An Energy Aware GAF protocol for Distributed Wireless Sensor Networks

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Abstract— In the design of protocols and algorithms energy awareness for computation and protocol management is becoming a crucial factor. On the other hand, to support node mobility many scalable routing strategies have been designed. These protocols try to consider the path duration with respect to some QoS constraints and to reduce the route discovery procedures. In this paper, a novel routing strategy is introduced called Energy Aware Geographic Adaptive Fidelity protocol, which uses nodes' location information, instead of links' information for routing of data packets. This protocol makes use of nodes which are not active into sleeping state over a period of time making cooperative network more energy efficient. When compared to a similar non-energy aware routing protocol such as GPSR, energy aware GAF not only reduces the energy consumption for the route setup, but also performs better than GPSR in terms of packet delivery ratio. This novel protocol minimizes the unnecessary channel access contention and thereby improves the packet drop rate without compromising the event detection latency. This is in contrast to the energy- latency tradeoffs that has been the main focus of many energy efficient in Wireless Sensor Networks (WSN).

Index Terms— Energy, GAF, GPSR, location, MANET

1 Introduction

RAPID development of Mobile Ad Hoc Networks (MANETs) has stimulated numerous wireless applications. MANETs feature self-organizing and independent infrastructures, which make them an ideal choice for uses such as communication and information sharing [1]. Since, location-based service (LBS) being a typical application for MANETs it is common for a node to issue nearest neighbor queries which search the information on the nearest neighbors from the specified location (query point) [2]. In the recent past, the adoption of geographic routing, which was introduced for the unicast case, has been proposed for the multicast scenario as well. In the unicast case, the basic assumption of geographic routing is that nodes know their own position and the position of the destination and the highest performance would be achieved by routing packets along a straight line going from the source to the destination. At each hop, the next relay node is chosen in such a way that the distance between the position of the selected relay node and the position of the destination node is minimized [4]. However, MANETs possess many notable characteristics such as limitations on network bandwidth, and dynamic topology changes due to the movement of mobile nodes. When nodes frequently exchange messages to neighboring locations there is higher consumption of energy by the nodes. In order to extend the lifetime of the network, energy needs to be preserved. On the other hand, the link and path stability among nodes allows the reduction of control overhead and offers benefits in terms of energy saving over ad hoc networks. Sometimes, trying to optimize the energy can lead to the selection of more fragile routes. Thus, it is evident that both the link stability and energy consumption should be considered in designing routing protocols, which allow right tradeoff between route stability and minimum energy consumption to be achieved [5].

In this paper, a novel routing strategy is proposed called Energy Aware GAF protocol that takes energy metrics into consideration. GAF is a location based routing protocol, which uses location information, of nodes instead of links' information for routing. This algorithm makes use of nodes which are not active into sleeping state over a period of time thus, making cooperative network more energy efficient using Geographic Adaptive Fidelity (GAF) algorithm.

2 Related Work

2.1 Background

In this section, the description of some related works with respect to the link stability, energy metrics and the respective routing protocols is given. Over distributed wireless systems there are few multiple metrics aware routing protocols. Nishio et al., [2] proposed two beacon-less kNN query processing methods: the Explosion (EXP) method and the Spiral (SPI) method to reduce traffic and maintain high accuracy of the query result in MANETs. In the EXP method, the nearest node from the query point floods the query to nodes within a specific circular region, and each node that receives the query replies with information on itself. In the SPI method, the nearest node from the query point forwards the query to other nodes in a spiral manner, and the node that collects a satisfactory kNN result transmits the result to the query-issuing node. Its advantages are that it reduces traffic and achieves high accuracy of the query result, in comparison with existing methods but with the drawback that these methods are not suitable for skewed node distribution.

Gallucio et al., [4] proposed a new geographic multicast protocol denoted as GEM. This protocol is inspired by the Euclidean Steiner Tree (EST) theory and does not require any information exchange for routing purposes. As compared to other geographic multicast protocol it reduces the overhead and provides lower multicast tree cost. But it has a disadvantage that the tree stated is two-dimensional only but the real scenario is different as it may contain three dimensional topology. Thus, it is not so far implemented for three dimensional mobile ad hoc networks.

Cheng et al., [6] proposed a position-based routing protocol with a power-saving scheme (called NRP-PB protocol) for ad hoc environments. The proposed protocol registered a better performance than did the ILAR protocol and resolved problems that plagued the ILAR protocol. This protocol proves to be more effective and reliable algorithm than the ILAR protocol, in regards to adaptation under dynamic ad hoc environments. The integration of power-saving technology into the protocol increases the work life of nodes and networks. The NCRP includes a cluster scheme and a power-balance scheme, and provides a routing protocol for discovering and maintaining routing paths in order balance the energy of each node. This mechanism reduces simultaneous loading of networks, providing energy conservation and ensuring prolonged lifetime of nodes and networks.

Liu et al., [7] designed a novel power-aware routing protocol named DELAR to utilize device heterogeneity. DELAR incorporates nodal residual energy information and nodal load status to save energy. The cross-layer designing framework achieves energy conservation from multiple facets, which includes power-aware routing, transmission scheduling and power control. Moreover, the novel notion of "mini-routing" is introduced into the data link layer and an Asymmetric MAC (A-MAC) scheme to support the MAC-layer acknowledgements over unidirectional links caused by asymmetric transmission power levels between powerful nodes and normal nodes. To improve the end-to-end delay performance a multi-packet transmission scheme is also presented striking a good balance between energy efficiency and other network performance metrics.

2.2 Existing Methodologies

1. An Anonymous Location- based Efficient Routing Protocol (ALERT): ALERT[1] protocol dynamically partitions a network field into zones and chooses nodes randomly in zones as intermediate relay nodes, which form a nontraceable anonymous route. Specifically, in each routing step, a data sender or forwarder partitions the network field in order to separate itself and the destination into two zones. It then randomly chooses a node in the other zone as the next relay node and uses the GPSR algorithm to send the data to the relay node. In the last step, the data is broadcasted to k nodes in the destination zone, providing k-anonymity to the destination.

2. Location based multicast addressing : In [3] for location-based multicast addressing, the delivery of a message by a receiver is conditioned by three matches, namely in logical space, physical space, and time. Matching in terms of logical space means matching on message content, which is achieved based on content queries expressed by receivers as in content-based publish/subscribe models. For a location match to occur, the receiver and the sender must both be located in the intersection of these two spaces during the lifetime of the message. LMA makes the assumption that all devices in the network have access to some location service.

3. LAER: The data forwarding strategy of LAER [5] is based on a greedy technique such as GPSR. The next hop selection tries to minimize the joint energy stability metric. LAER packet forwarding presents high scalability property because only the neighborhood and destination knowledge are necessary for the greedy technique. The flexibility of energy-stability-based greedy forwarding is offered through the capability to weight the stability and the energy consumption on the basis of the interest of the application layer. In order to avoid either routing loop or long packet detour and to offer always a progress direction, a combined euclidean distance-based forwarding and a joint stability-energy metric for the next hop selection are adopted. This approach guarantees, as GPSR, a progress direction in the application of greedy technique but, differently from GPSR, it permits also to select the best candidate for the joint metric rather than the node with only the highest euclidean progress direction.

2.3 Analysis and Discussion

In [1] ALERT has an efficient solution to counter intersection attacks. ALERT can offer high anonymity protection at a low cost when compared to other anonymity algorithms. It can also achieve comparable routing efficiency to the base-line GPSR algorithm. Like other anonymity routing algorithms, ALERT is not completely bulletproof to all attacks. Further its work lies in reinforcing ALERT in an attempt to thwart stronger and active attackers.

In [3] performances of three different implementation strategies for location- based multicast addressing have been compared and analysed under varying application workloads. Results show that break-even points allow to select the optimal implementation strategy for an expected ratio of query versus messages. With these results as starting point, currently work is going on an adaptive algorithm that can seamlessly change between strategies depending on the sensed communication pattern at runtime.

In [5] the performances have been compared with other three protocols such as GPSR, E-GPSR, and PERRA. LAER protocol inherits the scalability of GPSR and E-GPSR, improving the performance in terms of node selection with higher link duration when a higher weight is given to the stability index and a higher residual energy is given to energy aware index. In terms of control overhead and in terms of a higher capability LAER outperforms PERRA to balance traffic load due to the minimum drain rate metric included in the joint metric. Moreover, the average link duration proves to be longer in comparison with PERRA and E-GPSR, due to the capability to better discriminate the node behavior associated with the current node condition along with the history of link lifetime.

3 Proposed System

In this paper, an energy aware GAF protocol is proposed. This novel protocol uses location information while disseminating queries to the appropriate regions as the data queries often include geographic attributes. The Geographic Adaptive Fidelity (GAF) protocol along with energy aware metrics is used with geographically-informed neighbor selection heuristics to route a packet from the source region towards the destination region to improve the link stability during data transfer. The key idea behind this is to restrict the number of interests in directed diffusion by considering only a certain region rather than sending to the whole network. In this manner, the proposed Energy Aware GAF protocol conserves more energy than directed diffusion. Each and every node keeps information about its estimated cost and learning cost of reaching the destination through its neighbors. The estimated cost is a combination of residual energy and distance upto the 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 neighbor closer to the target region other than itself. If there are no holes, the estimated cost is equal to the learned cost. The learned cost is propagated through one hop back every time a packet reaches the destination adjusting the route setup for the next packet. The entire process of forwarding a packet to all the nodes in the target region consists of two phases:

1. Forwarding the data packets towards the target region:
On 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 node, 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. According to the convergence of the learned cost during the delivery of packets this choice can then be updated.

2. Forwarding the data 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. The process of splitting and forwarding continues until the regions with only one node are left.

Energy Aware GAF Protocol
Geographic Adaptive Fidelity termed as GAF is location-based routing algorithm incorporated with energy aware metrics and designed primarily for mobile ad hoc networks. This protocol is used in sensor networks as well. GAF aims at optimizing the performance of wireless sensor networks by identifying equivalent nodes with respect to forwarding the packets. There are three states defined in GAF, discovery, active and sleeping. When a sensor enters into the sleeping state, it turns off radio in order to conserve energy.
In discovery state, a sensor exchanges discovery messages in order to learn about other sensors in the grid.
In active state, a sensor broadcasts its discovery messages periodically to inform equivalent sensors about its state.
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 transition diagram is shown in Figure 1.

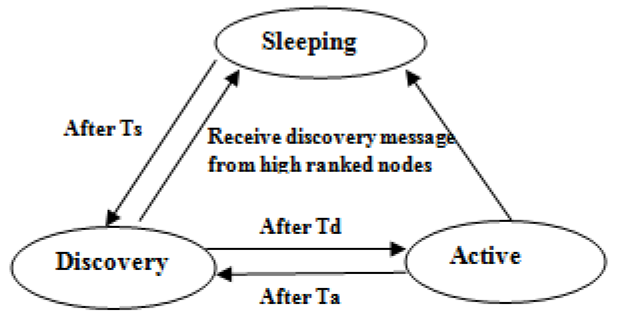

Fig 1: State transition diagram of GAF

In GAF protocol, nodes use their GPS-indicated location to associate itself with a point in the virtual grid. The entire area is divided into several square grids, and the node with the highest residual energy within each grid becomes the master of that grid. Two nodes are considered to be equivalent when they maintain the same set of neighbor nodes. Source and destination in the application are excluded from this characterization. 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, in fig 2, nodes 2, 3 and 4 in the virtual grid B are

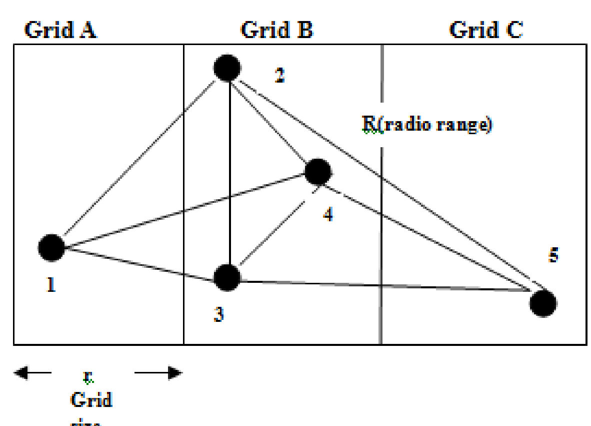

Fig 2: Virtual grid structure in the GAF protocol

equivalent in the sense that one of them can forward packets between nodes 1 and 5 while the other two can go to sleep in order to conserve energy. Hence, proposed GAF conserves energy by turning off unnecessary nodes in the network without affecting the level of routing fidelity.

4 POSSIBLE OUTCOME AND RESULT

When compared to a similar non-energy aware routing protocol such as, GPSR, energy aware GAF not only reduces energy consumption for the route setup, but also performs better than GPSR in terms of packet delivery. The proposed protocol minimizes unnecessary channel access contention and there by improves the packet drop rate without compromising the event detection latency. This is in contrast to the energy-latency tradeoffs that has been the main focus of many energy efficient in WSN. It also improves the throughput and average lifetime of the nodes.

5 CONCLUSION

In this paper, a novel routing strategy is introduced called Energy Aware Geographic Adaptive Fidelity protocol, which use of nodes' location information, instead of links' information for routing of data packets. This protocol makes use of nodes which are not active into sleeping state over a period of time thus, making cooperative network more energy efficient. When compared to a similar non-energy aware routing protocol such as, GPSR, energy aware GAF not only reduces energy consumption for the route setup, but also performs better than GPSR in terms of packet delivery. Energy Aware GAF minimizes unnecessary channel access contention and thereby improving the packet drop rate without making any compromises in the event detection latency.

6 FUTURE SCOPE

GAF is a hierarchical protocol with limited power usage. It achieves more energy efficiency by using location information instead of link's information for outing. As they operate on the basis of the geographic or location information for routing, data aggregation at any point is absent. Although GAF protocol is highly scalable, future direction may be conducted to enable QoS during data submission in the GAF algorithm.

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