BRD: Bilateral Route Discovery in Mobile Ad Hoc Networks

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Abstract. Traditionally, route discovery in MANETs operates in unilateral (source-initiated) manner. We propose a new scheme called bilateral route discovery (BRD), where both source and destination actively participate in a route discovery process. BRD has the potential to reduce the control overhead by one half. As an underlying protocol for BRD, we propose gratuitous route error reporting (GRER) to notify the destination of a broken route. The destination can thus play an active role in the upcoming route re-discovery.

Key Words: Mobile ad hoc networks, routing, on-demand, AODV, route discovery, unilateral, bilateral.

1 Introduction

On-demand routing is preferred in mobile ad hoc networks (MANETs). Related work [1] shows that the average life of a path in MANETs is fairly short (e.g., less than 7 seconds). Therefore, the control overhead of on-demand routing mainly comes from route discoveries, and the routing performance is directly determined by the efficiency of the route discovery scheme.

Traditionally, most responsibility of discovering a route is assumed by source node, while destination node simply responds to a route request (RREQ) with a route reply (RREP). We call the traditional manner of route discovery *unilateral route discovery (URD)*. URD is not balanced because one party bears more burden than the other. It is not efficient and the delay is longer.

This work proposes a new scheme called *bilateral route discovery (BRD)*. BRD has potential to improve the routing performance by reducing control overhead and route discovery latency. The main contributions are as follows:

(i) We address the disadvantage of traditional route discovery that operates in a unilateral manner, and propose BRD, where both source and destination actively participate in a route discovery process.

(ii) As an underlying protocol for BRD, we propose gratuitous route error reporting (GRER). GRER uses a relaying node to bypass the failed link and notifies the destination of a broken route. The destination can thus actively participate in the upcoming route re-discovery process.

* This research was partially supported by NSF grants IIS-0324836 and IIS-0242384.

(iii) We simulated BRD in conjunction with AODV [2]. The results show that BRD significantly improves the routing performance.

The rest of the paper is organized as follows. In the next section, we discuss the motivation for BRD. The GRER and the BRD protocols are presented in Section 3 and Section 4, respectively. Section 5 presents simulation results. We draw conclusions in Section 6.

2 Motivation

In this section, we investigate the request zone of route discoveries. The request zone of URD can be represented by a circle centered at the source, with the radius not less than the distance from the source to the destination (denoted as r), as shown in Figure 1 (the dashed-line circle).

If the destination participates in the route discovery, the search space can be depicted by two smaller circles (solid line in Figure 1): one is centered at the source (*source circle* or $\mathcal{C}_s$) and the other is centered at the destination (*destination circle* or $\mathcal{C}_d$). When $\mathcal{C}_s$ and $\mathcal{C}_d$ intersect and some intermediate nodes are located in the intersection, a route is likely to be established. We call these nodes *intersection nodes*.

BRD consists of two halves: a *source route discovery* (*srd*) and a *destination route discovery* (*drd*). *srd* and *drd* search for each other. We denote the radii of $\mathcal{C}_s$ and $\mathcal{C}_d$ as $\mathcal{R}_s$ and $\mathcal{R}_d$, respectively. The optimal values of $\mathcal{R}_s$ and $\mathcal{R}_d$ are one half of the distance between the source and the destination, and the area of the request zone $\mathcal{A}_{brd}$ is $\pi(r/2)^2 * 2 = \pi r^2/2$. On the other hand, when using URD, the area of the request zone $\mathcal{A}_{urd}$ is πr^2. Therefore, BRD may incur as less as a half of the overhead of URD.

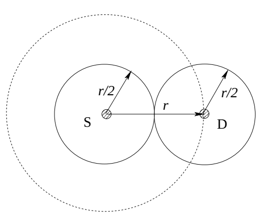


Fig. 1. Request zones of URD and BRD.

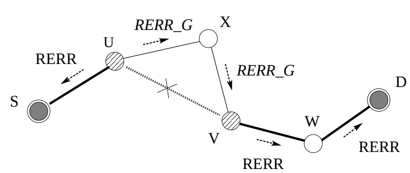


Fig. 2. Gratuitous route error reporting.

3 Gratuitous Route Error Reporting

One challenge in designing BRD is how to notify the destination when a route breaks at a link, so that the destination can actively participate the upcoming route re-discovery. We could implement the notification in a number of ways. In this paper, we propose *gratuitous route error reporting (GRER)*.

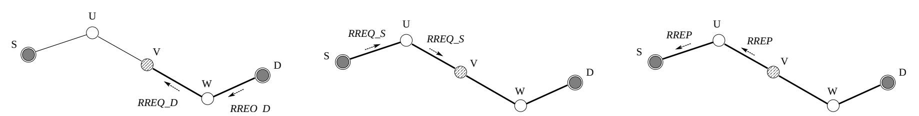
We call the upstream and the downstream nodes of the failed link the *start* and the *end* nodes, respectively. The basic idea is that the start node broadcasts a gratuitous route error message (RERR_G) with a TTL of 2 to bypass the failed link and reach the end node or other downstream nodes on the route. Figure 2 shows an example of how GRER works. When link UV fails, start node U broadcasts a RERR_G message. Node X relays (broadcasts) the message and end node V receives the message. When the end node or other downstream nodes receive the message, they send a regular RERR message to the destination informing it of the route error.

A RERR_G message is relayed at most once. A node relays the message if the end node is in its neighbor table and other neighbors have not relayed the message. The first condition avoids unnecessary relays. A RERR_G message would be more likely to reach the end node when it is in the neighbor table of the relaying node. The second condition suppresses duplicate relays.

We do not use a hello protocol to maintain neighbor tables at nodes. Instead, we utilize RREQ messages to build neighbor tables. This approach works well because a topology change that breaks a route typically triggers a route discovery process, which will generate sufficient RREQ traffic.

4 Bilateral Route Discovery (BRD)

After the source and the destination are notified of a route breakage, they conduct a BRD, which consists of a *srd* and a *drd*. Intersection nodes learn routes to both the source and the destination, and thus they can send cached route replies to the source. Figure 3 shows an example of BRD, where S is discovering a route to D. D initiates a *drd* and node V learns a route to D. Similarly, S initiates a *srd* and node V learns a route to S. V sends a cached route reply to S. When S receives the reply, a route is established from S to D.



(a) Destination route discovery.

(b) Source route discovery.

(c) Cached route reply

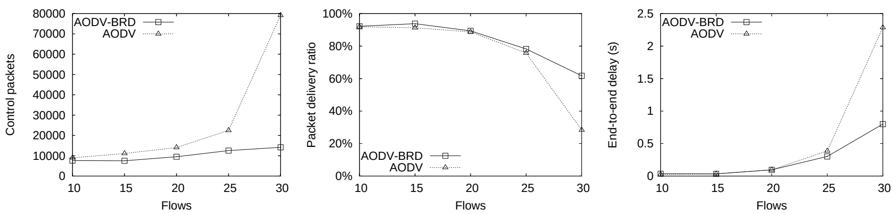
Fig. 3. (a) D initiates a *drd*, and V learns a route to D. (b) S initiates a *srd*. V learns a route to S. (c) V sends a cached RREP to S.

We denote the RREQ for a srd/drd as the RREQ_S/RREQ_D. The TTL of a RREQ_S message (ttl_s) and the TTL of a RREQ_D message (ttl_d) are set as follows: $ttl_s = ceil(HC_{known}/2)$ and $ttl_d = floor(HC_{known}/2)$, where HC_{known} is the hop count of a previously known route. We have designed the BRD scheme such that intersection nodes are able to send cached route replies regardless of the receiving order of RREQ_S and RREQ_D messages.

5 Performance Evaluation

We have implemented BRD in AODV, which is called AODV-BRD, and have conducted simulations to evaluate the performance of AODV-BRD and compared it with AODV. Simulations were conducted using GloMoSim 2.03 [3]. The radio bandwidth was $2Mb/sec$ and the radio range was $250m$. The traffic was $4packets/s$ CBR and the mobility model was random waypoint. Each simulation run lasted for $1200s$. The results were averaged over 20 runs.

Figures 4(a), 4(b) and 4(c) show the results of control overhead per flow, packet delivery ratio (PDR), and end-to-end delay, respectively, when the number of flows is varied from 10 to 30. We observe that BRD improves the performance over AODV significantly. For example, when there are 30 flows, the control overhead is reduced by 80%, the PDR is improved by 118%, while the end-to-end delay is reduced by 65%.



(a) Control overhead. (b) PDR. (c) End-to-end delay.

Fig. 4. Performance when number of flows changes. Minimum node speed $0.1m/s$, maximum node speed $20m/s$ and pause time $30s$.

6 Conclusion

We proposed bilateral route discovery (BRD) where both source and destination actively participate in a route discovery. BRD might incur as less as a half of the overhead of traditional unilateral route discovery (URD). We also proposed gratuitous route error reporting (GRER) to notify the destination of a broken route, and thus the destination could participate in the BRD. Simulation results showed that BRD improves the routing performance significantly. In the future, we plan to incorporate BRD into our Way Point Routing (WPR) framework [4] and integrate BRD with the Salvaging Route Reply (SRR) approach [5].

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