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Dynamic Probabilistic Approach for Improving the Route Discovery in MANETs

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Abstract: The pure flooding is considered the common mechanism have been proposed to distribute the Route Request Packet in DSR protocol. This strategy is simple and easy to implement but it suffers from a serious problem lead to the broadcast storm problem. There are several probabilistic approaches are used to overcome this problem. In this study we developed a mathematical model that can be used locally by each node within the network to calculate a retransmission probability (p_t) as a function of number of first-hop neighbors (k). In order to evaluate the performance of the proposed algorithm, a number of scenarios were simulated using the MANET Simulator (MANSim). The performance of the new model was evaluated and compared with pure and other probabilistic algorithms to estimate the enhancement it achieves over the current probabilistic algorithms. The model enhances the performance of probabilistic broadcast by increasing network reachability with an acceptable increase in the number of transmissions especially in the low and moderate node density.

Keywords: Dynamic source routing, flooding, mobile ad hoc networks, probability, route discovery

INTRODUCTION

A Mobile Ad Hoc Network (MANET) is a collection of mobile hosts that are utilized as multi-hop wireless network with no stationary infrastructure or centralized administration.

The mobile hosts in such situation are free to move randomly and organize themselves arbitrarily causing the dynamic topologies which may be changed rapidly and unpredictably.

In MANETs, two mobile hosts that want to communicate may not be within the same wireless transmission range, but could communicate if other hosts between them also participating in the ad hoc network are ready to forward packets for them. This means that the hosts in MANETs act as end-points as routers to forward packets in such multi-hop environment.

Due to the frequent change of network topology, the process of finding the route from source to destination with minimum overhead communication is a challenging task.

There are several unicast and multicast routing protocols for use in ad hoc networks have been proposed in literature (Perkins *et al*., 2002; Johnson *et al*., 2004; Park and Corson, 2001; Perkins and Bhagwat, 1994; Ko and Vaidya, 1998; Haas *et al*., 2002).

In general, the routing protocols for MANETs can be divided into three categories: proactive, reactive and hybrid (Abolhasan *et al*., 2004).

In proactive routing protocols (table-driven), such as DSDV (Perkins and Bhagwat, 1994), the routes to all destinations are determined statically at the start up and maintained by using a periodic route update process from each node to every other in the network.

In reactive routing protocols (on-demand), such as AODV (Perkins *et al*., 2002) and DSR (Johnson *et al*., 2004), routes are determined dynamically when they are required by the source using a route discovery process without periodic routing table exchanges or full network topological view.

When a source needs to send packets to a destination, it initiates a broadcast based route discovery process to look for one or more possible paths to the destination. Its routing overhead is lower than the proactive routing protocols if the network size is relatively small (Das and Castaneda, 1998; Broch *et al*., 1998; Johansson *et al*., 1999).

Finally, there are hybrid protocols that combine the best features of both proactive and on-demand protocols. The Zone Routing Protocol (ZRP) (Haas *et al*., 2002) is an example belonging to this class.

Because of the topologies in MANETs are changed frequently, all on-demand routing protocol such as DSR and AODV are utilizing a flooding strategy to discover the routes. Flooding is well appropriated for this purpose as it isn't requiring a topological knowledge. It consists in each node retransmitting a packet to all neighbors when receiving it at the first time.

In this study we will focus on the Dynamic Source Routing (DSR) protocol which is considered one of the common on-demand routing protocol used in MANETs.

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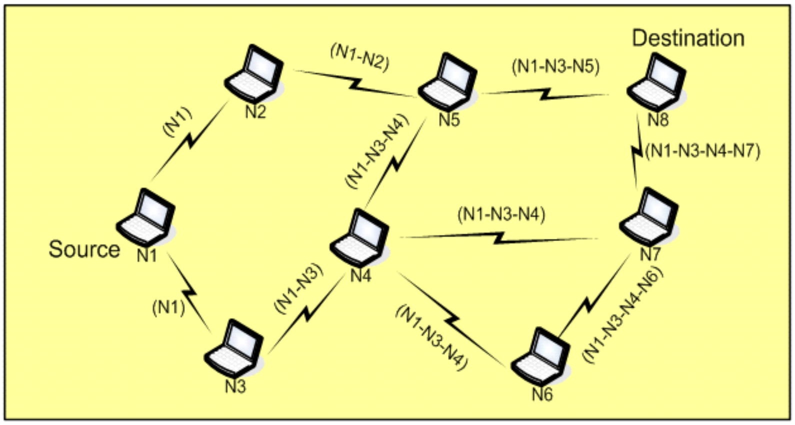

Fig. 1: Flooding the RREQ packet through the network

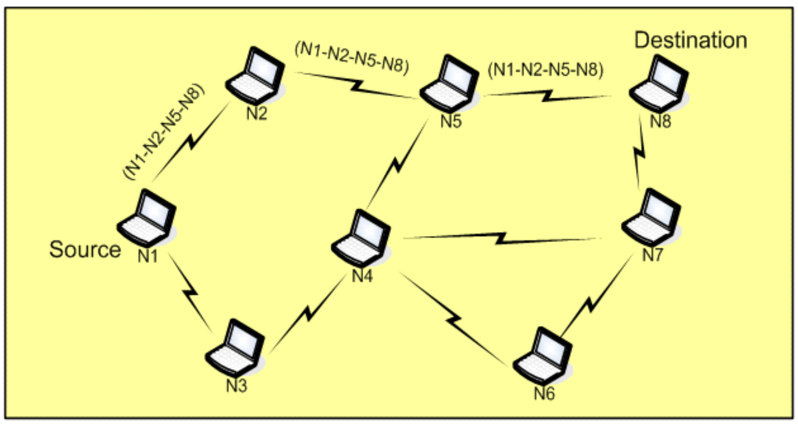

Fig. 2: Reply the RREP packet with the route record

The DSR protocol is based on the concept of source routing, which means that the source node puts in each data packet the whole route, from itself to the destination. The sender explicitly lists this route in the packet's header, identifying each forwarding "hop" by the address of the next node to which to transmit the packet on its way.

The DSR protocol divides the routing problem in two parts, Route Discovery and Route Maintenance, both of which operate entirely on-demand (Royer and Chai-Keong, 1999).

When a mobile node wants to send a packet to the destination, it first checks its route cache to determine whether it already has an unexpired route to the destination. If it has one, it will use this route to send the packet. Otherwise, it will initiate route discovery by broadcasting (flooding) a Route Request Packet (RREQ). While waiting for the route discovery to complete, the host may continue normal processing and may send and receive packets with other hosts.

When receiving a RREQ packet by an intermediate node, this node checks if it is itself the destination or it has an unexpired route to the destination. In this case, a Route Reply Packet (RREP), which includes the accumulated route in RREQ packet during its "travel", is returned to the source. If the intermediate node is not the destination, it checks if it has already received a copy of the packet. In this case, the RREQ packet is discarded. Otherwise, the intermediate node adds its own address to the route record in the RREQ packet and rebroadcasts the same packet to all its direct neighbors.

Figure 1 illustrates the formation of the route record as the RREQ propagates through the network. If the node generating the RREP is the destination, it places the route record contained in the RREQ into the RREP. If the responding node is an intermediate node, it will append its cached route to the route record and then generate the RREP. To return the RREP, the responding node must have a route to the initiator. If it has a route to the initiator in its route cache, it may use that route. Otherwise, if symmetric links are supported, the node may reverse the route in the route record. If symmetric links are not supported, the node may initiate its own route discovery and piggyback the RREP on the new route request.

Figure 2 shows the transmission of the RREP with its associated route record back to the source node.

Due to mobility, the wireless network are less reliable than conventional wired network, route maintenance (Yang *et al.*, 2005) is used for maintaining broken routes. Each packet is individually acknowledged by sending an ACK packet by the next hop. If sending node doesn't receive the ACK, it searches the route cache; if there is a route to the destination node, it just sends the packet through this route again; if there is no such a route in the cache, it sends route error packet to the source node to report a broken route. Then, the source node invokes another route discovery again to find a new route.

DSR doesn't maintain a routing table and update the route table periodically so that it does reduce a lot of overhead of information exchanged. But it also introduces some flooding overheads, especially if the network topology is changed very fast.

The pure flooding is considered the common mechanism have been proposed to distribute the RREQ packet. Although, this strategy is simple and easy to implement but it suffers from a serious problem lead to the broadcast storm problem (Tseng *et al.*, 2002). This problem could potentially lead to expensive redundant retransmissions in addition to high channel contention which causing collisions in the network.

Several techniques have been proposed to overcome this problem using probabilistic approaches (Muneer *et al*., 2010; Alia and Al-Shqeerat, 2011; Mohammed *et al*., 2007).

In this study, we develop and investigate the use of a new dynamic probabilistic model with DSR protocol in order to reduce the impact of broadcast storm problem due to flooding the RREQ packets, aiming to improve the performance of the network. In the proposed model, when a node receives a RREQ packet, it will rebroadcast the message with a certain retransmission probability (p_t). p_t is calculated locally by each intermediate node as a function of first hop neighbors (k).

In order to evaluate and analyze the performance of the new algorithm, a number of scenarios are simulated using the MANET simulator (MANSim) (Al-Bahadili, 2009). The outcomes of these simulations demonstrate that the proposed model presents higher network reachability (RCH) than the fixed and linear probabilistic algorithms at a reasonable increase in the number of retransmissions.

LITERATURE REVIEW

In this section, we are going to examine the related studies which are directly or indirectly aim to overcoming the broadcast storm problem and reducing the number of redundant broadcast packets during the route discovery.

Al-Bahadili (2010) developed a new probability adjusting model, in which the neighborhood densities are divided into three regions (low, medium and high). They assigned a fixed retransmission probability for low and high densities, while a linear function of number of first hop neighbors are used to calculate the retransmission probability.

A novel approach has been suggested by Bani and Khalaf (2009) called AODV-SPB based on probabilistic algorithm which leads to improve performance by reducing the PREQ overhead during rout discovery operation. The AODV-SPB routing algorithm reduces the average end-to-end delay and achieved low normalized routing load.

In Mohammed *et al*. (2009) the authors have proposed a new probabilistic algorithm called Counter-Based Route (PCBR) discovery. The performance of PCBR generates lower routing overhead and reduces the number of MAC collisions and improve throughput.

In Abdulai *et al*. (2007) the authors have equipped AODV with two probabilistic methods for on-demand route discovery that reduces the overhead involved in the dissemination of PREQ.

Another probabilistic attack method against DSR ad-hoc network routing protocol was given by Ocakoglu *et al*. (2004). The aforementioned model was analyzed the affects of this attack on route discovery success. The analysis shows that the attack leads to further improvement of the DSR route discovery mechanism.

Two efficient strategies have been proposed by Meghanathan (2007) based on DSR and FORP protocols. The simulation results compare that stability of DSR and FORP routes determined under certain conditions that guaranties 92-95% success in route discoveries and minimize the number of retransmissions.

The performance evaluation of using the probabilistic approach in DSR routing protocol is presented by Muneer *et al*. (2011).

METHODOLOGY

Probability-based scheme: Probabilistic algorithm is widely-used for flooding optimization during route discovery in MANETs. It aims at reducing number of retransmissions, in an attempt to alleviate the broadcast storm problem in MANETs. In this scheme, when receiving a RREQ packet, a node retransmits the packet with a certain pt and with probability (1 –*pt*) it discards the packet. A node is allowed to retransmit a given RREQ packet only once, i.e., if a node receives a packet, it checks to see if it has retransmitted it before, if so then it just discards it, otherwise it performs its probabilistic retransmission check. Nodes usually can identify the RREQ packet through its sequence number. The source node p_t is always set to 1, to enable the source node to

```
Probabilistic_Algorithm
If (the receiving node is within the radio
   transmission range of the sender)Then
      IRec(i)++ {Update the node reception index
             IRec(i)}
      If (IRet(i)=0) Then {The node has not
                           retransmitted the RREQ
                           before (IRet(i)=0}
         pt=function_pt()
         ξ=rnd() {ξ some random number
         between
                0 and 1}
         If (ξ <= pt) Then
            Retransmit RREQ
            IRet(i) = 1 {Update the node
                         retransmission index
                         IRet(i) by equating it to
      1}
         End If
      End If
   End If
Function_pt() {Determining pt}
   If (IProb="Static") Then {IProb is an integer
                             indicates the approach
                             to be used for
                             determining pt
                             whether it is static or
                             dynamic}
      pt=constant value
   Else (IProb="Dynamic")
      pt=f(k) { k represents the number of first-
      hop
            neighbors to node i}
End If
```

Fig. 3: Description of the probabilistic algorithm

initialize the RREQ. While, pt for intermediate nodes (all nodes except the source) is determined using one of the following approaches:

- Static approach in which a pre-determined p_t is set for each node on the network and it can be expressed as: $p_t = p_t$, where p_t is a constant value ($0<p_t\leq 1$). P_t = 1 for pure flooding.
- Dynamic approach in which each node on the network locally calculates its p_t as a function of k (p_t (k)), where p_t (k) could be any linear/nonlinear function of k.

In this study, we mainly concern with dynamic probability. Figure 3 shows briefly the probabilistic algorithm applied in MANETs.

The proposed dynamic probabilistic model: The core problem in broadcasting is how to minimize the number of nodes that rebroadcast the RREQ packets while maintaining a high degree of reachability in order to discover routes to the destination.

In this study, we propose a new dynamic probabilistic model to overcome the broadcast storm problem in order to reduce the number of nodes forwarding the RREQ packets while still guaranteeing the reachability of packet to the destination.

This section presents a description of a dynamic probabilistic model that can be used for calculating the pts of intermediate nodes for adjusted probabilistic broadcast in MANETs. In this model, we divide the value of k into two areas and each area has a different function may be used for adjusting p_t. This can be expressed mathematically as:

$$p_t(k) = \begin{cases} p_t - \dfrac{k - N_{\min}}{N_{\max} - N_{\min}}(p_2 - p_1) & for N_{\min} \leq k \leq N_{\max} \\ \dfrac{1}{k - a} + & for \quad N_{\max} < k \end{cases}$$

where,

- p_{max} The maximum retransmission probability could be assigned for a node.
- p_1 The retransmission probability could be assigned for a node, where $k = N_{min}$. p_1 should be less than or equal to p_{max}.
- p_2 The retransmission probability could be assigned for a node, where $k = N_{max}$. p_2 should be less than p_1
- p_{min} The minimum retransmission probability could be assigned for a node.
- p_t The dynamic retransmission probability for a node.
- k The number of first-hop neighbors for the transmitting node.
- N_{min} The minimum number of nodes at $p_t = p_1$.
- N_{max} the maximum number of nodes at $p_t = p_2$.

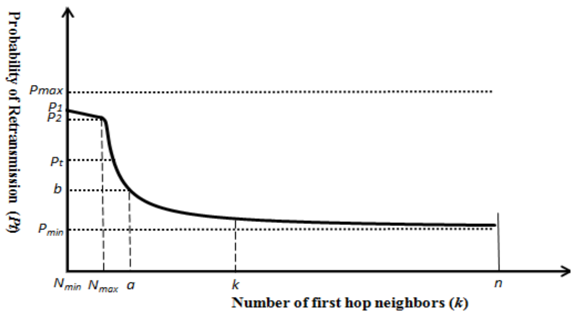

Fig. 4: The variation of retransmission probability with the number of first hop neighbors

The first function of the formula is used when the density of the nodes is low. In another world, when the number of first hop neighbors, k, lies between Nmin and N_{max} ($N_{min} \leq k \leq N_{max}$). In this case, the retransmission probability pt will lie between p_1 and p_2 and it is decreased linearly while increasing k to avoid unnecessary RREQ packets. However, p_1 and p_2 should be high enough to ensure high reachability.

The second function of the formula is used when the density of the nodes is high. In another world, when the number of first hop neighbors, k is larger than N_{max} ($k>N_{ma}$). In this case, the retransmission probability pt will decrease sharply due to k so the number of the forwarding RREQ packets will be reduced. Although some nodes will fail to retransmit the RREQ packets, other nodes will have a chance to do so and this is because of the high node density.

For this reason a and b should be assigned satisfactory values to keep the probability of retransmission within a convenience range. In this study we depend on the results showed in Al-Bahadili (2010), where to achieve 0.811 of the reachability, which is considered as an acceptable performance, the values of p_t and k should be equal to 0.708 and 7.142, respectively. So, we assigned a to 7.142 and b to 0.708. Although, different values can be assigned and investigated for p_1, p_2, Nmin and Nmax; in this study, these values are taken to be 0.95, 0.9, 0 and 10, respectively. Figure 4 shows the variation of p_t, with k.

SIMULATION RESULT

The network simulator used in this study is MANSim (Al-Bahadili, 2009), which is developed to simulate and evaluate the performance of a number of flooding optimization algorithms for MANETs. It is written in C++ language and it consists of four major modules: Network module, Mobility module, Computational module and Algorithm module.

In order to evaluate and compare the performance of the proposed Dynamic Probabilistic algorithm, a number of simulations were performed using MANSim. These simulations investigate:

Table 1: Input parameters

Parameters	Values
Geometrical model	Random distribution
Network area	600×600 m
Number of nodes (n)	120, 100, 80, 60, 40, 20 nodes.
Transmission radius (R)	100 m
Average node speed (u)	5 m/sec
Simulation time (T_{sim})	600 sec
Pause time (τ)	0.75*(R/u)

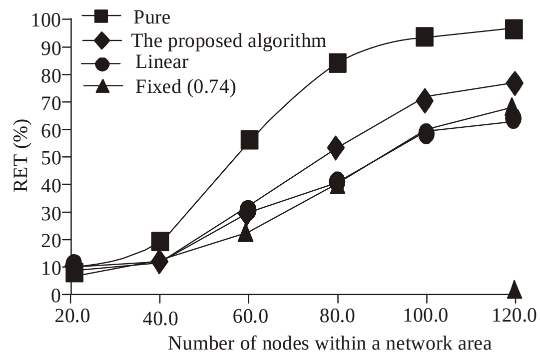

Fig. 5: Variation of ret with number of nodes

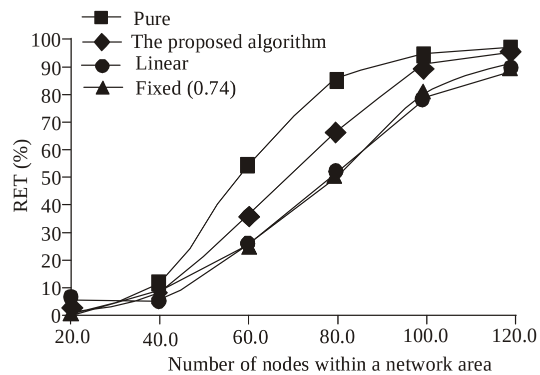

Fig. 6: Variation of RCH with number of nodes

- The variation of Rechability (RCH) which is defined as the average number of reachable nodes by any node on the network normalized to the total number of nodes
- Number of Retransmission (RET) which is defined as the average number of the retransmitted RREQ packets normalized to the total number of nodes

We investigate the variation of RCH and RET with different number of nodes within a network area. The simulation results obtained using the proposed algorithm, are compared with those obtained by using the following flooding optimization algorithms:

- Pure flooding, where (p_t = 1)
- Fixed probabilistic, where (p_t = 0.74)
- A linear mathematical model used by Al-Bahadili (2010)

The input parameters for these simulations are listed in Table 1. The simulations results are plotted in Figure 5 and 6.

The main points that are concluded from this scenario can be summarized as follows:

- For all different algorithms both RCH and RET decrease as number of nodes decreases. This is because the small number of neighboring will cause an insignificant increase in the number of retransmissions.
- It can be seen that the proposed dynamic probabilistic algorithm provides an excellent performance as it can achieve an excellent cost-effective reachability, for various number of nodes, as compared to pure flooding algorithm. Where the RET in the proposed algorithm is always lower than RET in pure flooding.
- For the high node density our proposed algorithm has almost the same reachability as pure flooding at a lower cost of retransmission. For example, when the number of nodes equals to 120, our proposed algorithm achieves the RCH and RET of 96 and 76.3%, respectively, while for the same environment pure flooding achieves 97.6% of RCH and 95.9% of RET.
- The proposed dynamic probabilistic algorithm presents the highest performance in terms of RCH for various numbers of nodes, when compared with the fixed and linear probabilistic algorithms. However, enhancing RCH is paid by increasing RET as shown in Figure 5.
- It is clear that the proposed algorithm achieves its best cost-effective performance within moderate and low node density. For example, when the number of nodes is 100 the proposed algorithm is 10% more than linear algorithm in terms of reachability, while the RET is 13% more. When the number of nodes is 60 the proposed algorithm achieves the reachability of 42.5% and pays cost of RET = 31.8%. In the other hand the linear algorithm achieves reachability of 34.1% and pay cost of RET = 30%. It means that our proposed algorithm achieves 8% more reachability, while it only pays 1% of RET than the linear algorithm.

CONCLUSION

The main conclusion of this study is that the proposed dynamic probabilistic algorithm provided better cost-effective performance than the current fixed and linear probabilistic algorithms. The model can achieve higher reachability with an acceptable increase in retransmission especially within moderate and low node density network. The model can achieve approximately the same network reachability with less redundant retransmissions compared to pure flooding, which is the main objective of any flooding optimization algorithm. For future study it is recommended to investigate the optimum values for the variables N_{max}, p_2 and p_1 on the performance of the new model.

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