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Sinchan Roychowdhury
Instrumentation Control Engineering Calcutta Institute of Engineering & Management Kolkata, India, src.official@gmail.com

Chiranjib Patra
Head, Dept. of Information Technology Calcutta Institute of Engineering & Management Kolkata, India, chiranjibpatra.ciem@gmail.com

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Sinchan Roychowdhury
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src.official@gmail.com

Chiranjib Patra
Head, Dept. of Information Technology
Calcutta Institute of Engineering & Management
Kolkata, India
chiranjibpatra.ciem@gmail.com

Abstract— **Location based routing protocols are the kinds of routing protocols, which use of nodes' location information, instead of links' information for routing. They are also known as position based routing. In position based routing protocols, it is supposed that the packet source node has position information of itself and its neighbors and packet destination node. In recent years, many location based routing protocols have been developed for ad hoc and sensor networks.**

In this paper we shall present the concept of location-based routing protocol, its advantages and disadvantages. We shall also look into two popular location-based protocols: Geographic Adaptive Fidelity (GAF) and Geographic and Energy Aware Routing (GEAR).

Keywords- Location based routing, Geographic Adaptive Fidelity, Geographic and Energy Aware Routing.

I. INTRODUCTION

In wireless sensor networks, building efficient and scalable protocols is a very challenging task due to the limited resources and the high scale and dynamics. Using location information to help routing is often proposed as a means to achieve scalability in large mobile ad-hoc networks. These location based routing protocols are also referred to as geographic routing protocols as the sensor nodes are addressed by means of their locations instead of the information that they carry. The distance between neighboring nodes can be estimated on the basis of incoming signal strengths. In these protocols, the state required to be maintained is minimum and their overhead is low, in addition to their fast response to dynamics.

Most of the routing protocols for sensor networks require location information for sensor nodes. In most cases location information is needed in order to calculate the distance between two particular nodes so that energy consumption can be estimated. Since, there is no addressing scheme for sensor networks like IP-addresses and they are spatially deployed on a region, location information can be utilized in routing data in an energy efficient way. For instance, if the region to be sensed is known, using the location of sensors, the query can be diffused only to that particular region which will eliminate the number of transmission significantly. The location of nodes may be available directly by communicating with a satellite, using GPS (Global Positioning System), if nodes are equipped with a small low power GPS receiver. These protocols select the next-hop towards the destination based on the known position of the neighbors and the destination. The position of the destination may denote the centroid of a region or the exact position of a specific node. Location-based routing protocols can avoid the communication overhead caused by flooding, but the calculation of the positions of neighbors may result extra overhead. To save energy, some location based schemes demand that nodes should go to sleep if there is no activity. More energy savings can be obtained by having as many sleeping nodes in the network as possible. The local minimum problem is also common for all decentralized location-based routing protocols: it might happen that all neighbors of an intermediate node are farther from the destination than the node itself. In order to circumvent this problem, every protocol uses different routing techniques. In the following sections of this paper we shall deal with two popular location based protocols: Geographic Adaptive Fidelity (GAF) and Geographic and Energy Aware Routing (GEAR).

II. GEOGRAPHIC ROUTING

In this section, we will discuss basic geographic protocols at the network layer: geographic routing, geocasting and geographic rendezvous mechanisms. Geographic routing provides a way to deliver a packet to a destination location, based only on local information and without the need for any extra infrastructure, which makes geographic routing the main basic component for geographic protocols. With the existence of location information, geographic routing provides the most efficient and natural way to route packets comparable to other routing protocols. Geocasting is the delivery of packets to nodes within a certain geographic area. It is an extension to geographic routing where in this case the destination is a geographic region instead of a specific node or point.

Geocasting is an important communication primitive in wireless sensor networks, since in many applications the target is to reach nodes in a certain region. In geographic-based rendezvous mechanisms, geographical locations are used as a rendezvous place for providers and seekers of information. Geographic-based rendezvous mechanisms can be used as an efficient means for service location and resource discovery, in addition to data dissemination and access in sensor networks.

Routing in ad hoc and sensor networks is a challenging task due to the high dynamics and limited resources. There has been a large amount of non-geographic ad hoc routing protocols proposed in the literature that are either proactive (maintain routes continuously) [1], reactive (create routes on-demand) [2] or a hybrid [3].

Non-geographic routing protocols suffer from a huge amount of overhead for route setup and maintenance due to the frequent topology changes and they typically depend on flooding for route discovery or link state updates, which limit their scalability and efficiency. On the other hand, geographic routing protocols require only local information and thus are very efficient in wireless networks. First, nodes need to know only the location information of their direct neighbors in order to forward packets and hence the state stored is least. Second, such protocols conserve energy and bandwidth since discovery floods and state propagation are not required beyond a single hop. Third, in mobile networks with frequent topology changes, geographic routing has fast response and can find new routes quickly by using only local topology information. In the discussion of geographic routing mechanisms we use the following assumptions:

- Each node knows its geographic location using some localization mechanism. Location awareness is essential for many wireless network applications, so it is expected that wireless nodes will be equipped with localization techniques. Several techniques exist for location sensing based on proximity or triangulation using radio signals, acoustic signals, or infrared. These techniques differ in their localization granularity, deployment complexity, and cost. In general, many localization systems have been proposed in the literature: GPS (Global Positioning System), infrastructure based localization systems [4] and ad-hoc localization systems [5].
- Each node knows its direct neighbors' locations. This information could be obtained by nodes periodically or on request broadcasting their locations to their neighbors.
- The source knows the destination location.

In geographic routing, each node knows the location of its direct neighbors (neighbors within its radio range). The source inserts the destination location inside the packet. During packet forwarding, each node uses the location information of its neighbors and the location of the destination to forward the packet to the next-hop. Forwarding could be to a single node or to multiple nodes. Forwarding to multiple nodes is more robust and leads to multiple paths to the destination, but it could waste a lot of resources (energy and bandwidth) and thus forwarding to a single node is more efficient and it is the common approach among unicast protocols. A main component in geographic routing is greedy forwarding, in which the packet should make a progress at each step along the path. Each node forwards the packet to a neighbor closer to the destination than itself until ultimately the packet reaches the destination. If nodes have consistent location information, greedy forwarding is guaranteed to be loop-free.

III. Greedy Algorithm

Under this approach, a node decides about the transmission path based on the position of its neighbors. To proceed, the source compares the localization of the destination with the coordinates of its neighbors. Then, it propagates the message to the neighbor which is closest to the final destination. The process is repeated until the packet reaches the intended destination. Several metrics related to the concept of closeness have been proposed for this context. Among them, the most popular metrics are the Euclidean distance and the projected line joining the relaying node and the destination.

With this strategy, flooding processes are restricted to one-hop and the network is able to adapt proficiently to the topological changes. This simple forwarding rule is modified according to the reliability of links in [6]. In this proposal, the unreliable neighbors are not taken into account for the retransmissions. On the other hand, the geographic information is also used in SPEED (Stateless Protocol for End-to-End Delay) to estimate the delay of the transmitted packets.

Similar to this algorithm, the greedy algorithm with the "most-forward-within-R forwarding technique opts to select the most distant neighbor of the packet holder which is closer to the final destination as the next hop [7]. In contrast, the "nearest-forward-process chooses the nearest neighbor that is closer to the intended destination as the next relaying node.

The main limitation of the greedy algorithms is that the transmission may fail when the current holder of the message has no neighbors closer to the destination than itself. This could occur even when there is a feasible path between the two extremes, for instance, when an obstacle is present.

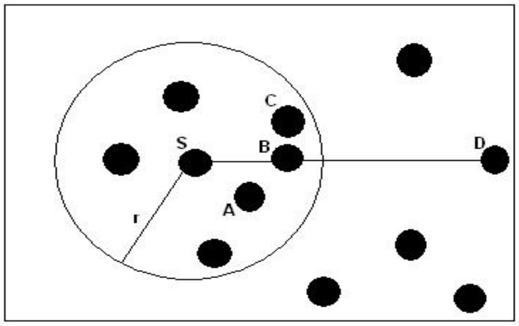

Fig 1 Greedy Protocol

In Fig. 1, S and D denote the source and destination (recipient) nodes of packet. The circle with radius *r* indicates maximum transmission range of S. One strategy is forwarding packet to closest neighbor to destination D. by using this strategy, node S sends packet to node C. This strategy is known as MFR, it tries to minimize the number of hops a packet has to traverse in order to reach D. In another strategy named NFP (Nearest with Forward Progress), packet sender node, sends packet to its nearest neighbor node (it's closest neighbor with forward progress towards destination node). In Fig. 1, by using this strategy, node S sends packet to node A. In compass routing strategy, packet sender node sends packet to neighbor closest to supposed straight line between sender and destination nodes, by using this strategy, node S sends packet to node B [8].

IV. GEOGRAPHIC ADAPTIVE FIDELITY (GAF)

Geographic Adaptive Fidelity or GAF [9] is an energy-aware location-based routing algorithm designed primarily for mobile ad hoc networks, but is used in sensor networks as well. This protocol aims at optimizing the performance of wireless sensor networks by identifying equivalent nodes with respect to forwarding packets. In GAF protocol, each node uses location information based on GPS to associate itself with a "*virtual grid*" so that the entire area is divided into several square grids, and the node with the highest residual energy within each grid becomes the master of the grid. Two nodes are considered to be equivalent when they maintain the same set of neighbor nodes and so they can belong to the same communication routes. Source and destination in the application are excluded from this characterization.

Nodes use their GPS-indicated location to associate itself with a point in the virtual grid. Inside each zone, nodes collaborate with each other to play different roles. For example, nodes will elect one sensor node to stay awake for a certain period of time and then they go to sleep. This node is responsible for monitoring and reporting data to the sink on behalf of the nodes in the zone and is known as the master node. Other nodes in the same grid can be regarded as redundant with respect to forwarding packets, and thus they can be safely put to sleep without sacrificing the "*routing fidelity*" (or routing efficiency). The slave nodes switch between off and listening with the guarantee that one master node in each grid will stay awake to route packets. For example, nodes 2, 3 and 4 in the virtual grid B in Fig 2 are equivalent in the sense that one of them can forward packets between nodes 1 and 5 while the other two can sleep to conserve energy. Hence, GAF conserves energy by turning off unnecessary nodes in the network without affecting the level of routing fidelity. Each node uses its GPS-indicated location to associate itself with a point in the virtual grid.

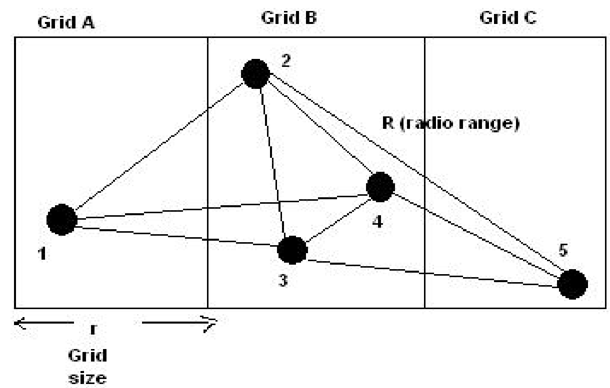

Fig 2 Virtual grid structure in the GAF protocol

The grid size *r* can be easily deduced from the relationship between *r* and the radio range *R* which is given by the formula:

$$r \leq R/\sqrt{5}$$

There are three states defined in GAF as shown in. These states are discovery, for determining the neighbors in the grid, active reflecting participation in routing and sleep when the radio is turned off. In order to handle the mobility, each node in the grid estimates it's leaving time of grid and sends this to its neighbors. The sleeping neighbors adjust their sleeping time accordingly in order to keep the routing fidelity. Before the leaving time of the active node expires, sleeping nodes wake up and one of them becomes active. The state transitions in GAF are depicted in Fig. 3.

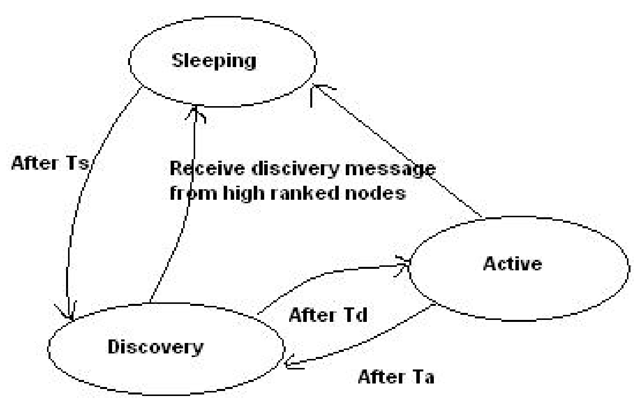

Fig 3 State transitions in GAF protocols

Master election rule in GAF is as follows. Initially, a node is in the discovery state and exchanges discovery messages including grid IDs to find other nodes within the same grid. Anode becomes a master if it does not hear any other discovery message for a predefined duration *Td*. If more than one node is in the discovery state, one with the longest expected lifetime becomes a master. The master node remains active to handle routing for *Ta*. After *Ta*, the node changes its state to discovery to give an opportunity to other nodes within the same grid to become a master. In scenarios with high mobility, sleeping nodes should wake up earlier to take over the role of a master node, where the sleeping time *Ts* is calculated based on the estimated time the nodes stays within the grid. Which node will sleep for how long is application dependent and the related parameters are tuned accordingly during the routing process.

GAF strives to keep the network connected as in [10][11], by keeping a representative node always in active mode for each region on its virtual grid. While such connectivity is ensured by self-organizing the router sensors, MECN maintains an enclosure graph of the network by dynamically changing the transmitting range assignment of the nodes. Simulation results show that GAF performs at least as well as a normal ad hoc routing protocol in terms of latency and packet loss and increases the lifetime of the network by saving energy. Although GAF is a location-based protocol, it may also be considered as a hierarchical protocol, where the clusters are based on geographic location. For each particular grid area, a representative node acts as the leader to transmit the data to other nodes. The leader node however, does not do any aggregation or fusion as in the case of hierarchical protocols.

V. GEOGRAPHIC AND ENERGY AWARE ROUTING (GEAR)

Yu et al. [12] proposed the use of geographic information while disseminating queries to appropriate regions since data queries often include geographic attributes. The protocol, called Geographic and Energy Aware Routing (GEAR), uses energy aware and geographically-informed neighbor selection heuristics to route a packet towards the destination region. The key idea is to restrict the number of interests in directed diffusion by only considering a certain region rather than sending the interests to the whole network. By doing this, GEAR can conserve more energy than directed diffusion.

In GEAR, each node keeps an estimated cost and a learning cost of reaching the destination through its neighbors. The estimated cost is a combination of residual energy and distance to destination. The learned cost is a refinement of the estimated cost that accounts for routing around holes in the network. A hole occurs when a node does not have any closer neighbor to the target region than itself. If there are no holes, the estimated cost is equal to the learned cost. The learned cost is propagated one hop back every time a packet reaches the destination so that route setup for next packet will be adjusted. The process of forwarding a packet to all the nodes in the target region consists of two phases:

1. Forwarding the packets towards the target region: Upon receiving a packet, a node checks its neighbors to see if there is one neighbor, which is closer to the target region than itself. If there is more than one, the nearest neighbor to the target region is selected as the next hop. If they are all further than the node itself, this means there is a hole. In this case, one of the neighbors is picked to forward the packet based on the learning cost function. This choice can then be updated according to the convergence of the learned cost during the delivery of packets.
2. Forwarding the packets within the region: If the packet has reached the region, it can be diffused in that region by either recursive geographic forwarding or restricted flooding. Restricted flooding is good when the sensors are not densely deployed. In high-density networks, recursive geographic flooding is more energy efficient than restricted flooding. In that case, the region is divided into four sub regions and four copies of the packet are created. This splitting and forwarding process continues until the regions with only one node are left. An example is depicted in Fig. 4.

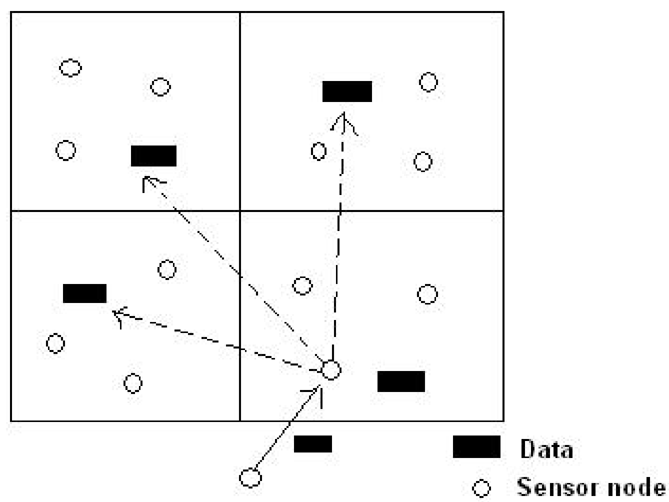

Fig 4 recursive geographic forwarding in GEAR

In [12], GEAR was compared to a similar non-energy-aware routing protocol GPSR [13], which is one of the earlier works in geographic routing that uses planar graphs to solve the problem of holes. In case of GPSR, the packets follow the perimeter of the planar graph to find their route. Although the GPSR approach reduces the number of states a node should keep, it has been designed for general mobile ad hoc networks and requires a location service to map locations and node identifiers. GEAR not only reduces energy consumption for the route setup, but also performs better than GPSR in terms of packet delivery. The simulation results show that for an uneven traffic distribution, GEAR delivers 70% to 80% more packets than GPSR. For uniform traffic pairs GEAR delivers 25%-35% more packets than GPSR.

VI. Comparison and Conclusion

Both GAF and GEAR are location based protocols, although GAF can also be classified as hierarchical protocol, with limited power usage. As they operate on the basis of the geographic or location information for routing, data aggregation at any point is absent. Although GAF is highly scalable, GEAR faces a problem of limited scalability and is often identified as one of the major disadvantages of GEAR. Another problem faced by both the protocols is that both the mechanisms have moderately high overhead which affects the energy efficiency.

A major difference in between the two protocols is in their respective data delivery model. GAF follows the virtual grid data delivery model and the data is transmitted by the operations performed by the master nodes and the slave nodes. On the other hand, GEAR operates on the principle of demand driven data delivery model. Although neither of the two protocols take care of QoS, but this provides scope for future research to be conducted to enable QoS in GAF and GEAR protocols during data transmission.

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