# An Effective QoS-Based Reliable Route Selecting Scheme for Mobile Ad-Hoc Networks

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**Abstract.** In mobile ad-hoc networks, the random mobility of nodes will result in unreliable connection. In addition, the bandwidth resource limit will affect the quality of service (QoS) critically. In this paper, an effective QoS-based reliable route selecting scheme (QRRSS) is proposed to alleviate the above problems. The route reliability can be estimated by received signal strength and the control packet overhead can be decreased by selecting more reliable link that satisfies the QoS requirements. Simulation results indicate that the reliable route selecting scheme presented in this paper shows obvious superiority to the traditional ad-hoc QoS on-demand routing (AQOR) in the packet successful delivery rate, the control packet overhead and the average end-to-end delay.

**Keywords:** Mobile ad-hoc networks · Quality of service (QoS) · QRRSS
Reliability · AQOR

## 1 Introduction

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With the development of mobile ad-hoc networks and continuous improvement of user demands, the limited bandwidth resource becomes difficult to guarantee high QoS for users [1]. Although such issues can get some improvement by a serial of QoS routing algorithms [2, 3] recently, no effective discussion of link reliability is available. Due to the link breakage caused by random mobility of nodes, source nodes need continue to trigger the route discovery process, which will lead to sharp increase in the

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control overhead, the probability of packet discard, and average end-to-end delay. Therefore, it will have a serious impact on the QoS. We can see that under the precondition of urgent QoS requirement, to establish a reliable end-to-end route for nodes is very important and necessary [4].

Many pertinent researches of route in mobile ad-hoc networks have been proposed. Nodes in Associative-Based Routing Protocol (ABR) measure the route reliability by sending pilot signal periodically, and meanwhile, ABR supposes that it must exist a stable period after an unstable period. During the stable time all nodes restart to move after experiencing an immobile time [5]. Obviously, this supposition is opposite to the real situation because of the random mobility of nodes in mobile ad-hoc networks. Link Life Based Routing Protocol (LBR) attains link lifetime by estimating the distance and maximum speed of the nodes. When link fails, proactive maintenance is started up to recover the route. However, estimating route lifetime is invalidation owing to the link failure. Consequently, the reliability of backup route may be hard to guarantee [6]. Entropy-Based Long-Life Distributed QoS Routing Protocol (EBLLD) algorithm proposes an idea of using entropy metric to weigh the route reliability and select the longer lifetime path, where the entropy for a route is a function about the relative positions, velocities, and the transmission ranges of the nodes [7]. Although these algorithms can be applied to the mobile ad-hoc networks better than the statistical models, they need the premise of assumption that the relative positions all nodes are known accurately, which is not realistic in most of the mobile ad-hoc networks.

With the gradual maturation of the signal strength measurement technology, the application of signal strength has come to the top in domains of the control of wireless networks [8], measuring distance and orientation [9]. Considering that the signal strength can reflect the connection state of the link indirectly, this paper proposes a method of estimating route reliability based on received signal strength and establishes an effective QoS-based reliable route selecting scheme QRRSS. QRRSS selects more reliable link that satisfies QoS requirement by adding relative information to (Route Request, RREQ)/(Route Reply, RREP), So that it can decrease control packet overhead by reducing frequent route discovery.

## 2 Effective Qos-Based Reliable Route Estimation Algorithm

A mobile ad-hoc network can be depicted as an undirected graph $G = (V,E)$. Where, $V$ is the set of nodes and $E$ is the set of bidirectional links between the nodes. Any link $l(i,j) \in E$ can be given by residual Bandwidth $B(l)$, Delay $D(l)$ and Link Reliability $LR(l)$. The path from one node $s$ to another node $d$ can be described as $P(s,d) = (s, l(s,x), x, l(x,y), y, \ldots, l(z,d), d)$, where $x, y, \ldots, z$ are some points in the path. The connection between any two nodes is made up of a serial of all possible paths, which is $P(s,d) = \{P_0, P_1, P_i, \ldots, P_n\}$. Accordingly, we can define a certain path $P_i$ between $s$ and $d$, whose delay, bandwidth and reliability satisfy the requirements as (1),

$$\begin{cases} Delay(P_i) = \sum_{l \in P_i} D(l) \\ Band(P_i) = \min\{B(l_0), B(l_1), B(l_i), \ldots, B(l_n)\} \\ Reliability(P_i) = \prod_{l \in Pi} LR(l) \end{cases} \tag{1}$$

Where, $l_0, l_1, l_i, \ldots, l_n$ are the links that make up the path [10]. Thus, the question can be described as searching the most reliable path $P_m$ which satisfies QoS requirement for nodes. Furthermore, we can depict the question as (2),

$$\begin{cases} Reliability(P_m) = & \max\{Reliability(P_0), Reliability(P_1), \\ & Reliability(P_m), \ldots, Reliability(P_n)\} \\ \forall Band(P_m) \geq \Delta b & \\ \forall Delay(P_m) \leq \Delta b & \end{cases} \tag{2}$$

Now, for the sake of expression convenience, we introduce the parameters as Table 1.

With the above parameter assumptions, the steps of QRRSS proposed in this paper based on (Decision Rules, DR) can be provided as follows:

DR1: If $SS_{1i,j} \geq Thr_1$, then it means that nodes $i$ and $j$ are close enough, and the link is very reliable. In that case, we set $LR_{i,j} = 1$ and $LU_{i,j} = 0$;

DR2: If $SS_{1i,j} \geq Thr_2$ and node $j$ is a new neighbor node of $i$, then we set $LU_{i,j} = 1$;

DR3: If $SS_{1i,j} \geq Thr_2$ and $SS_{2i,j} \geq RxThr$, it indicates that the situation of nodes $i$ and $j$ is not sure. If $DSS_{i,j} = SS_{2i,j} - SS_{1i,j}$, we set $LU_{i,j} = 0$; if $DSS_{i,j} \leq m_1$, we set $LR_{i,j} = 1$; if $DSS_{i,j} > m_1$ and $DSS_{i,j} \leq m_2$, we set $LR_{i,j} = (m_2 - DSS_{i,j})/(m_2 - m_1)$; if $DSS_{i,j} > m_2$, we set $LR_{i,j} = 0$.

**Table 1.** The parameters and meanings in this paper

| Parameters | Meanings |
|---|---|
| $RxThr$ | Reception threshold of received signal strength, we assume it is same for all nodes |
| $SS_{1i,j}$ | Current received signal strength for the link between nodes $i$ and $j$ |
| $SS_{2i,j}$ | The received signal strength stored in neighbor information table for the link between nodes $i$ and $j$, periodically updated by $SS_{1i,j}$ |
| $Thr_1$ | If a node receives signal with strength ≥ $Thr_1$, then the link can be assumed to be very reliable |
| $Thr_2$ | If a node receives signal with strength < $Thr_2$, then the link can be assumed to be unreliable to transfer the data |
| $DSS_{i,j}$ | The difference of signal strength between nodes $i$ and $j$ to indicate the changes of the signal strength |
| $m_1$, $m_2$ | $m_1$ is a threshold for $DSS$ to indicate small environment variations in signal strength, and that $m_2$ ($>m_1$) is used to detect whether two nodes are leaving away from each other fast |
| $LR_{i,j}$ | Link reliability between nodes $i$ and $j$, and $LR_{i,j} \in [0, 1]$ |
| $LU_{i,j}$ | Link uncertainty between nodes $i$ and $j$, means that the link's reliability cannot be determined due to lack of $SS_{2i,j}$ in neighbor information table |

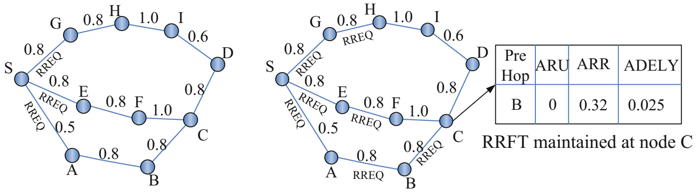
As a consequence, nodes can obtain the relative parameters from received packets, and estimate route reliability with DR. The packet, whose signal strength is less than or equal to $Thr_2$, is discarded. We define the route reliability and uncertainty as (3),

$$\begin{cases} RR_r = \prod\limits_{l \in r} LR_l \\ RU_r = \sum\limits_{l \in r} LU_r \end{cases} \tag{3}$$

If $RR_r$ is increasingly big and $RU_r$ is increasingly small, then the route is increasingly reliable.

## 3 Route Establishment of QRRSS

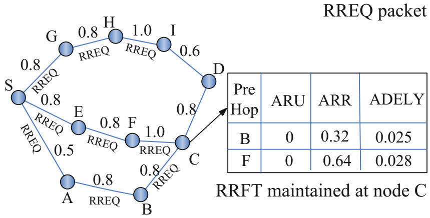
On the base of satisfying the QoS requirements, QRRSS proposed in this paper estimates route reliability by received signal strength. Every node estimates the route reliability depending on DR, and selects more reliable route to establish end-to-end connection by setting the route reply latency mechanism at the destination node. For the convenience of analysis, we suppose that all RREQ/RREP packets satisfy the QoS requirements. The process of route establishment is shown as Fig. 1. In this figure we



| Pre Hop | ARU | ARR | ADELY |
|---|---|---|---|
| B | 0 | 0.32 | 0.025 |

RRFT maintained at node C

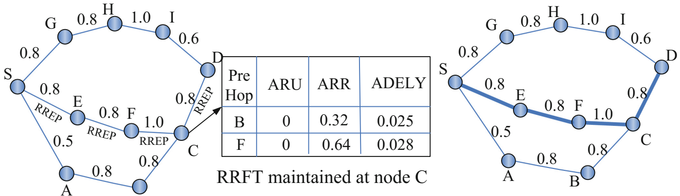
(a) Node S broadcasts RREQ packet (b)Mediate node C processes and forwards RREQ packet



| Pre Hop | ARU | ARR | ADELY |
|---|---|---|---|
| B | 0 | 0.32 | 0.025 |
| F | 0 | 0.64 | 0.028 |

RRFT maintained at node C

(c)Mediate node C receives tow RREQ packets



| Pre Hop | ARU | ARR | ADELY |
|---|---|---|---|
| B | 0 | 0.32 | 0.025 |
| F | 0 | 0.64 | 0.028 |

RRFT maintained at node C

(d)Dstination node D sends RREP packet (e)The route has established (with boldfaced line to represent)

**Fig. 1.** The principle figure of route establishment

can see that the numbers above the links represents the current reliability of the links. The detailed route discovery process is shown as following:

(1) Firstly, the source node *S* broadcasts the RREQ packet (including the information of bandwidth and delay requirements), which is shown in Fig. 1(a), and sets the initiate value of parameters as: Accumulated Delay of route, ADELY = 0; Accumulated Route Reliability, ARR = 1; Accumulated Route Uncertainty, ARU = 0. After sending the RREQ packet, *S* starts a timer of 3 × *Dmax* to wait the RREP packet.

(2) As shown in Fig. 1(b), mediate node *C* estimates the route reliability and updates the RREQ packet after receiving the RREQ packet. Before forwarding this received RREQ packet, node *C* sets the reverse route timer to 3 × *Dmax* and stores relative information of RREQ into the Route Request Forward Table (RRFT). RRFT of mediate node *C* has: ADELAY = 0.025, ARR = 0.32, ARU = 0. For the sake of selecting more reliable route, the RREQ packets are also disposed during a certain time, as shown in Fig. 1(c). Mediate node *C* receives another RREQ packet from node *F* and registers the information as below: ADELAY = 0.028, ARR = 0.64, ARU = 0. Obviously, we can see that this route reliability is higher.

In summary, if a mediate node receives an RREP packet, it firstly finds out the RRFT of relevant RREQ packet and selects a most reliable route. Secondly, it estimates the route reliability and updates ARR and ARU of RREP packet, since ARR and ARU can represent the current route reliability. Finally, before forwarding the RREP packet, it sets the RRFT timer to 3 × *Dmax* and stores relative information into the route table

(3) The destination node *D* may receive many RREQ packets from different paths, like the mediate node *C*. And it also estimates the route reliability with the same DR. On receiving the first RREQ packet, node *D* waits a period time, called Route Reply Latency (RRL), to receive other RREQ packets and find a more reliable route to satisfy the QoS requirements. Next, node *D* copies the value of QoS, ARR, and ARU to the RREP packet. Simultaneously, node *D* sets the RRFT timer to 3 × *Dmax* and stores relative information into the route table, which is shown in Fig. 1(d). Eventually, node *D* will select the route including node *F* to send the RREP packet via route selecting algorithm. As a consequence, the route from source node *S* to destination node *D* that can guarantee the QoS requirements has been established, as shown in Fig. 1(e).

## 4 Performance Evaluation

In this section, we compare our reliable route selecting scheme to a traditional real-time-flow based QoS routing protocol, AQOR, which is constrained by bandwidth and delay. Then, we give out the performance evaluation from packet successful delivery rate, control packet overhead and average end-to-end delay. Packet successful delivery rate is the ratio of the data packets successfully received at the destinations and the total data packets that are actually sent to the network. Control packet overhead is the ratio of the control packets sent to the network and the total data packets successfully delivered at the destinations. Average end-to-end delay is the average time of delivered time that all data packets have successfully arrived destinations. NS2 based simulation gives the performance evaluation to QRRSS. The simulation results are shown in Figs. 2, 3, 4 and the detailed simulation parameters are shown in Table 2.

**Table 2.** The parameters and values in the simulation

| Parameters | Values |
|---|---|
| Network topology | 1000 m × 1000 m |
| Number of nodes | 40 |
| Maximum mobility speed of nodes (m/s) | 0, 2, 5, 10, 15, 20 |
| Pause time (s) | 0 |
| Simulation time (s) | 300 |
| Minimum bandwidth (kbps) | 40 |
| $Thr_1$, $Thr_2$ | $1.4 \times RxThr$, $1.1 \times RxThr$ |
| $m_1$, $m_2$ | $0.04 \times RxThr$, $0.3 \times RxThr$ |
| RRL (msec) | $0.3 \times RxThr$ |
| RRL (msec) | 70 |

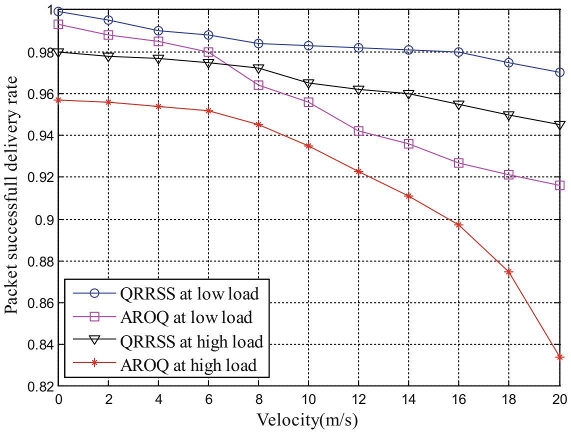


**Fig. 2.** Packet successful delivery rate

The route failure is one of the most important factors affecting the packet successful delivery rate. When the route fails, upriver nodes will store the data packets in buffers and wait until the route is established again. During this time, the buffers of nodes are filled in quickly, which will result in the subsequently discarding of the received data packets. Figure 2 shows the packet successful delivery rate performance of AQOR and our QRRSS at low/high load respectively. We can see that QRRSS can increase the packet successful delivery rate about 10% when the nodes move quickly, and also significantly improve the delivery performance of the whole network. The reason is that by establishing reliable end-to-end route connection, QRRSS can effectively avoid the data packets discarded extensively due to the route failure, no matter in low or high load environment.

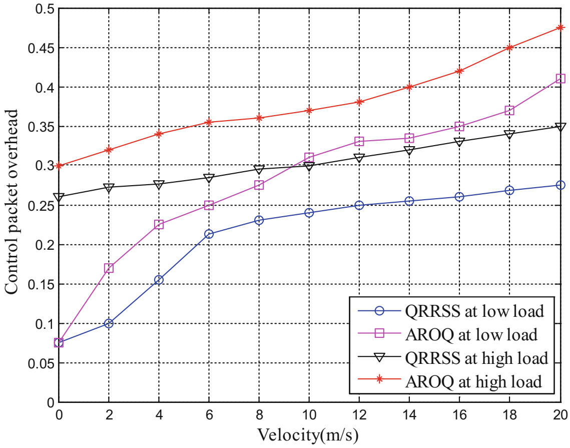


**Fig. 3.** Control packet overhead

From Fig. 3, it can be seen that the packet control overhead in QRRSS has reduces and especially in high load and nodes moving fast it reduces nearly 12%. The reason seems to be obvious, destination node in AQOR will send many RREP replies so that source node can select a most optimization route, but at the same time it will lead to the control overhead increasing. With contrast to the AQOR, QRRSS not only increases

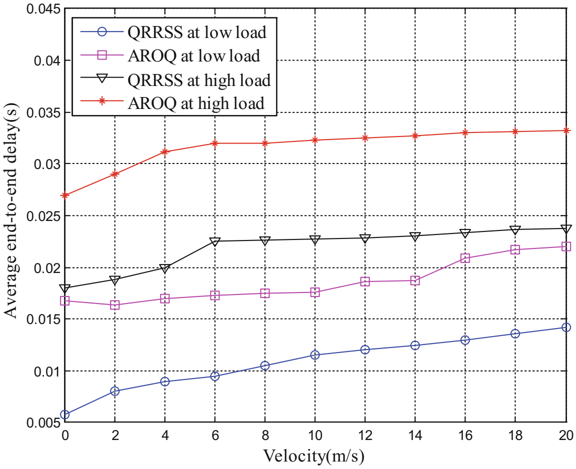


**Fig. 4.** Average end-to-end delay

the route reliability and reduces the ratio of route failure, but also reduces the route overhead indirectly from some kind of degree.

From Fig. 4, we can observe that the average end-to-end delay of AQOR and QRRSS are both not up to 0.04 s, and obviously, QRRSS has better delay performance than AQOR. That is because the algorithm sets the link uncertainty $(LU_{i,j})$ and other parameters to different values under different conditions, which makes QRRSS can guarantee the route reliability to some extent and decrease the probability of route rediscovery.

## 5 Conclusion

QRRSS proposed in this paper selects more reliable route connection that can guarantee the QoS requirements by adding relative information to RREQ/RREP. The scheme does not depend on the orientation equipments like GPS and the mobility model of network nodes. Simulation results indicate that QRRSS shows obvious performance improvements with contrast to traditional AQOR in packet successful delivery rate, control overhead and average end-to-end delay.

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