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Brief Literature Survey on WSN Routing Protocols

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Abstract- Recent advances in wireless sensor networks have prompted numerous new conventions particularly intended for sensor networks where energy awareness is a fundamental consideration. A wireless sensor network (WSN) consists of low cost, low power, small in size and multi functional sensor nodes. Routing protocols in WSNs emphasize on data dissemination, limited battery power and bandwidth constraints in order to facilitate efficient working of the network, thereby increasing the lifetime of the network. Routing protocols in WSNs are also application specific which has led to the development of a variety of protocols. WSN has a design trade-off between energy and communication overhead which forms the nerve center of the routing techniques. In this paper we present a survey of state-of-the-art routing techniques in WSN.

Keywords- Wireless Sensor Networks, Routing Protocols, Energy Efficient Protocols, Data Centric protocols, Hierarchical Protocols and Location Based Protocols, Routing protocols.

1 Introduction

Recent technological advancements in micro electronics and wireless communication technologies have enabled manufacturing of small, low cost, battery operated and multifunctional sensor nodes [1,2]. These sensor nodes measure ambient condition in the surrounding environment that can be processed to reveal the characteristics of the phenomena occurring at the location where the sensor nodes are deployed. A large number of these sensor nodes are either placed carefully or randomly deployed over a geographical area and networked through wireless links to form a WSN. Each sensor node in WSN is capable of communicating with each other and the base station (BS) for the purpose of data integration and dissemination. WSN are used mainly in military, civilian and for industrial applications. WSNs applications in the military field include battlefield surveillance, intrusion detection, target field and imaging. However, WSN are now being used in many civilian application areas too, including environment and habitat monitoring, health applications, home automation and traffic control.
One of the major problems in WSNs is the energy consumption, whereby the network lifetime is dependent on this factor. Traditional wireless communication networks like Mobile Ad hoc Networks (MANET) differs from WSN. WSN have unique characteristics such as denser level of node deployment, higher unreliability of sensor nodes and severe energy, computation and storage constraints which present many challenges in the development and application of WSN. Research has been made to explore and find solutions for various design architecture and application issues and significant advancement has been made in the development and deployment of WSNs. WSN typically contains hundreds or thousands of sensor nodes which allows for sensing over larger geographical regions with greater accuracy. Usually the sensor nodes are deployed randomly over geographical location and these nodes communicate with each other to form a network. Each node has three basic components as shown in figure 1[3]:

1. Sensing unit
2. Processing unit
3. Transmission unit

The node senses the data from the environment processes it and sends it to the base station. These nodes can either route the data to the base station (BS) or to other sensor nodes such that the data eventually reaches the base station. In most applications, sensor nodes suffer from limited energy supply and communication bandwidth. These nodes are powered by irreplaceable batteries and hence network lifetime depends on the battery consumption [4]. Innovative techniques are developed to efficiently use the limited energy and bandwidth resource to maximize the lifetime of the network. These techniques work by careful design and management at all layers of the networking protocol. For example, at the network layer, it is highly desirable to find methods for energy efficient route discovery and relaying of data from the sensor nodes to the base station.

2 Sensor Network Classification

On the basis of the sensor network modes of functioning and target application type, a simple classification can be prescribed [5].

1. Proactive Networks: This type of network is used when a periodic data monitoring is required. It provides a data processing (sensing, analysis, transmitting) at regular intervals.

2. Reactive Networks: The nodes have a sudden react and a drastic change after receiving the value of sensed attributes. This scheme is well suited for critical timing applications.

3 Network Characteristics

As compared to the traditional wireless communication networks such as mobile ad hoc network (MANET) and cellular systems, wireless sensor networks have the following unique characteristics and constraints:

Dense sensor node deployment: Sensor nodes are usually densely deployed and can be several orders of magnitude higher than that in a MANET.
Battery-powered sensor nodes: Sensor nodes are usually powered by battery and are deployed in a harsh environment where it is very difficult to change or recharge the batteries.
Severe energy, computation, and storage constraints: Sensors nodes are having highly limited energy, computation, and storage capabilities.
Self-configurable: Sensor nodes are usually randomly deployed and autonomously configure themselves into a communication network.
Unreliable sensor nodes: Since sensor nodes are prone to physical damages or failures due to its deployment in harsh or hostile environment.
Data redundancy: In most sensor network application, sensor nodes are densely deployed in a region of interest and collaborate to accomplish a common sensing task. Thus, the data sensed by multiple sensor nodes typically have a certain level of correlation or redundancy.
Application specific: A sensor network is usually designed and deployed for a specific application. The design requirements of a sensor network change with its application.
Many-to-one traffic pattern: In most sensor network applications, the data sensed by sensor nodes flow from multiple source sensor nodes to a particular sink, exhibiting a many-to-one traffic pattern.
Frequent topology change: Network topology changes frequently due to the node failures, damage, addition, energy depletion, or channel fading.

Sensor Network

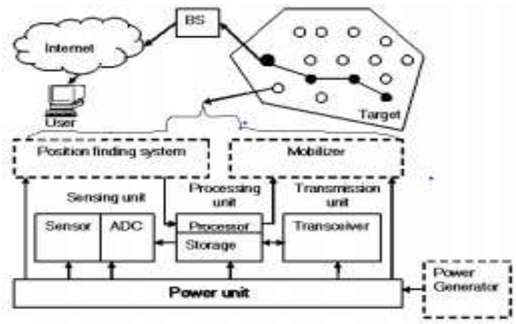

Fig. 1: Structural view of sensor network

Fig. 1 shows the Structural view of sensor network. The main responsibility of the sensor nodes in each application is to sense the target area and transmit their collected information to the sink node for further operations. Resource limitations of the sensor nodes and unreliability of low-power wireless links, in combination with various performance demands of different applications impose many challenges in designing efficient communication protocols for wireless sensor networks. Meanwhile, designing suitable routing protocols to fulfill different performance demands of various applications is considered as an important issue in wireless sensor networking. In this context, researchers have proposed numerous routing protocols to improve performance demands of different applications through the network layer of wireless sensor networks protocol stack. Most of the existing routing protocols in wireless sensor networks are designed based on the single-path routing strategy without considering the effects of various traffic load intensities. In this approach, each source node selects a single path which can satisfy performance requirements of the intended application for transmitting its traffic towards the sink node. Although route discovery through single-path routing approach can be performed with minimum computational complexity and resource utilization, the limited capacity of a single path highly reduces the achievable network throughput. Therefore, due to the resource constraints of sensor nodes and the unreliability of wireless links, single-path routing approaches cannot be considered effective techniques to meet the performance demands of various applications. In order to cope with the limitations of single-path routing techniques, another type of routing strategy, which is called the multipath routing approach has become as a promising technique in wireless sensor and ad hoc networks.

4 Routing Protocols In Wireless Sensor Network

Routing protocols in WSNs have a common objective of efficiently utilizing the limited resources of sensor nodes in order to extend the lifetime of the network. Different routing techniques can be adopted for different applications based on their requirements. Applications can be time critical or requiring periodic updates, they may require accurate data or long lasting, less precise network, they may require continuous flow of data or event driven output. Routing methods can even be enhanced and adapted for specific application.

Routing in wireless sensor networks differs from conventional routing in fixed networks in various ways. There is no infrastructure, wireless links are unreliable, sensor nodes may fail, and routing protocols have to meet strict energy saving requirements [6]. Many routing algorithms were developed for wireless networks in general. All major routing protocols proposed for WSNs may be divided into seven categories as shown in Table 1. Some of few protocols are reviewed as follows

CATAGORY	REPRESENTATIVE PROTOCOLS
Location-based Protocols	MECN, SMECN, GAF, GEAR, Span, TBF, BVGF, GeRaF
Data-centric Protocols	SPIN, Directed Diffusion, Rumor Routing, COUGAR, ACQUIRE, EAD, Information-Directed Routing, Gradient-Based Routing, Energy-aware Routing, Information-Directed Routing, Quorum-Based Information Dissemination, Home Agent Based Information Dissemination
Hierarchical Protocols	LEACH, PEGASIS, HEED, TEEN, APTEEN
Mobility-based Protocols	SEAD, TTDD, Joint Mobility and Routing, Data MULES, Dynamic Proxy Tree-Base Data Dissemination
Multipath-based Protocols	Sensor-Disjoint Multipath, Braided Multipath, N-to-1 Multipath Discovery
Heterogeneity-based Protocols	IDSQ, CADR, CHR
QoS-based protocols	SAR, SPEED, Energy-aware routing

4.1 Active Query Forwarding In Sensor Networks (ACQUIRE)

ACQUIRE[7] is based on the basic principle that considers query as an active query that is routed through the network in search of solution. At each node, the query is forwarded using the information from all nodes within d hops, which resolves the query partially. At the node where the query gets resolved completely, a response is generated and routed back to the querier. Regular data centric protocols work in two stages: query routing and response routing. In contrast, there are no distinct query / response stages in ACQUIRE because it uses an active query. The active query does not just get forwarded to the event, it also gets partially resolved at every intermediate node, as ACQUIRE incorporates a look-ahead parameter d at each node. The querier issues an active query, which can be a complex query i.e. can consist of several sub-queries each corresponding to a different variable/ interest. The active query is sent through a sequence of nodes until it is fully resolved. A node carrying the active query, also known as active node, utilizes updates received from all nodes within a look-ahead of d hops in order to resolve the query partially. After the active node has resolved the active query partially, it has to forward the active query to the next node. The next node can be selected randomly or selected intelligently based on other information such that the query gets resolved as quickly as possible.

Thus, the active query gets smaller and smaller as it is forwarded through the network until eventually it reaches an active node which is able to completely resolve the query. The last active node answers the last remaining piece of the original query. At this point, the active query is transformed into the response and is routed back along either the reverse path or the shortest path to the original querier.

If the intermediate node has stale information about the nodes d hops away, an update is done. Update is initiated by a request being sent to all sensor nodes d hops away by the intermediate node. The sensor nodes who get the request will then forward their information to the intermediate node. The update frequency is modelled by an average amortization factor, such that an update is likely to occur at any given node only once every 1/C queries.

Depending on the application, different types of queries are used in WSN. The ACQUIRE protocol is well suited for one shot, complex queries for replicated data. The average latency of ACQUIRE in answering a query is far better than a random walk. Also, ACQUIRE saves energy by utilizing a probabilistic flooding approach.

4.2 Gradient Based Routing – Routing On Fingerprint Gradient In Sensor Networks (RUGGED)

Every physical event occurring in the environment results in a natural information gradient in the proximity of the phenomenon. Such information gradient is known as fingerprint of the event caused by the events effect. RUGGED [8] protocol routes the query to the event by effectively utilizing the finger print of the event. Also, most of the physical phenomena follow diffusion law with distance. Unlike other information driven protocols, it eliminates the overload of preparing and maintaining the gradient information. RUGGED uses an environmental model in which the effect of the event follows a diffusion function with respect to both distance and time. The diffusion function of the event is given by,

$$f(d,t) \propto t/d^{\alpha}$$

The effect of the event decreases with time as a liner function. Also, the diffusion can be expressed as a function of distance alone. RUGGED works as a basic information driven routing protocol, where the query is sent to a randomly selected node and forwarded from the node to the event.

Using the information gradient of the event, the network is divided into two regions- 1) Flat region and 2) Gradient region. Gradient region is the space over which the sensor nodes are able to sense the event. The rest of the space in the network forms the flat region. At any instant of time, there could be multiple gradient regions active throughout the network. Depending on the location of the query, it could exist in two modes- Flat region mode and gradient region mode. Initially, the query is in a flat region mode. Once it finds the gradient information about the events effect, it switches to gradient region mode. Thus, the query packet needs fields for query ID and query mode in addition to other information.

4.3 Power Efficient Gathering In Sensor Information System (PEGASIS)

PEGASIS[9] is a near optimal chain based protocol. The basic idea is for the nodes to communicate their sensed data to their neighbors and the randomly chosen nodes will take turns in communicating to the BS. It assumes that the BS is fixed at a far distance from the sensor nodes. The sensor nodes are homogeneous and energy constraint with uniform energy. The energy cost for transmitting a packet depends on the distance of transmission. All the nodes maintain a complete database about the location of all other nodes.

The objectives of PEGASIS include energy efficient method of communication between the nodes along the chain, load balancing by switching between the nodes that communicate with the BS, allows only local coordination between the nodes that are close to each other so that bandwidth used in the communication is minimized. The nodes are deployed randomly over a geographical location. The nodes are organized to form a chain which can be accomplished either by nodes communicating with each other using a Greedy algorithm or the BS can compute the chain and broadcast it to all the nodes. Because we have assumed that each node has global knowledge of the network, we can employ the greedy approach to construct the chain.

We begin the chain construction with the node farthest from the BS. Using the greedy approach, each node connects to its closest neighbor and the nodes already on the chain cannot be revisited. During every round, each node receives data from its neighbor, fuses it with its own data and transmits to the other neighbor on the chain. (The nodes take turns transmitting the BS). The node 'i' at some random position 'f' on the chain is chosen to transmit to the BS. Thus the leader in each round of communication will be at random position on a chain which is important for nodes to die at random locations. This makes the protocol robust to failures. It uses token passing approach to determine the leaders for communicating with the BS.

The improvement of PEGASIS, Hierarchical PEGASIS [10], was introduced with the objective of decreasing the delay incurred for packets during transmission to the BS. Energy balancing PEGASIS is the energy efficient chaining algorithm in which a node will consider average distance of formed chain. PEDAP, Power Efficient Data Aggregating Protocol uses spanning tree approach instead of Greedy approach to form the chain resulting in considerable savings of energy.

4.4 Energy Aware routing Protocol (EAP)

EAP[11] is a hierarchical cluster based protocol which achieves a good performance in terms of lifetime by minimizing energy consumption for in-network communication and balancing energy load among all nodes. It introduces a new clustering parameter for cluster head election which enables better handling of the heterogeneous energy capacities and it also adopts an efficient method known as the intra cluster coverage, which copes with the area coverage problem.

EAP assumes that the sensor nodes are location unaware, for a sensor node there are three kinds of methods to get its location information, i.e., global positioning system (GPS), directional antenna and positional algorithms. The use of GPS and directional antenna methods will lead to an increase in the cost of sensors node and positional algorithms that need to exchange a large quantity of messages to compute the nodes location information will also result in high energy consumption. The last assumption is that the transmission power can be controlled. This can be achieved by using intra cluster and inter cluster communication methods.

4.5 Geographic Adaptive Fidelity (GAF)

GAF [12] is a location based routing protocol for WSN. It is also an energy aware routing protocol. GAF works in such a way that, it turns off unnecessary nodes in the network without affecting the level of routing fidelity, this conserves energy. A virtual grid for the area that is to

be covered is formed. The cost of packet routing is considered equivalent for nodes associated with the same point on the virtual grid. Such equivalence is exploited in keeping some nodes located in a particular grid area in sleeping state in order to save energy. By doing this the network lifetime is increased as the number of nodes increases. There are three states in this protocol and they are discovery, for determining the neighbors in the grid, active tells that the nodes are participating in routing and sleep when the radio is turned off. The load is balanced when nodes change states from sleeping to active in turns.

GAF keeps the network connected, by keeping a representative node always in active node for each region on its virtual grid. Although GAF is a location based protocol, it can be considered as a hierarchical protocol, where the clusters are based on geographic location.

4.6 Minimum Energy Communication Network (MECN)

MECN [12] is a location based routing protocol. It maintains a minimum energy network for wireless networks by utilizing low power GPS. This protocol can be used for mobile networks but it is best suited for sensor networks. This is because sensor networks are not mobile [13]. A master node is included to a minimum power topology for stationary nodes. MECN assumes a master-site as the information sink, which is always the case for sensor networks.

MECN identifies a relay region. This region consists of nodes in a surrounding area where transmission through those nodes is more energy efficient than direct transmission. 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 two nodes. MECN consists of two phases, firstly, it constructs a sparse graph or an enclosure graph, by taking positions of a two dimensional plane. This construction requires local computations in the nodes. The enclosure graph contains globally optimal links in terms of energy consumption. Secondly, it finds optimal links on the graph using the Belmann Ford shortest path algorithm.

MECN is self organizing and dynamically adapts to nodes failure or the deployment of new sensor nodes. Small Minimum Energy Communication Network (SMECN) [14] is an extension of MECN. In SMECN, possible obstacles between any pair of nodes are considered.

5 Conclusion

WSNs have discovered a wide range of applications in the recent era. Growing demand for WSN has accelerated the research and development of routing protocols used in WSNs. In this paper we classify the routing protocols in WSNs into data-centric, hierarchical and location based depending on the network structure. Data-centric protocols use the metadata structure to transmit the sensed information to the BS. Naming the data helps to construct a query which requests for only certain attributes of the data, thus known as data-centric routing techniques. Regardless, the sensor nodes can also be grouped for efficient data dissemination to the sink. Hierarchical routing protocols adopt the clustering approach by grouping sensor nodes. This approach is highly scalable and thus used in a number of applications. Location based protocols use the information of position of sensor nodes intelligently to route data. For each of these categories, we have discussed a few example protocols.

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