

Quadrant Based Intelligent Energy Controlled Multicast Algorithm for Mobile Ad Hoc Networks

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Abstract— Mobile Ad Hoc Networks (MANET) are a peer-to-peer communication network that can be used to transmit data using a mobile or wireless link without the support of fixed infrastructure. A literature survey highlighted that the key characteristics of efficient MANET nodes are reputation value, residual battery level and energy consumption. Various MANET algorithms and routing techniques such as location aided routing, broadcasting, multicasting and energy efficient routing have been developed. MANET intelligent routing algorithm requirements include a range of characteristics. This paper proposes a new MANET routing algorithm that includes quadrant based opportunistic routing, an intelligent energy matrix and energy status request messages with packet receipt acknowledgement notification. In quadrant based routing packets are transmitted towards the quadrant that the destination resides within. The proposed algorithm uses an intelligent energy matrix that creates a look up table including the key characteristics: reputation value, residual battery level and energy consumption. The proposed algorithm balances the traffic uniformly across four intermediate nodes in any desired quadrant. The simulation results presented in this paper demonstrate that due to the inclusion of the energy matrix and quadrant based routing, the number of broadcast messages decreases, reducing data flooding, providing improved channel efficiency and improves bandwidth utilization. Load balancing also increases the lifetime of intermediate nodes which provides improved route stability. The proposed algorithm also includes packet receipt acknowledgement notification which guarantees end-to-end packet delivery and provides reliable MANET routing. Comparison with two other MANET broadcast algorithms identifies that a slower transmission speed is offset by the proposed routing algorithm providing higher energy efficiency, reliability and stability.

Keywords— MANET routing; Energy efficient routing; Multicasting; Quadrant based routing; Energy matrix;

I. INTRODUCTION

Mobile devices utilizing a Mobile Ad Hoc Network (MANET) communicate with other mobile devices using a wireless or cellular link. MANET permits users to maintain connectivity with their peers without the support of fixed infrastructure such as base stations, wired transmission links and access mediums. MANET can provide rapid communication deployment into disaster regions, military operations, multi-hop cellular network, collaborative computing and public events where the fixed infrastructure is inadequate to support the number of users. MANET is a self

configuring and autonomous communication system that uses node-to-node hops to transmit data from one node to another. In MANET, traffic that does not terminate at a node is forwarded by that node to other nodes within range and a node may therefore act as a simple router.

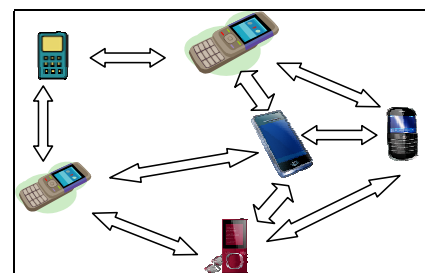


Figure 1. Model of a MANET network

Fig. 1 provides the model of a conventional MANET network. Devices on a MANET may provide connection to other networks such as the public switched telephone network or other broadband networks. MANET devices may be battery operated and therefore for mobile battery operated devices power efficiency is one of the key criteria for efficient and effective MANET routing. Power inefficient nodes tend to drop packets which reduce network stability. This paper presents a new routing algorithm that provides network stability by utilising an intelligent energy matrix and distributing the traffic load among a maximum of four nodes within transmission range of an originating node which increases the average lifespan of each node. The proposed algorithm also multicasts the data in one quadrant only so that the number of broadcast packets reduces and thereby improves channel efficiency and bandwidth utilization. Simulation results presented in this paper show a comparison of the research outcomes with a conventional sender based broadcast algorithm, quadrant based routing algorithm and balanced network lifetime algorithm.

The paper is organized as follows: a literature review is provided in Section II; overview and different aspects of the proposed model is described in Section III; the actual algorithm is presented and described using a MANET model in Section IV; simulation results and analysis are presented in Section V; testing scenarios are briefed in Section VI and the conclusion and future work is provided in Section VII.

II. RELATED WORK

MANET is a well research topic and a large number of routing algorithms and techniques have been proposed. There are advantages and disadvantages with the routing approaches and at times, the proposed algorithms are based on particular operating scenarios. This paper proposes a new routing algorithm that uses quadrant bases location aided opportunistic routing and introduces an intelligent energy controlled multicast technique.

A. Location Aided Routing

There are two types of MANET routing protocol: (1) topology based and (2) position based [4]. In a conventional topology based algorithm, data packets are flooded onto the network and transmitted to all the neighboring nodes within the transmission radius of the transmitting node. In a position based algorithm, the sender uses the geographical information of the neighboring nodes within a set transmission radius and then transmits data to the nearest nodes so that the data packet will travel along the shortest path and thereby provide network transmission optimization.

Yang et al. proposed a type of location-aided routing algorithm called opportunistic routing for MANET where the location information of intermediate nodes is used to define the forwarding candidate set and hence prioritizes the forwarding sequence [3]. The priority is defined by the distance between source and destination node and the closest node is given the highest priority. But the limitation of their work is that the average end-to-end delay increases rapidly due to the incremental mobility speed.

Latiff et al. proposed another type of location aided routing called power reduction quadrant based directional routing protocol for MANET which defines one quadrant using directional routing and broadcasts in that region only instead of transmitting the packet to all of the quadrants [4]. Hence the routing overhead is reduced significantly along with limiting packet flooding. But as the proposed algorithm does not follow any energy lookup table so the battery lifetime of each MANET node might not be enough.

Liu and Wu proposed a geometric routing protocol for MANET called the virtual force based geometric routing protocol [11].

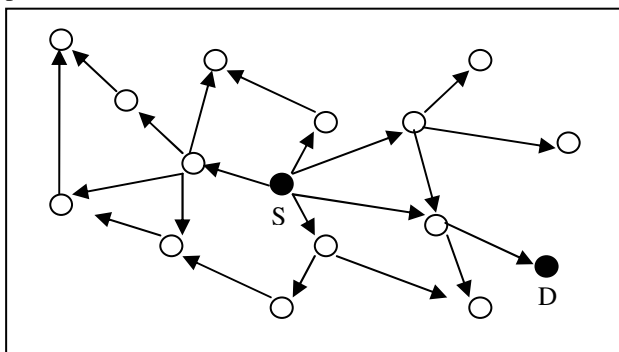


Figure 2. A conventional broadcast model

B. Broadcasting and Multicasting

The most common and widely used MANET communication technique is generic packet broadcasting [1]. Broadcasting to a set of nodes is called multicasting. The simplest broadcasting algorithm is called flooding where every intermediate node broadcasts messages received for the first time. Fig. 2 provides the model of a Broadcast network. Packets may be retransmitted multiple times and broadcast redundancy increases along with the number of nodes. High broadcast redundancy can result in high power and bandwidth utilization which may increase packet collisions. This is known as the broadcast storm problem and is considered a significant challenge for a generic broadcast algorithm.

To reduce the possibility of a broadcast storm, Khabbazian and Bhargava proposed two broadcast routing algorithms called sender based and receiver based broadcasting that operate using one-hop neighbors [1]. In the first algorithm the broadcasting nodes select a subset of their neighbors and forward the message to this subset. The second algorithm ensures that the intermediate node will disregard any message it has received before so that only one node will broadcast the message at a time. The limitation of these algorithms is high overhead.

While most of the MANET routing algorithms are proposed in a bi-dimensional environment, Carofiglio et al. proposed a new routing algorithm for stable MANET routing where the nodes are moving in random directions in a mobile environment [2].

C. Energy efficient routing

Most of the MANET devices are battery operated and power efficiency is one of the most important aspects of MANET routing. Because the longer a battery operated intermediate node operates, the better connection stability it provides and nodes with low residual battery level tend to drop packets. Hence the concept of balanced load routing appears. If one node is constantly carrying data then it tends to use more power. But if packets are carried over a number of intermediate nodes, then the battery lifetime time for each node will be longer.

Lim et al. proposed the randomcast technique [7] which is an energy efficient communication scheme for MANETs but packet transmission speed is not as high as for other algorithms.

Naruephiphat and Charnsripinyo proposed a routing algorithm for balancing network lifetime and reliable packet delivery in MANETs [8] but the algorithm does not utilize the channel bandwidth efficiently. Zhang et al. proposed an energy efficient MANET routing algorithm [13].

MANET routing algorithms proposed in the literature are affected by advantages and disadvantages and for some of the MANET routing algorithms efficiencies are achieved for particular operating scenarios.

III. OVERVIEW OF PROPOSED ALGORITHM

The proposed algorithm has three key components that are coupled to provide the combined outcome: (A) quadrant based location aided opportunistic routing; (B) intelligent energy control; and (C) packet receipt acknowledgement notification. In this section the three algorithm components are described and the combined algorithm is proposed.

A. Quadrant based location aided opportunistic routing

In location aided routing, the sending node registers the location information of the next node by utilizing a position locating system such as the Global Positioning System (GPS). Opportunistic routing is similar to geographic routing except that the routing may occur through multiple intermediate nodes. Location aided opportunistic routing uses nodes' positioning information to define the forwarding candidate set and priority [3].

Quadrant based routing is an enhancement of location based opportunistic routing. In this technique the sending node limits the broadcast region to the quadrant where the destination node or the next intermediate node is located. As packets are broadcast to a specific subset of nodes in one quadrant, it can also be called multicasting. Quadrant based routing reduces the total network power consumption. The nodes can locate and identify themselves using GPS, Self Positioning System (SPS) or Remote Positioning System (RPS) [4]. Upon receiving a packet, an intermediate node will again select the quadrant where the next intermediate node or destination node resides. Hence, the nodes will multicast the packets and this process is repeated node by node until the packets reach the destination node.

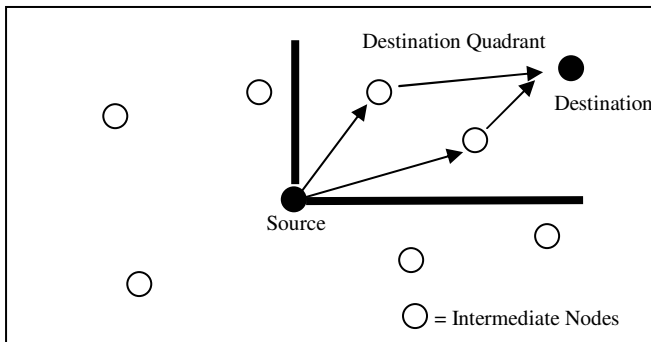


Figure 3. Quadrant based routing

Fig. 3 shows a quadrant based routing system where the originating node identifies which quadrant the destination node or intermediate nodes reside and broadcasts the message into that quadrant only. The number of broadcast messages is reduced compared with conventional flooding algorithms.

B. Intelligent Energy Control

Two common methods for energy efficient routing are: (1) maximum lifetime routing protocol; and (2) minimum energy consumption protocol. The maximum lifetime routing protocol balances the load among a number of intermediate nodes. In this protocol, no single node has to carry traffic

constantly and therefore does not reduce power any more rapidly than its neighbors. Distributing the traffic load ensures that each node maintains an average power lifetime. For the minimum energy consumption protocol a single node is used to carry traffic for its battery lifetime and as a result the overall network consumes less energy but the individual node carries all of the traffic and will expend its energy store more rapidly.

A normalized link capacity cost is: $C_{ij} = E_{ij} (B_{init} / B_i)$ where E_{ij} is energy consumption for link (i,j), B_{init} is the initial battery level and B_i is the residual battery level at node i [8].

The total energy consumed by a node is: $E_{TOT} = E_{TX} + E_{RX}$ where E_{TX} is energy consumed for packet transmission and E_{RX} is energy consumed when receiving packets.

Energy consumed to transmit data b for a distance of d is $E_{TX}(b,d) = (E_{elec} \times b) + (\epsilon_{fs} \times b \times d^2)$ where $\epsilon_{fs} = 10 \text{ pJ/bit/m}^2$ is the energy consumed in free space at the output transmitter for a transmitting range of one meter. For N-node MANET, if a node i has neighbors x,y,z, the energy consumption can be calculated as: $E_{TX}(i) = \max\{E_{TX}(b,d_{ix}), E_{TX}(b,d_{iy}), E_{TX}(b,d_{iz})\}$. The energy consumed by the receiving node $E_{RX}(b) = E_{elec} \times b$ where E_{elec} is the energy expended in the radio electronics which is equal to 5-nJ/bits [8].

The key matrix of measuring the battery operated MANET node energy status is: (1) reputation value; (2) residual battery level; and (3) energy efficiency. The key matrix values are:

1. Reputation value. It is a decimal value of the data packet forwarded by a node. For example: If a node forwards 80 packets out of 100 and drops 20 packets then the reputation value of that node will be $80/100 = 0.8$. This paper proposes to multiply the decimal value by 10 to get an integer value which can be used at a later part of the algorithm.

2. Residual battery level. It is the power level of a MANET device using an index range between 1 to 10. If a node is having 80% battery level then the node's residual battery level will be considered to be index value 8.

3. Energy efficiency. It is the overall energy rating of a MANET device using an index range between 1 to 10. This matrix value depends on the hardware connected, surrounding conditions etc. Energy consumption is unlike the previous two matrix values and is inversely proportional to the performance. For example, if a device consumes less energy then it is more energy efficient.

Intelligent energy control systems propose to utilize the three energy level measuring values and hence tend to provide a numeric value that will indicate the node's the energy rating.

TABLE 1. INTELLIGENT ENERGY RATING VALUES

Parameter	Node A	Node B
Reputational Value	8	7
Residual Battery Level	8	9
Energy Efficiency	7	6
Overall Energy Rating	23	22

Intelligent energy rating values for two nodes are shown in Table I. If the two nodes, A and B have reputation values of 8

and 7, residual battery level of 8 and 9 and energy efficiency of 7 and 6 consecutively then by adding the three values, node A has an overall energy level of 23 whereas node B provides an overall energy level of 22. The originating node will transmit the data to node A. The proposed algorithm also considers that the energy values will change constantly and hence the overall energy rating of a node will change over time as well. The algorithm identifies that the node with the highest energy rating value will receive data packets from the originating nodes. This paper also proposes to store the changeable intelligent energy rating values of each device in memory and will share the value when requested by neighbouring nodes for data transmission purpose.

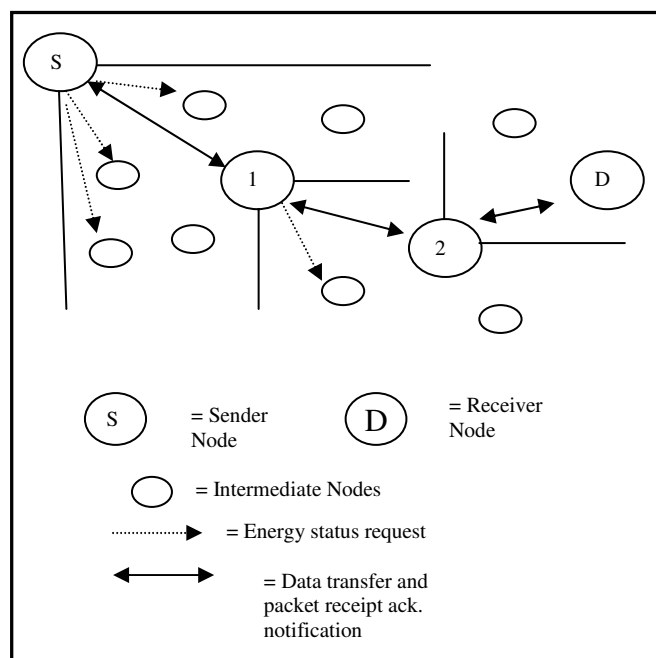


Figure 4. Proposed MANET Model

C. Energy status request and Packet receipt Acknowledgement Notification

In the proposed algorithm, an originating node determines a subset of four nodes residing in the destination or next intermediate quadrant and sends an energy status request to learn the node's reputation value, residual battery level and energy efficiency rating. The proposed algorithm selects a maximum of four nodes because analysis shows that for a condense network anything less than 4 nodes does not provide accurate status and for anything more than 4 nodes might create unnecessary data transmission. For heavily condense network a subset of more than 4 nodes can be selected, but for uniformity subsets of 4 nodes are selected in this paper. The node status request message is normally much smaller when compared to typical message streams. Upon receiving a broadcast message the intermediate node or destination node sends an acknowledgement back to the originating node to advise packet receipt. The acknowledgement message includes: (1) confirmation of receipt; (2) size of the data packet received and (3) the intermediate node position. If the

packet receipt acknowledgement notification is not received by the originating node, then the originating node will retransmit the packet and hence guarantee packet delivery.

IV. PROPOSED ALGORITHM

In this paper a new MANET routing algorithm is presented called the quadrant based intelligent energy controlled multicast routing algorithm (QBIECRA) for MANET. The proposed algorithm reduces the number of broadcast messages, provides better node lifetime and improved routing stability. The algorithm is as follows:

1. Information M to be transmitted is put into a message format.
2. If M has been scheduled to broadcast or does not contain the Node and destination ID, then
 - a. Drop the message
 - b. Else
 - Set a defer timer
3. When Timer expires
4. Select a subset of 4 closest neighbours using positioning system locating at specific quadrant.
5. Multicast the energy level request to the 4 neighbours
6. Neighbours reply with energy status report
7. Sender updates the look up table including energy status of neighbouring nodes.
8. Sender transmits M to the node having highest overall energy rating
9. IF, No energy status report received from any of the four nodes, then retransmit the message (Go to 4)
10. IF M has been received before by the receiving node
 - THEN Drop the message
 - ELSE Send an acknowledgement to the broadcast node.
11. Return to 2
12. IF no acknowledgement is received by the sender then send M again (Go to 8), End;

The source S has received information M to transmit to Destination D as shown in Fig. 2. The algorithm determines the quadrant where the destination node resides. Node S selects a subset of four nodes within that quadrant. It multicasts the energy status request message which is considered much smaller when compared to any standard information message stream. The four nodes reply to node S with their reputation value, residual battery level and energy efficiency. Once node S receives the replies from the intermediate nodes, node S updates its look up table and calculates which intermediate node has highest overall energy rating. The process of calculating the overall energy rating is called the intelligent energy control algorithm. Node S transmits the packet to node 1 as shown in Fig. 2. If node 1 had received the packet previously, it would disregard the packet. For a new packet node 1 sends an acknowledgement signal to node S which confirms the packet delivery from node S to node 1. Node 1 then uses the same algorithm and finds the appropriate quadrant and subset of two intermediate

nodes residing within the transmission radius. In this scenario Node 1 has selected a subset of only two nodes because in this scenario the maximum number of intermediate nodes within transmission range is two. Node 1 then multicasts the energy status request message to the two nodes. Upon receipt of the energy level response message from the nodes, node 1 transmits the packet to node 2. Node 2 then sends an acknowledgement to node 1 and packet delivery is confirmed. If node 1 had not received the acknowledgment for any reason, it would retransmit M to node 2 and if subsequent failures occur then node 1 would select a different node.

Node 2 uses the same quadrant based algorithm and finds that the destination node is within its transmission radius and transmits the packet to the destination node. Thus using the quadrant based intelligent energy controlled routing algorithm, packets are transmitted from source to destination.

V. RESULT

The main objective of the proposed algorithm is to reduce the number of broadcast messages and thereby improve channel efficiency and provide better bandwidth utilization. Along with a reduction in broadcast messages the proposed algorithm increases the intermediate node lifetime to provide stable and reliable routing.

TABLE 2. SIMULATION PARAMETERS

Parameter	Value
Simulation	C++
MAC Layer	IEEE 802.11g
Packet size	256 Kb
Data rate	54 Mbps
Transmission range	95 m

The simulation outcome shown in Fig. 5 includes a comparison for number of broadcast messages generated by a conventional Sender based broadcast algorithm discussed in [1], quadrant based routing algorithm proposed in [4] and the proposed algorithm. The comparison shows that for uniformly distributed nodes, the proposed algorithm reduces the number of broadcast messages significantly when compared with a conventional Sender based algorithm and a conventional quadrant based algorithm.

The simulation outcome shown in Fig. 6 provides a comparison of the average node lifetime using the conventional Sender based broadcast algorithm discussed in [1], balanced network lifetime algorithm proposed in [8] and the proposed algorithm. For uniformity purposes it was assumed that the maximum lifetime of a MANET node is 10 hours. According to the proposed algorithm the load is balanced among intermediate nodes in one quadrant only. As a result the nodes in other quadrants do not have to carry unnecessary data and do not lose power. On the other hand as the traffic is shared among intermediate nodes in desired quadrant so no single node runs out of power quicker, rather

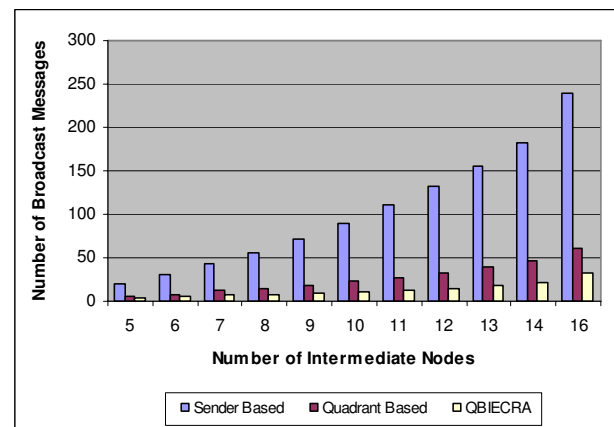


Figure 5. Number of broadcast messages vs Number of intermediate nodes for different MANET algorithms

the neighbouring nodes share the load and provides longer lifetime for individual nodes as well as the network. Thus the simulation result shows that the proposed algorithm increases the average lifetime of an intermediate node.

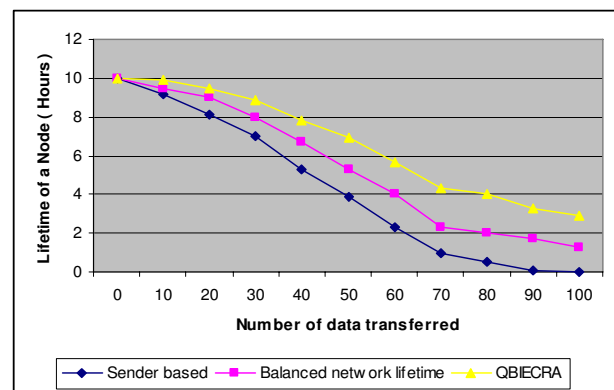


Figure 6. Lifetime of a Node Vs number of data transferred through the node

The simulation result shown in Fig. 7 provides a comparison of the packet transfer rate. Though the proposed algorithm reduces the number of broadcast messages and provides extended intermediate node lifetime it uses a larger number of intermediate nodes and as there is processing delay in every node the packet transfer rate decreases slightly.

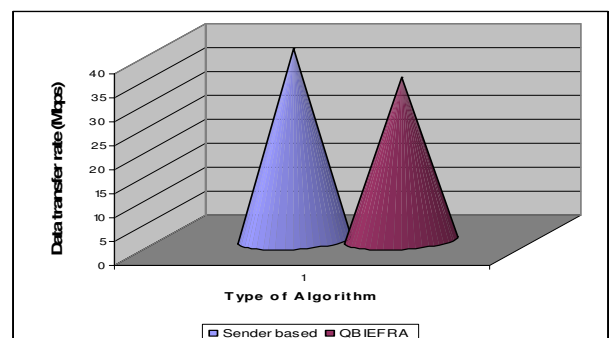


Figure 7. Number of broadcast messages for a conventional sender based algorithm and QBIECRA

VI. TESTING

The Portable Real time Emulator (PoEm) can be used for the algorithm testing as it is one of the more accurate MANET emulation techniques [9]. PoEm uses a client-server structure and runs on a range of work stations. Both server and client software can run on a single hardware platform since they are connected through TCP/IP socket connections.

Client nodes will interact with the server using TCP/IP sockets. The server creates the network scenario by controlling the topology and configuration and the proposed algorithm can be implemented within the simulation. The Packet Scheduler holds the record, database, and statistics. The Replay entity schedules the clients which can be a node. The proposed algorithm can be implemented and results achieved for a number of network scenarios.

VII. CONCLUSION

The simulation result provided in Fig. 5 shows that the proposed algorithm reduces the number of broadcast messages used to transmit a data packet from source to destination node when compared to a conventional flooding type broadcast algorithm and quadrant based routing algorithm. Fig. 6 shows that the proposed algorithm provides an improved intermediate node energy lifetime which reduces the packet loss rate due to low power levels and increases routing stability and reliability. The proposed algorithm also ensures that the packets reach the destination node because until the next node in the chain sends a packet receipt acknowledgement message to the originating node, the originating node will re-broadcast after a set delay. Hence the proposed algorithm provides improved reliability.

But the limitation of this proposed algorithm is that the data transfer rate is slightly lower when compared with the standard algorithms. The reduction in the data transfer rate is offset through the availability of improved compression and higher transmission rates available through improved electronics and algorithms. The overall simulation result shows that with the relatively slower packet transfer rate, the proposed algorithm ultimately provides better channel efficiency and bandwidth utilization.

In this paper, it is assumed that all the nodes are in a two dimensional surface. Future scope includes implementing the

algorithm in the three dimensional environment. Security is a key concern for next generation communication system development. So, increased security parameters have to be added to avoid unauthorized packet interception.

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