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Mobile Ad-hoc Network Internetworking with Next generation Internet

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Abstract: Mobile ad-hoc networks (MANETs) are infrastructure-less dynamic networks allowing mobile nodes to communicate beyond transmission range by supporting multihop communication through IP routing. A MANET connected to the Next generation internet (IPv6) is more useful in enriching the application range of ad-hoc networks. This interconnection is achieved by using an internet router called as gateway, which act as bridges between a MANET and the internet. The concept of Gateway Discovery is introduced into an existing reactive ad-hoc routing protocol AODV with enhancement called as EAODV. In this approach, a source finds a route to the destination either through another mobile node or fixed wired node in internet. Here the intermediate nodes in the MANET just pass the message request to find the default route to the gateway. The packet formats for EAODV are changed and newly added for this scenario. Three methods for gateway discovery are available. The first is a proactive scheme, which allows periodical gateway advertisements to all nodes in the ad-hoc network from the gateway. The second is a reactive scheme, which utilises solicitation and advertisement signaling between a wireless node and the gateway. The third is a hybrid scheme, which allows mobile nodes within a certain range around gateway use proactive, while mobile nodes residing outside this range use reactive gateway discovery to obtain information about the gateway. Simulation results show that with EAODV routing protocol with different gateway discovery approaches display comparable results for packet delivery ratio, Normalized overhead and normalized packet drop. The simulation is performed to test node mobility and movement characteristics in communication between not only mobile nodes in an ad-hoc network, but also between a mobile node in an ad-hoc network and a fixed node in internet.

Key words: AODV, Gateway Discovery, proactive, reactive, hybrid

INTRODUCTION

Availability of small, inexpensive wireless communicating devices has played an important role in moving adhoc networks closer to reality. Consequently, mobile ad-hoc networks (MANETs)[1] are attracting a lot of attention from the research community. Since the field of MANET is still in its developing stage, not many MANETs have been deployed yet. MANETs are advantageous because of their readily deployable nature as they do not need any centralized control or fixed infrastructure. MANETs have been evolving to serve a growing number of applications that rely on multihop wireless infrastructures that can be deployed quickly. The potential applications include emergency disaster relief, battlefield command and control, mine site operations and wireless classrooms or meeting rooms in which participants wish to share information or to acquire data.

Today, advances in wireless technologies such as IEEE 802.11[2], Bluetooth[3] and HiperLAN/2[4] have led to a proliferation of mobile devices. The number of mobile internet devices is expected to reach a billion in the near future[5] and exceed the number of stationary nodes. Therefore, we expect MANETs to be interconnected to the internet in many applications. In this study, we consider a mobile networking environment in which mobile hosts can access the internet directly via one or more gateways or indirectly via other mobile hosts as shown in Fig. 1.

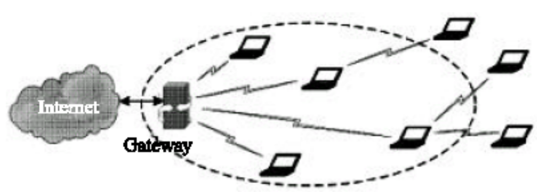

Fig. 1: Mobile ad-hoc network interconnected to internet

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Mobile hosts that are near the gateway can communicate directly with the gateway via single-hop connections. However, mobile hosts that are outside the transmission range of the gateway have to use multihop connections that rely on the neighboring mobile nodes to relay their packets. Thus, a gateway acts as a bridge between a MANET and the internet and all communication between the two networks must pass through any of the gateways. In addition to providing internet access, this network configuration may also serve other practical scenarios; e.g., the gateways may represent nodes that host special services such as Service discovery in local MANET, Domain Name Service (DNS) accessed by other nodes in the MANET.

Various MANET routing protocols are proposed in the recent years. Some of them are categorized as proactive routing protocol, because the routing table of node is periodically exchanged and updated. Some others are classified as reactive routing protocol, since, for each node, the route to destination is on demand discovered only when it is needed. The internet Engineering Task Force (IETF) has proposed several routing protocols for MANET, such as Ad-hoc On-Demand Distance Vector (AODV)[6], Dynamic Source Routing (DSR)[7], Optimized Link State Routing Protocol (OLSR)[8] and Topology Dissemination Based on Reverse-Path Forwarding (TBRPF)[9]. However, these protocols were designed for communication within an autonomous MANET, so a routing protocol needs to be modified in order to achieve routing between a mobile device in a MANET and a host device in a wired network (e.g. the internet). To achieve this network interconnection, gateways that understand not only the IP suite, but also the MANET protocol stack, are needed.

Most of the research in this area is simulation-based. These simulations have several parameters such as the mobility model, traffic pattern, propagation model, etc., to name a few. We acknowledge that these and other factors like channel characteristics, Medium Access Control (MAC) effects, etc., do impact the protocol performance. However, we realize that the study of the interplay of these factors may be very complex. Hence, in this study, we only focus on developing a detailed approach to study the effect of mobility on the performance of reactive MANET routing protocol. AODV has been modified to achieve routing of packets towards a wired network called as Enhanced Ad-hoc On-Demand Distance Vector (EAODV). This study evaluates three approaches for gateway discovery. An interesting question is whether the configuration phase with the gateway should be initiated by the gateway (proactive method), by the mobile node (reactive method) or by mixing these two approaches (hybrid method). The implementation of these three methods with AODV in Network Simulator 2 (ns-2)[10] and compare them by means of simulation. We also discuss the advantages and disadvantages of the three alternatives.

EAODV-PROTOCOL DESCRIPTION

Enhanced Ad-hoc On Demand Distance Vector (EAODV) is a reactive MANET routing protocol where the reactive property implies that a mobile node requests a route only when it needs one. Consequently, the node maintains a routing table containing route entries only to destinations it is currently communicating with. Each route entry contains a number of fields such as Destination IP Address, Next Hop (a neighbor node chosen to forward packets to the destination), Hop Count (the number of hops needed to reach the destination) and Lifetime (the expiration or deletion time of the route). AODV guarantees loop-free routes by using sequence numbers that indicate how fresh a route is?

Route discovery: Whenever a mobile node (source) determines that it needs a route to another node (destination) it broadcasts a route request (RREQ) message and sets a timer to wait for the reception of a route reply (RREP). A node that receives a RREQ creates a reverse route entry for the source in its routing table. Then it checks to determine whether it has received a RREQ with the same Originator IP Address and RREQ ID within the last PATH_DISCOVERY_TIME. If such a RREQ has been received, the node discards the newly received RREQ in order to prevent duplicated RREQs from being forwarded. If the RREQ is not discarded the node continues to process it as follows: If the node is either the destination or if it has an unexpired route to the destination it unicasts a RREP back to the source; otherwise it rebroadcasts the RREQ. If a RREP is generated, any intermediate node along the path back to the source creates a forward route entry for the destination in its routing table and forwards the RREP towards the source.

If the source does not receive any RREP before the RREQ timer expires, it broadcasts a new RREQ with an increased time to live (TTL) value. This technique is called expanding ring search and continues until either a RREP is received or a RREQ with the maximum TTL value is broadcasted. Broadcasting a RREQ with the maximum TTL value is referred to as a network-wide search since the RREQ is disseminated throughout the MANET. If a source performs a network-wide search without receiving any corresponding RREP, it may try again to find a route to the destination, up to a maximum of RREQ_RETRIES times after which the session is aborted.

Route discovery for internet access: Whenever a mobile node is about to communicate with a fixed wired node, it searches its routing table for a route towards the destination. If a route is found, the communication can be established. Otherwise, the mobile node starts a route discovery process by broadcasting a RREQ message as described above. When an intermediate mobile node receives a RREQ message, it searches its routing table for a route towards the wired destination. If a route is found, the intermediate node would normally send a RREP back to the originator of the RREQ. But in that case, the source would think that the destination is a mobile node that can be reached via the intermediate node. It is important that the source knows that the destination is a fixed node and not a mobile node, because these are sometimes processed differently.

The assumption for this problem is preventing the intermediate node to send a RREP back to the originator of the RREQ if the destination is a wired node. Instead, the intermediate node updates its routing table and rebroadcasts the received RREQ message. To determine whether the destination is a wired node or not, an intermediate node consults its routing table. If the next hop address of the destination is a default route the destination is a wired node. Otherwise, the destination is a mobile node or a gateway (Table 1).

Since neither the fixed node nor the mobile nodes in the MANET can reply to the RREQ, it will be rebroadcasted until its TTL value reaches zero. When the timer of the RREQ expires, a new RREQ message is broadcasted with a larger TTL value. However, since the fixed node cannot receive the RREQ message (no matter how large the TTL value is) the source will never receive the RREP message it is waiting for. This assumption for this problem has been solved by letting the source assume the destination is a fixed node if a network wide search has been done without receiving any corresponding RREP. In that case, the source must find a route to a gateway and send its data packets towards the gateway, which will forward them towards the fixed node.

Using the expanding ring search, a considerable route discovery delay will occur if the destination is a fixed node. Modifying the parameters involved in the expanding ring search technique (such as TTL_START and TTL_THRESHOLD) can decrease the route discovery delay if the destination is a fixed node. However, the modification can also result in increased routing overhead if the destination is a mobile node. The modification could for example be to increase TTL_START. Assuming the destination is a fixed node, increasing TTL_START would result in less number of broadcasted RREQs (and consequently less delay) before the source assumes that the destination is a fixed node.

Table 1: Mobile node routing table after creating a route entry for a fixed node

Destination address	Next hop address
Fixed node	Default
Default	Gateway
Gateway	Intermediate Mobile Node (IMN)

Routing maintenance and update: Another issue that must be taken into consideration is how the routing table should be updated after a network-wide search without receiving any corresponding RREP. Once the source has determined that the destination is a fixed node located on the internet, it has to create a route entry for the fixed node in its routing table. If the route entry for the fixed destination would not be created in the routing table, the source would not find the address to the fixed node in its routing table when the next data packet would be generated and hence, the source would have to do another time consuming network-wide search.

The routing table of a mobile node after creation of a route entry for a fixed node should contain three entries (Table 1). First entry should tell the node that the destination is a fixed node since the next hop is specified by the default route aim is to provide route aggregation. The second entry specifies which gateway the node has chosen for its internet connection. The third entry gives information about the next hop towards the gateway. The routing table of an Intermediate Mobile Node (IMN) chosen to forward data packets towards the gateway containing the forward route entries are created for the gateway (the source of the RREP_I) and not for the fixed node, which is the final destination of the data packets. IMN will not find any valid route for the fixed node when it receives data packets from the source. Therefore, it would normally drop the data packets because it does not know how to forward them. In our assumption, if IMN does not find a valid route to the destination and if the destination is a fixed node, it creates a (or updates the) route entry for the fixed node in its routing table and forwards the data packets towards the gateway.

GATEWAY DISCOVERY

The reactive routing approach is the basic approach described by Wakikawa *et al.*[11]. RREP and RREQ messages are extended with a new flag (I) which is used to differentiate control messages used to discover routes to the internet from usual RREP and RREQs. We refer to the new messages as RREP_I and RREQ_I. A source willing to communicate with a node in the fixed network, will first attempt to contact it within the ad-hoc network doing an extended ring search. If no answer is received after a network-wide search, then the source tries to find a route towards the internet. So, it broadcasts a RREQ_I to the ALL_ MANET_GW_MULTICAST address. When a gateway receives a RREQ, it consults its routing table for the destination IP address specified in the RREQ message. If the address is not found, the gateway sends a RREP_I back to the originator of the RREQ. On the other hand, if the gateway finds the destination in its routing table, it unicasts a RREP as normal, but may also optionally send a RREP_I back to the originator of the RREQ. This will provide the mobile node a default route although it has not requested it. Then the source will select one of the gateways (based on the hop count) and will send the data towards the fixed node through that gateway. If the mobile node is to communicate with the internet later, the default route is already established and another time consuming gateway discovery process can be avoided.

Three different gateway discovery approaches based on the dynamic adjustment of the TTL of GWADV (Gateway Advertisement) messages are given by Pedro *et al.*[12].

Proactive gateway discovery: The proactive gateway discovery is initiated by the gateway itself. The gateway periodically broadcasts a gateway advertisement (GWADV) message within the ad-hoc network to inform all the nodes about the availability of that gateway. The period determined by ADVERTISEMENT_INTERVAL, period must be chosen with care so that the network is not flooded unnecessarily. The mobile nodes that receive the advertisement, create a (or update the) route entry for the gateway and then rebroadcast the message. To assure that all mobile nodes within the MANET receive the advertisement, the number of retransmissions is determined by NET_DIAMETER defined by EAODV. Upon reception of a GWADV message, mobile nodes will select their preferred gateway based on the hop count and they will store a default route entry in their routing table.

However, GWADV retransmission by mobile node will lead to enormously many unnecessary duplicated advertisements. A conceivable solution that prevents duplicated advertisements is to introduce a GWADV ID field in the advertisement message format similar to the RREQ ID field in the RREQ message format. The mobile nodes randomize their rebroadcasting of the GWADV message in order to avoid synchronization and subsequent collisions with other nodes' rebroadcasts.

Reactive gateway discovery: The reactive gateway discovery is initiated by a mobile node that is to create or update a route to a gateway. When a source mobile node wants to communicate with a destination, it tries first to find a direct route within the MANET and if it does not manage to do it, it then uses its default route. The mobile node broadcasts a RREQ with an I flag (RREQ_I) to the ALL_MANET_GW_MULTICAST[13] address, i.e. the IP address for the group of all gateways in a MANET. Thus, only the gateways are addressed by this message and only they process it. Intermediate mobile nodes that receive a RREQ_I are not allowed to answer it, so they just rebroadcast it. When a gateway receives a RREQ_I, it unicasts back a RREP_I which, among other things, contains the IP address of the gateway.

Hybrid gateway discovery: The combined approach is hybrid proactive/reactive method for gateway discovery. For mobile nodes in a certain range around a gateway, proactive gateway discovery is used while mobile nodes residing outside this range use reactive gateway discovery to obtain information about the gateway. Gateways will periodically flood TTL-limited GWADV messages which will only be forwarded upto a few hops away from the gateway. The sources within that flooding area, upon reception of the GWADV messages, will behave as in the proactive approach. Those nodes beyond that number of hops will find default routes proactively using the same RREQ I-based reactive scheme described before. So, this approach is somehow a trade-off between the reactive and proactive approaches.

It is reasonable to use the TTL of the GWADV messages as the parameter to adjust depending on the network conditions. The higher the TTL, the higher the overhead due to the periodic advertisement and the lower the overhead associated to the reactive discovery of the internet gateways. That is, the higher the TTL the higher the proactive of the approach. In fact, a TTL = 0 corresponds to the totally reactive approach whereas a TTL = NETWORK DIAMETER corresponds to a completely proactive scheme. The different criteria to determine when the TTL should be adjusted and the rate at which neighbors change or the mean duration of the links can be an indication of the network mobility. However, these kinds of metrics are not usually easy to interpret. In addition, they do not capture one of the key parameters according to our model which is the number of sources.

For a gateway to be aware of the total number of sources communicating with nodes in the internet it is required some kind of signaling mechanism facilitating such information to the gateway. However, that would incur an extra overhead and it is something which can require changes to the routing protocols. So, we propose to use simpler metrics, being able to convey the required information without any additional overhead and being able to be locally computed in real scenarios. If mobility degree increased, probability of packet loss is also increased. In such case active control packet receives warning message and adaptively reduces data packet into more small size to minimize the chance of data packet loss. It is performed in any region where frequent data packet losses are detected or frequent control packet updates occurs.

PERFORMANCE EVALUATION

Here, we present the evaluation of the reactive EAODV routing protocol with gateway discovery approaches reactive, proactive and hybrid ones and compare them. For this evaluation we have conducted extensive simulations of the different schemes under a variety of networking scenarios in ns2 [2.26] network simulator with varying movement patterns and traffic loads.

Simulation scenario: In the present simulation, each gateway will only know about the sources which are accessing to the internet through them. This scheme is very convenient because that information is very easy to learn by the gateway provided that it is routing those datagram that it would receive anyway. The gateways will keep track of the number of hops at which each of its active sources is located. This information is easy to extract by simply looking at the IP header of data packets. Table 2 gives the parameters used during simulation. Mobile nodes start the simulation being static for pause time seconds. Then they pick up a random destination inside the simulation area and start moving to the destination at a speed uniformly distributed between 5 and 25 m s^{-1} (mean speed = 10 m s^{-1}). After reaching its destination this behaviour is repeated until the end of simulation. For each of these pause times 10 different scenarios where simulated. The results were obtained as the mean values over these 10 runs to guarantee a fair comparison among the alternatives.

Table 2: Parameters of simulation

Transmission range	250 m
Simulation area	800 x 500
Simulation time	900 sec
Radio channel capacity	2 Mb s^{-1} (IEEE 802.11 b)
Number of nodes	10-50
Band width	100 MHZ
Traffic type	Constant Bit Rate(CBR)
Packet size	512
Maximum speed	5-25 m sec^{-1}
Packet rate	5 packets/sec
Maximum connections	2-6
Number of gateways	1-6
Number of wired nodes	4
Pause time	10-50 sec
Advertisement_Interval	Varied from 5-50 sec
Advertisement_Zone	3 hops

Performance metrics: To assess the effectiveness of the gateway discovery mechanisms, we have used the following performance metrics:

Packet Delivery Ratio (PDR): Defined as the number of data packets successfully delivered over the number of data packets generated by the sources.

Normalized Overhead: Defined as the total number of control packets, including gateway discovery over the data packets sent during the simulation time.

Normalized Packet Drop: Defined as the total number of data packets dropped over the number of data packets sent, used to measure the reliability of the gateway discovery mechanism.

Simulation results: The simulation results in Fig. 2 shows the mobility characteristics for varying speed conditions the protocol performance in packet delivery ratio is high in reactive approach as the speed increases it decreases and tries to achieve an average of 98%. Proactive is good for low mobility condition but high mobility conditions it is worse. Hybrid approach is a compromise in both low and high mobility conditions. Figure 3 shows the normalized overhead in reactive approach in low and high mobility conditions are providing very low overhead, but in proactive approach overhead is more for low and high mobility conditions. In hybrid approach it is a compromise between low and high mobility conditions. Figure 4 shows the Normalized packet drop is very less for reactive and hybrid approach for low and high mobility conditions, but proactive approach is very high for low and high mobility conditions.

The static characteristics for the same scenario is evaluated with pause time varying in steps and the protocol performance shown in Fig. 5 gives the packet delivery for reactive, proactive and hybrid approaches is

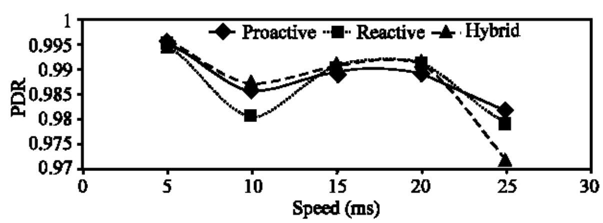

Fig. 2: Packet delivery ratio for varying speed

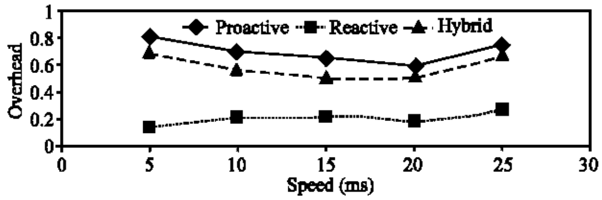

Fig. 3: Normalized routing overhead for varying speed

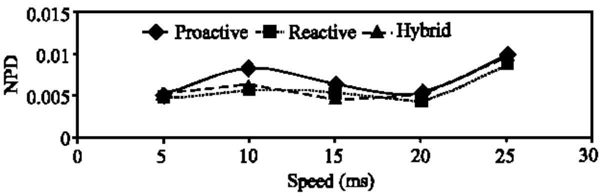

Fig. 4: Normalized packet drop for varying speed

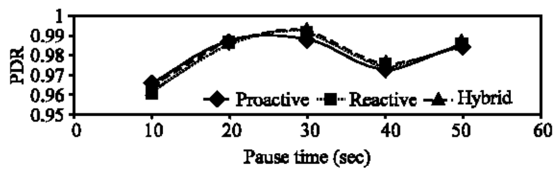

Fig. 5: Packet delivery ratio for varying pause time

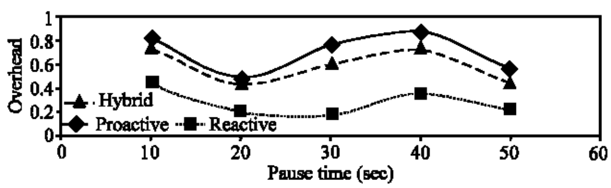

Fig. 6: Normalized routing overhead for varying pause time

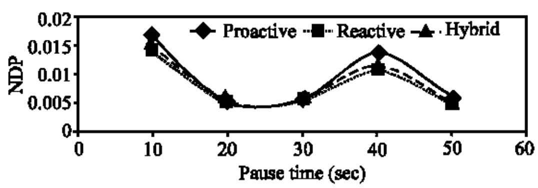

Fig. 7: Normalized packet drop for varying pause time

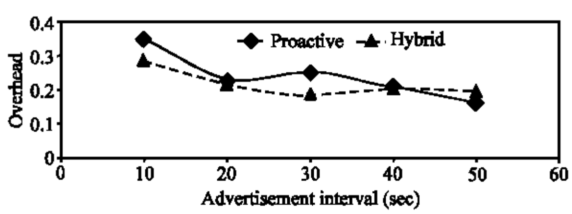

Fig. 8: Normalized overhead for varying advertisement interval

low because of the routing protocol reactive EAODV, but as pause time increases, that is more stationary the nodes, the packet delivery ratio increases for all the same.

Figure 6 gives the Normalized routing overhead for reactive approach is low for less pause times and also remains the same for high pause times. But proactive approach is giving more overhead for low and high pause time values. In hybrid approach which is a compromise between the reactive and proactive for low and high pause times.

The normalized packet drop shown in Fig. 7 is same for all reactive, hybrid and proactive approaches for low and high pause times. The normalized overhead for varying advertisement interval for proactive is less compared to hybrid approach (Fig. 8). The simulation results are matching with the expected results.

CONCLUSIONS

In this study, we have considered internet connectivity of MANETs via internet gateways. The reactive routing protocol to discover route for fixed node in internet using different gateway discovery approaches with varying mobility characteristics, pause times and advertisement intervals are simulated and tested for the scenario. The reactive discovery approach is providing good protocol performance among others. As the nodes are having high mobility all three approaches are varying in the same way. The disadvantage of reactive gateway discovery is that a handover cannot be initiated before a mobile node looses its internet connection. As a consequence, a situation can occur where a mobile node uses a gateway for its internet connection although there are other gateways that are closer. Further work can be done with gateway discovery algorithms for optimum internet gateway selection and Seamless handover.

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