Journal of Advances and Scholarly Researches in Allied Education
Vol. 16, Issue No. 5, April-2019, ISSN 2230-7540

An Analysis on Some Improvement of Routing Protocols in Mobile Ad Hoc Networks

Sudesh Kumari*

Master of Technology, OPJS University, Churu, Rajasthan

Abstract – Wireless ad hoc networks utilize multi-hop radio relaying and are capable of operating without the support of any fixed infrastructure. In Wireless ad hoc networks or Mobile ad hoc networks (MANETs), the responsibility of routing is exchanging the route information and finding a feasible path to a destination. To discover a route to a particular destination node, existing routing protocols can be categorized into three main categories such as Proactive or table-driven routing protocols, Reactive or on-demand routing protocols and Hybrid routing protocols. On-demand routing protocols increase the required path when it is necessary, by using connection establishment technique. The on-demand routing protocols initiate Route discovery (RREQ) packet to discover the path between source node and destination node. Every node receiving the RREQ message will retransmit it to all its neighbors. This broadcasting is referred to as blind flooding. This can lead to unnecessary redundant retransmissions, causing high channel contention and packet collisions in the network, a phenomenon called a broadcast storm.

In existing probabilistic based broadcast algorithms, each forwarding node is permitted to rebroadcast a received packet with a fixed forwarding probability. An innovative probabilistic route discovery method is proposed to decrease the dissemination of route request packets. To improve the fixed probabilistic mechanism, the adjusted route discovery concept is proposed based on the density. If possible, the forwarding probability should be high for a node positioned in a sparse region of the network while comparatively lower for a node situated in a denser region of the network. The performance of this technique is superior than the fixed probabilistic route discovery mechanism.

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INTRODUCTION

Wireless communication networks have a number of advantages compared with the usual wired networks. It can be established connections without a pre-existing wired-communication infrastructure or where it is difficult to put cables. The installation of a wireless network is much cheaper and easier than a wired infrastructure based network. The wireless network is a beautiful option and it gives a flexible and instant communication setup. For example, mobile users can turn on their laptops and PDAs and can immediately connect to the Internet at public places like airports. University campuses and coffee shops. Conference participations can have wireless access to the Internet and can even share presentation files with other attendees.

The wireless communication industry has a number of partitions such as cellular telephony, satellite-based communication, WLANs and Worldwide interoperability for Microwave Access (WiMAX). The IEEE 802.11 standard is the most accepted WLAN standard that classifies the specifications of the first two layers such as physical and Media Access Control (MAC) layer of the Open System Interconnection (OSI) protocol stack and works in the unallocated frequency band 2.4 GHz or 5 GHz of the electromagnetic spectrum.

The IEEE 802.11 standard explains two main wireless networks for WLANs depending on the configurations such as infrastructure-based and infrastructure less-based (or ad hoc) networks. The infrastructure-based WLANs require special devices called Access Points (APs). The APs are linked via existing wired local area networks (LANs). The APs are used to arrange communication between the mobile nodes and wired networks. This configuration is used to give connections for Wi-Fi hotspots. It is used for wireless internet access at airports, conferences and other public places. The set of Mobile Nodes (MN) that are linked with a particular AP is called the Basic Service Set (BSS). To increase the Wi-Fi coverage area, a number of BSSs can be linked jointly which is called Distribution System. The later configuration is referred to as the Extended Service Set (ESS) in the IEEE 802.11 classification. All APs in an ESS are specified the same service set identifier, which serves as a network identification for the network users. The ESS is the grouping of tw'o BSSs. In difference to a wired LAN, mobile nodes in an ESS are not physically connected by cables and may communicate with each other, even though MNs may be in different BSSs, and they may move between BSSs. Setting up of infrastructure based network is associated with huge cost and some difficulty, which may not be acceptable for dynamic environments such as battlefields, disaster sites, temporary conference meetings and vehicles that need to be temporarily interconnected. In these cases, infrastructure less or ad hoc WLANs provide an efficient a new solution. The ad hoc WLANs do not need any fixed infrastructure and require only the mobile nodes to help in a peer-to-peer method to form an Independent Basic Service Set (IBSS) in order to exchange data. The IEEE 802.11 standard is limited to single-hop communication which is only applicable to mobile nodes within a mutual transmission radius.

Today, the processing power and transceiver services of mobile nodes have increased. It has become feasible to increase the communication range of IBSS using the mobile nodes themselves as forwarding agents and relying on the upper layers of the protocol stack for multi-hop paths. This requires the routing mechanisms at each mobile node so that it can forward packets towards proposed destinations, The MNs are acting as router and may form the backbone of unstructured network that extends the range of the ad hoc WLAN outside the transmission range of the source. This later configuration of ad hoc WLANs is popularly referred to as a Wireless Ad Hoc Network or Mobile Ad hoc Network (MANET).

Wireless Ad hoc networks are defined as the category of wireless networks that utilize multi-hop radio relaying and are capable of operating without the support of any fixed infrastructure. The absence of any central coordinator or base station makes the routing a complex one compared to cellular networks. The base station simplifies routing and resource management in a cellular network. The routing decisions are made in centralized manner with more information about the destination node. But in a wireless ad hoc network, the routing and resource management are done in a distributed manner in which all nodes coordinate to enable communication among them. This requires each node to be more intelligent so that it can function both as a network host for transmitting and receiving data and as a network router for routing packets from other nodes. The network topology in MANETs can be highly active because of the movement of nodes and therefore an ongoing communication meeting suffers regular path breaks. The frequent path breaks in a MANET can be due to the movement of nodes in the network. Moreover, it can be due to the ability of nodes to leave or join the network at any time. This can be due to individual random mobility, group mobility, motion along pre-planned routes etc, Establishing and maintaining network connectivity in such a mobile atmosphere will need periodic exchange of network information that leads to a possible increase in communication overhead. As a consequence, routing protocols for MANETs must be able to carry out efficient and successful mobility management.

ROUTING IN MOBILE/WIRELESS AD HOC NETWORKS

Providing capable routing protocols is one of the most significant challenges in Wireless Ad hoc networks and dangerous for the basic operations of the network. A route consists of an ordered set of intermediate nodes that transport a packet across a network from source to destination by forwarding it from one node to the other. One of the characteristic of routing is a challenging job in MANETs. First, the mobility of nodes outcome in a highly dynamic network with quick topological changes creating frequent route failures. Second, the fundamental wireless channel, functioning as a shared medium, gives a much lower and more variable bandwidth to communicating nodes than in wired networks. An effective routing protocol for a MANET environment has dynamically adapted to change network topology. The routing protocol should be considered bandwidth-efficient by reducing the routing control overhead.

Major research has been dedicated to developing routing protocols for wireless ad hoc networks. These protocols can be categorized into three types based on the route discovery and routing information update mechanisms such as proactive (or table driven), reactive (or on-demand driven) and hybrid.

Proactive Routing Protocols -

The authors T. Clausen and P. Jacquet have explained the concept of Proactive routing protocols to maintain reliable and up-to-date routing information from one node to every other node in the network. Topology updates are propagated throughout the network in order to keep up a consistent view of the network. The nodes keeping routes for all destinations have the benefit that communication with random destinations experiences minimal initial delay. Also, a route could be immediately chosen from the route table. These protocols have the disadvantage of generating additional control traffic that is required to continually update stale route entries. Particularly in highly mobile environments, communication overhead acquired to apply a proactive algorithm can be costly.

Classic and well-known examples of proactive routing protocols are destination-sequence distance vector (DSDV) and optimized link state routing (OLSR).

Reactive Routing Protocols -

The Reactive routing protocols projected found routes only when they are needed. When a source node needs a route to a destination, it initiates a route discovery process by flooding the entire network with a Route REQuest (RREQ) packet. Once a route has been recognized by receiving a Route REPly (RREP) packet at the source node, some form of route maintenance process is used to maintain it. until either the destination becomes remote or the route is no longer desired. These protocols use less bandwidth for maintaining the routing tables at every node compared to proactive routing protocols by avoiding unnecessary periodic updates of routing information. Route discovery latency can be seriously increased, which leads to long packet delays before a communication can start. Ad hoc On-demand Distance Vector (AODV) and Dynamic Source Routing (DSR) protocols are reactive routing protocols.

Hybrid Routing -

The hybrid routing protocols is to join the best features of proactive and reactive algorithms. It often consists of the two classical routing protocols such as proactive and reactive. Hybrid protocols split the network into areas called zones which could be overlapping or non-overlapping depending on the zone creation and management algorithm employed by a particular hybrid protocol. The proactive routing protocol operates inside the zones, and is answerable for establishing and maintaining routes to the destinations located within the zones. On the other hand, the reactive protocol is responsible for establishing and maintaining routes to destinations that are located outside the zones. The Zone-based Routing Protocol (ZRP) and Sharp Hybrid Adaptive Routing Protocol (SHARP) are examples of hybrid routing protocols.

BROADCASTING IN WIRELESS AD HOC NETWORKS

Broadcasting or flooding is a necessary operation in wireless ad hoc network. A source node sends the same packet to every other node in the network. In multi-hop MANETs where all the nodes may not be within the transmission range of the source, intermediate nodes may require to assist in the broadcast operation by retransmitting the broadcasting packet to other remote nodes in the network. In conventional broadcast settings, the propagation of packets utilizes valuable network resources such as node power and bandwidth. Therefore, it is important to carefully choose the intermediate nodes so as to avoid redundancy in the dissemination process.

Broadcasting at the physical layer can be supported on two transmission models in one-to-all model and the one-to-one model. In the one-to-all model, transmission by each node can reach all nodes that are within its transmission radius. In the one-to-one model, each transmission is going towards only one neighbor using narrow beam directional antennas or separate frequencies for each node. But, broadcasting has been considered in the literature mainly for the one-to-all model. This is primarily because most of the current mobile devices have omni-directional antenna implementation where the communication signal is propagated and received from all directions.

Broadcasting at the network layer has many important uses and a number of MANET protocols guess the availability of broadcast service. Applications that rely on broadcasting include paging a particular node or information dissemination to the whole network. Furthermore, broadcasting is the backbone of most network layer protocols, providing important network management control and route organization functionality. Broad casting techniques are used in the routing protocols AODV, DSR and ZRP to establish routes. Other routing protocols, Temporally-Ordered Routing Algorithm (TORA), used broadcast techniques to disseminate error packets for broken links in the entire network.

Broadcasting is also often used as a building block for multicast protocols. Some broadcast approaches have been suggested in the literature survey including probabilistic, counter-based, location-based and neighbor-knowledge-based approaches. In the case of probabilistic approaches, a node rebroadcasts the packets according to a certain probability. In counter-based approaches, a node rebroadcasts a packet only when the number of duplicate packets expected at the node is less than a certain counter-threshold value. The location-based approaches reduce the number of forwarding nodes by exploiting the geographic information of the network using location information assisted devices called as GPS receivers. In neighbor-knowledge-based approaches, periodic swap over neighborhood information among nodes in the network is used to reduce the redundant transmission of broadcast packets.

ROUTE DISCOVERY METHOD

In traditional on-demand routing protocols similar to AODV and DSR, route request (RREQ) packets are disseminated all over the network to search a particular destination. Each node promotes a received RREQ packet once, until a destination is reached. This technique of route discovery is identified as simple flooding, In on-demand routing protocols, once a route to a destination has been recognized, all the intermediate nodes along the route hold to the forwarding tasks of data packets.

For that, some of the RREQ packet transmissions linked with a route discovery is unnecessary. The number of retransmissions of RREQ packets during the route discovery procedure can seriously affect the performance of the routing protocol in communication overhead and end-to-end delay.

To decrease the communication overhead linked with the dissemination of broadcast packets in "pure" broadcast scenarios are maintaining the acceptable level of reachability. The probabilistic approaches have been projected in the literature as an alternative to simple flooding. The probabilistic schemes receiving a broadcast packet for the first time, a node forwards the packet with a pre-determined forwarding probability ‘p’ and drops the packet with the probability 1-p. Every forwarding node is allocated the same forwarding probability ‘p‘ when the probabilistic scheme reduces to simple flooding p=l.

The properties of network density and mobility on probabilistic flooding in a pure broadcast scenario have been analyzed over a wide range of forwarding probabilities. M. A. Spohn and J. J. Garcia-Luna-Aceves have explained that probabilistic broadcast algorithms can achieve improvements in conditions of saved rebroadcast in high mobility and dense networks. There has not been a learning that estimates the performance impact of probabilistic broadcast on practical applications such as route discovery over a wide range of forwarding probabilities and varying network operating situation, particularly, network density, node mobility, traffic load and network size.

In probabilistic route discovery, each received RREQ packet is forwarded once with the forwarding probability ‘p'. The performance analysis is carried out over a range of forwarding probabilities from 0.1 to 1 in steps of 0.1. This simulation study is the first estimation to be reported in the literature and will help to provide insight into the potential performance discrepancies of the two routing protocols and, considerably, to outline the relative performance of the various forwarding probabilities under varying network operating conditions. The performance analysis is conducted using performance metrics like throughput, delivery ratio, network connectivity, end-to-end delay, routing overhead and collision rate.

In this study, mobile nodes move according to the widely used random waypoint mobility model, where each node at the starting of the simulation remains stationary for pause time seconds, then selects a random destination and starts moving towards it with a speed chosen from a uniform distribution. After the node reaches its destination, it again stands still for a pause time interval and picks up a new random destination. This series repeats until the simulation terminates. The maximum speed is varied for each simulation scenario from Im/sec to 25m/sec which are measured to allow constant mobility. Other simulation parameters used in this research have been extensively adopted in existing performance evaluation studies of MANETs. The table 3.1 illustrates system parameters in simulation experiments.

Each randomly generated topology characterizes an experimental trial.

Different numbers of tests were first considered and it was observed that the means of 20, 25 and 30 tests are within the same confidence gap of 95% confidence level. Thus the statistics have been collected using a 95% confidence level over 30 randomly generated topologies which have been found to have the lowest relative error evaluated with the 20 and 25 topologies.

Analysis of Fixed Probabilistic Route Discovery-

This part conducts a performance relationship analysis of the fixed probabilistic route discovery method in both AODV and DSR. The present AODV and DSR implementations of the Ns-2 simulator, which are applied according to the RFC-AODV and RFC-DSR correspondingly, have been modified in order to implement the Fixed Probabilistic route discovery. Such implementations of AODV and DSR are referred to as FP-AODV and FP-DSR. In each of the modified routing protocols, a route discovery process is started when the source node needs to send a data packet, but does not have a valid route to the destination, or when an active route to the destination is broken.

Network Density of FP-AODV - This section presents the performance impact of network density on FP-AODV and FP-DSR over dissimilar forwarding probabilities. The network density has been varied by deploying 100 and 150 nodes over a fixed area of 1000m X 1000m for dissimilar forwarding probabilities. Each node in the network moves with a speed randomly chosen between 0 and 20m/sec. 10 equal random sources to destination connections, each generating 4 data packets per second. The packet size is 512 bytes. In the simulated graph result, the x-axis represents the variations of forwarding probabilities, while the y-axis represents the performance metric.

Node Mobility of FP-AODV - This section displays the properties of node mobility on the performance of FP-AODV and FP-DSR. In this research, 150 nodes are placed over 1000m x lOOOm with each node moving according to the random waypoint mobility model with a maximum node speed. The node mobility is calculated based on the node speed. For each simulation scenario, 10 identical round randomly selected source to destination relations are used in Ns-2.

Traffic Load of FP-AODV - This section demonstrates the effects of traffic load on the performance of FP- AODV and FP-DSR for different forwarding probabilities which are discussed in this section. In this study, 150 nodes are located over 1000m x 1000m and each node is moving according to the random way point mobility model with a maximum speed of 20m/s. To examine the impact of traffic load, the numbers of source to destination connections have been mixed of 5 and 10 flows. The source and destination pair for each of the connections is selected at random and consists of a CBR flow from the source to destination.

ROUTE DISCOVERY WITH FIXED PROBABILITY

The traditional on-demand route discovery process used in AODV and DSR can be significantly reduced by allowing each node in the network to rebroadcast an established RREQ packet with a given forwarding probability. The traditional on-demand routing protocols rely on simple flooding for the dissemination of the RREQ packets. In simple flooding, every node rebroadcasts a received RREQ packet that is received for the first time and rejects any subsequent duplicate packets. In fixed probabilistic route discovery, each forwarding node is permitted to rebroadcast a received packet with a fixed forwarding probability regardless of its relative location with respect to the locations of the source and destination.

In this study, a new probabilistic route discovery approach is introduced. The new approach decreases the routing overhead by localizing the dissemination of RREQ packets to a limited area in the network where the destination is estimated to be located. This is achieved by making bright use of routing histories at forwarding nodes and the fundamentals of both fixed probabilistic and flooding-based route discovery approaches. The forwarding history at a node represents the last proved time at which the node forwarded a packet on behalf of a particular source to destination pair.

The performance analysis of the new probabilistic route discovery approach, referred to as Route Discovery with Fixed probability and Simple Flooding (FF-AODV) has been carried out by comparing it against the traditional AODV and its fixed probabilistic variant (FP-AODV).

The new algorithm combines the characteristics of two route discovery approaches such as fixed probabilistic approach and simple flooding. It makes use of two sets of network information, routing histories and neighborhood information at mobile nodes. The route discovery algorithm is divided into two phases; the discovery phase and the maintenance phase. The route discovery phase is used to identify the route based on the fixed probabilistic route discovery. But, the route maintenance phase reinitiates the route discovery processes whenever the existing route is broken and hence finds optimal path.

Route Discovery Phase -

The route discovery phase is started whenever a node needs to communicate with another node. It does not have a known route or prior routing history. The source node broadcasts an RREQ packet to its 1-hop neighbors. Each neighboring node that receives the RREQ packet forwards it to its neighbors with a forwarding probability ‘p ’ and drops it with a probability 1-p. The procedure of dissemination continues until the RREQ packet is received by the destination or a node with a suitable route to the destination. The destination replies by sending the RREP packet. The RREP packet is unicast towards the source node along the reverse path set-up by the forwarded RREQ packet. Each intermediate node that contributes in forwarding the RREP packet creates a forward route pointing towards the destination.

Route Maintenance Phase -

Route maintenance starts when there is a change in the network topology which changes the validity of an active route. Once an active node identifies that the next hop towards the destination is unreachable, it disseminates a route error packet to inform the source node and other active nodes on the path which has no longer valid. The affected paths are subsequently deleted from all the nodes that established the route error packet. The source node upon receiving the route error packet begins a new route discovery process using the fixed probabilistic and the simple flooding-based route discoveries. Furthermore, the process exploits the prior routing history information collected at active nodes just before the route was considered invalid.

Choosing the Forwarding Probabilities -

To estimate the performance of the new probabilistic route discovery, the present AODV implementation of the NS-2 simulator has been modified to integrate the new probabilistic route discovery and the results are evaluated against the traditional AODV and its fixed probabilistic variant (FP-AODV).

In the traditional AODV, a specified node rebroadcasts a received RREQ packet once and drops all the duplicate packets received. As a result, there are N-2 possible rebroadcasts of an RREQ packet, if no intermediate node has a valid route to the destination and ‘N’ is the number of nodes in the Network. In the case of FP-AODV, a received RREQ packet at a node is forwarded based on a fixed forwarding probability, ‘p’. The node to forward a packet is independent of the others, the total number of possible retransmissions is p x (N-2), with assumption that the destination node exists. But there is no intermediate which node has a valid route to the destination. The FF-AODV utilizes two different fixed-value probabilities, each assigned at a node based on the state of the routing history at the node.

DYNAMIC PROBABILISTIC ROUTE DISCOVERY

The fixed and adjusted probabilistic route discovery approaches are used for prearranged forwarding probabilities. The probabilistic route discovery approach joins the functionalities of both the fixed probabilistic route discovery approach in FP-AODV and simple flooding based route discovery in the traditional AODV. The performance of the probabilistic route discovery could be improved when the local neighbor density of the forwarding node is developed. In this study, a new probabilistic route discovery approach is proposed to as dynamic probabilistic route discovery (DPR). The nodes in DPR dynamically calculate their forwarding probabilities using a probability function which depends on the local neighbor thickness at a forwarding node and the number of its neighbors that have been covered by the broadcast.

Dynamic Probabilistic Route Discovery method-

The probability function of the DPR algorithm depends on the node density and the enclosed node set (i.e. the set of neighbors that have received the broadcast packets) at a forwarding node. It is critical to incorporate a neighborhood information gathering algorithm in order to use the functionalities of the DPR algorithm. Like the AP-AODV, the DPR algorithm first divides the network into sparse and dense networks using the local neighbor density at a node. The nodes in the sparse networks are permitted to forward the broadcast packet with a probability p = 1, while in a dense network the node is permitted to forward the broadcast packet with a probability p < 1, which is determined by the neighbor density at the forwarding node and the covered neighbor set.

The use of covered neighbor set to control the dissemination of broadcast packets has been planned in broadcasting with self-pruning. According to the design of the self-pruning scheme, each node before forwarding the broadcast packet attached the set of its 1-hop neighbors. When node 'X' accepts the broadcast packet from node ‘Y* for the first time, it chooses to rebroadcast the packet according to the status of the set N(X) -N(Y). If the set N(X) -N(Y) is vacant (i.e. when node ‘X' cannot cover new neighbors), node ‘X* refrains from retransmitting the broadcast packet.

Performance Analysis of DPR-AODV -

To estimate the performance of the dynamic probabilistic route discovery algorithm (i.e. DPR), the implementation of the AODV routing protocol in the Ns-2 simulator has been modified to integrate the functionality of the DPR algorithm and the self-pruning algorithm. The modifications of the traditional AODV have been referred to as DPR-AODV and SP-AODV respectively. The simulation outcome of DPR-AODV and SP-AODV are evaluated against the traditional AODV and its fixed probabilistic variant (i.e. FP-AODV).

The performance metrics that have been considered to perform the performance analysis include the routing overhead in terms of packets, routing overhead in terms of bytes, collision rate, normalized network throughput, end-to-end delay and route discovery delay.

CONCLUSION

The majority broadcast algorithms proposed in the Hterature have been studied in limited scenarios where the network traffic consists of broadcast packets only. The route discovery processes are in on-demand routing protocols used to delivering a data packets to a particular node. The first part of this research has analyzed the performance of fixed-value probabilistic route discovery considering important system parameters of a MANET, network density, offered traffic, and node mobility over a wide range of prearranged forwarding probabilities. Extensive simulation analysis has exposed the given set of system parameters, the performance of the probabilistic versions of the two routing protocols FP-AODV and FP-DSR. These can be enhanced significantly with appropriate forwarding probabilities for route discovery processes.

In the fixed probabilistic route discovery, each node forwards an RREQ packet that is received for the first time according to a fixed forwarding probability. But. the network topology in MANETs is highly dynamic due to the movements of nodes in the network. The node distribution is often chance and changes frequently. So, the forwarding probability should be set dynamically to return the local topological characteristics of a given node. The adjusted forwarding probability AP-AODV is used at a node based on its 1-hop neighborhood information. To get accurate and up-to-date node information, periodic exchange of “hello" packets among neighboring nodes, previously executed in the AODV has been used.

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Corresponding Author

Sudesh Kumari*

Master of Technology, OPJS University, Churu, Rajasthan