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Effective Stale Routes Management Using Preemptive Routing in DSR

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Abstract: Dynamic network topology is a major routing issue in MANETs, where effective management of the routes as the nodes move in and out of each other's range is a mandatory requirement to reduce data packet loss, end to end delay and the network overhead. Routes are maintained in route cache by every node as they learn from forwarding data packets. While route cache has their own benefits of reducing the overhead in the network, it possesses inefficiencies due to stale paths and use of low quality paths when feasible paths become available. Based on the studies of performance of DSR, a new approach to update the route cache to remove the stale paths effectively using preemption in route switching by predicting the possibility of current link breakage by sensing the RSSI value is discussed in this paper. The effectiveness of the proposed methodology is highlighted with the simulated results.

Key words: MANET · Source Routing · Cache freshness · Overhearing · Route cache update and energy efficiency

INTRODUCTION

In the present era of communication the use of wireless technologies has increased rapidly. One such field is Mobile Ad hoc Networks(MANETs) in which the network is self organizing without any central administration or infrastructure. Users can communicate or use the web services while on mobility. In such a network uninterrupted communication services becomes a mandatory requirement for which routing protocols must be effective and faster in computing the new routes at the time of communication link breakage when the nodes in the network move in and out the operating range. Routing protocols for MANETs are categorized as Proactive, Reactive and Hybrid routing protocols. The reactive routing protocols search and establish the route for a node only if it has data packet to send and maintain the learned routes in the route cache. In general reactive routing protocols perform better than proactive routing due to the reduced overhead of periodic updates of the route.

Dynamic Source Routing (DSR) is a simple and efficient routing protocol specifically useful in multi-hop wireless ad hoc networks of mobile nodes [1] and also routes in multipaths. The DSR composed of two phases, namely Route Discovery and Route maintenance, which work together to discover and maintain the source route from the source to the arbitrary destination. Dynamic Source Routing (DSR) for mobile ad hoc networks maintains route caches to store routes that have been found via discovery or through promiscuous overhearing [2]. One of the drawbacks of DSR route cache is stale route cache entries, incomplete error notification and insufficient cache size etc, which affects the performance of DSR protocol in terms of increased end to end delay, packet loss, overhead. Hence some mechanism to improve the route cache performance in DSR protocol is required. The rest of the paper outlines the working of DSR protocol, Route cache strategies, performance issues of route cache, optimizing techniques to update the route cache entries, its disadvantage and the proposed improvement the methods.

Dynamic Source Routing: DSR is designed with the objective of having notable features such as low overhead and ability to react quickly to changing topology. The DSR protocol is highly reactive helps ensure successful delivery of data packets in spite of frequent node movement or other changes in network conditions.

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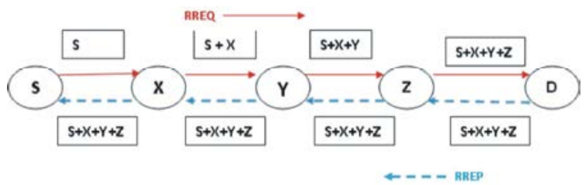

Fig. 1: Route Discovery process

The DSR protocol is composed of two main mechanisms that work together to establish new routes "Route Discovery" and identify alternate/new route during link breakage "Route Maintenance".

Route Discovery: The mechanism of the initiator of the communication finding a feasible route to target node is known as Route Discovery. As shown in the Figure 1, the source node S that wants to send a packet to a destination node D broadcast the Route Request (RREQ) in the network. The nodes that receive the RREQ packet check the destination address, if it is its own address, it will unicast the Route Reply (RREP) packet to the source. If the nodes are intermediate nodes it will either forward the RREQ packet to the next node after recording its identity in RREQ such that the destination can unicast the RREP to the source along same reverse path. Meanwhile the intermediate nodes also update its own route cache with the routes it learned.

On receiving the RREP at the source end updates its route cache with the new route learned during this process.

Route Maintenance: When nodes in the network moves in and out of the present network range the communication breaks down. This detection of Link disturbance between the source and the destination, the source can no longer use the current route. This monitoring of link breakage and searching for new route is known as Route maintenance [1]. When the current route to D is no more valid, source node S either tries to use any other route available to D from its route cache or initiates the route discovery again and updates its route cache with the new route to the destination D. Route Maintenance is done only if there is active communication between source and destination during the route disturbance.

Route Cache: Route cache is the structure in which the nodes store the learned routes for various destinations during the route discovery process. The routes are stored

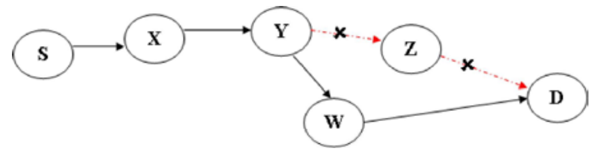

Fig. 2: Route cache update in link breakage

S → X → Y → Z → D
S → X → W → Z → D : When Y disconnects
S → X → Y → W → D : when Z disconnects
S → X → Y → E : Link XY common to Destination 'D' and 'E'

Fig. 3: Path cache structure

in the cache to avoid unnecessary route discovery for frequently used routes [3]. The route caches are of two cases, source route cache, when the source caches the discovered routes and intermediate node caching, the nodes participating the route discovery overhears the packet and records the route. Thus the cache will be having the current topology of the network.

There are two kinds of caches i) path cache and ii) Link cache [4].

Path Cache: The entire path or every destination is stored in the route cache. As in the Figure 1 above, the route cache will store the path as S-X-Y-Z-D. In this case when there is a link break in the path as node Z moves from the network, node X will inform the source as well as the other node using node Z. When the source finds a new route to a destination via another node W the route cache entry will updated with the new path as S-X-Y-W-D as in the Figure 2 and the old route to D via Y will be deleted as in Figure 3. When a link is common in routes to two destinations from the source, it will have distinct entries in route cache.

Link Cache: The route cache stores the route in conventional graph data structure by storing the links to every node. When there is break in the link as in the above Figure 2, in the route the links Y-Z and Z-D is disconnected as Z moves from the network. The source node performs a BFS search on the cache entry and replaces only the broken link in the existing entry rather than replacing the entire path with a new entry. As shown in Figure 4, the advantage of Link cache is the common link X-Y can be shared between Z and E as stored in the cache.

Route in path cache is always present in link cache but vise versa is not true [5]. By connecting individual links a better path can be formed, which may not be present in path cache. Whenever a link breaks a complete

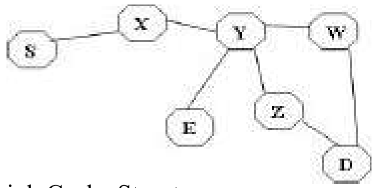

Fig. 4: Link Cache Structure

route in path cache is replaced while in link cache only broken link is deleted and other links remains same, as in the Fig. 4.

Performance Issues of Route Cache: DSR extensively uses the route cache. As per the DSR protocol every intermediate node overhears the routing packet and caches the route for future use. The destination also replies to every request packet it receives which enables the source to get multiple paths to same destination which is used in case of current route breakage. Hence a large number of routing information is acquired by the route cache with a single route discovery process [7]. The route discovery process consume much resource increasing the end to end delay in communication when the current route is disturbed, hence the route cache reduces the flooding of the network with RREQ frequently improving the performance of DSR. So an effective maintenance and updation technique of route cache is of necessity. The main problem in the route cache in DSR is the existence of stale routes. Stale routes may contain broken links that causes decrease in packet delivery ratio and increase use of network bandwidth [8]. The current route cache in DSR protocol does not have any mechanism to update the routing information to distinguish between stale routes and fresh routes.

Various research studies spots three main causes of the stale route cache problem in DSR [7], Incomplete error notification, No expiry and quick pollution.

Incomplete Error Notification: On receiving RERR message the source and the intermediate nodes along route take an alternate route and clear their route cache, but the other nodes using the broken link are not informed about the mobility of the node from the path, hence only limited number of caches are cleaned up. The remaining unused routes are the stale routes.

No Expiry: If the route caches are not cleaned up DSR protocol doesn't provide any mechanism for determining the duration of the unused route to stay in the route cache. The stale routes are cleared from the cache only by the RERR propagation mechanism.

Quick Pollution: There is no way to distinguish between the fresh route information and the stale route. The old routes for a destination can be erased by error mechanism, but an upstream node carrying the data packet can make an entry of the stale route back into the cache. These types of stale route would be overheard by the other intermediate nodes, hence the polluted cache entry will be propagated in the network which is termed as quick pollution.

Related Work: Many researchers proposed different solutions for the effective management of the route cache which are discussed below.

R. Bhuvaneswari *et al*. [6] in this work author discuss about reduce the effect of overhearing and avoid the stale route problems while improving the energy efficiency using the Efficient Source Routing Scheme (ESRS) algorithm. Due to the lack of route cache update, the stale route entry and overhearing is originated among the network. For that, they developed five mechanisms to improve route cache performance in DSR. By simulation results the proposed algorithm achieves better performance than the existing methods.

Mahesh K. *et al*. [7] proposed the techniques of wider error notification, timer based route expiry and negatives route caches primarily focus on effective removal of stale cache entries and preventing cache pollution. These combined technique improved the packet delivery by 15 % and 70% in quality cache replies. They have not commented about checking of freshness of cached routes.

Sofiane Boukli Hacene *et al*. [9] propose a technique based on cleaning route caches for nodes within an active route. When learning new routes, a node must set an expiration time for each route inserted in the cache and when this time expires, the route is removed from the route cache of the node. Each time a route is used the expiration time is set. This technique can overall generate lower communication overhead, fewer broken links and lower Average end-to-end delay.

Abolfazl Akbari *et al*. [16], proposed a new route maintenance algorithm for AODV protocol to detect the possibility link breakage based on received radio, overlap of routes, Battery capacity and the number of neighbor node around each intermediate neighbor nodes.

G. Narasa Reddy *et al*., [11] Author proposed a modification to the existing DSR protocol. In this paper, they add a link breakage prediction algorithm to the Dynamic Source Routing (DSR) protocol. The mobile node uses signal power strength from the received packets to predict the link breakage time and sends a warning to the source node of the packet if the link is soon-to-be-broken. The source node can perform a pro-active route rebuild to avoid disconnection.

Imran Ali Khan *et al*. [17] describes a dynamic angle aware probabilistic broadcasting algorithm which set the forwarding probability of a node based on the cover angle of a node with respect to its neighbors for analyzing the need for retransmission of packets which would lead to delay in communication. The signal strength is estimated by the Global Positional System (GPS) or any other localization technique based on the angle of arrival, triangulation or signal strength indicators.

Based on the above studies we propose a new tactic of handling the stale routes.

Proposed Technique: In this technique the stale routes are identified by determining the freshness of the path entry in cache. This technique is a proactive process where the link prediction is computed before actual route breaks up and an alternate search for the route is initiated by the corresponding node (source/intermediate nodes). The old route used is time stamped when the new route is selected for the transmission. The stale routes are removed after a time expiry.

Link Breakage Prediction: In the normal DSR there is no scheme of proactive route maintenance [12], the route cache maintains the route learned in route discovery process. Consider the following scenario (Figure 5a), the source S initiates the route discovery to D and broadcasts RREQ to its neighboring nodes <X,Y,Z>. Nodes X, Y, Z re-broadcasts the RREQ packet to its neighbors appending its id in the packet. Similar process is continued until the destination receives the RREQ and the destination unicasts the RREP to the source through all the available routes viz (<S, X, R, D>, <S, Y, V, W, D>, <S, Z, V, W, D>). The source selects the route with minimum number of hops <S, X, R, D> as the primary route [13] and the other routes are stored in the route cache as backup routes. In the Figure 5b as the node 'R' moves away from the transmission range, the breakage of link is predicted based on the value of received signal strength indicator (RSSI). RSS is measured at physical layer [14] that is used to choose reliable links to form stable routes by monitoring the signal quality to judge whether the neighbors are approaching or leaving to predict the stability of the current link and compute path loss incurred in order to identify and reject the unidirectional links. When the RSSI value drops below

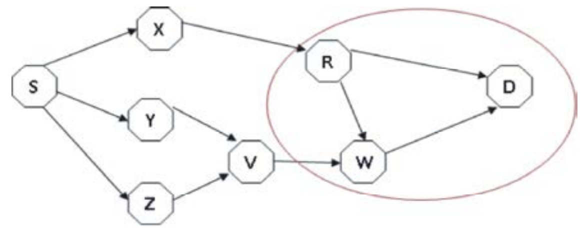

Fig. 5a: Initial Route Discovery Process

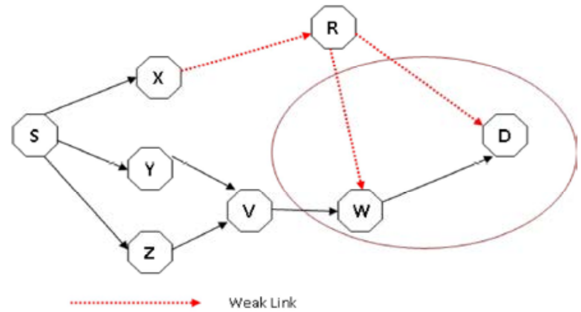

Fig. 5b: Route when node R moves away from its transmission range

the threshold level, any of the cached backup routes <S, Y, V, W, D> will be selected to transmit the data packet even before the link break occurs.

Removal of Stale Routes: The threshold value of RSSI is fixed as the 50% of reduction in the original RSSI computed when first RREP arrived at the source. While selecting the alternate route the previous old route is time stamped with the time when the source RSSI value drops below the threshold value. This stale route is then deleted from the cache when the source receives the RERR message for that route. The time elapsed between the time stamp of decreased RSSI and receipt of RERR message is the time of expiry of the stale routes. With this scheme, the freshness of the route is indicated by the time stamp and the removed as soon as the RERR message is received. As the alternate route is selected based on link prediction, the data packets would have taken the new route, hence the problem of data packets carrying the stale route (quick pollution) is considerably reduced. Figure 6 depicts the flow of cache updation mechanism of our approach.

Simulation and Results: With our proposed technique simulation shows 60% - 70% performance improvement in the DSR algorithm. The performance of the proposed modified- DSR 'M-DSR' in measured in terms of throughput, average end to end delay, link updation time, number of packets dropped with the varying mobility speeds and the number of nodes per route.

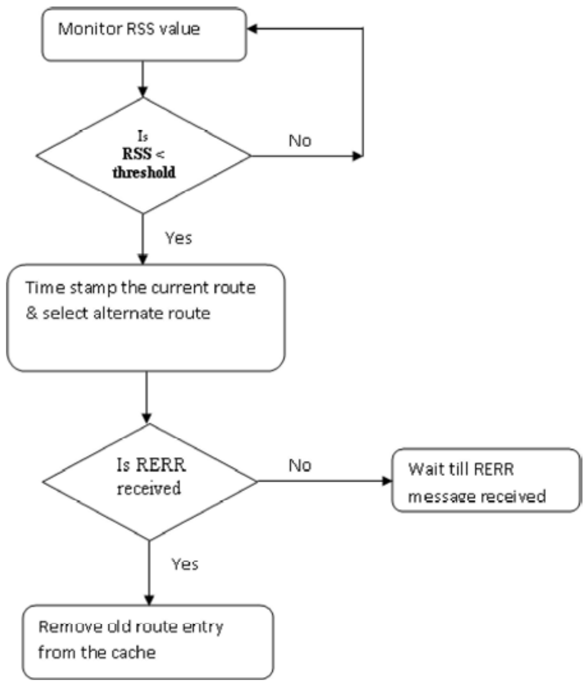

Fig. 6: Flow chart for Stale route removal

Table 1 : Simulation Environment

Parameter	Values
Traffic type	CBR(constant bit rate)
Simulation time	200 seconds
Number of nodes	80
Pause time	5s after every relocation
Maximum connections	15
Mobility Model	Random Way point model
Topology Size	500m x 500 m
Max. No: of parallel routes	1-5
Max. No: of intermediate nodes	5 -30
Motion Time	10s

Simulation Setup: The discrete event simulator NS-2 is used for the analysis study. The simulation is run for 100s within area of 500 square meters restricted with 80 nodes. The simulation environment details are given in Table 1.

The Performance Parameter Consider for the Study Are

No: of Packets Dropped: It is the count of packets lost during the switch over between current route and new route, computed as the difference between number of packets generated at the source and the number of packet received by the destination. This is measured against the mobility speed of the nodes and the number of nodes per route.

New Route Acquisition Time: The time taken to select an alternate route either selecting from cache or through route discovery, when a link breakage is predicted by the node. It is measured as the time elapsed between the time of decreased threshold and activation of the new route.

Throughput: Is total packets successfully delivered to individual destination over total time divided by total time. The amount of data transferred from one place to another or processed in a specified amount of time measured in units of kbps. The computation of through is given by throughput = (total no. of bytes received /simulation time)* (8/1000) kbps.

End to End Delay: The ratio of time difference between every CBR packet sent and received to the total time difference over the total number of CBR packets received. It refers to the time taken for a packet to be transmitted across a network from source to destination given as:

$$D_{etoe} = N\ (D_{trans} + D_{prop} + D_{proc})$$

where,
D_{trans} = Transmission delay
D_{prop} = Propagation delay
D_{proc} = Processing delay

RESULTS AND DISCUSSION

Figures 7 to 10 shows the various results obtained from the simulation. In overall the 60% -70% improvement with the modified DSR is observed when compared with the original DSR.

In Figure 7a, the number of packets drop in case of M-DSR is less and it almost minimum as the mobility speed increases. From the Figure 7b, it is evident that the number of packets dropped even though increases with the number of nodes per route, it is considerable lesser than the basic DSR protocol performance.

The time incurred in updating the cache with new routes is also much less in the modified route maintenance procedure as show in the graph in Figure 8. The increase in time with increase in mobility speed of the node doesn’t make much increase in time for updating in the case of the proposed algorithm.

From the Figure 9, it can be noticed that the end to end delay in case of the new method is considerably minimized than the basic DSR algorithm as the link breakage is predicted and alternate route is adopted even before the communication is distrupted and hence the delay incurred is mostly due to processing, propagation etc.

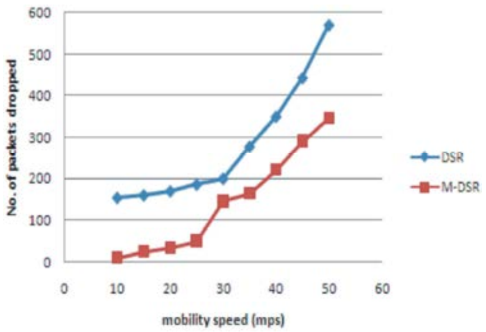

Fig. 7a: No: of Packets dropped Vs mobility speed

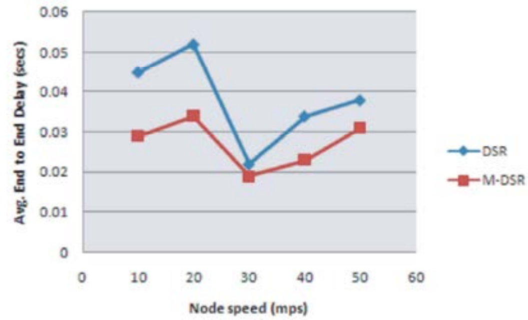

Fig. 9: End to End Delay vs Mobility speed

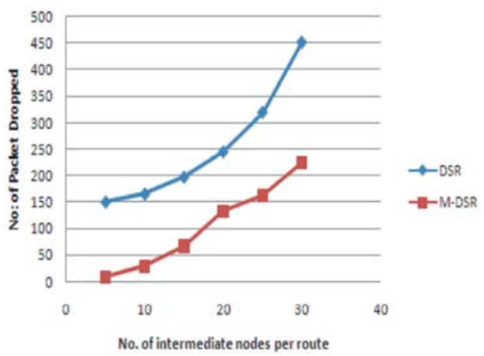

Fig. 7b: No: of packets dropped Vs nodes per route

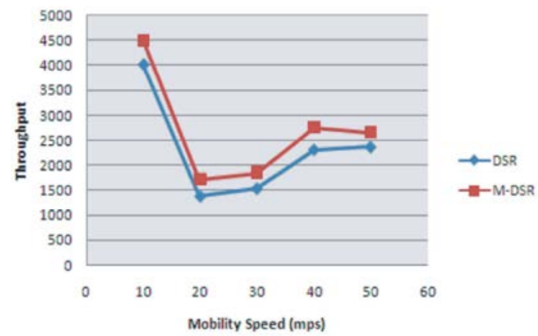

Fig. 10: Througput Vs Mobility speed

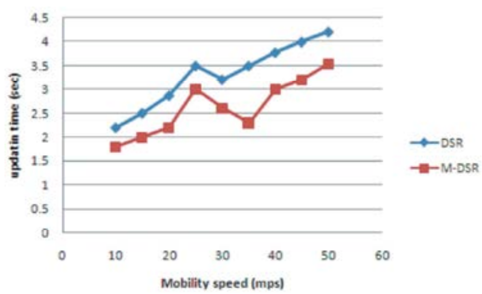

Fig. 8: Cache updation time Vs Mobility speed

On overall the graph in figure 10, proves that the throughput of the network on cumulative is increase noticeably in the new approach of DSR compared to the basic DSR working.

Conclusion and Future Works: Reactive routing protocols have an advantage of reduced routing overhead as it initiates the route discovery only if it is required, avoiding the periodic updates of the route cache, at the same time incurs end to end delay and packet loss due to sudden breakage in the link and then find an alternate route to resume communication. In our proposed modification in the DSR, the link breakage can be realized earlier and take an alternate route without loss of time and data packet, parallelly the stale routes that cause various performance issues is also removed efficiently. With simulation results analyzed our technique improves the performance of DSR by 60% with high mobility compared with basic DSR route cache management.

In this paper only the mobility of the intermediate nodes of primary route away from the network is considered. The movement of the destination nodes or the intermediate nodes of the backup routes for the case of stale routes removal are yet to be analyzed as the extension of the present work.

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