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Simulation & Performance Evaluation of QoS Routing Protocol for Ad-hoc Networks Using Directional Communication

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ABSTRACT

A wireless ad-hoc network is a self-organized wireless network without fixed or backbone infrastructure. All nodes have routing capability and use peer-to-peer packet transmission or forward packets to other node using multi hop communication. Now days mobile ad-hoc networks are being used for different applications and traffics, so it require quality of service (QoS) support in routing protocol. In this paper, a modified QoS routing protocol using directional antenna has been proposed. High and normal priority can be assigned based on type of traffic. All the nodes in the path used by high priority flow are reserved as high priority flow for that flow and normal priority flow will avoid the paths used by high priority flows. If no disjoint paths are available, there may be two possibilities: Normal priority flows are blocked and other is, normal priority flows are allow using the coupled path with high priority flow. Blocking the normal priority flow, QoS routing protocol improves the performance of high priority flow. This concept may be use in emergency communication. Simulation results show that by assigning the priorities to flows, performance of high priority flows are improved and it will further improved by blocking the normal priority flow.

Keywords: Ad-hoc Networks; Directional Antenna; Routing Protocol; QoS Routing Protocols

1. Introduction

An ad-hoc network is a dynamic network formed on demand by a group of nodes without any pre-existing network infrastructure. Wireless ad-hoc network may be classified in two types, Mobile Ad-hoc Network (MANET) and Stationary Ad-hoc Network (SANET). Self-configurability and easy deployment feature of the Mobile Ad-hoc network (MANET) resulted in numerous applications in modern era. Community network, military and emergency rescue are some application of ad-hoc network where infrastructure is unavailable or difficult to install. Directional antenna offers the great benefits for wireless ad-hoc networks, with directional transmission and reception. With increasing application of ad-hoc wireless network, the need for supporting quality of service (QoS) is becoming essential. However, Distributed Coordination Function (DCF) [1] MAC (Medium Access Control) of IEEE 802.11, which is the most widely used MAC protocol in MANETs, does not support the QoS in MANETs due to its inherent problems [2,3].

Our main concern is to propose a QoS routing protocol for wireless ad-hoc network using directional antenna and directional MAC based on the priority assigned to traffic. Any source node can assign high priority or normal priority to flow generated by it. If a high priority flow is running in the network, nodes and their respective beam used for this high priority communication are set as reserved node and communication zone formed is called as reserved zone. Normal priority flows will try to avoid the high priority reserved zone and that will reduce the interference of normal priority flow with high priority flow. It is not necessary that normal priority flow always found the disjoint path. As number of high priority flow increases, it is difficult for normal priority flow to find the disjoint path. It may happen that normal priority flow always search for disjoint path but never reach the destination.

A concept of call blocking is being used to improve the performance of high priority flow. In call blocking normal priority, flows are forced to block their communication if no disjoint paths are available. But, in the case of without call blocking, normal priority flows are allowed to use the coupled paths with high priority flows that reduce the performance of high priority flow. This QoS routing scheme improves the performance of high priority traffic in term of timely and reliable delivery. Major application of this scheme will be area of medical emergency, roadblock or traffic control and battle field where emergency massage is required to propagate with high priority.

The remainder of this paper is organized as follows. Section 2 describes the related work already done. Section 3, presents the basic definitions and some basic concepts of antenna, network model used, coupling factor, zone disjointness, priority assignment and network topology information update. Section 4 describes zone disjoint routing and QoS routing. Section 5 discusses the performance evaluation, which includes the simulation setup and results; finally, Section 6 concludes the paper.

2. Related Works

One major challenge of routing protocols is data delivery to destination in wireless ad-hoc network. They must define efficient and balanced way of data forwarding (routing). Nemours routing protocol have been proposed for ad-hoc network using omni-directional antenna. These routing protocols are categorized by network topology change, quality of service, and bandwidth constraints etc. To improve the performance of ad-hoc network directional routing protocols with directional antenna with multiple beams are being used [4-6]. For efficient utilization of directional antenna different directional MAC protocols has been proposed [7-10]. To support quality of service in wireless network different QoS based schemes have been proposed [11-15]. In paper [14] authors addressed the problem of supporting real-time communications in a multi-hop mobile network using QoS routing, and proposed a protocol for QoS routing. S. Chen and K. Nahrstedt proposed a ticket-based probing algorithm [11] for QoS routing in MANETs.

QoS routing protocols search for routes with sufficient resources for QoS requirements. The QoS routing protocols should work together with resource management to establish paths through the network that meet end-to-end QoS requirements, such as delay jitter bound, bandwidth demand, or multiple constraints. Siuli Roy *et al*. [16] proposed an adaptive routing protocol with maximally zone disjoint shortest path and they used this scheme to balance the traffic load using multipath routing. In this, node should detect the signal strength and angle of arrival of each signal it hear and maintains a table that will be used to find the location of neighbors. They used the directional antenna at physical layer and 802.11 MAC at MAC layer, which did not fully exploit the features of directional antenna. Further, they used this scheme for QoS support to priority-based traffic [12].

3. Basic Concepts

3.1. Antenna and Network Model Used

In switched beam directional antenna model, each node have M highly directional, fixed predefined antenna beam elements which are deployed into non overlapping fixed sectors, each spanning an angle of $360/M$ degree. Each node can operate in two modes: Omni-directional and directional mode. When node operates in omni-directional mode, it is capable of transmitting and receiving signals from all direction. In directional mode, node can point its beam in specific direction and transmit directionally but it receives omni-directionally. It is assumed that, antenna gain in both mode of operation, omni-directional (G^{omni}) and directional (G^{dir}) are equal. Switched beam antenna is comprised of multiple fixed beams that are formed by shifting the phase of each antenna element of an antenna array by a predetermined amount, or simply by switching between several fixed directional antennas. Switched beam directional antenna with four beams (beam number 0 to 3) is used for simulation as shown in **Figure 1**.

An ad-hoc network is modeled as a graph $G = (M)$, where M is finite set of nodes. Node N_i has a set of neighbors $NB_i = \{N_j \in M\}$ and N_j is located in the transmission zone formed by any beam of node N_i. Transmission beam (TB) of node N_i having four transmission beams (0, 1, 2 and 3) is represented as $TB_{i,z}$ where $z = 0$, 1, 2 and 3. So node N_i has the transmission beams $TB_{i,0}$, $TB_{i,1}$, $TB_{i,2}$, $TB_{i,3}$. Transmission zone formed by beam of node N_i is represented as $TZ_{i,z}$ where $z = 0$, 1, 2 and 3. Transmission zone formed by node N_i are $TZ_{i,0}$, $TZ_{i,1}$, $TZ_{i,2}$, $TZ_{i,3}$. In single channel systems, nodes transmit and receive on the same shared channel. Neighboring transmitters contend for channel access by means of a media access control protocol. When node N_i transmit to node N_j by using the beam $TB_{i,z}$ then other nodes located in the transmission zone $TZ_{i,z}$ should sit idle to avoid the collision. Nodes located in other transmission zone of node Ni can participate in the other transmission. Communication ID C_n is a unique identification (ID) number assign to each communication initiated for specific source destination pair.

3.2. Route Coupling and Disjointness

Ad hoc network can be implemented by single channel or multi channel. In single channel systems, nodes transmit and receive on the same shared channel. Single channel system has significant impact on the performance due to route coupling. Two routes are said to be coupled if they have common nodes or links. Two nodes are said to be coupled, if they are physically close enough to interfere the transmission of each other. Two routes are physically close to interfere with each other during transmission is called as route coupling. Coupling factor $\left[\eta_{N_i}^{C_n}\right]$ of node N_i in a path P for communication ID C_n is define as the sum of number of communication ID handled by each

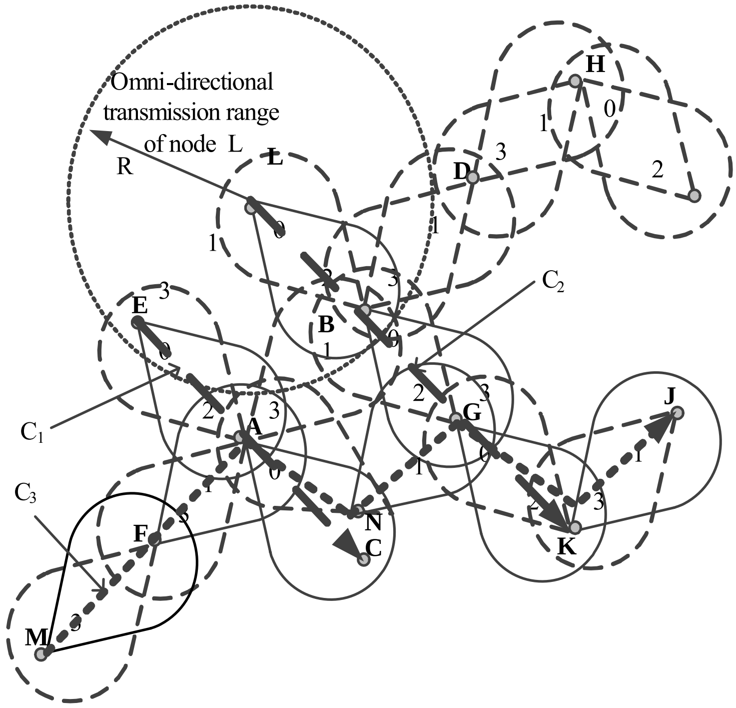


Figure 1. Simultaneous transmission through coupled routes using directional antenna.

active neighbor of node N_i in the transmission zone $TZ_{i,z}$ excluding the current communication ID C_n, $TZ_{i,z}$ is the transmission zone formed by the node N_i toward neighbor N_j in the path P. Coupling factor $\left[\eta_{N_i}^{C_n}\right]$ of node N_i is as follow:

$$\eta_{N_i}^{C_n} = \sum_{\forall n \in \text{Act } NB_i TZ_{i,z}} \left(C - C_n\right) \quad (1)$$

where C is number of all communications through active neighbors of node N_i (Act NB_i) using transmission zone $TZ_{i,z}$ including current communication C_n and Act NB_i is active neighbor nodes of N_i participate in any communication.

Coupling factor of path P for communication ID $C_n[\eta C_n(P)]$ is define as the coupling factor of all nodes in the path P. Path coupling factor $[\eta C_n(P)]$ is given as:

$$\eta C_n\left(P\right) = \sum \eta_{N_i}^{C_n} \quad (2)$$

where N_i is number of node starting from source to destination in path P used for communication ID C_n. From the **Figure 1**, node A use its transmission zone $TZ_{A,0}$, $TZ_{A,1}$, $TZ_{A,2}$, $TZ_{A,3}$ formed by the beam 0, 1, 2 and 3 to communicate node (C, N), F, E and B respectively. So node A has a set of neighbor nodes $NBA = \{(C, N), F, E, B\}$.

Two flows having the communication IDs C_1 and C_2 start from nodes E to C and L to K. Routing path used for communication are *E-A-C* and *L-B-G-K*. Using omni-directional antenna these two routes are coupled with each other. Transmission zone of node L using the omni-directional antenna is around the node L in coverage range of R. Node E is in the transmission zone of node L and vice-versa. Coupling factor of node L can be calculated by using question (1) as follow: Act $NB_L = 2$, two active neighbors E and B participate in communications C_1 and C_2 respectively so coupling factor of node L will be 1, $\left(\eta_L^{C_2} = 2 - 1 = 1\right)$, because node B participate in the communication C_2 itself. Similarly active neighbors of node B (Act NB_B) are L, A and G. Coupling factor of node B will be 1, $\left(\eta_B^{C_2} = 3 - 2 = 1\right)$ because L and G participate in flow (communication) C_2. Coupling factor of node G $\left(\eta_L^{C_2}\right)$ will be one and for node K will be zero. Coupling factor of path P used by the flow C_2 $[\eta C_n(P)]$ will be coupling factor of all nodes (L, B, G, K) in path P that will be 1 + 1 + 1 = 3. It represents that two paths used by the flows C_1 and C_2 are coupled (joint) to each other by factor of three using the omni-directional antenna.

When directional transmission is used at each node and only two flows C_1 and C_2 are initiated, paths (P_1 and P_2 respectively) used by these flows are fully disjoint. Node B is located in the transmission zone $TZ_{L,0}$ formed by the beam $TB_{L,0}$ of node L. There is only one active neighbor node B in the transmission zone $TZ_{L,0}$. Node B participates in the flow C_2 only, no other flows go through this node. So coupling factor of node L $\left(\eta_L^{C_2} = 1 - 1 = 0\right)$ will be zero. All other nodes (B, G and K) in path P_2 have the coupling factor zero because these nodes participate in only flow C_2. So coupling factor of path P_2 used by flow C_2, [$\eta C_2(P_2)$] is zero. Similarly coupling factor of path P_1 used by flow C_1 [$\eta C_1(P_1)$] will be zero. These two active paths are fully disjoint by using directional transmission. Using the directional transmission routes *E-A-C* and *L-B-G-K* are fully disjoint so both communications can run at simultaneously without affecting the performance of each other.

Third flow with communication ID C_3 initiated from node *M* to *J* using the path P_3 (*M,F,A,N,G,K,J*). Path P_3 is coupled with both active path P_1 and P_2. Path P_3 is coupled with P_1 and P_2 individually by factor of two. Total coupling factor of P_3 with all other active path is four.

3.3. Priority Assignment

Any source may assign priority to the flow according to the type of traffic or flow initiated, that might be high and normal priority flow. Transmission zone formed by the high priority flow is called as high priority communication zone. If a high priority communication is going on between node *A* to node *B* using the beam 1 and 3 of node *A* and *B* respectively. Then transmission zone formed by these beams (beam 1 of node *A* and beam 3 of node *B*) is called as high priority reserved zone. All nodes belongs to any high priority communication are reserved as high priority reserved node. Node *A* and *B* are reserved as high priority reserved nodes so that other flows avoid this zone to reduce the interference. Each node maintains the reserved node list that have the information of all reserved nodes of entire network. This reserved node list should be updated regularly and forwarded to other neighbors. If reserved node does not receive the high priority packet for certain duration of time, it will becomes unreserved node and modify its table.

3.4. Network Topology Update

At the MAC layer, circular MAC is being used. In this scheme RTS (request to send) is transmitted directionally in circular way until it scan all the area around the transmitter. If the node is the destination of RTS it will send the CTS (clear to send) directionally toward the source of RTS node. Nodes receive and transmit the CTS, DATA and ACK (acknowledgement) Omni-directionally and directionally respectively. As shown in **Figure 1** node *A* want to communicate with node *B*, it start transmitting RTS using beam 0. After short duration of time, same RTS with next beam (beam 1). This process is continuous until node *A* covers all area around it. Node *B* sends the CTS directionally toward the node *A* using beam 1. Nodes *A* use beam 3 to transmit to *B* that use beam 1 to receive. Similarly, node *B* use beam 1 to transmit and node *A* use beam 3 to receive.

3.4.1. Neighbor Node Beam Table (NNBT)

Each node maintains a table, called node beam table (NNBT), with one entry of each node it has heard. Initially node beam table is empty and it is updated with information received by neighbor node in form beacon signal. Due to mobility of node, table may be updated regularly. In every record, the nodes maintain the following information: Me (itself), Neighbor (the node from which it receives a packet), My beam (the beam by which the transmitter receives the packet), Neighbor's beam (the beam by which receiver sent the packet) [10]. **Table 1** illustrates the NNBT maintain by node *A*. One entry for each node, first entry show that *A* use beam 3 to connect node *B* and *B* use beam 1 to connect node *A*.

3.4.2. Node Activity List (NAL)

On the basic of activity information of all nodes in the network, each node prepares its node activity list. This contents node ID, status (0 for inactive, 1 for active with normal priority flow, and 2 for high priority flow), communication IDs (flow ID) for which that node being used as shown in **Table 2**. In second column, communication Id C_1 and C_2 indicates that flow C_1 and C_2 use node *A* in it routes. In third column all communication Id field are 0, it show that node *B* is not involve in any flow (communication). Second flow C_2 is normal priority flow that uses the route *E*, *A* and *F* so status of node *E* and *F* are set as 1. Initially, when networks start working each node have activity information of neighbors only. Each node periodically broadcast the node activity list to its neighbors. After receiving the NAL from its neighbors each node update its NAL and broadcast to their neighbors after regular interval. Using this process each node capture the activity status of all node in the network. Entry of each neighbors in NAL are time stamped. If any node receives the update message from different node related

Table 1. Neighbor node beam table at node *A*.

Me	Neighbor	My beam	Neighbor's beam
A	*B*	3	1
A	*C*	0	2
A	*F*	1	3
A	*E*	2	0

Table 2. Node activity list at node *A*.

Node	*A*	*B*	*C*	*E*	*F*
Status	2	0	2	1	1
Communication ID	C_1	0	C_1	0	0
	C_2	0	0	C_2	C_2

to same node then recent message is accepted and older one is rejected, so each node know the latest activity status of all nodes.

3.4.3. Global Node Beam Table (GNBT)

In Each node maintains a global node beam table (GNBT) to capture the networks topology information. Each node broadcast its NNBT periodically and it serves as beacon. GBNT updated by the NNBT of that node. During initial phase of network topology generation, each node has the information of its neighbors only and no information about the network connectivity. Each node broadcast its GNBT to its neighbors. Therefore, each node update its GNBT based on the update message received from the neighbor's GNBT. This update message is being slowly propagated from one node to other node. Now, node has the information of their neighbors and all other nodes in the network. If two GNBT update message have a set of data for same node, recent update message that have most recent information about the node is used, and old one is discarded. In GNBT first column is node ID and second column is neighbor nodes and beam number use to communicate these neighbors. First row of the **Table 3** and **Figure 1**, illustrate that node *A* use beam number 3 to communicate node *B*, similarly beam number 0, 1 and 2 are use to communicate node *C*, *F* and *E* respectively. Structure of NNBT, NAL and GNBT are very simple and smaller in size compare to routing protocol presented by authors in [12].

4. QoS Routing

4.1. Zone-Disjoint Routing

In this sub-section, a zone-disjoint routing protocol is discussed using directional antenna. Zone-disjoint routing protocol will reduce the coupling factor, so it reduces the interference of active routes in the network. It allows to select the routes for each communication that are maximal disjoint to other active routes. Each node has the latest status of all nodes and communications activity at any instant of time by the node activity list and global node beam table. Based on this information, routing path of each flow are selected.

As illustrated in **Figure 2**, first flow with ID C_1, started from *A* to *E*. It will search for the shortest and disjoint path. Shortest path P_1, which will be use for communication is *A-B-E*. This path is fully disjoint because this is only flow present in the network. Node activity list is updated and communicated to neighbor nodes and this update message is passed to other nodes in entire network. Second flow with ID C_2 started after some time from node *F* to node *D*. Multiple paths $P_2\{F\text{-}A\text{-}B\text{-}C\text{-}D\}$, $P_3\{F\text{-}A\text{-}B\text{-}E\text{-}D\}$ and $P_4\{F\text{-}H\text{-}I\text{-}J\text{-}D\}$ are available. Maximal disjoint shortest path will be selected. Coupling factor of path P_2 with path P_1 will be sum of coupling factor of all node (*F*, *A*, *B*, *C*, *D*) in path P_2. Coupling factor of node *B*, *C*, *D* and *E* will be zero. Coupling factor of node *F* participate in flow C_2 $\left(\eta_F^{C_2}\right)$ will be one, because active neighbor of node *F* is *A* only which participate in both flow C_1 and C_2. Coupling factor of node *A* $\left(\eta_A^{C_2}\right)$ will be one. Coupling factor of path P_2 (hop count is 4) used by flow C_2 $[\eta C_2(P_2)]$ will be two. Similarly coupling factor of path P_3 (hop count is 4) $[\eta C_2(P_3)]$ will be three. Coupling factor of path P_4 (hop count 4) is zero. Routing path P_j for flow C_n will be selected, having the lower value of $\left[\eta C_n\left(P_i\right)*H\right]$ where H is hop count of path P_j that is limited to maximum value of 18. Path P_4 (*F-H-I-J-D*) will be selected because it has zero coupling factors, so it is fully disjoint with other active paths. Updated node activity list at node *D* is forwarded to other nodes in entire network. Other node will modify their activity table and global node beam table (GNBT).

Third flow initiated after some time form node *D* to node *B*. Paths available for this flow are $P_1 = \{D\text{-}C\text{-}B\}$, $P_2 = \{D\text{-}E\text{-}B\}$ and $P_3 = \{D\text{-}J\text{-}I\text{-}H\text{-}F\text{-}A\text{-}B\}$ having the hop count 3, 3 and 6 respectively. Path P_3 having lower (cou-

Table 3. Global node beam table at node A.

Node	Neighbors node and beam
A	*B*(3), *C*(0), *F*(1), *E*(2)
B	*A*(1), *D*(3), *G*(0), *L*(2)
C	*A*(2), *G*(3)
E	*A*(0), *L*(3)
F	*A*(3), *M*(1).

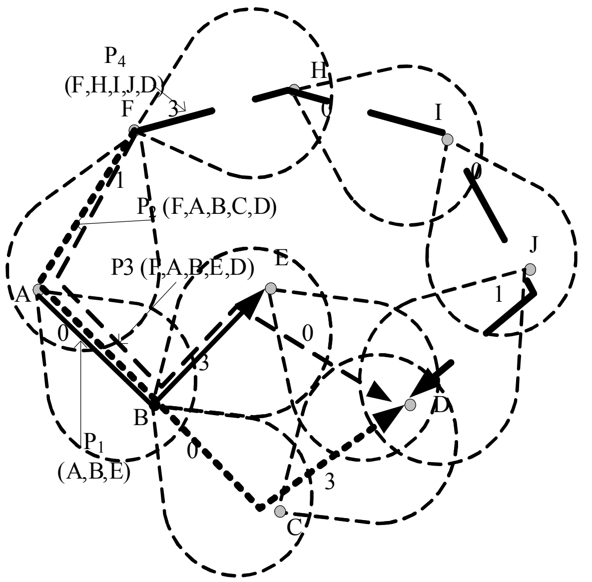


Figure 2. Fixed topology of 10 nodes using directional antenna.

pling factor * hop count) is selected for communication.

4.2. Zone Disjoint QoS Routing

Source assigns the high or normal priority to flow depending upon the type of traffic. When any high priority communication is running in network, then normal priority flow will try to avoid the path used by high priority flow and it will search for disjoint path but it is limited to maximum hop count. Otherwise normal priority packets move around the network in search of disjoint path but may not reach the destination. To avoid this maximum number of hop count is limited to 18 [12].

When any high priority communication is started from source to destination, it will try to search shortest path, all the nodes in this path set their activity as high priority node, and they are reserved for this specific high priority communication. Status information of nodes is updated in NAL and reserved node activity information is periodically transmitted to all other nodes in the net-work. All other nodes update their information of reserved nodes in the network. If any node reserved for high priority communication does not receive the high priority packet for certain duration of time, it will change its status form high priority to normal priority and update their node activity list. This update information is transmitted to other nodes also.

4.2.1. Routing without Call Blocking

Initially a high priority communication is initiated form *A* to *E*. As given network topology in **Figure 2**, if no other communication is running it will search for shortest path only based on global node beam list and node activity table that is {*A*-*B*-*E*}. All nodes through this path set as reserved node and set status field as 2 in node activity table. Node activity table of *B* is updated and this update massage is transmitted to entire network. The entire nodes in network update their node activity table based on updated massage received from neighbors. After some time a normal priority flow is started from *C* to *F*. Multiple routing paths are found using the global node beam list. Paths available from *C* to *F* are P_1{*C*-*B*-*A*-*F*} and P_2{*C*-*D*-*J*-*I*-*H*-*F*}. It will calculate the coupling factor of each nodes and path involved in communication using Equations (1) and (2). Path P_2 is disjoint path while P_1 is joint (coupled) with high priority flow active path. Disjoint path P_2 is selected for normal priority communication.

Suppose node *H* is not present in the network and normal priority flow from node *C* to *F* is initiated. It will search for disjoint path but no disjoint paths are available. Shortest path {*C*-*B*-*A*-*F*} is available that is coupled with path used by high priority flow. If call blocking is not implemented normal priority flow is forced to use the coupled path and that will degrade the performance of high priority flow. To guarantee the minimum bandwidth requirement of high priority flows, rate of normal priority flows are regulated.

4.2.2. Routing with Call Blocking

If call blocking is implemented then normal priority flow will be blocked because normal priority flow are not allow to use the node that are reserved for high priority flow in their routing path. If normal priority flow is blocked only high priority flow will be in network that improves the performance of high priority flow. All nodes regularly check the node activity table for reserved node status. If any reserved node does not receive the high priority flow packets it reset as normal flow, and reset the status field as one. This update massage is transmitted to other node and all nodes change the status of that node. Flow chart for QoS routing without call blocking and with call blocking is given in **Figure 3**.

5. Performance Evaluation

5.1. Simulation Setup

Simulation is done on Qualnet [17] that is written using PARSEC [18], a C language base discrete event simulator. Traffic model used in our simulation is CBR with packet size of 512 bytes and packet transmission interval 2 ms to 100 ms. Directional and omni-directional transmission range is 250 m. Data transmission rate is 2 Mbps. The simulations have been done for different random seed and the results are statistically averaged out for 10 iterations, each running for 300-simulation seconds. There was no network partition throughout the simulation. The simulation has been done in various network scenarios to assess the performance of protocols.

5.2. Performance of Random Topology with 10 Nodes

In this scenario stationary ad-hoc network with random topology and 10 nodes has been taken in area of 1000 × 1000 m. For first case without priority (normal priority) simulations has been done considering different conditions.

- Only single flow (flow 1) from node *A* to node *E* that gives the high throughput and normal delay because no coupling path with other active flow;
- Other three flows from different source destination combination has been taken flow 2 (*C*-*F*), flow 3 (*B*-*I*) and flow 4 (*D*-*A*). These simulations have been repeated for different combination of source and destination for all flow with different seed value. As illustrated in **Figure 4** throughput of flow1 is high when only flow 1 is present in the network. Throughput re-

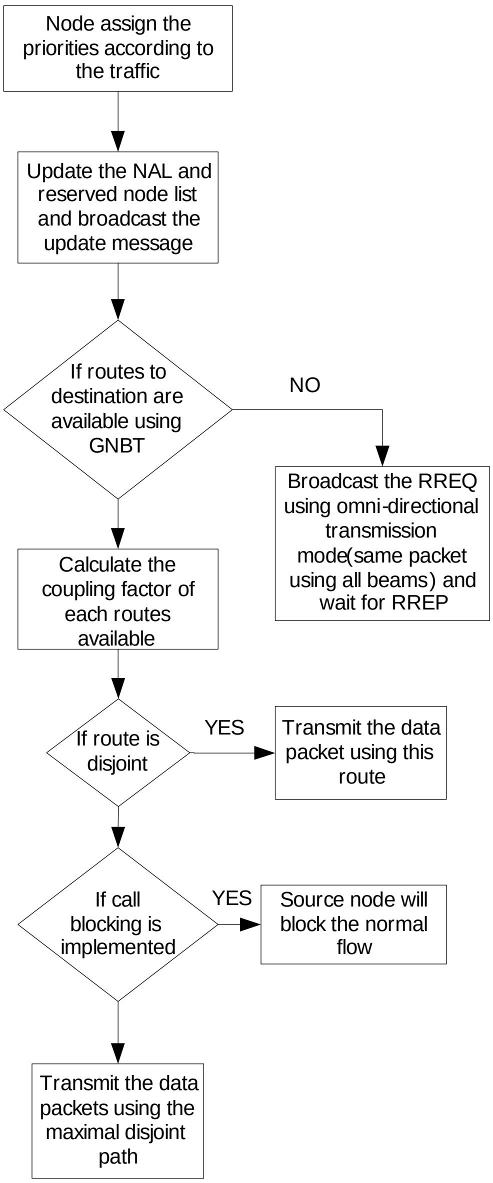


Figure 3. Flow chart of QoS routing protocol for without and with call blocking.

duced when all four flow (flow 1, flow 2, flow 3 and flow 4) are active because routing path used by these paths are coupled with other active path;

- In last case one flow out of four is assigned as high priority and other three are assigned as normal priority. This simulation is done assuming one flow of different source destination combination as high priority and other three flows as normal priority and they are coupled with high priority flow path. In this case flow having high priority shows the considerable improvement in throughput with compare to the flows without priority.

Figure 5 shows the performance of flow 2-flow 4 without assigning flow1 as high priority throughput of normal priority flows (flows 2-4) is reduced because priority is given to high priority flow.

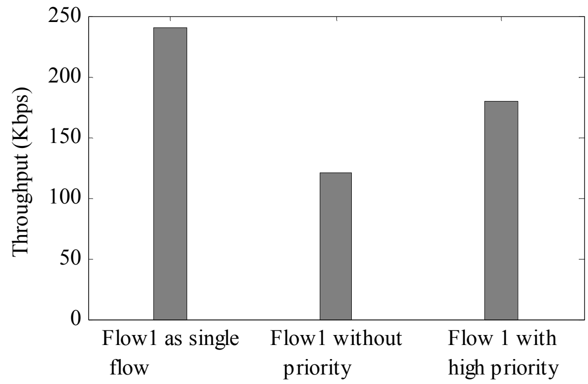


Figure 4. Performance of throughput of flow 1 when only single flow 1 and four flows (1-4) are present in the network with and without priority.

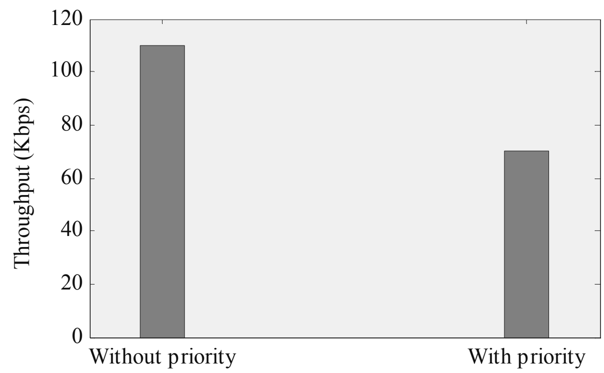


Figure 5. Throughput of flows 2-4, with flow 1 as high priority and without priority.

5.3. Performance of Random Topology with 50 Nodes

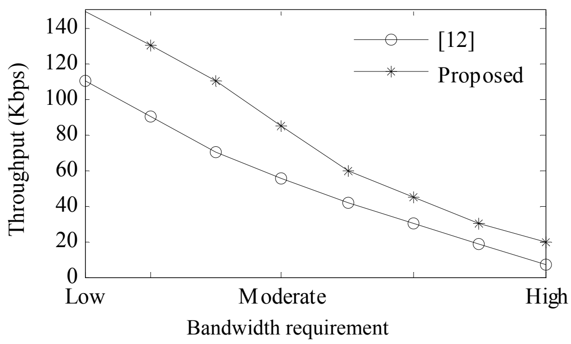
In this scenario, simulation was done for an ad-hoc wireless network with 50 nodes. This modified QoS routing protocol is compared with priority based QoS routing with call blocking [12]. Randomly selected, source and destination combinations are used for CBR flow with packet size of 1024 bytes. Nodes follow the random way mobility mode having the speed of 0-to-10 meter per seconds. Data transmission rate is 2 Mbps. Band-width requirement vary from high (150 kbps) to low (10 kbps) for high priority flow to normal flow. Different flows preset in the network are assign the high priority randomly. Throughput, end-to-end delay and control overhead are used as performance metrics.

5.3.1. Throughput

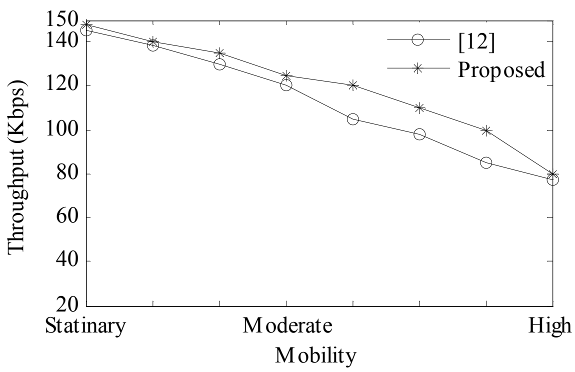
Figure 6 illustrate the performance of throughput vs. bandwidth requirement and mobility. Throughput is defined as the ratio of all received packets for all destinations and total number of data packet transmitted by all sources. **Figure 6(a)** shows the performance of throughput vs. bandwidth requirement. As bandwidth requirement is increased, reduce the data transmission rate of normal flows and they may be blocked. That will reduce the aggregated throughput of the network. As illustrated in **Figure 6(a)** modified QoS routing shows the improvement in performance of throughput. **Figure 6(b)** shows the performance of throughput vs. mobility. Due to mobility, there will be link failure and packet drops, which will reduce the throughput.

5.3.2. End-To-End Delay

Figure 7 show the performance of average end-to-end delay vs. bandwidth required and mobility. End-to-end delay is defined as average time taken by packets from source to destination. **Figure 7(a)** shows the performance of end-to-end delay vs. bandwidth required. As bandwidth requirement is increased, flow rate of normal flow will be regulated to guarantee the through-put requirement of high priority flow or that may be blocked. That decrease the end-to-end delay of high priority flow but it increase the end-to-end delay of normal flows. **Figure 7(b)** shows the performance of end-to-end delay vs. mobility. It shows that, as the mobility increases average end-to-end delay increases due to link failure.

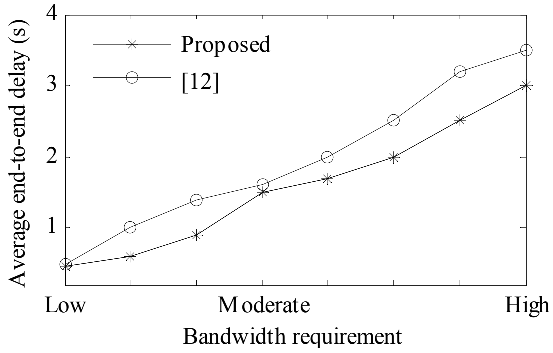


(a)

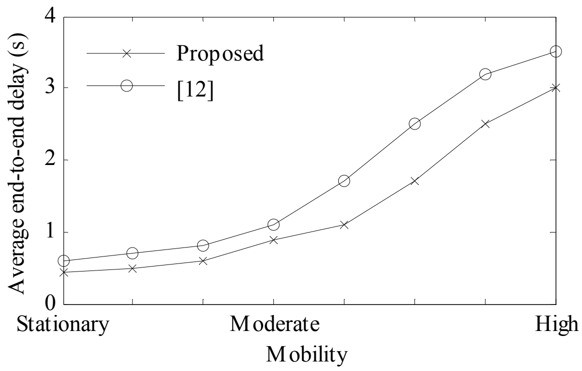


(b)

Figure 6. Throughput vs. bandwidth requirement (a), and throughput vs. mobility.



(a)



(b)

Figure 7. Average end-to-end delay vs. bandwidth requirement (a), and average end-to-end delay vs. mobility (b).

5.3.3. Control Overhead

Figure 8 shows the performance of control overhead vs. mobility. Each node periodically broadcast the GNBT and NAL to its one-hop neighbors after the time interval of 10 s and 500 ms respectively. Size of GNBT and NAL depend on the number of nodes in the network, as number of node increase, size of GNBT and ANL increase. Modified QoS routing gives the improvement in the control overhead due to reduce size of GNBT and NAL. In mobile scenario, network information should be updated more frequently, so the periodicity of GNBT and NAL should be small.

Simulation was done with stationary, moderate and high mobility. At the speed of 5 mps (moderate), periodicity of GNBT and NAL reduced up to 5 s and 500 ms respectively similarly for high mobility 1 s and 100 ms.

6. Conclusion

A modified QoS routing protocol based on priority of traffic using directional antenna for wireless ad-hoc network is proposed and simulated for different scenario like fixed and mobile. Priorities assigned to traffic are high priority and normal priority (no priority). Routing paths used by high priority flows should be avoided by the normal priority flow in the without call blocking.

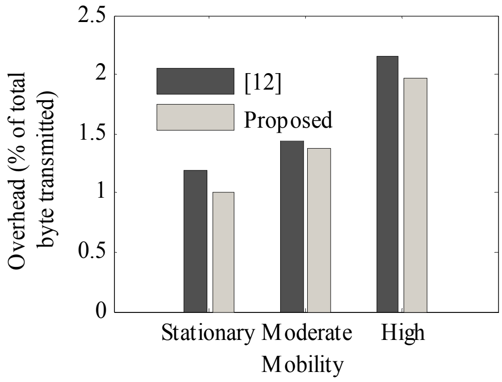


Figure 8. Overhead vs. mobility.

When call blocking is implemented the normal priority flows are blocked if disjoint paths are not available for them. This improves the performance of high priority flow but blocked the normal priority flow. This scheme can be use in different traffic condition where traffic required time bound transmission like emergency message. Using the directional MAC with directional antenna and reduced size of NAL and GNBT improve the performance of modified QoS routing protocol. A performance evaluation throughput, end-to-end delay and control overhead of modified routing protocol is presented. This improves the throughput of high priority flows but degrade the normal priority flows and they may be blocked. The overall system performance may degrade due to blocking of coupled normal priority flows. This feature limits the application for this scheme in emergency cases only, where emergency message is required to propagate timely and it does not care that other flows are affected or not. There is scope of a hybrid routing protocol, which will provide the balance between link state and on-demand nature of routing protocol.

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