Optimisation of route discovery for dynamic source routing in mobile ad hoc networks

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A novel technique for optimising the efficiency of route discovery is proposed. The optimisation aims to minimise the number of cached route replies (RREP), which is a significant source of overhead for the dynamic source routing (DSR) protocol. Performance results show that the overall route discovery overhead can be reduced by more than 30% under high node mobility.

Introduction: Route discovery is the process by which a node searches the network for a route to its intended destination, typically by flooding the network with a route request (RREQ). In DSR [1], a number of optimisations exist to improve the efficiency of this flood-based process. These include promiscuous route learning, expanding ring search, and having a non-destination node reply to the RREQ if that node has a cached route to the destination. Each of these different optimisations has a common objective, which is to minimise the number of RREQ transmissions.

These optimisations have by far been effective in reducing the routing packet overhead of DSR [2], mainly from a large saving on RREQs. But even so, DSR still generates a large number of RREPs, most of which are cached RREPs from non-destination nodes. RREPs form more than half the sum of route discovery packets generated by DSR, an observation also reported in [2].

RREPs are more expensive to transmit than RREQs because they are unicast packets (whereas RREQs are broadcast packets), which use additional control packets for RTS/CTS exchanges in the 802.11 MAC. Besides, RREP packets will be larger in size as they must carry the complete source route acquired by the RREQ, back to the source. Therefore, a large number of RREPs can still take up a significant portion of the wireless bandwidth, in addition to the device power needed to process them. Both bandwidth and power are premium resources in mobile ad hoc networks.

Besides for reasons of resource-efficiency, a large number of cached RREPs can also be more detrimental than beneficial to the routing performance, particularly under high node mobility, as routes acquired become obsolete more frequently, rendering their use less effective [2]. This letter proposes a novel yet simple technique to minimise number of cached RREPs (as opposed to RREQs), based on the observation of a rarely noticed but commonly occurring phenomenon, which we illustrate through examples in the following.

Observation: Referring to Fig. 1a, suppose a source node A broadcast at time t_0 a RREQ, which is received by two non-destination nodes B and C. Assume B has a cached route to the RREQ destination, while C does not. Also assume B successfully contended for the channel and transmits ahead of C its cached RREP at time t_1, which is overheard by node D. After transmission from B is over, C rebroadcast the RREQ at time t_2, which is also received by D. Therefore, *D notices the RREP for a RREQ it receives only later.*

This phenomenon also occurs in other scenarios. For example, Fig. 1b illustrates a case where the RREQ travels over a longer path (A-C-E) than the RREP (A-B) to reach D. In Fig. 1c, D is in direct range of A, but did not receive its RREQ due to a packet collision caused by a simultaneous broadcast from E at time t_0 for a separate route discovery. Then as in Fig.1a, D hears the RREP at time t_1 and receives the RREQ at time t_2. Fig. 1d further considers the effects of mobility, where D moves into range of B, and later into range of C at times t_1 and t_2 respectively, thereby observing the RREP ***before*** receiving the RREQ for the same route discovery.

Optimisation: This phenomenon can be put to good use to minimise the number of cached RREP. For example, the overheard RREP contains information about i) the hop length of the returned source route, and ii) the ID of the RREQ, for which this RREP is generated. Together with the source address of the RREQ, which is found from either the returned source route, or destination address of the RREP, these three pieces of information could be used to decide if a node should reply upon receiving a RREQ, even for the first time.

Existing DSR algorithm dictates that a node will reply if it receives a RREQ for the first time, for which it has a route to the destination. It is almost certain that node D in Fig. 1 would send a cached RREP, since it knows at least a route to the destination, which is that it overhears from the RREP. However, the returned route may not be useful if it is longer than the one previously returned, since route selection at the source is typically based on the shortest path.

We thus propose that if a node overhears a RREP for a RREQ it has not seen before (known by the RREQ ID and source address), the node shall record the three pieces of information from the RREP, namely the i) hop-length of returned source route, ii) RREQ ID, and iii) RREQ source address, as mentioned before. Subsequently, if the node receives this RREQ, it will compare the hop-length of its route (to be returned) with that seen previously. It will reply if it has a shorter route, and discard otherwise.

DSR has a scheme with some similarity for preventing “Route Reply Storms” [1]. However, the scheme does not propose the use of other information received from the RREP as we mentioned above. Furthermore, the scheme listens for shorter routes only ***after*** RREQ is received. This inherently introduces a delay, which adds to the route acquisition latency.

Simulation environment:

We evaluate the performance of our proposed technique using an *ns* simulator [3] with Monarch wireless extensions [4]. A total of 100 nodes are simulated for 500s over a network space of 1342m x 1342m. The network traffic is modelled as 40 CBR sources with data sent in 64-byte packets at 2 packets/s. Five movement patterns are generated based on random waypoint model for each value of pause time: 0, 100, 200, 300, 400, 500s. A pause time of 0s corresponds to continuous motion (at speed of up to 20m/s) and a pause time of 500s (length of simulation) corresponds to no motion.

Performance results:

Fig. 2 shows the number of RREPs transmitted by both DSR, and a modified version of DSR with our optimisation. The DSR herein operates with all of its existing optimisations, thus providing a more challenging base for comparison than with a non-optimised, simple flooding-based DSR. The RREPs are further segregated into Cached RREPs and Target RREPs, the former being transmitted by non-destination nodes, the latter by destination nodes. Due to source routing and aggressive caching, DSR has an inherent high hit ratio for its route caches [2], which could explain why there are much more Cached RREPs than Target RREPs as shown in the figure.

The results show that the proposed optimisation reduces the number of cached RREP significantly, in particular at higher node mobility (lower pause time). At pause time of 0s (highest mobility) where all nodes are in continuous motion, the number of Cached RREPs is fewer by slightly more than 50%. And expectedly, this margin of improvement decreases with mobility, since lower speed lead to fewer route discoveries to be performed. At pause time of 500s (lowest mobility) where all nodes are stationary, no significant difference in the number of Cached RREPs is observed. Also, since our optimisation is aimed at Cached RREPs, the number of Target RREPs remains relatively unchanged. The same can be said for the RREQs. Fig. 3 shows the overall route discovery overhead, comprising of both RREQs and RREPs. By taking RREQ into account (not shown in the figure for clarity but should be easily extracted), Modified DSR achieves an overall overhead reduction of 33.8% under highest mobility (zero pause time).

Conclusion: We have presented a new optimisation for DSR to minimise the number of cached RREPs in a route discovery. The proposed optimisation is simple in concept and implementation, and is shown to be effective in decreasing the route discovery overhead, in particular under high node mobility.

References

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Figure captions:

Fig. 1 Different scenarios of route discovery

Fig. 2 Cached RREP and Target RREP

Fig. 3 Route discovery overhead

Figure 1

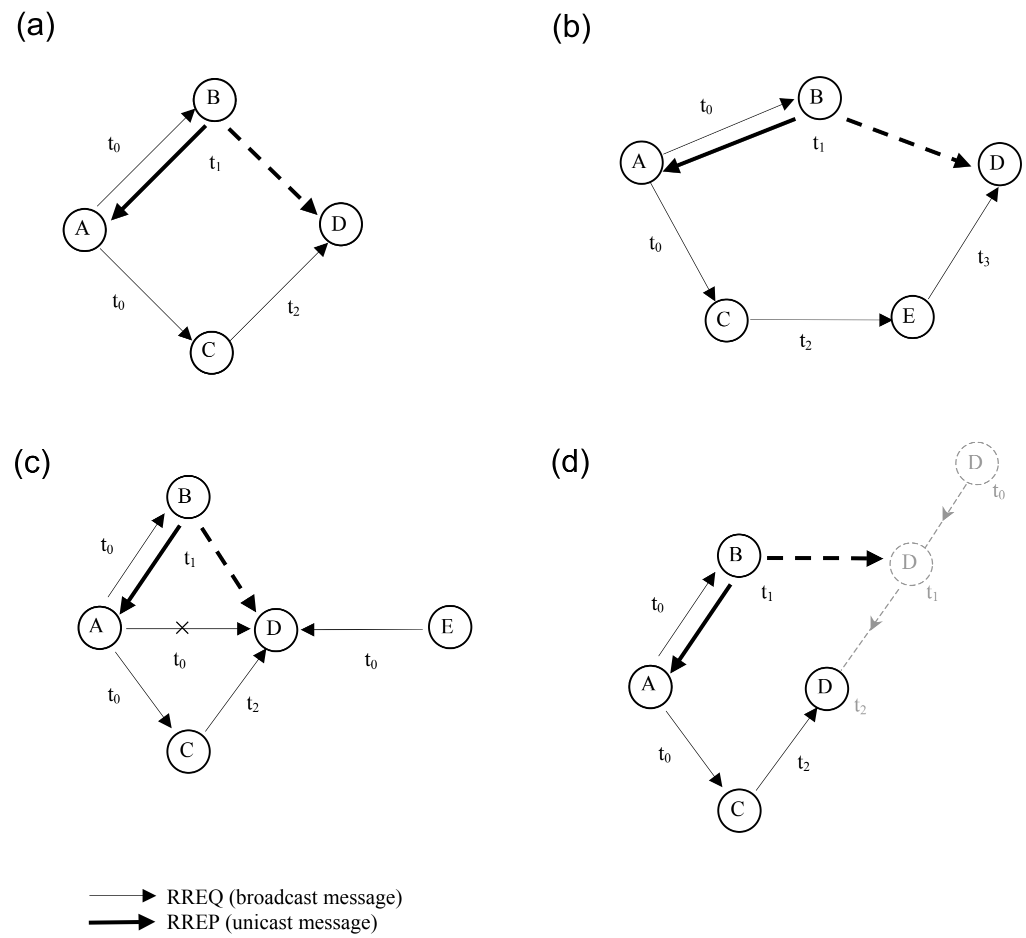

(a)
(b)
(c)
(d)
A
B
C
D
E
t_0
t_1
t_2
t_3
RREQ (broadcast message)
RREP (unicast message)

Figure 2

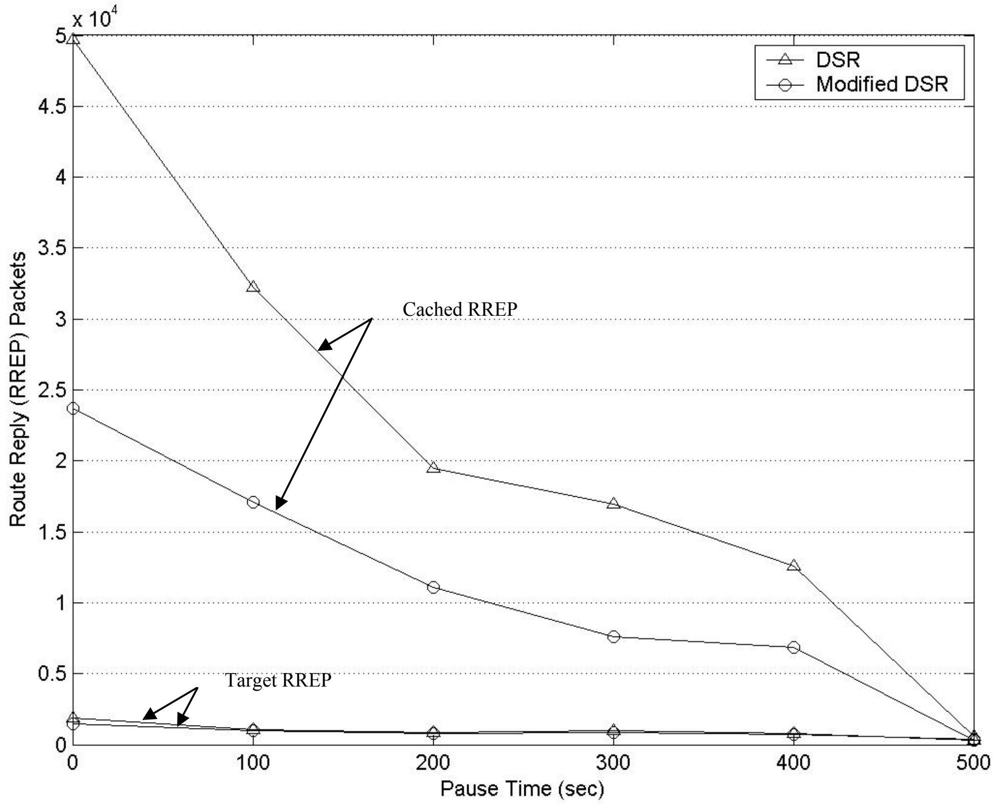
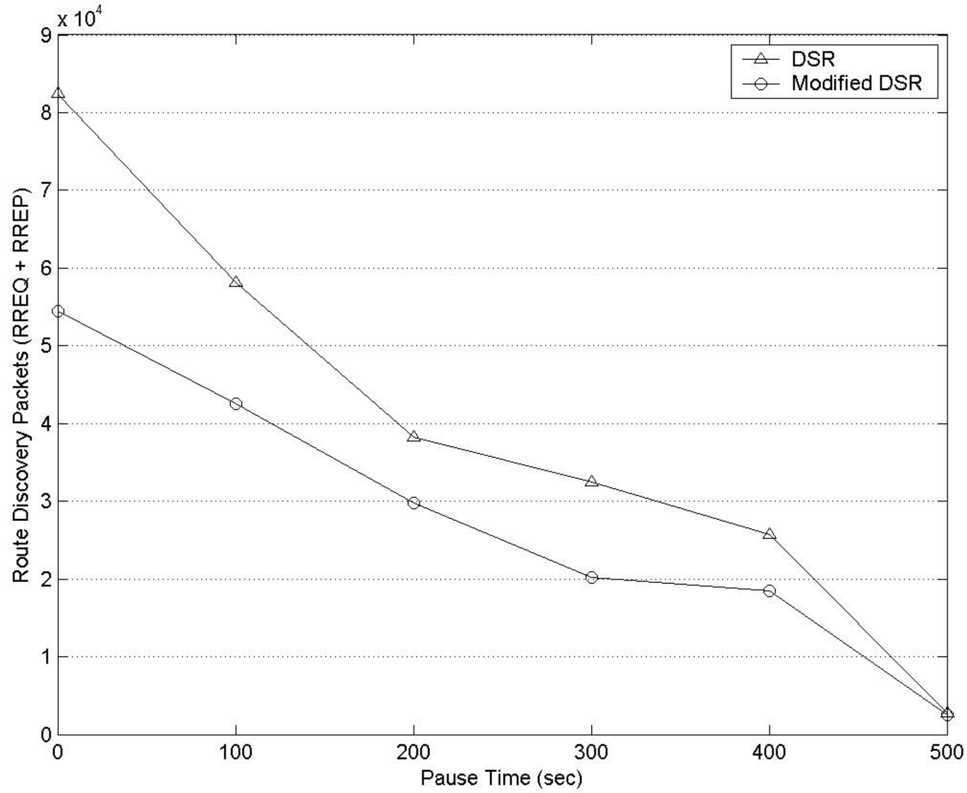

x 10^4
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Route Reply (RREP) Packets
0
100
200
300
400
500
Pause Time (sec)
DSR
Modified DSR
Cached RREP
Target RREP

Figure 3


x 10^4
9
8
7
6
5
4
3
2
1
0
Route Discovery Packets (RREQ + RREP)
DSR
Modified DSR
0
100
200
300
400
500
Pause Time (sec)