only be generated by the destination node in QS-AODV, which results in longer time to find a route. From the graphs (Figs. 4 & 5) it is observed that lower the speed of node higher the packet delivery ratio, because increase in speed of mobile node will increases the probability of breaking the routes.

4. Conclusions

QS-AODV was simulated and compared with AODV using the NS-2.34 network simulator. The results obtained during the simulation were good. Under light traffic, QS-AODV provides a packet delivery ratio comparable to AODV, but needs more routing overhead and longer delay due to the fact that the RREP of QS-AODV has to be generated by the destination, and the routes created are not always the shortest. However, when the traffic is fairly high or the number of sessions increases in the network, QS-AODV has better performance than AODV as the AODV provides only the best effort route and also it does not consider the bandwidth constraint of each node. When the traffic is heavy, packets are dropped and the routes may be considered broken due to network congestion, which in turn increases the number of routing packets used to find and maintain routes. Therefore, QS-AODV protocol presented in this paper proves to be the best one as it requires less routing overhead to find and maintain routes.

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