A Survey on Routing Protocols of Location Aware and Data Centric Routing Protocols in Wireless Sensor Network

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Abstract: ***Wireless sensor network consists of thousands of tiny nodes. The nodes in network are directly connected. Routing protocols are used to discovering and maintaining route in network. There are mainly three types of routing protocols i.e. proactive, reactive and hybrid. They are further classified in flat based, hierarchical based and location based routing protocols. In this paper we discuss location based routing protocols. Here we briefly discuss existing routing protocols their advantages and disadvantages and also open research issue on them.***

Keywords: WSNs, routing protocols, sensor network, energy.

1. Introduction

The concept of wireless sensor networks [1, 2] is based on a simple equation: Sensing + CPU + Radio = Thousands of potential applications. Wireless sensor networks [3] consist of multiple sensor nodes exchanging data per wireless connection. The main task of a wireless sensor node is to sense and collect data from a certain domain, process them and transmit it to the sink where the application lies. The different ways in which routing protocols operate make them appropriate for certain applications. Each of the disseminated sensor nodes typically consist of one or more sensing elements, a data processing unit, communication components and a power source which is usually a battery (Fig. 1). The sensed data is collected, processed and then routed to the desired end user through a designated sink point, referred as base station. WSNs are initially moved for the use in military applications, such as border monitoring. Now it is mainly focused on civilian applications such as environment monitoring, object tracking, biomedical applications, gathering meteorological variables like temperature and pressure, disaster management, etc. The main advantage of WSNs is their ability to operate in unattended environments, where human life is infeasible [4].

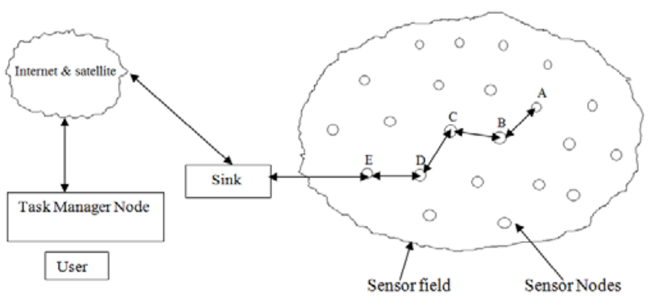

Figure 1: Components of wireless sensor network

In WSN there are the routing protocols that minimize the used energy, extending subsequently the life span of the WSN. Energy awareness is an essential in routing protocol design issue.

Depending on the network structure, routing in WSNs can be divided into:

- Flat-based routing
- Hierarchical-based routing
- Location-based routing

Depending on the protocol operation, routing in WSNs can be divided into:

- Multipath-based routing
- Query-based routing
- Negotiation-based routing
- QoS-based routing
- Coherent based routing

2. Research Objectives

The main objectives of the research are:

1. To investigate the performance of WSN routing protocol
2. To design new energy efficient routing protocol for WSN
3. To increase the life cycle of WSN
4. To enhance the power efficiency of WSN
5. To enhance the reliability of WSN
6. To enhance the real time data transfer in WSN

3. Routing

A variety of routing protocols has been proposed in recent past. WSN architecture is a multi-hop communication system in which data is send via multi hops to the destination. The major challenges that a routing protocol designed for WSNs faces are mobility of nodes and resource constraints.

3.1 Data centric protocols

In data-centric routing, the sink sends queries to certain regions and waits for data from the sensors located in the selected regions. Since data is being requested through queries, attribute based naming is necessary to specify the properties of data. SPIN [4] is the first data-centric protocol, which considers data negotiation between nodes in order to eliminate redundant data and save energy. Later, Directed Diffusion [4] has been developed and has become a breakthrough in data-centric routing. Then, many other protocols have been proposed either based on Directed Diffusion or following a similar concept [6].

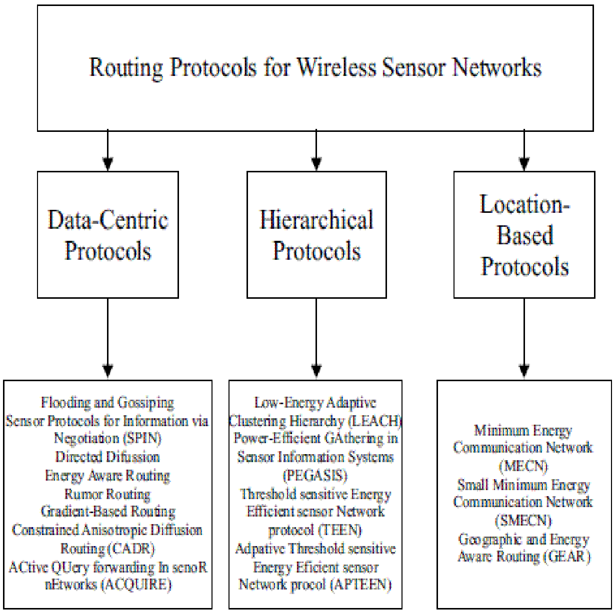

Figure 2: Routing Protocols for Wireless Sensor Networks

Sensor Protocols for Information via Negotiation: (SPIN) [6] the idea behind SPIN is to name the data using high level descriptors or meta-data. Before transmission, meta-data are exchanged among sensors via a data advertisement mechanism, which is the key feature of SPIN. Each node upon receiving new data, advertises it to its neighbors and interested neighbors, i.e. those who do not have the data, retrieve the data by sending a request message. SPIN's meta-data negotiation solves the classic problems of flooding such as redundant information passing, overlapping of sensing areas and resource blindness thus, achieving a lot of energy efficiency. There is no standard meta-data format and it is assumed to be application specific, e.g. using an application level framing. There are three messages defined in SPIN to exchange data between nodes. These are: ADV message to allow a sensor to advertise a particular meta-data, REQ message to request the specific data and DATA message that carry the actual data. Fig. 3, redrawn from [26], summarizes the steps of the SPIN protocol.

One of the advantages of SPIN is that topological changes are localized since each node needs to know only its single-hop neighbors. SPIN gives a factor of 3.5 less than flooding in terms of energy dissipation and meta-data negotiation almost halves the redundant data.

However, SPIN's data advertisement mechanism cannot guarantee the delivery of data. For instance, if the nodes that are interested in the data are far away from the source node and the nodes between source and destination are not interested in that data, such data will not be delivered to the destination at all. Therefore, SPIN is not a good choice for applications such as intrusion detection, which require reliable delivery of data packets over regular intervals.

Directed Diffusion: Directed Diffusion [7][8] is an important milestone in the data-centric routing research of sensor networks. The idea aims at diffusing data through sensor nodes by using a naming scheme for the data. The main reason behind using such a scheme is to get rid of unnecessary operations of network layer routing in order to save energy. Direct Diffusion suggests the use of attribute-value pairs for the data and queries the sensors in an on demand basis by using those pairs. In order to create a query, an interest is defined using a list of attribute-value pairs such as name of objects, interval, duration, geographical area, etc. The interest is broadcast by a sink through its neighbors. Each node receiving the interest can do caching for later use. The interests in the caches are then used to compare the received data with the values in the interests. The interest entry also contains several gradient fields. A gradient is a reply link to a neighbor from which the interest was received. It is characterized by the data rate, duration and expiration time derived from the received interest's fields. Hence, by utilizing interest and gradients, paths are established between sink and sources. The sink resends the original interest message through the selected path with a smaller interval hence reinforces the source node on that path to send data more frequently. Fig.3, redrawn from [7], summarizes the Directed Diffusion protocol.

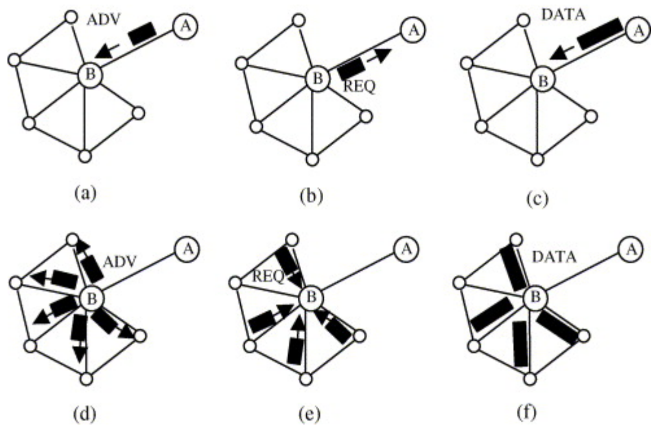

Figure 3: SPIN protocol

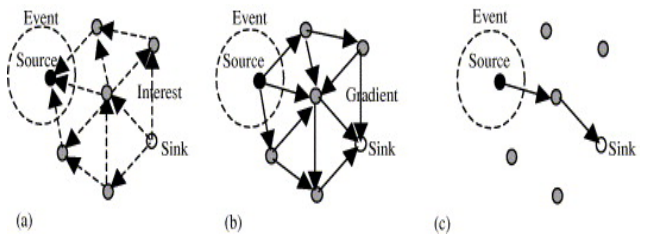

Figure 4: Directed diffusion protocol

Rumor routing: Rumor routing [9] is another variation of Directed Diffusion and is mainly intended for contexts in which geographic routing criteria are not applicable. Generally Directed Diffusion floods the query to the entire network when there is no geographic criterion to diffuse tasks. However, in some cases there is only a little amount of data requested from the nodes and thus the use of flooding is unnecessary. An alternative approach is to flood the events if number of events is small and number of queries is large. Rumor routing is between event flooding and query flooding. The idea is to route the queries to the nodes that have observed a particular event rather than flooding the entire network to retrieve information about the occurring events.

In order to flood events through the network, the rumor routing algorithm employs long lived packets, called agents. When a node detects an event, it adds such event to its local table and generates an agent. Agents travel the network in order to propagate information about local events to distant nodes. When a node generates a query for an event, the nodes that know the route, can respond to the query by referring its event table. Hence, the cost of flooding the whole network is avoided. Rumor routing maintains only one path between source and destination as opposed to Directed Diffusion where data can be sent through multiple paths at low rates.

Simulation results have shown that rumor routing achieves significant energy saving over event flooding and can also handle node's failure. However, rumor routing performs well only when the number of events is small. For large number of events, the cost of maintaining agents and event-tables in each node may not be amortized if there is not enough interest on those events from the sink. Another issue to deal with is tuning the overhead through adjusting parameters used in the algorithm such as time-to-live for queries and agents.

Routing Protocols	*Data aggregation*	*Problem Associated*
Flooding	P	Implosion
Gossiping	P	Overlap problem
Directed Diffusion	P	Not fit for the application where continues flow of the data is required.
Rumor routing	P	Unable to handle large number of events
Gradient-Based	P	
CADR	N	
COUGAR	P	1. We have to dynamically maintain a leader node to avoid failure. 2. Extra overhead to sensor nodes by introducing additional query layer on each sensor node. 3. For data computation it requires synchronization.
ACQUIRE	N	If d is equal to network size, then the protocol behaves similar to flooding

Table1: Data centric routing protocols

3.2 Location Based Protocols

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.

GAF: Geographic Adaptive Fidelity (GAF) [10] is an energy-aware location-based routing algorithm designed primarily for mobile ad hoc networks, but may be applicable to sensor networks as well. GAF conserves energy by turning off unnecessary nodes in the network without affecting the level of routing fidelity. It forms a virtual grid for the covered area. Each node uses its GPS-indicated location to associate itself with a point in the virtual grid. Nodes associated with the same point on the grid are considered equivalent in terms of the cost of packet routing. Such equivalence is exploited in keeping some nodes located in a particular grid area in sleeping state in order to save energy. Thus, GAF can substantially increase the network lifetime as the number of nodes increases. A sample situation is depicted in Fig. 4, which is redrawn from [10]. In this figure, node 1 can reach any of 2, 3 and 4 and nodes 2, 3, and 4 can reach 5. Therefore nodes 2, 3 and 4 are equivalent and two of them can sleep. Nodes change states from sleeping to active in turn so that the load is balanced. There are three states defined in GAF. These states are discovery, for determining the neighbors in the grid, active reflecting participation in routing and sleep when the radio is turned off. The state transitions in GAF are depicted in Fig. 5. Which node will sleep for how long is application dependent and the related parameters are tuned accordingly during the routing process. In order to handle the mobility, each node in the grid estimates its 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. GAF is implemented both for non-mobility (GAF-basic) and mobility (GAF-mobility adaptation) of nodes.

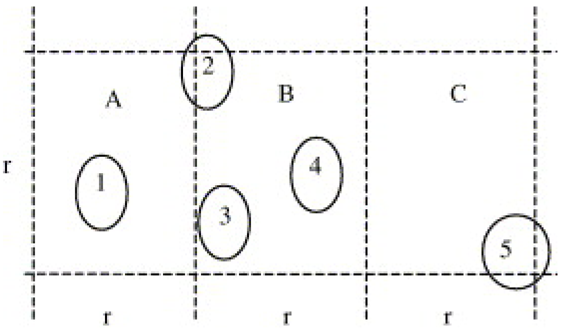

Figure 5: Example of virtual grid in GAF

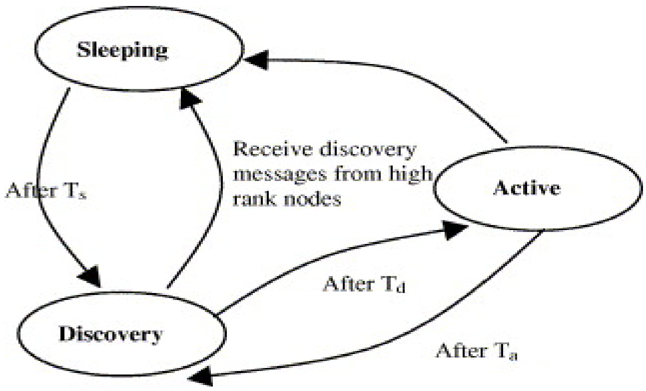

Figure 6: State transitions in GAF

GEAR: Yu et al. [11] have suggested the use of geographic information while disseminating queries to appropriate regions since data queries often includes geographic attributes. The protocol, namely Geographic and Energy Aware Routing (GEAR), uses energy aware and geographically informed neighbor selection heuristics to route a packet towards the target region. The 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. GEAR compliments Directed Diffusion in this way and thus conserves more energy. 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.

There are two phases in the algorithm:

1) Forwarding 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.6, which is redrawn from [11].

GEAR is compared to a similar non-energy-aware routing protocol GPSR [12], 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 GPSR decrease 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.

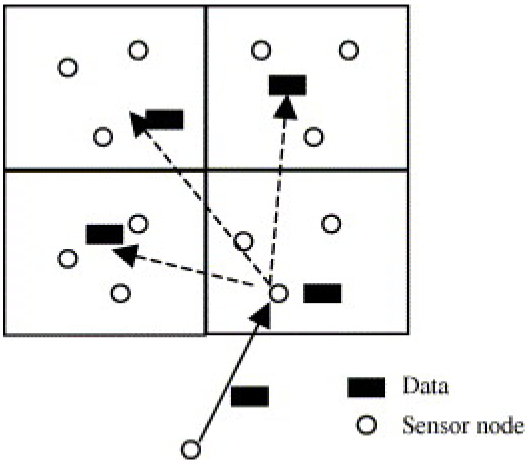

Figure 7: Recursive Geographic Forwarding in GEAR

MECN and SMECN: Minimum Energy Communication Network (MECN) [13] sets up and maintains a minimum energy network for wireless networks by utilizing low power GPS. Although, the protocol assumes a mobile network, it is best applicable to sensor networks, which are not mobile. A minimum power topology for stationary nodes including a master node is found. MECN assumes a master-site as the information sink, which is always the case for sensor networks .MECN identifies a relay region for every node. The relay region consists of nodes in a surrounding area where transmitting through those nodes is more energy efficient than direct transmission. The relay region for node pair (i, r) is depicted in Fig. 7, redrawn from [13]. The enclosure of a node i is then created by taking the union of all relay regions that node i can reach. The main idea of MECN is to find a sub-network, which will have less number of nodes and require less power for transmission between any two particular nodes. In this way, global minimum power paths are found without considering all the nodes in the network. This is performed using a localized search for each node considering its relay region.

The protocol has two phases:

1) It takes the positions of a two dimensional plane and constructs a sparse graph (enclosure graph), which consists of all the enclosures of each transmit node in the graph. This construction requires local computations in the nodes. The enclose graph contains globally optimal links in terms of energy consumption.

2) Finds optimal links on the enclosure graph. It uses distributed Bellmen-Ford shortest path algorithm with power consumption as the cost metric. In case of mobility the position coordinates are updated using GPS. MECN is self-reconfiguring and thus can dynamically adapt to node's failure or the deployment of new sensors. Between two successive wake-ups of the nodes, each node can execute the first phase of the algorithm and the minimum cost links are updated by considering leaving or newly joining nodes.

The small minimum energy communication network (SMECN) [13] is an extension to MECN. In MECN, it is assumed that every node can transmit to every other node, which is not possible every time. In SMECN possible obstacles between any pair of nodes are considered.

However, the network is still assumed to be fully connected as in the case of MECN. The sub network constructed by SMECN for minimum energy relaying is provably smaller (in terms of number of edges) than the one constructed in MECN if broadcasts are able to reach to all nodes in a circular region around the broadcaster. As a result, the number of hops for transmissions will decrease. Simulation results show that SMECN uses less energy than MECN and maintenance cost of the links is less. However, finding a sub-network with smaller number of edges introduces more overhead in the algorithm.

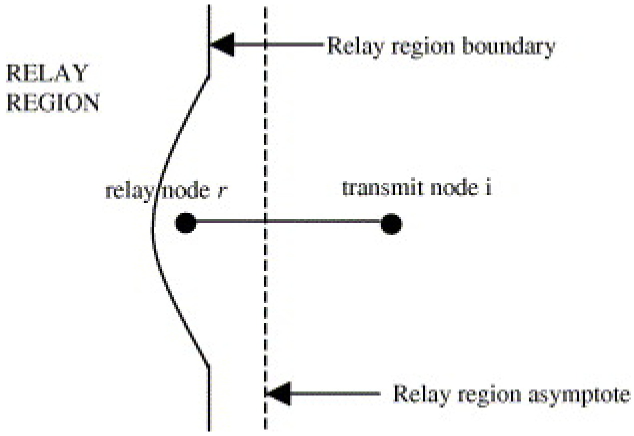

Figure 8: Relay region of transmit-relay node pair (i, r) in MECN.

4. Conclusion and Open Issues

Routing in sensor networks has attracted a lot of attention in the recent years and introduced unique challenges compared to traditional data routing in wired networks. However, we have also observed that there are some hybrid protocols that fit under more than one category.

Other possible future research for routing protocols includes the integration of sensor networks with wired networks (i.e. Internet). Most of the applications in security and environmental monitoring require the data collected from the sensor nodes to be transmitted to a server so that further analysis can be done. On the other hand, the requests from the user should be made to the sink through Internet. Since the routing requirements of each environment are different, further research is necessary for handling these kinds of situations.

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