Energy Conservation for Wireless Mobile Ad hoc Networks using Hexagonal GAF Protocol

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Abstract- For mobile ad hoc networks (MANET) optimization of energy consumption has greater impact as it corresponds directly to lifetime of a network. Geographic adaptive fidelity (GAF) protocol extends the lifetime of self configuring system while preserving connectivity. By identifying the redundant nodes GAF switch off their radios to conserve the energy. Due to limited radio range, node connectivity is limited to adjacent vertical and horizontal grids only and neighbors in diagonal are out of reach. This issue is known as unreachable corner of GAF square grid architecture. This paper proposes hexagonal grid architecture for GAF named as GAF-HEX which replaces virtual square grid into hexagon grid. This paper introduces two node mapping algorithms GAF-C and GAF-E for GAF-HEX. GAF-C maps nodes with reference node at centre and GAF-E maps with reference node at the end of hexagonal grid. These architectures are evaluated on different performance metrics like packet delivery ratio, throughput and energy consumption. Our simulation results shows that GAF-HEX improves packet delivery ratio and throughput by keeping energy consumption almost same as GAF. These protocols are tested for different mobility and traffic rate.

Key words: MANET, GAF, throughput, packet delivery ratio.

I. INTRODUCTION

A mobile ad hoc network is a self organizing, self configuring and easy to deploy network of mobile devices connected by wireless links. Each device in a MANET is free to move independently in any direction, and will therefore change its links to other devices frequently. So for a MANET, each device has to maintain the information required to properly route traffic. Every device in MANET acts as a router. MANETs are highly suitable for applications involving special outdoor events, communications in the regions with no infrastructure, emergencies and natural disasters and military operations [1].

Routing is one of the key issues in MANETs due to their highly dynamic and distributed nature. In particular, energy efficient routing is the most important design criteria for MANETs since mobile nodes will be powered by batteries with limited capacity. Power failure of a mobile node not only affect the node itself but also its ability to forward packets on behalf of others and thus the overall network lifetime. For this reason, many research efforts have been devoted so as to develop energy aware routing protocols.

One of well known energy efficient protocol is Geographic Adaptive Fidelity (GAF) [2], GAF states that it locates nodes in the network and makes the best use of them to have a better fidelity. All the nodes use a location identification technique to locate itself within the network along with its nearest neighbors by using location information systems like GPS. In GAF the entire network area is divided into virtual square grids. All the nodes in the network divide themselves in virtual square grids and all those nodes which are under a same grid known as equivalent nodes with respect to forwarding packets. Nodes under a same grid coordinate among themselves to decide the sleep time interval and sequence of sleep. Load balancing is performed and a single node will not get drained with extraneous work.

GAF algorithm can communicate directly to its adjacent horizontal and vertical grid cells. But the diagonal cell cannot be covered directly by virtual grid method due to range limitations. For the diagonal cell, packets to be transferred through vertical and horizontal cell which cause the longer path else if node transmits directly the packet drop rate increases. In this paper we propose hexagon grid architecture of GAF, which takes care of unreachable diagonal cell. This paper proposes two ways of node mapping within the cell. The protocol performance is tested for different quality of service (QoS) metrics like packet delivery ratio, throughput and energy consumption.

The rest of the paper organized as follows: Section II discusses the issue of unreachable diagonal cell of GAF and its impact on data delivery. In section III we introduce the proposed algorithm. Node mapping and their association with cell is described in section IV. Section V presents the performance evaluation. Finally we conclude the paper in the last section VI.

II. Unreachable Diagonal Cell in GAF

For GAF [2] size of virtual square grid depends on the nominal radio range R. According to the definition of a virtual grid of size $r_G$, the distance between two nodes at
the extreme end of diagonal of any two adjacent grid cells must not be larger than \( R \). From figure (1), the maximally spaced points in adjacent grid cells \( O \) and \( B \) are nodes \( o \) and \( b \). Therefore the distance between nodes \( o \) and \( b \) is

\[
l_{(o,b)} = \sqrt{r_G^2 + (2r_G)^2} \text{ or } r_G \leq \frac{R}{\sqrt{5}}
\]

In GAF protocol only one node per grid is active and rest nodes within the grid can go to sleep to save energy due to this the network life time in GAF depends on number of nodes per grid. For large number of nodes per grid, more nodes can go to sleep that increases the network life time. To evaluate the upper bound of the lifetime achieved by GAF, \( r_G \) is set to at its maximum value \( r_{G_{\text{max}}} \)

\[
r_{G_{\text{max}}} = \frac{R}{\sqrt{5}}
\]

If \( n \) nodes are uniformly distributed in network area denoted by \( A \), the minimum total number of grids given by \( m \) is

\[
m = \frac{\text{Network area}}{\text{maximum grid size}} = \frac{A}{(r_{G_{\text{max}}})^2} = \frac{A}{(R/\sqrt{5})^2}
\]

The maximum number of nodes per grid is

\[
N_G = \frac{\text{no. of nodes in network}}{\text{minimum no. of grids}} = \frac{n}{m} = nR^2 / 5A
\]

In GAF nodes can only communicate to adjacent grids. From equation (2) cell \( O \) can directly communicate to cell \( B \) and \( D \) because of limited radio range. However we can see from figure (1) that some part of cell \( C \) is not reachable from cell \( O \). Some of the nodes in diagonal cell \( C \) are not reachable from some nodes in cell \( O \). For example, in figure (1) an active node at \((0, 0)\) would not be able to reach any node in the shaded area in cell \( C \). This corner of cell \( C \) is unreachable by nodes of cell \( O \).

Effect of this unreachable event is the **data packet drop** and **longer path**. Packet delivery ratio and throughput are the two QoS parameters for data packet drop and longer path. Our aim is to find out algorithm which can overcome the unreachable corner problem of GAF without reducing its life time.

### III. HEXAGON GAF GRID ARCHITECTURE

Hexagonal tessellations have been used in the literature for various applications. Examples are cellular phone station placement, the representation of benzenoid hydrocarbons, computer graphics, image processing and parallel computing [5].

The hexagon GAF grid architecture uses the hexagonal grid structure [3]. In this the square grid in GAF is replaced with a hexagon mesh as shown in Figure (2). Cell \( O \) now has six neighbors covering destinations from all directions. The hexagon architecture is named as GAF-HEX.

A Hexagon cell in GAF-HEX is defined as, for two adjacent cell \( O \) and \( B \), all nodes in cell \( O \) can communicate with all nodes in cell \( B \) and vice versa. The hexagon mesh has the nice property that for a cell \( O \), all of its six adjacent cells are at next hop. They have the same maximum distance to cell \( O \). In the square grid architecture there are eight neighboring cells (four diagonal, two vertical and two horizontal cells) but only four (vertical and horizontal two each) are at next hop distance while the hexagon cell covers all six possible next hop cells with a single maximum distance due to its symmetry property. Therefore all of the next hop cells for cell \( O \) are equally reachable by definition.

In Figure (2), if \( r \) is the edge length of the hexagon then the longest distance between two adjacent cells, e.g. cells \( O \) and \( B \), is represented by line \((o, b)\),

\[
l_{(o,b)} = \sqrt{13r}
\]

In order for all nodes in adjacent cells to be able to reach each other, the longest length must satisfy

\[
l_{(o,b)} = \sqrt{13r} \leq R
\]
To evaluate the upper bound of the lifetime achieved by GAF-HEX, maximum value of $r$ is taken which is

$$r_{H_{\text{max}}} = \frac{R}{\sqrt{13}}$$

(7)

Therefore the area of one hexagon cell is

$$S = 3\sqrt{3} (r_{H_{\text{max}}})^2/2 = 3\sqrt{3}R^2/26$$

(8)

In a network of size $A$ with nodes $n$, the number of nodes in one hexagon cell is

$$N_H = \frac{3\sqrt{3}nR^2}{26A}$$

(9)

Comparing GAF-HEX with the original GAF, from equation (4) and (9) the number of nodes in each cell is reduced by

$$\frac{(N_G - N_H)}{N_G} = \left[ (nR^2/5A) - (3\sqrt{3}nR^2/26A) \right] / (nR^2/5A)$$

$$= (0.2 - 0.19985) / 0.2$$

$$= 0.00074 = 0.074\%$$

(10)

That is, the network lifetime is reduced by a negligible amount of 0.074%. Now with the hexagon mesh, all next hop cells become reachable all of the time. This has removed the unreachable corner suffered by the original GAF. This improvement can be interpreted in terms of either reduced packet loss or shorter path length.

IV. NODE MAPPING WITH HEXAGON CELL

Now the network area is divided into hexagon cells grid cell of edge length $r$. GAF-HEX uses location information to find out its position. Figure (3) shows the node mapping of GAF-C and GAF-E algorithms. The two reference nodes are separated by $d$ and $h$, the horizontal and vertical distance between two reference nodes respectively.

$$d = \frac{3}{2r_{H_{\text{max}}}}$$

(11)

$$h = \sqrt{3} r_{H_{\text{max}}}$$

(12)

Both $d$ and $h$ are used to find out the position of reference node for both the protocols.

The arrangement of hexagon cell is such that it has one router and few randomly placed node. In each cell there is only one active node. The active node stays awake to take part in communication, while rest node within the cell can go to sleep and wait their turn to become active.

The GAF-HEX protocol only changes the node association scheme of GAF protocol. Other parts of GAF protocol can be used without any modification.

V. PERFORMANCE EVALUATION

A. SIMULATION MODEL

We use network simulator ns-2.3[4] for simulation. GAF-C and GAF-E are implemented on ns-2.31. These protocols are compared with GAF protocol. We use the same energy model used for GAF that requires 1600 mW transmit power, 1200 mW receive power, 1000 mW idle power and 250 mW for sleep. The nominal transmission range is 250 m with two-ray-ground model propagation.

Node moves according to random way-point model. Nodes alternate between pausing and then move to a random location at a fixed speed. We evaluate protocols on two different speed 0m/s and 25m/s with pause time 100 seconds. Nodes move in area of 1000x1000 square meters.

On scenario we use 50 transit nodes and 10 traffic nodes acting as source and sink. Initial energy to traffic nodes is 20000 J and to transit nodes is 500 J.

Simulation traffic was generated by continuous bit rate (CBR) source spreading the traffic randomly among 10 traffic nodes. The packet sent rate (PSR) was set to 4 pkts/s and 10 pkts/s to evaluate traffic sensitivity. The simulation last for 1000 seconds.

B. PERFORMANCE METRICS

We use three metrics to evaluate performance of GAF-C and GAF-E with respect to GAF for MANET.

Throughput (THR): Throughput is aggregate traffic (b/s) supported by the network.

Energy Consumption (EC): Energy consumption is defined as total energy network consumes. In ad hoc network energy consumption is sum of transmit, receive, idle and sleep power.

Packet Delivery Ratio (PDR): Number of data packet received by the destination to the number of data packets transmitted by the source node.
C. SIMULATION TABLE

i) Impact of node mobility and traffic at speed 0m/s

Figure 4 variation of PDR at PSR 4 Pkts/s

Figure 7 variation of PDR at PSR 10 Pkts/s

Figure 5 variation of THR at PSR 4 Pkts/s

Figure 8 variation of THR at PSR 10 Pkts/s

Figure 6 variation of EC at PSR 4 Pkts/s

Figure 9 variation of EC time at PSR 10 Pkts/s
ii) Impact of node mobility and traffic at speed 25m/s

- **Figure 10** variation of PDR at PSR 4pkts/s

- **Figure 11** variation of THR at PSR 4pkts/s

- **Figure 12** variation of EC at PSR 4pkts/s

- **Figure 13** variation of PDR at PSR 10pkts/s

- **Figure 14** variation of THR at PSR 10pkts/s

- **Figure 15** variation of EC at PSR 10pkts/s
**Simulation Results continue:**

From the figures (4-9) and correspondence values in table (1) at zero speed the packet delivery ratio and throughput of GAF-C are improving by 18% and 20% respectively than GAF with almost same value of energy consumption. GAF-E is behaving same as GAF at zero speed.

From the figures (10-15) and correspondence values in table (1) we can observe that packet delivery ratio and throughput of GAF-C is improving by 15% and 15% respectively and for GAF-E by 7.5 % and 3% as compared to GAF.

**VI CONCLUSION**

This paper identifies the unreachable corner of GAF and its effect. Unreachable corner of the cell causes the packet drop and longer path which is measured in terms of Packet Delivery Ratio and Throughput. This paper introduces the Hexagonal GAF algorithm and tests that with different speed and traffic. The two algorithms GAC-C and GAF-E improve the packet delivery ratio which means the less packet drop and throughput. Energy consumption of GAF-C and GAF-E is same as GAF.

**TABLE I**

<table>
<thead>
<tr>
<th>PSR (pkts/s)</th>
<th>Speed (m/s)</th>
<th>PDR</th>
<th>THR (b/s)</th>
<th>EC (W)</th>
<th>Protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0</td>
<td>61.34</td>
<td>85.47</td>
<td>1027.39</td>
<td>GAF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>71.55</td>
<td>101.42</td>
<td>1038.19</td>
<td>GAF-C</td>
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<tr>
<td></td>
<td></td>
<td>60.86</td>
<td>85.67</td>
<td>1033.14</td>
<td>GAF-E</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>58.56</td>
<td>237.44</td>
<td>1012.97</td>
<td>GAF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>68.66</td>
<td>285.17</td>
<td>1046.43</td>
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<tr>
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<td>59.02</td>
<td>257.27</td>
<td>1040.49</td>
<td>GAF-E</td>
</tr>
<tr>
<td>4</td>
<td>25</td>
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<td>1027.81</td>
<td>GAF</td>
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<tr>
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<td>77.66</td>
<td>115.42</td>
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<tr>
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<td></td>
<td>71.62</td>
<td>104.16</td>
<td>1031.48</td>
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<tr>
<td>10</td>
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<td>1085.17</td>
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<td>74.66</td>
<td>258.27</td>
<td>1082.50</td>
<td>GAF-E</td>
</tr>
</tbody>
</table>

From table (1) we can conclude that GAF-C and GAF-E are better performing protocols at higher speed and heavy traffic rate. So by adding some complexity to GAF we can avoid the problem of unreachable corner with better packet sent rate and throughput.

**References**