Problematic of QoS-based On-demand Routing Protocols to Improve Communication in Mobility Context

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Abstract—**In mobile ad hoc networks, achieving good QoS is a critical issue and is very difficult to guarantee due to rapidly changing of network topology and the lossy nature of wireless links. In this context, routing protocols must be smart enough to select better paths for data transmissions. In this paper, we focus on the well-known Ad-hoc On-demand Distance Vector (AODV) protocol. Standard route discovery approach used in AODV is expected to obtain the best path in term of delay. However, in lossy-links context, multimedia data packet transmission success, on path established thanks to control packets, may require several attempts. These retransmissions increase delay and overhead. Many QoS-based methods failed to make a meaningful improvement due to added complexity and additional delay and overhead. In this paper, we use a metric based on number of Packet Retransmissions to show that improving performance of on-demand routing protocols, in the mobility context, lies on effective control of node neighborhood.**

Keywords-mobility; reliability; wireless networks; quality of service; on-demand routing.

I. INTRODUCTION

Mobile Ad hoc NETworks (MANET) are characterized by instability of their topology. This is mainly due to node mobility and the lossy nature of wireless links. Selecting reliable paths for data transmission in this context is a challenge. In order to guarantee Quality of Service (QoS), routing protocols should be smart enough to choose a reliable route in order to avoid packet loss. To deal with the problem, Qos-based routing protocols are proposed. Route selection process should take into account link quality. However, most methods proposed for link quality estimation and best path selection are not appropriate for this rapid topology change. They require a long period to find QoS path and the obtained path is, very often, longer than the shortest path (in terms of number of hops). Long paths are more vulnerable to breakage than shortest paths.

The main contributions of this paper include:

- Use of a convenient and pratical way to evaluate quality of links in mobile context,
- Design of QoS-based Ad-hoc On-demand Distance Vector (AODV) protocol [1]. The QoS metric used (called PR-metric) is based on the number of retransmissions. It takes into account accurately the proportion of retransmission time with respect to time of first issue. We use this metric to compare effectiveness of different QoS-based methods used to improve on-demand routing protocols performance,
- A detailed analysis of differend QoS-based AODV protocol performance. For our tests, we used realistic wave propagation model and realistic mobility model.

The remainder of the paper is organized as follows: In Section II, we present and analyze related work. In Section III, we present our QoS-based routing protocols. Performance evaluation and discussions are made in Section IV. We conclude in Section V.

II. RELATED WORK

In recent years, much effort has been made to improve the standard AODV protocol [1]. In this section, after presenting the critical behaviors of the protocol, we review various proposed improvements.

A. AODV protocol

On-demand routing approaches are source-initiated reactive mechanisms. When a node desires to sent a packet to an other node and does not have a valid route, it intiates a path discovery process in order to locate the destination node [1]. Then, a route request (RREQ) packet is issued and flooded in the network. Once the first RREQ packet reaches the destination node or an intermediate node with a fresh route toward the destination, a route reply (RREP) packet is sent back to the source node. The source node rebroadcasts the RREQ if it does not receive a RREP during a Route Reply Wait Time (RREP_WAIT_TIME). It tries discovery of path up to a given maximum number of attempts and aborts the session if it fails. As the RREP packet is routed back along the reverse path, the intermediate nodes along the path record a tuple for the destination in their routing tables which point to the node from which the RREP is received. This tuple indicates the active forward route.

AODV uses a timer-based technique to remove stale routes promptly. Each routing entry is associated with a route expiration timeout. This timer is refreshed whenever a route is used. Periodically, newly expired routes are invalidated.

Route maintenance is done using route error (RERR) packets. When a link breakage is detected, routes to destinations that become unreachable are invalidated. RERR propagation mechanism ensures that all sources using the failed link receive the RERR packet. RERR packet is also generated when a node is unable to forward a data packet for route unavailability.

The *first RREQ* consideration approach means the selected path is the one with the better Round Trip Time (RTT) and the sorthest path in term of hops count if all links are considered as similar. Contrary to proactive routing approaches, in on-demand routing methods, nodes maintain information only for active routes. But, route request and route error broadcasted may be important if established routes are much bits error-prone. This can be demonstrated by simulation with the use of a realistic physical layer and a realistic wave propagation model.

B. Enhanced AODV

One of the well-known problem of AODV protocol is the long end-to-end delay due to overtime induced by route discovery process. Also, when the frequency of link failures is high, routing load and jitter become important. Since the publication of standardized version of AODV, many efforts have been made to improve it. The major challenge is to limit the frequency of route discovery process. Thus, several optimizations have been proposed in the literature. Among them, we note taking into account link quality in the route selection process and adapting timers to the network dynamics.

1) Tacking into account link quality: To take into account link quality in the route selection process, several methods are proposed with different QoS metrics including bandwidth, delay, packet delivery ratio, Bit Error Rate (BER).

Khaled et al. [2] propose a path robusteness-based quality of service routing for MANET. They proposed that before processing RREQ packet, an intermediate node must assure that its lifetime and the delay toward the neighbor from which it receives the RREQ packet are above given delay-threshold and lifetime-threshold. At each hop, at least five checks are made and RREQ packet size increased with a node address. Destination node and source node must wait for copies (that have followed different paths) of RREQ and RREP packets until a timeout. The overhead (additionnal delay and routing load) and the complexity of this approach hypothecate protocol effectiveness.

Some works, such as [3], use optimal link metric value in the path choice. Path selection choice based on optimal link metric value may not allow to get the best path. For example, for number of hops or retransmissions count-based metric, a path with minimum link metric value m (the minimal metric value amoung other feasible paths), is prefered than anyone with just one link with metric value upper than m even if the other links are better.

Some authors use additive and multiplicative metric to enhance AODV route discovery process. To find the optimal path in wireless mesh networks, Kim et al. [4] modify the standard AODV RREQ process. They propose that duplicate RREQs with better cumulative link metric value be forwarded, so that all the possible routes are considered. As link quality metric, they use an improved Expected Transmission Time (ETT) [5]. Their RREQ packet carries the cumulative link ETT value. They estimate the archievable throughput of their approach more than twice compared to standard AODV. We presume it is not necessary to re-broadcast duplicate RREQ packets. The intermediate node may note all possible reverse paths and retain as active reverse path to the source the better one according to the considered QoS metric. Their approach needs to be tested in MANET context with realistic simulation assumptions.

2) Taking into account network dynamics: Mobility of nodes is one of the essential issue of MANET. Taking into account the mobility of nodes is countered, first, by difficulties to adequately measure the mobility degree of a node. Many papers [6][7] propose to privilege nodes with low speed but network topology change is not local problem. A node may be fixed but if its neighborhood moves a lot, integrating this node into transmission path will not allow efficient communication.

Some authors propose to use link breakage prediction for packet loss avoidance. In fact, when intermediate node detects degradation of neighbor link quality on active route, it may anticipate route maintenance process. Then, source node is advertized to the probable path failure and anticipates route recovery process. This avoids transmission interruption. QoS metrics used in this method include received signal strength [8], packet delivery ratio of control packets [9]. Very often, the power of modeled signal depends only on the distance to the concerned neighbor node. It is known that obstacles in wave progation environment has an impact on signal strength [10][11]. Even if these metrics are accurately measured, the approach only anticipate the break of the link. The source must initiate a new route recovery process. The impact on delay improvement is not significant.

Amruta et al. [8] and Naif et al. [12] focused on accessibility prediction to restric route discovery for future communications. Indeed, during the usual routing operations, a node can collect significant information enabling it to predict the accessibility and the relative mobility of the other nodes in the network. However, due to rapid change of network topology and since they are not actively maintained, these routes become obsolete.

III. QOS-BASED ON-DEMAND ROUTING PROTOCOLS

In this section, we present the PR-metric and three variants of AODV based on this metric. However, comprehensive presentation of this metric is beyond the scope of this paper.

A. QoS metric

To quantify link quality, we focus on metrics based on link reliability. Very often, criteria like as BER, Packet Delivery Ratio (PDR, e.g., Expected Number of Transmissions, ETX) are used. For this study, we use a new metric based on the expected number of retransmissions required to communicate successful data packet on this link. Let us call it PR-metric. With PR-metric, distance between a node and its neighbor will not be 1 but $1 + a * (n - 1)$, where n represents the average number of transmissions required to make a data transmission successful and a is a parameter to weigh retransmission cost.

For retransmission, we want to design a transmission made after the first issue (after the first transmission attempt). The coefficient a is the ratio between the average time required for a retransmission over the time necessary for an initial successful transmission. Statistical analysis and results permit us to estimate a to 0.65 with 0.03 as standard deviation.

The number of retransmissions can be obtained from network interface statistics (MAC level). This metric has a direct impact on delay and throughput. Contrary to the well-known metrics like BER or Expected Transmission Count (ETX) [13], it takes into account real time network load. Its estimation is local. It does not induce a significant routing load or a large computation time. It is a good compromise between the number of hops criterion and the BER or ETX criterion which induces selection of long route [14].

B. AODV-BL-PR

AODV-BL-PR picks out AODV where we apply blacklisting approach to route recovery process. With AODV-BL-PR, when an intermediate node receives a RREQ packet, it compares the PR-metric value of link on which this packet is received to a predetermined threshold. If this PR-metric value is higher than this treshold, the packet is discarded, otherwise it is managed as in standard AODV. We set this threshold to 2. We estimate that, in mobility context, after 2 attempts to transmit data, the path used is no longer valid. Note that maximum number of retransmissions at MAC layer is 4 for our test. We note that a control message (usually lighter) can be successfully transmitted on a poor quality link when a normal payload message can not be transmitted. With this route selection approach, paths containing bad links are disregarded. This will also limit the dissemination of RREQ messages and then reduces routing overhead.

C. AODV-sum-PR

To design AODV-sum-PR, two main modifications are made to standard AODV, namely QoS-information dissemination and duplicate RREQ packets process by intermediate node.

- QoS-information dissemination: for AODV-sum-PR, RREQ and RREP packets are extended with the cumulative PR-metric (C-PR-metric) field. Source node initializes this metric to 0.0. An intermediate node increases the value of C-PR-metric by the PR-metric of the link on which it received the packet. The intermediate node also integrates reverse path into its routing tables. Each entry is improved with the C-PR-metric as QoS-metric. The RREP packet also carries the C-PR-metric. The field is, this time, initialized to 0.0 by the destination node or to the current value of entry related to this destination by intermediate node which initiates the RREP packet.
- Duplicate RREQ packet process: contrary to standard AODV, an intermediate node manages duplicate RREQ packet. Indeed, if the C-PR-metric of a duplicated RREQ packet is lower than the recorded one, the entry for source node (reverse path) is updated: the previous hop to the source node will be the new transmitter. Finally, the source node obtains a path to the destination with the lowest C-PR-metric value.

Note that intermediate node does not need to re-broadcast the duplicate RREQ packet and does not need to integrate the PR-metric value of all its neighbors as control packets header information, as widely done.

In Table I, we summarized the duplicate packet processing.

TABLE I. SAMPLE OF DUPLICATED PACKET PROCESSING ALGORITHM

```
for the concerned reverse path
if new C–PR–metric < current C–PR–metric
        update next–hop
        update C–PR–metric
else
        drop the packet
```

D. AODV-Timer

In AODV-Timer, we reduce the timers associated to the various recorded routes, established links with neighbors and waiting for a response (hello timer, route validity timer, waiting RREP packet timer, etc.). These timers are used to manage routes and links validation or recovery processes. The new parameters are presented in Table II. This coordinated reduction globally means that a node more frequently inventories its links and routes.

With this approach, we want to know the determining factor between taking into account link quality or a convenient control of neighborhood information for better performance in mobility context.

TABLE II. DEFAULT (AT LEFT) AND MODIFIED (AT RIGHT) AODV PARAMETERS FOR OUR TESTS

Timer Parameter	AODV-st	AODV-Timer
MY_ROUTE_TIMEOUT	10s	5s
ACTIVE_ROUTE_TIMEOUT	10s	5s
REV_ROUTE_LIFE	6s	3s
BCAST_ID_SAVE	6s	3s
MAX_RREQ_TIMEOUT	10s	5s
NETWORK_DIAMETER	30 hops	10hops
RREP_WAIT_TIME	1.0s	0.7s
HELLO_INTERVAL	1s	0.5s
BAD_LINK_LIFETIME	3s	1.5s

In summary, the reduction of route timeout value to 5s means that a path that is not used 5s ago is considered obsolete. The default value in standard AODV is 10s. The source waits less time (0.7 instead of 1.0) to restart a new request if it receives no response to a previous query. The network diameter is reduced to 10 instead of 30. We estimate that over 10 hops it is impossible to communicate in node mobility context. A HELLO_INTERVAL timer set to 0.5s instead of 1.0s, means that nodes should test their neighborhood more frequently.

IV. PERFORMANCE EVALUATION

In this section, we first present our simulation environment, we then present the results of simulation tests and analyze the performance of different protocols.

A. Experimental setup

To compute more real simulations, we use a realistic wave propagation model taking into account environment characteristics. Therefore, we enhanced NS2 [15] with a ray-tracer simulator, Communication Ray Tracer (CRT) [16], that has been developed at the XLIM-SIC laboratory. CRT simulator provides a 3D ray-tracer wave propagation model. It takes into account the geographical data, electrical properties of materials, the polarization of the antennas, the position of the transmitters and receivers, the carrier frequency and the maximum number of interactions with the surrounding obstacles.

To realistically model the movement of the node, we use the VANET-Mobisim [17] software. Node speed is computed by this software. The mobility model implemented is more realistic than widely used ones [18][19][20]. Paths are defined in correlation and consistency with our environment model. VANET-Mobisim is also easily interfaced with NS2. Specifically, VANET-Mobisim uses a mobility file in XML format, which contains all the detailed informations of the microscopic and macroscopic models that govern mobility of nodes. The mobility model used in this software takes into account the environmental parameters of the mobile nodes (traffic lights, speed limits, etc.) and possible interactions between mobile nodes. A node may thereby accelerate, decelerate according to environment constraints.

The global parameters for the simulations are given in Table III.

TABLE III. SIMULATION PARAMETERS.

Parameters	Values
Network simulator	ns-2
Simulation time	180s
Simulation area	1000m*1000m
Maximum number of transmissions	4
Transmission power	0.1w
Data types	CBR
Data packet size	512 bytes
MAC layer	IEEE 802.11a

We also use a realistic model of the Munich town (urban outdoor environment, see Figure 1), obstacles (building, etc.) are printed red. Dots represent nodes. Other real environments could be used in a more comprehensive study.

As routing protocols, we compare AODV-st, the standard AODV protocol [1], to the three PR-metric based ones presented in Section III.

B. Simulation results

In this section, we study the impact of mobility on performance of the four protocols. 60 mobile nodes move in the Munich town environment (Figure 1). Their average speeds range from 4m/s to 20m/s. 10 simultaneous end-to-end transmissions are initiated during 165s. As performance parameters we rely primarily on average end-to-end delay of data packets, PDR and Routing Overhead (RO). End-to-End Delay concerns only successfully delivered packets. PDR is the ratio of the number of successfully delivered data packets over the number of sent data packets. Routing overhead is the number of routing protocol control packets. It permits to evaluate the effective use of the wireless medium by data traffic.

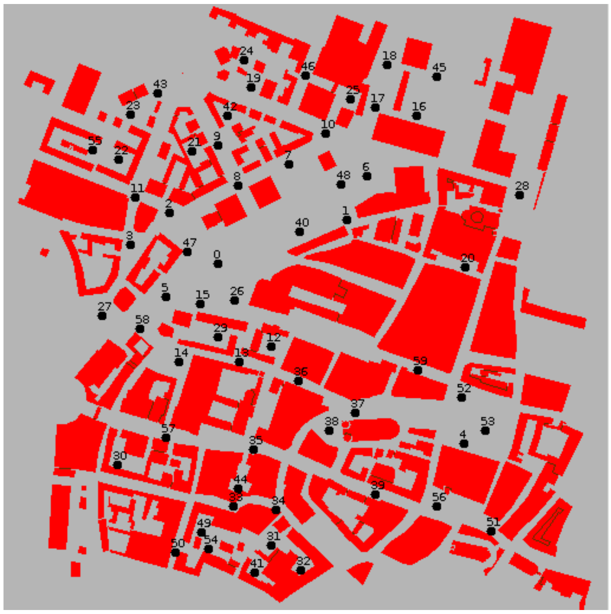

Figure 1. Simulation environment when number of nodes=60. Obstacles are printed red.

Figure 2 and Figure 3 show that AODV-new-timer is better in delay and PDR. It reduces unnecessary waiting time and the knowledge of neighborhood, in real time, avoids node to process obsolete paths. The node implementing AODV-new-Timer detects links breakage quickly. For QoS-based AODV (AODV-BL-PR and AODV-sum-PR), determining QoS routes requires substantial time and with node mobility, established routes become obsolete quickly. These show that better neighborhood information control is more important than taking into account link quality for AODV efficiency.

A thorough analysis of the simulation shows that the majority of communications where source and destination are far apart from each other have failed. Established routes become obsolete even before the first data packets arrive at the destination.

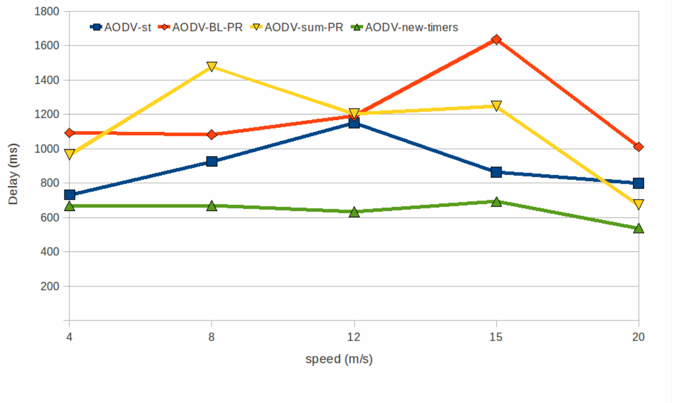

Figure 2. Delay evolution when speed increases.

Protocol's performance in RO parameter is presented in

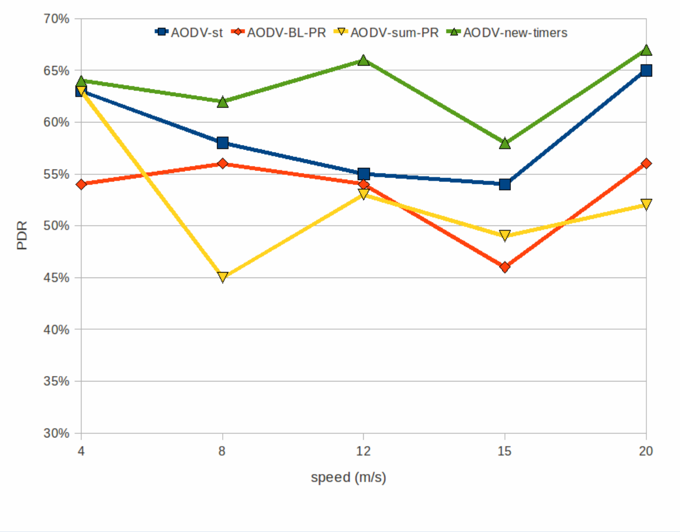

Figure 3. PDR evolution when speed increases.

Figure 4. The high cost of AODV-new-Timer is expected since Hello and RREQ messages emiting frequency increased. The better performance of QoS-based AODV compared to standard one can be explained by better paths selection. In addition, blacklisting approach of AODV-BL-PR limits the dissemination of RREQ messages.

Figure 4. RO evolution when speed increases.

V. CONCLUSION AND FUTURE WORK

We tested the effectiveness of different QoS-based methods under realistic wave propagation model and realistic mobility model. For QoS metric, we use number of retransmissions count-based metric. Although we used a simple and effective method for link quality estimation, the results show that taking into account the quality of links is not effective for the MANET performances improvement. The additional complexity, induced by QoS management, increases delay and precipitated the obsolescence of the links.

To achieve better performance in high speed MANET context, the real challenge is the effective control of node neighborhood and accurate established routes lifetime and waiting RREP packet timeout.

A solution where the inventory frequency of the neighborhood depends on the network dynamics might improve the performance of on-demand routing approach in mobility contexts.

A more comprehensive study of the problematic of on-demand routing protocol performance could concern other real environments (than Munich town one) and a refinement of the penalty coefficient due to retransmissions.

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