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POWER REDUCTION QUADRANT-BASED DIRECTIONAL ROUTING PROTOCOL (Q-DIR) IN MOBILE AD HOC NETWORK

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ABSTRACT

Flooding of request packet in the route discovery phase in Mobile Ad Hoc Network (MANET) creates a broadcast storm which increases the probability of packet collisions. With location information of the destination node, the source node and also of the current node, route request will be more directed towards destination since nodes that are within the directed region will participate in the routing process. Hence, nodes that are out of the trajectory will ignore the packet and thus reduces the number of broadcasting nodes and consequently, less probability of collisions. This paper presents Quadrant-based directional routing protocol (Q-DIR) algorithm that limits the broadcast region to a quadrant where the destination node and source node are located. Q-DIR utilizes location information of the destination node, the source node and the current node. With Q-DIR as a reactive routing protocol, routing overhead will be reduced and consequently, reduces total network power consumption through limited flooding. This paper will present the performance of Q-DIR in a densely populated network of 49 nodes.

KEY WORDS

Position-based routing protocol, restricted flooding, AODVbis, Quadrant-based directional routing.

1. Introduction

Mobile Ad Hoc Network (MANET) is a peer to peer wireless infrastructureless 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].

Routing in MANET is a challenging task because of the mobility of nodes and more than 50 MANET routing protocols have been proposed. Various routing metrics usually used are shortest path, link stability and minimum number of hops towards the destination. But, recent routing metrics that have been extensively researched are power conservation and optimized bandwidth because mobile nodes in MANET are stand-alone devices and operate on batteries.

Routing protocol in MANET can be categorized into topology-based [3] and position-based protocols [4]. In the former, on-demand or proactive flooding of route request (RREQ) are broadcast at each node to all neighbors to detect routes and are generally considered to be not scalable. However, in position-based protocol, routing is optimized by making use of geographical information available at each node. The location information of the destination are assume available by a position service while location information of the neighbors are made known through beaconing to all neighbors. It is assumed that nodes can locate themselves via self-positioning system or remote positioning system proposed so far. Position-based protocols are further categorized into greedy forwarding and restricted flooding [4]. In greedy forwarding [5], based on location information of the destination node, source node will select the node with the best progress towards the destination. The location information of the destination will then be inserted in their data packet and unicast to the selected node. Upon receiving the unicast data packet, the selected node will then select the best node among its neighbors and the process continues until the data packet reaches the destination. Greedy forwarding only works in specific topology as stated in [4] and several work proposed recovery techniques to overcome voids. However, with location information, restricted flooding can be implemented whereby limited nodes will participate in the flooding and not network-wide participation. As the name implies, in restricted flooding, nodes that are located nearer to the destination or in a forwarding zone, will broadcast the packet. Distance and forwarding zone information are computed at the respective nodes to determine their progress towards destination. These 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 and to consider test bed implementation of the routing protocol in the kernel environment, these computations will incur further processing delay in the current node [6, 7]. In addition, position-based protocol requires local topology updates via periodic beaconing among the neighbors. It is shown in [8] 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.

Based on these factors, we proposed Q-DIR that will limit the broadcast area to a quadrant where the source node and destination are located. This algorithm will only require a simple mathematical computation in the kernel environment which does not incur processing delay but in fact further reduces the end-to-end delay due to path accumulation (PA) feature [9,10]. This paper will present the algorithm of Q-DIR and the simulation work carried out in a dense network of 49 nodes. The effect of varying simulation time and varying transmission rate are studied and analyzed. 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 of Q-DIR will be described in Section 3 followed by Section 4 which will present the network simulation 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) [11] and MANET environment-based self-positioning [12] and remote-positioning system [13, 14], location information can be easily disseminated to the requesting node as required in the position-based routing protocol. Only Position-based routing protocols utilizes location information of the destination node to select the node with the best progress as in greedy forwarding or to limit the flooding region based on distance, angle and distance covered by the next intermediate node. It also requires an up-to-date local topology via periodic beaconing. Hence, the route discovery can be eliminated and only data packet forwarding are employed until it reaches the destination. In this paper, only restricted flooding routing protocols are considered.

A. Restricted flooding

In [15, 16, and 17], 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 [15] calculates distance from the destination based on location information of the destination that will be extracted from the request packet while [16] 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 [17] 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 [18] and DREAM [19] 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 [8] 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 [15, 16, 17, 18 and 19] but [8] send the source node as well.

B. Implementation Environment

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) [20] and Dynamic Source Routing (DSR) [21]. 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 [9] which was based on the work reported in [22]. 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.

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 [7] 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 [23].

Therefore, considering the mathematical computation constraints by the kernel environment, a simple comparison made on-the fly with the relevant location information extracted from the request packet will be used as proposed in Q-DIR. This information will determine the quadrant both source and destination node are located and intermediate nodes that received this broadcast will compare its location compared to source and destination and then decide to broadcast or not. 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 based on the same quadrant an intermediate is located compared to source and destination, less nodes will participate in the routing process which will reduce the number of routing packets that traverse through the network as shown in Figure 2.

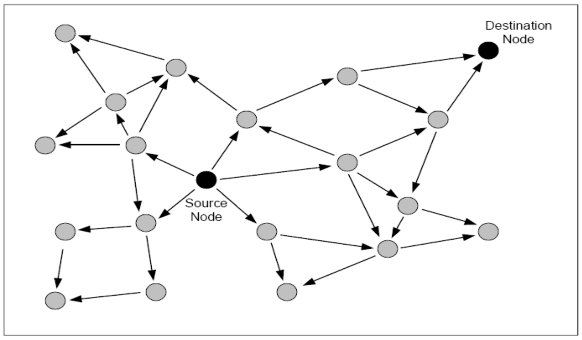

Figure 1. Participating nodes in total flooding algorithm.

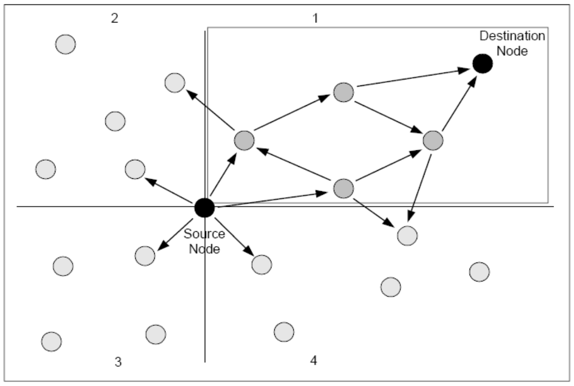

Figure 2. Less participating nodes in Q-DIR algorithm.

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 and as illustrated in Figure 3. 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.

Quadrant of me compared to source?
Quadrant of destination compared to source?
If same, FORWARD
If not, DROP.

Figure 3. Q-DIR decision at each intermediate node.

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.

Upon receiving the RREQ, 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. Figure 4 shows the format of the RREQ packet in Q-DIR where the source and destination nodes location information are inserted are highlighted.

<table>
<tr><th>0 1 2 3 4 5 6 7</th><th>0</th><th>1</th><th>2 3 4 5 6 7 0 1 2 3 4 5 6 7</th><th>0 1 2 3 4 5 6 7</th></tr>
<tr><td>Type</td><td>D</td><td>G</td><td>Reserved</td><td>Hop Count</td></tr>
<tr><td colspan="5">RREQ ID</td></tr>
<tr><td>X_s</td><td colspan="2">Y_s</td><td>X_d</td><td>Y_d</td></tr>
<tr><td colspan="5">Destination IP Address</td></tr>
<tr><td colspan="5">Destination Sequence Number</td></tr>
<tr><td colspan="5">Originator IP Address</td></tr>
<tr><td colspan="5">Originator Sequence Number</td></tr>
<tr><td colspan="5">Path Node IP Address</td></tr>
<tr><td colspan="5">Path Node Sequence Number</td></tr>
<tr><td colspan="5">(additional path node IP address and sequence number pairs) ...</td></tr>
</table>

Figure 4. RREQ format in Q-DIR.

4. Simulation Model

Q-DIR was simulated in ns-2 [24] 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. 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.

Figure 5 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. 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.

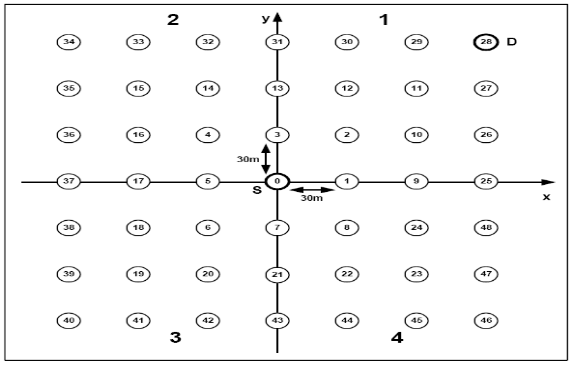

Figure 5. Simulation Network Model of 49 nodes

Table 1 shows the simulation configuration parameters used in the simulation which conforms to the Internet-Draft [9]. 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. For correct operation, the route delete period must be greater than both (Allowed HELLO loss* HELLO interval) and the total traversal time.

Table 1 Simulation Configuration Parameters.

Configuration Parameters	Value
Maximum number of possible hops between two nodes	10
Average one hop traversal time	60 milliseconds
Route discovery time	5000 milliseconds
Route delete period	25000 milliseconds
Number of RREQ tries	3
Total traversal time	1200 milliseconds
HELLO interval	1000 milliseconds
Allowed HELLO loss	2

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 [25]. The receive threshold power is set as 1.20475e-08 watts. The data packet length has been set to 1000 bytes with a CBR (Constant Bit Rate) traffic pattern. Table 2 shows the simulation parameters used in the simulation.

Table 2. Simulation Parameters.

Parameters	IEEE 802.11b Standard
Propagation Model	Shadowing
Path Loss Exponent	2.4
Shadowing Deviation (dB)	4.0
Reference Distance (m)	1.0
Physical Layer Type	Phy/WirelessPhy/802.11
MAC Layer Type	MAC/802.11
Carrier Sense Threshold	1.20475e-08
Receive Threshold	1.20475e-08
Default Transmitting Power	2.8318 watts
Traffic Type	Constant Bit Rate (CBR)

5. Simulation Results

Two scenarios were simulated and they are to study the effect of varying simulation time and 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:

- *normalized routing overhead* - The number of routing packets transmitted per data packet received at the destination.
- *Effective energy consumption per data packet received* - The total energy consumption in the network for every data packet successfully received by the destination. This is the metric on the effectiveness of energy consumption when routing data packets.

A. Varying Simulation Time

The simulation time was varied from 100s to 800s in steps of 100s. The number of routing packets that are broadcast and the corresponding data packet received at the destination in the network are counted for both AODVbis and Q-DIR routing protocol. Figure 6 shows the normalized routing overhead graphs for both protocols. As the simulation time increases to 800s, both protocols show reduced routing packets and leveled to a constant as it approaches 800s. The average normalized routing overhead in AODVbis is 338 packets while in Q-DIR, the average normalized routing overhead is 128 packets per data packet received. It is observed that 160% more routing packets are transmitted in AODVbis compared to Q-DIR due the higher number of node participations in the network in AODVbis.

Figure 7 shows graph for effective energy consumed per data packet received for both protocols. Both protocols shows a reduced energy consumption as the simulation time increases The average effective energy is 2.43 J in AODVbis and 1.48 J in Q-DIR. Q-DIR consumes 64% less energy to send packets since only a quarter of the number of nodes participated in the routing process which is a limited flooding protocol based on quadrant.

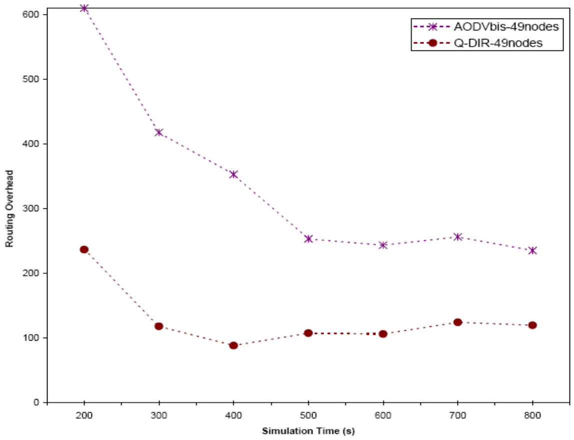

Figure 6. Normalized routing overhead with simulation time.

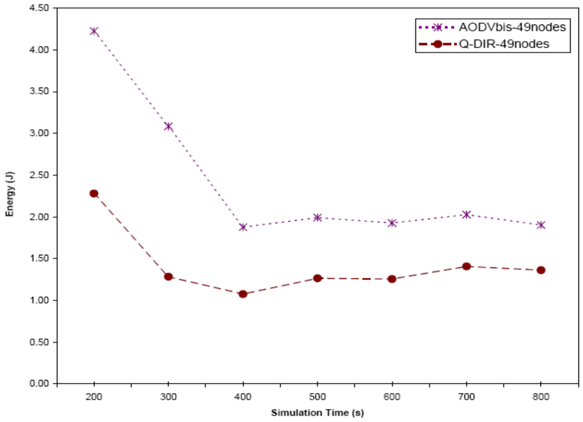

Figure 7. Effective energy consumed per data packet received in Q-DIR.

B. 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 remains 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 8 shows the average normalized routing overhead for both protocols which increases as the transmission rate increases. The graph for AODVbis shows large fluctuations as the transmission rate increases. AODVbis sends out an average of 255.664 normalized routing packets compared to Q-DIR which sends out only 108.08 packets. The large fluctuations in AODVbis are due to the total flooding algorithm of AODVbis and hence the routes taken vary for different transmission rate. However, the graphs in Q-DIR remain consistent throughout due to the directed flooding based on quadrant.

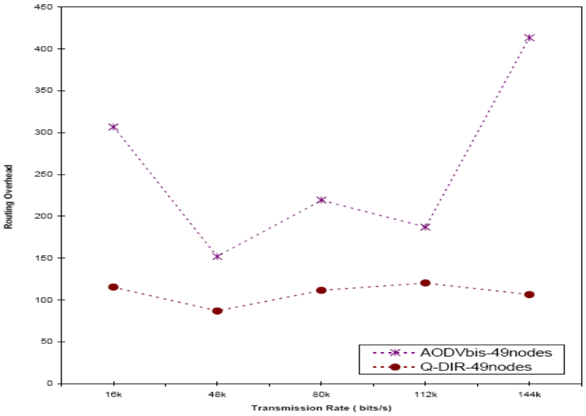

Figure 8. Normalized routing overhead for 49 nodes.

Figure 9 shows the graphs for effective energy consumed per data packet received for both AODVbis and Q-DIR protocols. The effective energy for AODVbis fluctuates as the transmission rate increases but for Q-DIR, it remains constant. Again, the fluctuation in AODVbis is due to different route taken at different transmission rate. .AODVbis consumes an average of 1.574 J of energy while Q-DIR consumes only 1.084 J of energy which 45% less energy consumed compared to AODVbis. Based on this trend in energy consumption, less power is consumed if only a section or an area of a network participates in the routing.

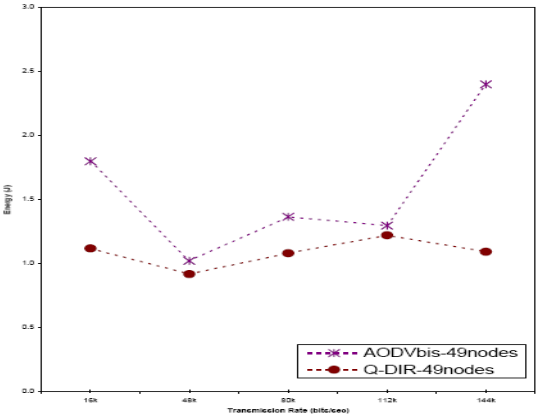

Figure 9. Effective energy consumed per data packet received

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 reduces the power by 160% as the simulation time is increased and by 45% as the transmission rate increases compared to AODVbis. 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 reduced routing overhead and power consumption are achieved in Q-DIR. We have only considered static networks and intend to simulate in mobile environment.

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