REDUCED LATENCY IN RESTRICTED FLOODING ROUTING PROTOCOL FOR MOBILE AD HOC NETWORK

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Abstract - Packet delivery and latency are several performance metrics used to determine the effectiveness of a new routing algorithm. The multiple access protocol in Mobile Ad Hoc Network (MANET) requires nodes to contend for the shared medium when transmitting route request (RREQ) in the route discovery phase and this will create a broadcast storm which increases the probability of packet collisions despite utilizing the normal access technique for wireless networks. With location information of the destination node, the source node and also of the current node, RREQ will be more directed towards destination since nodes that are within the directed region will participate in the routing process. This paper presents Quadrant-based directional routing protocol (Q-DIR) algorithm that restrict the broadcast region to a quadrant where the destination node and source node are located. With Q-DIR as a pure reactive routing protocol which is a modified AODVbis, latency of packets will be further reduced and consequently, increases the delivery ratio. This paper will present the performance of Q-DIR in a network of 49 nodes of which the nodes are static.

Keywords: Restricted flooding, AODVbis, Quadrant-based directional routing.

1. Introduction

Mobile Ad Hoc Network (MANET) is a peer to peer wireless infrastructure less network where communication among nodes can be made and setup almost immediately especially in emergency and disaster operations, military battlefield and even in a building for security and surveillance [1,2].

Many routing protocols were proposed that are based on topology and recently, based on position to determine the route to destination. Position-based routing protocols uses location information from a location service and nodes are aware of their locations. Position-based protocols are further categorized into greedy forwarding and restricted flooding [3]. In greedy forwarding [4], based on location information of the destination node, a selection process by the source node will be made of the node with the best progress towards the destination. After the selection process, the data packet is unicast to the selected node. This process will continue until the data packet reaches the destination. Greedy forwarding only works in a specific topology as stated in [3] and several work proposed recovery techniques to overcome voids. On the other hand, restricted flooding identifies a limited number of nodes in a certain geographic region that will participate in the route discovery and not network-wide participation. The RREQ packet is first broadcast and metrics such as distance, the area located and forwarding zone information are computed at the respective nodes to determine their participation. Participating nodes will then broadcast the packet and the process is repeated at each intermediate node until it reaches the destination.

The routing protocols proposed so far require complex mathematical computation at each node and to consider a simple and implemental algorithm in the kernel space, we propose Q-DIR which utilizes a simple mathematical computation in the kernel environment which does not incur processing delay if it were developed in the user space.

The remainder of this paper is organized as follows. Section 2 will present related work on restricted flooding in position-based routing protocol and test bed implementation of MANET routing protocols. The algorithm and verification of Q-DIR via simulation and implementation will be described in Section 3. Section 4 will present the simulation of the 49 nodes network model and Section 5 will present the results followed by Section 6 which concludes the paper.

2. Related Work

With the advent of Global Positioning System (GPS) [5] and MANET environment-based self-

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positioning [6] and remote-positioning system [7, 8], location information can be easily disseminated to the requesting node as required in the position-based routing protocol.

2.1 Restricted flooding

In [9, 10, and 11], distance from the node to the destination is used to determine nodes participation in the route discovery process. Nodes that are further away from source will not participate. LAR [9] calculates distance from the destination based on location information of the destination that will be extracted from the request packet while [10] uses the relative neighborhood graph (RNG) which together with local information of distance to neighbours and distances between neighbours will minimize the total energy consumption while still maintaining the whole network coverage through broadcasting. LGF [11] calculates distances to all nodes in the network and will compare the distance information of the source to the destination extracted from the request packet to determine its participation. On the other hand, ARP [12] and DREAM [13] uses the angle made from the straight line drawn from source to destination as the restricted region whereby all nodes in this region will participate in the route discovery. However, DDB [14] uses the location information of the destination node and also of the intermediate node which are inserted in the request packet. With this additional information, an intermediate node can calculate the estimated additional covered area that it would cover with its transmission which is based on Dynamic Forwarding Delay (DFD). The concept of DFD is to determine when to forward the packet and node with more area covered will be given a smaller delay to broadcast and hence, will broadcast it first.

All the proposed protocols require computation of the distance and angle at all intermediate nodes to determine the nodes that are located in the forwarding region. Location information of destination node is sent in the request packet as in [9, 10, 11, 12 and 13] but [14] send the location of source node as well.

2.2 Implementation Environment

There are two approaches to consider when developing a MANET test bed; kernel environment or the user space. Several test bed implementation were developed as reported in [15] that shows that developing MANET routing protocol in the kernel reduces the user-kernel crossings inherent in user domain test bed implementation. However, complex mathematical computation in kernel cannot be employed due to the floating point problem [16].

Therefore, test bed implementation in the kernel environment is the best approach but simple computations are required. It is shown in [14] that by inserting location information of the source node or the previous intermediate node in the data packet, periodic beaconing can be eliminated which will reduce further the routing overhead.

2.3 Underlying Routing Protocol

Among the reactive protocols that are actively researched and in fact have been upgraded to Recommended for Comments (RFC) in the Internet Engineering Task Force (IETF) are Ad-hoc On-demand Distance Vector (AODV) [17] and Dynamic Source Routing (DSR) [18]. Between them, there are several drawbacks and advantages and work to converge these two protocols are submitted to IETF as an Internet-Draft and are called AODVbis [19] which was based on the work reported in [20]. The protocol optimizes AODV to perform effectively in terms of routing overhead and delay during high load. The differences between AODVbis and AODV are path accumulation in the RREQ and RREP packet, more efficient beaconing, adding Originator Sequence Number in RREP and lastly, removal of precursors list. Therefore, considering the mathematical computation constraints in the kernel environment, a simple comparison made on-the fly with the relevant location information extracted from the request packet will be used as being proposed in Q-DIR. With restricted flooding based on quadrant, and the path accumulation feature in AODVbis, the number of nodes participating in the route discovery will be reduced and hence reduces the routing overhead, and consequently total power consumption. Figure 1 show the participating nodes if total flooding is employed that will result in the more routing packets being broadcast in the network. On the other hand, if restricted flooding is employed, less nodes will participate in the routing process which will reduce the number of routing packets that traverse through the network.

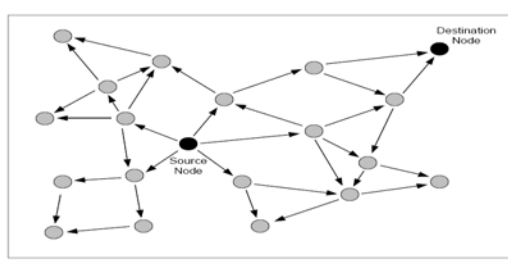

Figure 1. Participating nodes in total flooding algorithm.

3. Quadrant-based Directional Routing Protocol (Q-DIR)

Q-DIR is a restricted flooding routing protocol that concentrates on a specified zone using location information provided by a location service. In Q-DIR operation, the location information of the source and destination nodes is piggy-backed in the route request (RREQ) packet and then broadcasted.

Upon receiving the RREQ, intermediate nodes will compare using a simple mathematical comparison based on the coordinates of source, destination and the current node that directs the packet towards the destination. This mathematical processing will be done in the kernel environment to eliminate the cross-over from user to kernel space and vice versa. The decision to participate is made immediately and a neighbors table is not required.

Once the decision to broadcast has been made, the intermediate node will insert its location by replacing the source node coordinates and append its address and sequence number at the end of the RREQ packet. It will then broadcast the packet. The process will repeat at each intermediate node until it reaches the destination. The replacement of the source node location information with the intermediate node coordinates will make the packet more directed towards the destination since the comparison now is based on the previous node.

Destination node will send a route reply message (RREP) back to source via the path taken to reach the destination that was appended in the RREQ as it traverses across the network. There is no need for the route discovery to the source node.

The test bed implementation of Q-DIR has been successfully been developed as reported in [21] that shows that the there is a reduction in end-to-end delay while maintaining a comparable delivery ratio. However, in order to study the performance of Q-DIR in a large network, the algorithm needs to be simulated.

4. Simulation of Q-DIR

Ns-2 [22] which is a discrete event simulator written in C++ and uses Massachusetts Institute of Technology (MIT) Object Tool Command Language (OTcl) as a command and configuration interface. Compared to other simulation tools, such as Opnet and QualNet, ns-2 is widely used and easily downloaded. There is a one to one correspondence between the compiled C++ hierarchy and the interpreted OTcl. Since our work involves routing, we need to develop the algorithm in the compiled C++ hierarchy and compiled it through commands *make* and *make clean* in the Linux OS.

A network of 6 nodes as shown in Figure 2 is used to verify that the algorithm works and the coordinates are carefully chosen so that there will be at least 2-hops transmission to the destination. The imaginary *x*- and *y*-axis are drawn to show in which quadrant the nodes are located with reference to their immediate neighbors. Based on the transmission range set at 30m, nodes 1, 2, 3 and 4 are neighbors of node 0 while nodes 0 and nodes 5 are neighbors of node 2.

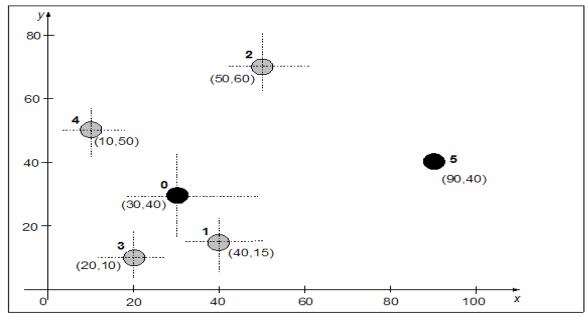

Figure 2. Verification network model

The simulation configuration parameters used in the simulation conforms to the Internet-Draft [19]. The maximum number of hops between nodes has been set to 10 while the estimated average of one hop traversal time is set to 0.6 s.

The MAC layer protocol used is IEEE 802.11 DCF CSMA/CA. The data rate has been set to 2 Mbps and the network protocol is IP. The path loss model used is the log-normal path loss model [23]. The receive threshold power is set as 1.20475e-08 watts to enable reception within 30m distance. The data packet length has been set to 1000 bytes with a CBR (Constant Bit Rate) traffic pattern.

The simulation was run and messages displayed show that nodes 1, 2, 3 and 4 will all receive the RREQ packet from source node 0 destined for destination node 5. However, nodes 1, 3, and 4 will drop the packet since they are in different quadrant from the source and destination. The snapshot of the decisions made when running the simulation shows that node 1, 3 and 4 drop the RREQ received from source node 0. On the other hand, node 2 forwards the packet to destination node since it is in the same quadrant as destination compared to source. The results shows that the algorithm is functioning as proposed.

5. Simulation Results

A scenario was simulated to study the effect of varying packet transmission rate. The two protocols that were simulated are AODVbis which is a total flooding protocol and Q-DIR which is based on restricted flooding. The performance metric used:

- *Delivery ratio* – The ratio of the number of successfully received data packets by the destination to the number of data packets transmitted by the source. Packets originate from the application layer or Agent level in ns2 and said to arrive until it reaches the Agent level of the destination.
- *End-to-end delay* - The delay experienced by a packet from the time it was sent by a source till the time it was received at the destination.

Figure 3 shows a network model of 49 nodes that forms a 7 by 7 grid model where the distance from adjacent nodes are 30m. Based on this grid model, the density is 1 node per 661m^2. This grid model is the densely populated model which reflects the worst case scenario for a network model. In reality, the distribution of the nodes is less dense. In the network model, the x- and y-axis of the Cartesian coordinate system have been drawn to denote in which quadrant the nodes are located. The source and destination are denoted by the letter S and D respectively and destination node is at the top right edge of the grid.

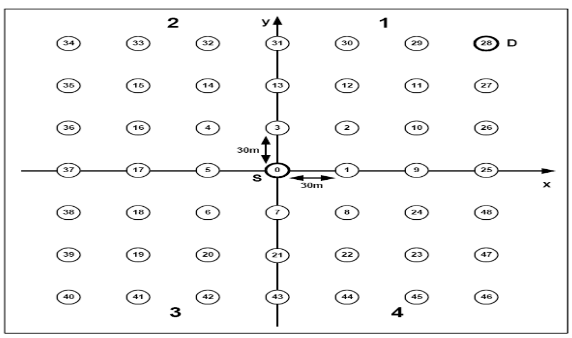

Figure 3. Simulation Network Model of 49 nodes

5.1 Effect of Varying Transmission Rate

Both AODVbis and Q-DIR routing protocols are simulated in the 49 nodes topology for a simulation time of 400s because the performance of both protocols are constant. The transmission rate was varied in steps of 32 kbits/s with initial rate of 16 kbits/s to a maximum of 144 kbits/s. Figure 4 shows the graphs for percentage of packet delivery in AODVbis and Q-DIR as a function of varying transmission rate. In the 49 nodes topology, the delivery ratio slides even further down to 4% in AODVbis and 4.9% in Q-DIR. The decrease in delivery ratio as the number of nodes and the transmission rate increases is mainly due to more packets transmission and more nodes in the network thus causing higher probability of collisions and packet loss which pose a problem in densely populated network. However, performance of Q-DIR is 22.5 % higher compared to AODVbis.

Figure 5 shows the graphs for end-to-end delay for both AODVbis and Q-DIR protocols. AODVbis requires an average of 154 ms for a data packet to reach destination while Q-DIR takes 132 ms. Q-DIR takes 16.67% less time in the 49 nodes compared to AODVbis.

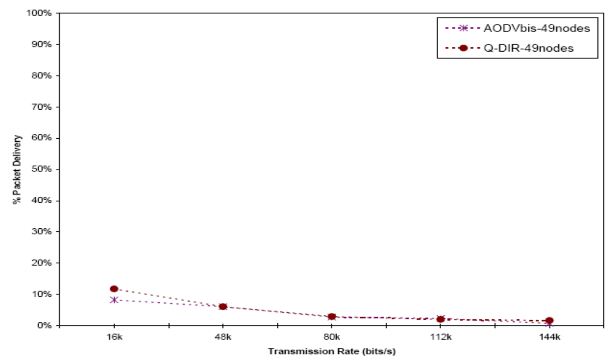

Figure 4. Delivery ratio with varying transmission rate.

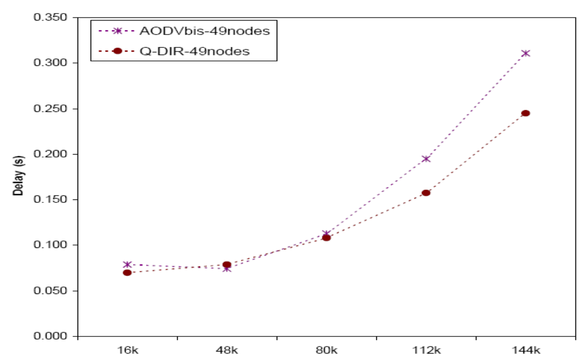

Figure 5. End-to-end delay with varying transmission rate.

6. Conclusion and Future Work

This paper has presented the performance of Q-DIR which is a restricted flooding algorithm which uses location information of the source, destination and the intermediate node to determine the broadcasting decision. Nodes that are in the restricted broadcast region will broadcast while other nodes which are out of this region will ignore the RREQ packet. The simple mathematical comparison is implemental in the kernel environment which does not incur processing delay due the crossing from user to kernel space and vice versa. The simulation results shows that implementing Q-DIR increases the delivery by 22.5% as the transmission rate increases compared to AODVbis. Q-DIR also showed a reduced latency of 16.67% less time as the packet transmission rate is increased. The restricted flooding and directional routing reduces the number of participating nodes as the RREQ traverses in the network towards the destination node and hence reduces delay while maintaining a comparable delivery ratio for a densely populated network.

The authors intend to study the performance of Q-DIR if nodes are mobile which hope to verify the robustness of Q-DIR.

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