B-GRID: Location Aware Bandwidth Efficient Routing Protocol for Wireless Ad Hoc Networks

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***Abstract* - An Ad Hoc network results from a cooperative engagement of a collection of mobile nodes without requiring any intervention of any centralized access point. The term ad hoc means that the network structure in not permanent but it can take different forms depending on the task it needs to perform. An ad hoc on-demand routing protocol starts with route discovery procedure from a source to a destination. In this paper, we propose a bandwidth efficient routing protocol called Bandwidth efficient GRID (B-GRID).**

***Index terms* - Ad Hoc Networks, Bandwidth efficient, B-GRID, mobile nodes, Routing.**

I. Introduction

Wireless access networks came into existence in 1970's. Since then, these have become increasingly popular for applications in the computing industry. Wireless network technology is now a fast developing technology that allows users to access information and services, regardless of their geographic locations. This is due to the recent advances in the devices' technology for portable communications. The growing applications of mobile devices are also due to the continued miniaturization of mobile computing devices and an extraordinary rise in processing power embedded in such devices. At the end of 2004 there were more than two billion wireless communication devices in use. Recent projections show that more than 200 million wireless telephone handsets will be purchased annually [1].

Today, we expect "the network" to follow us, that is it should provide services to the subscribers regardless of their locations. For example, the navigational systems based on Global Positioning System (GPS) available in our car to direct us on alternate routing in the presence of congestions on preferred routes largely depend on the processing power of wireless terminals and inexpensive wireless communications services.

In the conventional wireless networks, the network infrastructure keeps track of the link between the mobile terminals and the network in order to avoid network disruption. The infrastructure of the network being expensive, ways are sought to create networks that do not require any infrastructure. Adhoc networks fall into the category of infrastructure-less networks. To establish communication link between two wireless terminals, we may require more than one hop due to a limited coverage range of low power wireless devices. Such arrangement is called multi-hop communication. The multi-hop communication eliminates the infrastructure usually used in the conventional cellular systems. The connection between to arbitrary nodes in the network requires a procedure known as route discovery. These are also known as routing protocols.

Many routing protocols for mobile Ad hoc networks have been proposed [1]-[5]. These protocols are classified as reactive and proactive. In the reactive routing protocols the route from a source to a destination is established only when there is a need to communicate. In case of proactive routing protocols the nodes maintain routing information to all other nodes in the network, irrespective of the requirement. In proactive routing protocols there is a substantial exchange of routing information between the nodes in the form route updates. Thus expending a major portion of the valuable bandwidth with routing information. In reality not every node needs to communicate with all other nodes in the network at all times. Hence, there is no need to maintain routing information at nodes to all other nodes in the network. Reactive routing protocols, therefore, are more bandwidth efficient compared to the proactive routing protocols.

The reactive routing protocols also flood the network with route request packets whenever there is a need to establish a route from a source to a destination node. Many bandwidth efficient routing protocols have been proposed in the literature [6,7]. Location aided routing also helps in efficient usage of the available bandwidth resources. Some of the location aided routing protocols proposed in the literature are discussed in [7,9]. The GRID routing protocol achieves bandwidth efficiency by maintaining the routes [9]. As only the gateway nodes take part in route discovery, the problem is reduced to maintenance of the gateway nodes. A gateway election protocol is used to elect the gateway nodes. This procedure also uses the available bandwidth for sending GATE, BID and RETIRE packets. In this paper we present a routing protocol, which is bandwidth efficient called B-GRID. It is an on-demand routing protocol i.e. the routes are discovered only when they are needed for communication. The B-GRID protocol achieves bandwidth efficiency by restricting the route request packets to a small search area. It divides the cell area into number of virtual grids. The search area is defined from the present grid locations of the source and the destination nodes. GPS-related applications are quickly gaining popularity as wireless devices come equipped with GPS receivers. The location-aware applications are also becoming important in the case of mobile computing [8]. Some of the GPS-related mobile applications are navigation systems, telematic systems, geocasting systems and tour guide systems. Availability of location information will have a broad impact at the application as well as the network level.

In the work reported in this paper, it is assumed that the mobile nodes are equipped with Global Positioning System (GPS). The route discovery procedure relies on the GPS units for efficient bandwidth usage. The route maintenance is done in a more intelligent manner wherein the route request packets are sent from the point of link breakage in the route, thus avoiding unnecessary route request packets. The combination of route discovery and route maintenance results in saving the precious bandwidth. The simulation results presented in this paper illustrate the bandwidth efficiency achieved using this protocol.

The rest of the paper is organized as follows. Section 2 presents the B-GRID routing protocol. In Section 3, we present some simulation results. Section 4 concludes the paper.

II. B-GRID ROUTING PROTOCOL

The proposed algorithm is a modification to the GRID based location-aware routing protocol discussed in [9]. To achieve larger bandwidth efficiency in the GRID based routing protocol, a protocol, called B-GRID, is proposed. The cell area is divided into number of grids in order to achieve greater bandwidth efficiency. To decrease the number of hops in a route, the concept of gateway per grid is not used. The route overhead packets are reduced, as this protocol does not require a grid leader. Hence, the grid election procedure is not required.

The search range for route discovery is found from the locations of source and destination. A few methods that help to confine the search are as follows [9]:

1) Rectangle – The smallest rectangle that can cover the grid of source node and grid of destination is the search area.
2) Bar (ω) – Here the search area is the bar between the grid of source node and grid of destination node with width ω.
3) Fan (θ, *r*) – Here the search area is the fan between the grid of source node and that of destination node with angle θ and radius *r*.
4) Two Fans (θ, *r*) – Here the search area is the intersection of two fans. One from the grid of source node to that of destination node and the other from the grid of destination node to that of source node. Both with the angle θ and radius *r*.

In the simulations we use the Bar search method as shown in the Fig. 1.

The size of the grid is also varied to study the influence of the size on the performance of the protocol [9]. In this study, 3 variations of the grid sizes are used to study the protocol performance. These are:

$$d = \frac{2r}{\sqrt{10}}, \; d = \frac{\sqrt{2}r}{3} \text{ and } d = \frac{r}{2\sqrt{2}}$$

(labelled as GRID-1, GRID-2, GRID-3 for GRID routing protocol and B_GRID-1, B_GRID-2, B_GRID-3 for B-GRID routing protocol respectively).

If ω is the width of the rectangular search area and *l* is the distance between the source node and the destination node with coordinates (x_1,y_1) and (x_2,y_2), then,

$$l = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \quad (1)$$

The search area depends on the rectangular width ω. If ω is increased the search area increases and the route cost increases. If ω is very less the search area is small and the route discovery procedure fails to find a route. One way of selecting ω is to make sure that at least a single grid appears in the width of the rectangle.

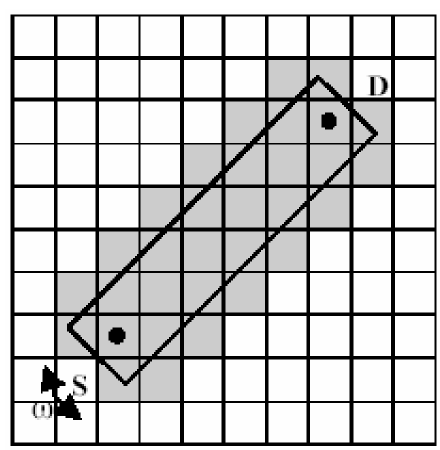

Fig. 1. Bar search method for Route Discovery

A. Route Discovery and Route Reply

The route search packets are sent in a small area as discussed above. The locations of the source and destination nodes determine the boundary of the search area. In the GRID routing protocol only the grid leaders take part in the route discovery procedure However, in our proposed protocol, all nodes in the search area take part in the route discovery. Also the routing table is set up in a node-by-node manner. In GRID routing protocol the routing table is set up in a grid-by-grid manner. A source node, initiates a route request (RRQ) to a destination node. The location of the destination is known through the GPS unit, which is attached to all mobile hosts. This information of the location of nodes is broadcast to all the nodes in the network in the form of *node_location* packets. But this may flood the network with *node_loction* packets. To avoid this, *node_location* packets are sent only when a node moves in and out of a grid. This reduces the *node_location* packets by a significant number. To avoid the number of *node_location* packets in the network, a node having the present location of 'n' nodes, adds its own location and sends it as a single packet.

The route request (RRQ) packet has fields *S*, *D*, id, range and nodes. *S* is the source node and *D* is the destination node. To avoid duplication of RRQ packets and also to avoid the formation of routing loops, the pair *(S, id)* is used. The *range* parameter is to specify the area to be searched for the route discovery. The *nodes* parameter specifies the mobile host located in the search area. This takes care of the irrelevant nodes from receiving the RRQ packet. A node receiving RRQ packet will first check whether it is the destination node specified in the RRQ packet. If not, it will forward the RRQ packet to its neighbour in the search area and will also sets up a reverse pointer to the immediate sending node.

When a destination node receives the RRQ packet a route reply packet RREP will be sent back to the source node. The RREP packet travels in the path specified in RRQ packet, which is established earlier in the form of reverse pointers. When RREP is received by source node, it updates its routing table with this entry.

B. Route Maintenance

When an existing route breaks due to the movement of nodes, route maintenance procedure has to be performed. The point of the link breakage is determined and a route discovery from this intermediate node to the destination node is initiated. If this results in a route from an intermediate node to destination node, the packet forwarding is continued. If not a route discovery is initiated from the source node to the destination node again.

C. Elimination of broadcast storm in B-GRID

In B-GRID routing protocol the number of route overhead packets are lower compared to GRID protocol. In GRID protocol the route overhead is more due to the presence of gateway nodes. As the gateway nodes move out of a grid, new gateway is elected and the route tables are handed over to the new gateway. This is similar to hand off in cellular networks. In B-GRID the concept of gateway communication does not exist and any node can communicate with any other node. It can be shown that the overhead of B-GRID is less compared to GRID as follows:

Let P_g be the probability of existence of a gateway node in a grid. According to the GRID protocol the GATE packets are transmitted every Δt seconds. Let n be the number of grids in the cell area and N_h is the number of hops in a route. Then the number of GATE packets N_g, required for route maintenance can be given by,

$$N_g = \frac{P_g N_h T}{\Delta t} \tag{2}$$

where T is total time of simulation.

Similarly the number of BID packets N_b, is given by,

$$N_b = \frac{(1-P_g) N_h \delta T}{\Delta t} \tag{3}$$

where δ is the number of nodes in a grid. Also the number of RETIRE packets broadcasted by the gateway nodes can be calculated as follows:

A gateway node is most probably located at the centre of a grid. If d is the size of the grid, then a gateway node would travel a distance of $d/\sqrt{2}$ (utmost) to broadcast a RETIRE packet. The number of RETIRE packets N_h, for a given time T is given by,

$$N_r = \frac{T}{d/\sqrt{2}\,v} \tag{4}$$

where v is the average velocity of a node.

Hence the total overhead packets N_o, can be given by,

$$N_o = N_g + N_b + N_r \tag{5}$$

$$N_o = \left[\frac{P_g N_h}{\Delta t} + \frac{(1-P_g) N_h \delta}{\Delta t} + \frac{1}{d/\sqrt{2}\,v} \right] T \tag{6}$$

In case of B-GRID protocol the number of overhead packets is sent only when a destination node moves from one grid to another. Here the worst possible case is taken into account i.e., a node moving along diagonally opposite edges of a grid. The overhead packets N_{ob}, for the B-GRID protocol is given by,

$$N_{ob} = \left[\frac{T}{\sqrt{2}\,d/v} \right] N_d \tag{7}$$

where N_d is the number of destination nodes. From the (5) and (6) it is clear that the numbers of overhead packets are more in case of GRID compared to B-GRID routing protocol. In case of GRID the overhead count is proportional to $\sqrt{2}$ and in B-GRID it is proportional to $1/\sqrt{2}$. Also in case of GRID, we have GATE and BID packets that increase the route overhead count.

III. SIMULATION SCENARIO

Simulation experiments were conducted over a physical area of size $1000m \times 1000m$ with 50 to 300 mobile hosts. The transmission range of the mobile is 300 meters. And the transmission power of the mobile host is 100 milliwatts. This is power with which a data packet is transmitted. Also the simulation is repeated for different grid size as follows:

$$d = \frac{2r}{\sqrt{10}},\ d = \frac{\sqrt{2}r}{3} \text{ and } d = \frac{r}{2\sqrt{2}}$$

The simulations are carried out for 10 source-destination pairs. The mobile hosts move every 0.5 second. The simulation is carried out for 500 seconds and repeated for 50 iterations. The route discovery procedure adopted for the simulation is rectangular grid search method. The data traffic generated at the source is exponentially distributed, with means 0.1 sec interarrival time throughout the simulation.

The routing cost is compared for B-GRID and GRID routing protocols for bandwidth efficiency. The *routing cost* is defined as the number of packets sent to discover a route (RRQ and grid update packets) per data packet. As the mobile host density increases the *routing cost* increases. Also, as the grid size is made smaller the *routing cost* increases in the form of greater number of grid updates. In Fig. 2 to Fig. 7, the routing cost for different host density is compared for the B-GRID and GRID routing protocols. We notice, that the B-GRID is bandwidth efficient compared to GRID routing protocol. And the routing cost for the B-GRID protocol does not increase more with the host density. The B-GRID routing protocol is less sensitive to host density when compared to the GRID routing protocol.

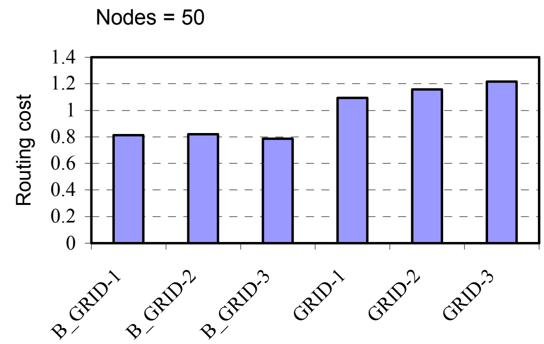

Fig. 2. Average Routing cost for B-GRID and GRID routing protocols with 50 nodes

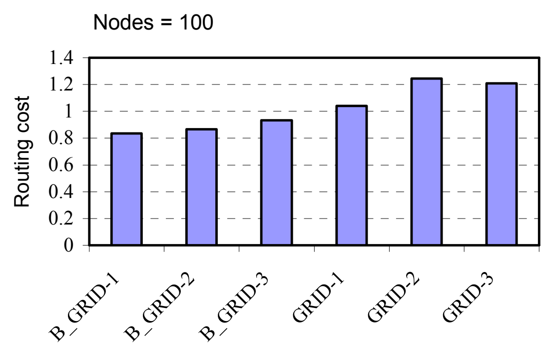

Fig. 3. Average Routing cost for B-GRID and GRID routing protocols with 100 nodes

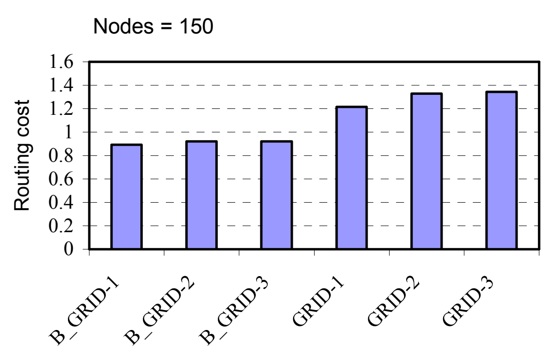

Fig. 4. Average Routing cost for B-GRID and GRID routing protocols with 150 nodes

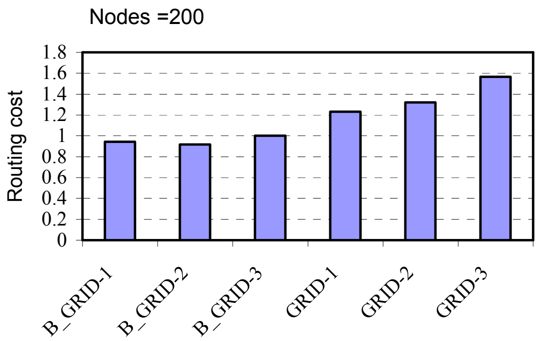

Fig. 5. Average Routing cost for B-GRID and GRID routing protocols with 200 nodes

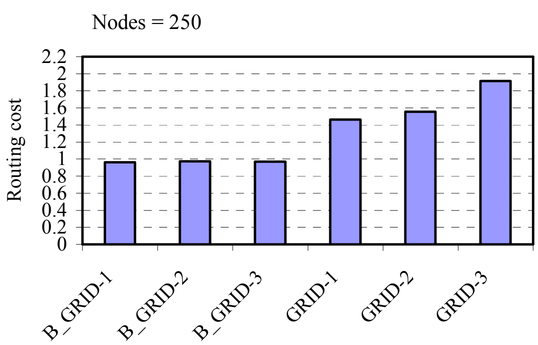

Fig. 6. Average Routing cost for B-GRID and GRID routing protocols with 250 nodes

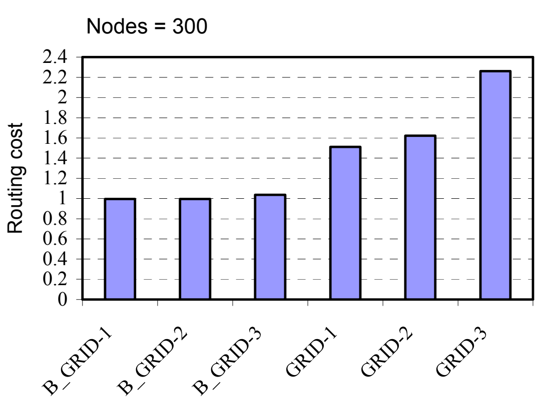

Fig. 7. Average Routing cost for B-GRID and GRID routing protocols with 300 nodes

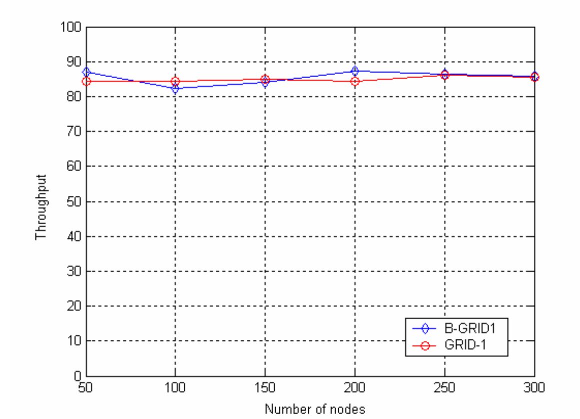

Fig. 8. Average throughput for B-GRID and GRID routing protocols with grid size as GRID-1 and average speed of the nodes being 30 km/hr

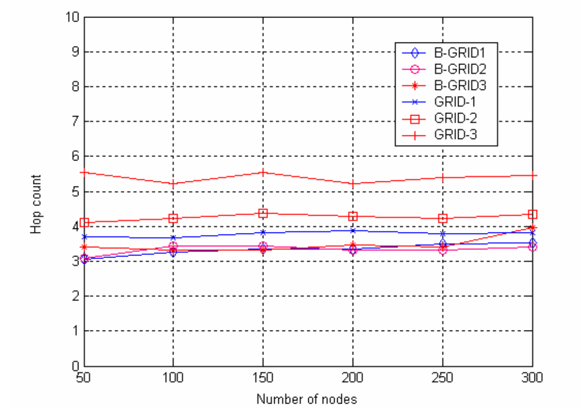

Fig. 9. Average hop count for B-GRID and GRID routing protocols with average speed of the mobile nodes as 30 km/hr

The throughput for the B-GRID and GRID routing protocols is almost the same and does not change with the grid size (see Fig. 8). The route length of B-GRID protocol is shorter compared to the GRID protocol. This is due to the presence of one gateway node per grid in GRID protocol.

On an average the hop count is 3.5 for B-GRID protocol and does not change with the grid size. This is due to the fact that B-GRID uses grid concept to locate the nodes and does not have one gateway per grid. The average hop count for GRID-1 GRID-2 and GRID-3 is 3.75, 4.25 and 5.5 respectively. This is shown in Fig. 9. This is due to the grid-to-grid communication in the GRID routing protocol. As the grid size decreases the number of grids in the cell area increases and hence the number of grids in the route search area increases. The hop count for GRID protocol makes it power inefficient because more number of hops in a route means more power is used to send a packet from a source to a destination. B-GRID is power efficient when compared to the GRID routing protocol.

In the Table I, GRID, B-GRID and Dynamic Source Routing (DSR) protocols are compared for bandwidth efficiency. It can be seen from the table that B-GRID protocol with grid size as GRID-2 achieves highest bandwidth efficiency compared to DSR and GRID routing protocol.

TABLE I
COMPARISON OF BANDWIDTH EFFICIENCY

Protocol	**Bandwidth Efficiency**
DSR	inefficient
B-GRID1	95.87%
B-GRID2	96.83%
B-GRID3	96.16%
GRID1	94.29%
GRID2	93.88%
GRID3	94.31%

IV. Conclusions

A new grid based protocol called B-GRID has been proposed. The protocol results in saving the bandwidth by limiting the route search area compared to the conventional broadcast based methods. It also results in saving the bandwidth compared to the GRID routing protocol by avoiding the route packets to maintain the gateway nodes. In B-GRID protocol, the route discovery procedure minimizes the number of route request packets in the network by localizing the route search area. On the other hand the route maintenance procedure tries to discover the route from the point of its discontinuity. Thus avoiding unnecessary route request packets.

The simulation results show that the B-GRID routing protocol is bandwidth efficient compared to GRID routing protocol. This is illustrated from the routing cost for B-GRID and GRID routing protocols.

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