# Evaluation of a QoS-Aware Protocol with Adaptive Feedback Scheme for Mobile Ad Hoc Networks

## (Short Paper)

Wilder Castellanos, Patricia Acelas, Pau Arce, and Juan C. Guerri

Multimedia Communication Group, ITEAM Institute, Technical University of Valencia, Camino de Vera, s/n, 46022, Valencia, Spain
wilcashe@posgrado.upv.es,{patacdel,paarvi}@iteam.upv.es, jcguerri@dcom.upv.es

**Abstract.** Due to bandwidth constraint and highly dynamic topology in ad hoc network systems, one of the major challenges is the deployment of end-to-end quality-of service support mechanisms. Time-sensitive communications like video applications may be seriously disrupted if these QoS support mechanisms don't exist. In this paper we propose a QoS routing protocol based on AODV (AQA-AODV), which creates routes according to application QoS requirements. We have introduced link and path available bandwidth estimation mechanisms and an adaptive scheme that can provide feedback to the source node about the current network state, to allow the application to appropriately adjust the transmission rate. The simulation results reveal the performance improvements in terms of packet loss and delay while the end-to-end throughput is not affected compared with the throughput achieved by other protocols like AODV.

**Keywords:** Wireless ad hoc networks, quality-of-service aware routing, AODV, Bandwidth estimation.

## 1 Introduction

A mobile ad hoc network is a group of autonomous wireless devices organized themselves dynamically in a mesh topology. The key feature of this type of networking is the nonexistence of any permanent infrastructure. Perspective video communication over such networks can be expected in various scenarios, both in civil and military activities. However, hard communication conditions because the wireless channel is shared among adjacent hosts and network topology can change as hosts move, do intensify challenges against transmission of video packets. Especially when video applications generate a huge data volume that is delay-sensitive, bursty and loss of some important data segments, such as synchronization data, may seriously disrupt a long sequence of frames [1]. Additionally, to maintain an acceptable playback quality, excessive communication delay is not tolerated.

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The main issue is how to efficiently transmit a large volume of time-sensitive data given that many packets are dropped due to the fact that network resources are limited and time-varying.

We propose a strategy based on a QoS-aware routing protocol that allows the source to adapt the transmission rate. Our protocol AQA-AODV (Adaptive QoS-Aware AODV) is a modified and enhanced version of the Ad hoc On-demand Distance Vector [2] (AODV). More precisely, we have introduced link and path available bandwidth estimation mechanisms and an adaptive feedback scheme into the original AODV protocol. Similar mechanisms are studied in [3][4]. In addition, a QoS extension is added to the AODV control packets and the routing table. The only QoS metric considered in our solution is bandwidth for a QoS flow, because finding a route subject to multiple metrics in many cases is considered to be an NP-complete problem [4]. The result is a QoS path finding mechanism that can provide feedback to the application about the current network state to allow the application to appropriately adjust the transmission rate.

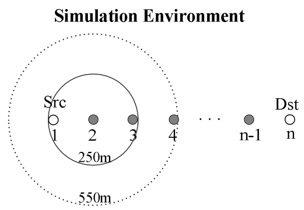
In order to test the performance of our protocol we have implemented the proposed protocol in the NS-2 simulator. Results indicate that the packet loss and packet delay decrease significantly, while the overall end-to-end throughput is not impacted, compared with routing protocols that do not provide QoS support.

This paper is organized as follows. Section 2 describes the impact of packet forwarding over delay, packet loss and channel capacity in wireless ad hoc networks for very simple linear topology with very regular traffic patterns. Section 3 describes our proposed Qos-aware routing protocol that incorporates QoS into Ad hoc On-demand Distance Vector (AODV). Section 4 presents the performance evaluation of our QoS-aware routing protocol and Section 5 offers some conclusions.

## 2 Capacity of Ad Hoc Wireless Networks

One of the limitations of wireless ad hoc networks is the achievable capacity due to the fact that nodes cannot simultaneously access the shared medium. More specifically, when a node is transmitting a packet, neighbor nodes within its Interference Range (IR), have to keep silent. This fact degrades the wireless data rate.

This section examines the feasible capacity of a well known single linear network topology of nodes where the source of traffic is the first node, destination is the last node and the packets are being forwarded through the intermediate nodes. The source node sends data as fast as its MAC allows it. In this scenario only adjacent nodes are in transmission range of each other. A more detailed study is presented in [6]. The results of our simulations are shown in the Fig 1. The simulation suggests that capacity along chain can be surprisingly low. We can see that, when the source node is sharing the channel with only 1 node, the throughput could reach up to 1.4 Mbps for 1000 bytes/packets, due to the overhead produced by RTS, CTS and ACK packets. When the hop count is increased, the maximum throughput of one flow is decreased substantially and falls down until 0.2 Mbps due to the overhead of MAC layer and the mutual interference between packets of the same flow, also called “Intraflow contention” [7].




| Simulation Scenario | |
|---|---|
| Num. of nodes | Variable (2-15) |
| Topology | Lineal-static |
| Simulation time | 300 seg. |
| TRAFFIC | |
| Type | CBR |
| Packet size | 1000 Bytes |

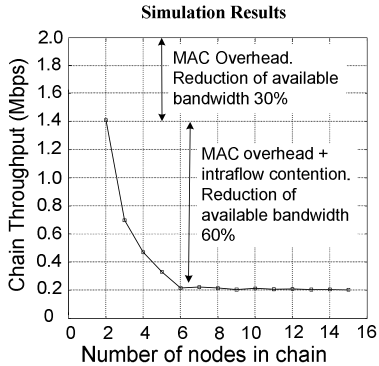
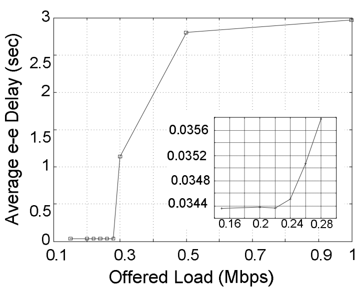
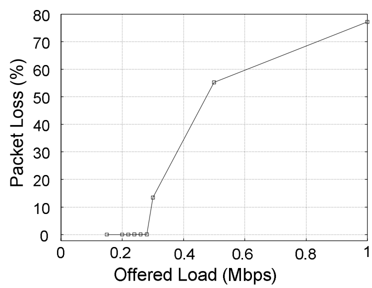



**Fig. 1.** Relationship between maximum throughput and number of nodes along a linear network topology




(a)




(b)

**Fig. 2.** Average end-to-end Delay (a) and Packet Loss (b) over linear topology of 7 nodes

For a linear topology of 7 nodes where the source of traffic is the first node and the destination is the node 7, the packet losses are increased significantly when the maximum throughput that can reach a chain of 7 nodes (about 0.20 Mbps) is slightly exceeded by the source. Fig. 2 shows the increase of the end-to-end delay and packet losses, as the source increases its transmission rate.

These results show that the relation between ad hoc routing and capacity suggests that any evaluation or implementation of a wireless ad hoc network requires an understanding of network capacity. In particular, 802.11 MAC interacts with forwarding impact over the end-to-end delay and packet loss, both important metrics for video transmission over wireless ad hoc networks.

## 3 QoS-Aware AODV Protocol with Adaptive Feedback Scheme

Our proposed routing protocol called AQA-AODV (Adaptive QoS-Aware Ad-hoc On-demand Distance Vector), is an AODV-based protocol. Our key modifications include new fields in RREQ and RREP packets to the bandwidth requirements and a “session ID”, used to identify each QoS flow that is established. The solution in reference [8] is an admission control based protocol. However, available bandwidth estimation and consumed bandwidth prediction algorithms are not defined. An important difference between our proposed protocol and other AODV-based solutions is the adaptive feedback scheme by which the source node can easily adapt its transmission rate according to the state of the route For this reason, nodes along the path must know their available resources (in terms of bandwidth) by using some algorithms.

### 3.1 Route Discovery in AQA-AODV

For route discovery, if a source node requires a route to a destination node with specific bandwidth requirements, it broadcasts a RREQ packet with the QoS extension to its neighbor nodes. The RREQ packet is rebroadcasted as in AODV until the RREQ packet reaches the destination node [2]. Only the destination will be able to send the route reply. This will ensure that all nodes in the selected route satisfy the bandwidth constraints. When the destination node receives a RREQ packet, before sending the RREP to the source, local available bandwidth is checked and estimation of the intraflow contention is necessary, by using the relation between the number of hops and the end-to-end throughput. This will allow the node to estimate the bandwidth along a path while taking into account the contention between packets of the same flow. Finally, the RREP will be transmitted to the source with a modified header that includes the minimum value between required bandwidth for the source and the maximum bandwidth that all hosts along the route could support. Once an intermediate node receives the RREP packet, it compares its available bandwidth with the bandwidth indicated in the RREP. If its local available bandwidth is lower, it updates the min-bandwidth field in RREP, using its available bandwidth. Otherwise, the node forwards the RREP. This procedure will ensure that the source knows the min-bandwidth along the path which will be the maximum rate that it may transmit. Fig. 3 illustrates the overall operation of the key phases of AQA-AODV.

### 3.2 Estimation of the Available Bandwidth in AQA-AODV

AQA-AODV uses a similar method to one presented in [9] to determine the available bandwidth at a node. To estimate the available bandwidth, BWav, nodes simply add up the size of packets sent, received and detected in a fixed period of time T. The channel bandwidth when transmitting a packet is calculated using the equation (1).

$$BW_{av} = \frac{S}{Tr - Ts} \tag{1}$$

In (1) S = RTS+CTS+HELLO+ACK+RTS+CTS+HELLOACK, i.e. the size of all packets (in terms of bits) sent from the source to destination during the period T, where T is equal to Tr –Ts. Ts is the time when the data packet is ready to be sent at the source, while Tr is the time when the ACK for the data is received at the source.

With the information of the available bandwidth at the nodes, it is still not simply to compare the available data rate at node and the required data rate for one traffic when deciding whether the node satisfy the requirement, it has to check if the given flow fits or not into the n-hop route. The method to provide an estimation of the consumed bandwidth along the route used in AQA-AODV was adapted from [10].

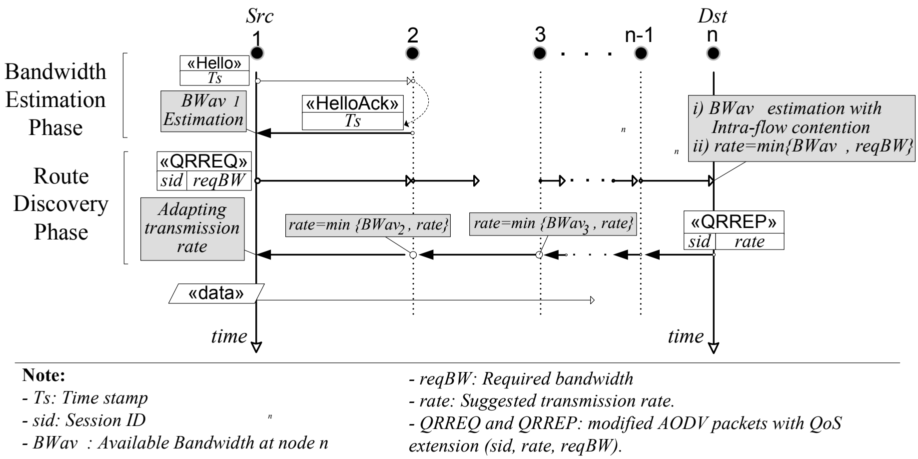



**Fig. 3.** Overview of AQA-AODV

## 4 Performance Evaluation

Network Simulator (NS-2) has been used to test the performance of our QoS-aware routing protocol. This simulator implements the IEEE802.11 protocol for the MAC layer, working in the Distributed Coordination Function (DCF) mode with a channel data rate of 2 Mbps. The transmission range and interference range are 250 m and 550 m respectively.

The performance of our QoS-aware routing protocol was evaluated by comparing it with conventional AODV, which has no QoS support, using two simulation scenarios. The first scenario consists of a chain of nodes where the performance was evaluated as a function of the chain length. The second scenario consists of 30 nodes move in a 1000m x 1000m area according to the random waypoint model with pause time set to 20sec. The nodes move toward a random destination using a speed randomly chosen between 0 – 3 m/s. A random source-destination pair send packets using a request rate between 0,1 and 1,0 Mbps. All traffic flows are Constant Bit Rate (CBR) streams over UDP with a packet size of 1000 bytes.

### 4.1 Simulations Results

We evaluated the performance of AQA-AODV by measuring three parameters: end-to-end data packet delay, packet loss and the maximum throughput achieved along the route. Each data point shown in the figures is the average of 10 simulations with different random seed. The results are presented as follows, according to the aforementioned scenarios.

In the first scenario (static linear topology with variable length), the performance of AQA-AODV is tested as function of the number of hops on the path. Node 1 is the source of data traffic and the last node in the chain is the traffic sink. Fig. 4a shows the ability of our Adaptive CBR source to adjust its rate according to network status and according to the number of competing nodes. Initially the source required a

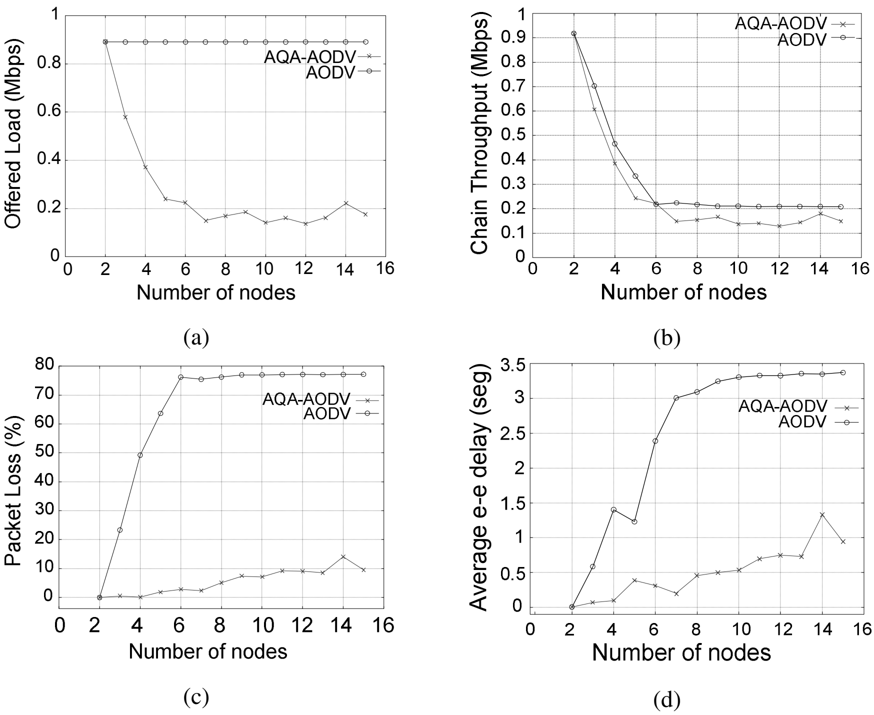



**Fig. 4.** Transmission rate (a), Throughput achieved along the path (b), Packet Loss (c), Average end-to-end delay (d) with variable chain length

transmission rate of 0,9 Mbps. In a 2-nodes chain it is possible without leading network congestion. However, when chain has 3 or more nodes, this transmission rate is not supported efficiently. Therefore our adaptive source adjusts its data rate. While using AODV, the source sends packets to a fixed rate of 0,9 Mbps.

As seen in Fig. 4b the total network throughput achieved with AQA-AODV is very close to throughout achieved using AODV. However, using AQA-AODV, the network congestion is significantly reduced. Therefore, the time used for waiting in the packet queue and contending for the channel decreases. In other words, our adaptive feedback scheme allows getting an important decrease in packet loss (Fig. 4c) and delay (Fig. 4d) without any bandwidth sacrifice.

Fig 5 shows the results of our simulations in the mobile topology. In terms of packet loss, AQA-AODV shows great improvement over AODV, which achieves very high packet losses for some requested rates. For example, the packet loss is between 19% and 83% using AODV, whereas using AQA-AODV the packet loss remains lower than 24%. Fig. 5b shows that the average end to end delay of AQA-AODV is always below 0,4s, whereas, the end to end delay of AODV increases badly when the transmission rate increases from 200 kbps to 1000 kbps. With AODV, the maximum average end to end delay reaches 1,9s at 700 kbps, about 16 times higher than using AQA-AODV. As seen in Fig. 5c the total network throughput achieved with AQA-AODV is very close to throughput achieved using AODV. We would

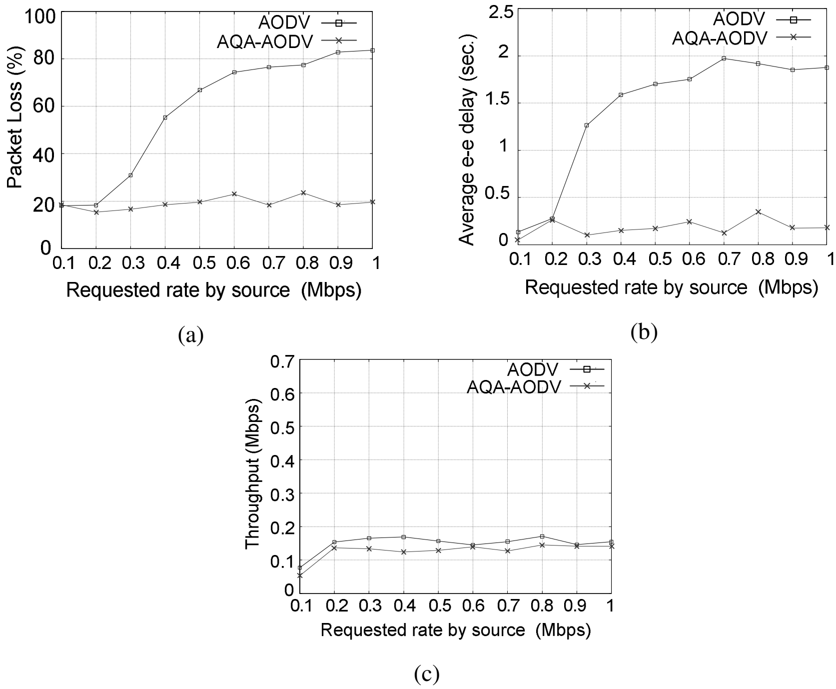



**Fig. 5.** Packet Loss (c), Average end-to-end delay (b) and Throughput (c) with variable requested rate

expect that the AQA-AODV protocol's performance will degrade in scenarios with high mobility because the nodes will need a specific time for exchange information about the network status.

## 5 Conclusions

A novel QoS-aware routing protocol (AQA-AODV) is proposed in this paper for carrying out time-sensitive communications over wireless ad hoc networks. AQA-AODV can avoid network congestion by a simple and precise cross layer approach with adaptive feedback scheme to provide information to the application about the network status. Our protocol incorporates bandwidth estimation through Hello packets and a prediction of consumed bandwidth that take into consideration the interference between packets of the same flow. Simulations show that this proposed scheme could reduce significantly both the dropping rate and the end-to-end delay without impact the overall end-to-end throughput.

In the future, we plan to examine how to implement a predictive way to foresee a route break, which would avoid performance degradation in mobile environment. Hence, methods such as pre-emptive maintenance routing [11] might be implemented to help the routing protocol to reduce the transient time when the required QoS in not guaranteed due to a route break. Also, our future work includes a mechanism to periodically check that the available bandwidth is still available. In this paper, in terms of metrics used in the QoS extension, only data bandwidth is considered in the simulations. End-to-end delay could be added during the route discovery and maintenance in the routing protocol.

Our ultimate goal is to provide a cross-layer framework where the video source exploits the feedback information from the underlying protocol (AQA-AODV) to tune a parameter on the source coding to adapt the traffic rate to the path.

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