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Study of Different Routing Protocols in Wireless Sensor Networks

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ABSTRACT: *Wireless sensor networks consist of small nodes with sensing, computation, and wireless communications capabilities.Routing as one key technologies of wireless sensor network has now become a hot research because the applications of WSN is everywhere, it is impossible that there is a routing protocol suitable for all applications. Routing protocols in WSNs are also application specific which has led to the development of a variety of protocols. In this paper, we give a brief survey of different routing algorithms for Wireless Sensor Network and compare their strengths and limitations. Each routing protocol is described and discussed under the appropriate category. The paper concludes with issues open for research.*
Keywords: *Wireless Sensor Networks (WSN), Routing Protocols, flat Routing, Hierarchical Routing, Location based Routing, Data centric Routing, Multipath Routing, QoS based Routing, Bio-Inspired Routing, Coherent and Non-Coherent based Routing, Query based Routing.*

I. INTRODUCTION

Wireless Sensor Networks(WSN) are systems that comprise large numbers (hundreds or thousands) of wirelessly connected heterogeneous sensor nodes that are spatially distributed across a large field of interest [1], and these systems process data gathered from multiple sensors to monitor events. Sensor networks are one of the most interesting research areas with a profound effect on technological developments [2]. The concept of wireless sensor network is based on a simple equation: Sensing+CPU+ Radio= Thousands of potential application[3]. Sensor nodes are typically battery-powered and should operate without attendance for a relatively longer period of time. In most cases, it is very difficult and even impossible to change or recharge batteries for the sensor nodes. The design of routing protocols in WSNs is challenging because of several network constraints with an emphasis on energy efficiency Minimizing energy consumption is a key requirement in the design of sensor network protocols and algorithms. In addition to this, WSN design also demands other requirements such as fault tolerance, scalability, production, costs and reliability. It is therefore

critical that the designer takes these factors into account when designing protocols and algorithms for WSN [4].Routing protocols for wired networks and ad-hoc networks are not applicable to wireless sensor networks asthere is no infrastructure, wireless links are unreliable, sensor nodes may fail, and routing protocols have to meet strict energy saving requirements [5]. Based on the underlying network structure routing techniques are classified into three categories: flat, hierarchical and location based routing. Based on the protocol operation it can be classified into Negotiation based, Multi-path, Query based, QoS based and Coherent based routing.

The growing interest in WSN and the continual emergence of new architectural techniques inspired surveying the characteristics, applications and communication protocols for such a technical area [4-6].In this paper we give a brief survey of different routing algorithms used in WSN listing some important protocols in each category along with their merits and demerits.

II. FLAT ROUTING

Usually WSN consists of sensor nodes and base station. In flat topology all sensor nodes are treated uniformly. When a node needs to send the data it calculates the shortest path from it to the BS. After that it sends their sensed data to the BS through intermediate (neighbourhood) nodes.

III. HIERARCHICAL ROUTING

Hierarchical routing protocols organize the networkinto groups called clusters .Each cluster selects a node that serves as the cluster head. The cluster-head is responsible for collecting the sensor data from all the cluster members, aggregating them and transmitting a summary to the base station. Depending on the energy level of the node, higher energy nodes can be used to process and send the information while low energy nodes

can be used to perform the sensing in the propinquity of the target [6].This results eliminating a large number of redundant messages from the nodes, thereby reducing the overall power consumption in the network.

The disadvantage of cluster-based algorithms is that the base station should be reachable from allthe cluster-heads. This drains the power reserves ofthe cluster-heads quickly, thereby disconnecting thecorresponding clusters from the network. It is possible to avoid this problem by periodically rotating the cluster heads among the nodes to ensure uniformenergy consumption.LEACH [7] is one of the first hierarchical routingapproaches for sensors networks. The idea proposed in LEACH has been an inspiration for many hierarchical routing protocols [8], [9], [10], [11], although some protocols have been independently developed [12], [13]. Some of thehierarchical routing protocols are PEGASIS, Hierarchical-PEGASIS, TEEN, APTEEN, MECN, SMECN, SOP, VGA,HPAR, HEED, CPCHSA [6,14].

A. Low-EnergyAdaptive Clustering Hierarchy(LEACH):

LEACH is a cluster-based protocol, which includes distributed cluster formation. LEACH randomly selects a few sensor nodes as cluster heads (CHs) and rotates this role to evenly distribute the energy load among the sensors in the network. In LEACH, the cluster head (CH) nodes compress data arriving from nodes that belong to the respective cluster, and send an aggregated packet to the base station in order to reduce the amount of information that must be transmitted to the base station. LEACH uses a TDMA/CDMA MAC to reduce inter-cluster and intra-cluster collisions. However, data collection is centralized and is performed periodically. Therefore, this protocol is most appropriate when there is a need for constant monitoring by the sensor network. A user may not need all the data immediately. Hence, periodic data transmissions are unnecessary which may drain the limited energy of the sensor nodes. After a given interval of time, a randomized rotation of the role of the CH is conducted so that uniform energy dissipation in the sensor network is obtained [15]. The operation of LEACH is separated into two phases, the setup phase and the steady state phase. In the setup phase, the clusters are organized and CHs are selected. In the steady state phase, the actual data transfer to the base station takes place. The duration of the steady state phase is longer than the duration of the setup phase in order to minimize overhead.

IV. LOCATION BASED ROUTING

The location information based routing protocol uses location information to guide routing discovery and maintenance as well as data forwarding, enabling directional transmission of the information and avoiding information flooding in the entire network. In most cases, location information is needed to calculate the distance between two particular nodes so that energy consumption can be estimated. Geographic Adaptive Fidelity (GAF) protocol [16] is a location based protocol although proposed for Mobile Adhoc Networks (MANETs), it favours energy conservation and thus can be used for WSNs. Some of the other famous geographic based routing protocols are SPAN, GOAFR, MFR & GEDIR, GEAR and GAF [6,14].

A. Geographic Adaptive Fidelity (GAF):

GAFis an energy-aware, location-based routing algorithm [16].Location information is used by each node to associate itself to a virtual grid. This location information will be provided by GPS or by other location systems Nodes in the same grid square are equivalent in regard to packet forwarding and take turns in sleeping and being awake in order to load balance energy consumption. State transition diagram of GAF consists of three states. They are active, sleep and discovery. In sleeping state sensor will turn off its antenna for energy savings. In discovery state a sensor trades exchange messages to look into other sensors in the same lattice. Even in the active state the sensor occasionally shows its discovery message to inform proportionate sensors about its state. The time used in each of the state will be depending upon few components like its needs and sensor mobility. GAF means to expand the network lifetime by arriving at a state where each grid contains one active sensor focused around sensor ranking rules. The highest rank will handle routing within their respective grids.

V. DATA CENTRIC ROUTING

Data-centric protocols differ from traditional address-centric protocols in the manner that the data is sent from source sensors to the sink. In *address-centric* protocols, each source sensor that has the appropriate data responds by sending its data to the sink independently of all other sensors. However, in *data-centric* protocols, when the source sensors send their data to the sink, intermediate sensors can perform some form of aggregation on the data originating from multiple source sensors and send the aggregated datatoward the sink.This process can result in energy savings because of less transmission required to send the data from the sources to the sink. The protocols used in data centric routing include: Flooding and Gossiping, Sensor Protocols for Information via Negotiation (SPIN), Directed Diffusion, Energy – aware routing, Rumor routing, Constrained Anisotropic Diffusion Routing(CADR), COUGAR, Active QUery forwarding In sensor nEtworks (ACQUIRE).

A. *Sensor protocols for information via negotiation (SPIN):*

The key feature of SPIN [17] is advertisement mechanism.In this mechanism Meta data is exchanged among sensors.Each node on receiving new data advertise to its neighbours then interested neighbours (one who do not have data) retrieve the data by sending request message[14].

Here three types of messages are used,([14][17]):

ADV message: This allow sensor node to advertise particular Meta data

REQ message: Request specific data.

DATA message: carry actual data

SPIN protocol has advantages like nodes need to know only its single Hop neighbour's,Also it overcome resource blindness andno redundant information passing thus achieving lot of energy efficiency. But problem is that SPIN doesn't guarantee the delivery of data i.e. if the destination node is far away from source node and between nodes are not interested in data then data will not be delivered to destination node.

VI. MULTIPATH ROUTING

Routing protocols may maintain single or multiple routes to a given destination. Single path protocols can discover one or multiple routes and then always select the best path for data transport, discarding the other paths. On the other hand, multipath routing refers to the protocols that discover, maintain, and use multiple paths to transport the sensed data. Multipath routing protocols can help in extending the network lifetime because they favour battery depletion of different nodes at a comparable rate. In the case of so-called alternate path protocols, the information about multiple paths is maintained inthe routing table but is used only as a backup in case the primary path fails.

A. *Disjoint Paths:*

Sensor-disjoint multipath routing [10,18] is a multipath protocol that helps find a small number of alternate paths that have no sensor in common with each other and with the primary path. In sensor-disjoint path routing, the primary path is best available whereas the alternate paths are less desirable as they have longer latency. The disjoint makes those alternate paths independent of the primary path. Thus, if a failure occurs on the primary path, it remains local and does not affect any of those alternate paths. The sink can determine which of its neighbors can provide it with the highest quality data characterized by the lowest loss or lowest delay after the network has been flooded with some low-rate samples. Although disjoint paths are more resilient to sensor failures, they can be potentially longer than the primary path and thus lessenergy efficient.

VII. QOS BASED ROUTING

In QoS-based routing protocols, the network has tobalance between energy consumption and data quality. In particular, the network has to satisfy certain QoS metrics,e.g., delay, energy, bandwidth, etc. when delivering data to the BS [6].SAR [19] is one of the first routing protocols for WSNs that introduces the notion of QoS in the routing decisions. It is a table-driven multi-path approach striving to achieve energy efficiency and fault tolerance. Routing decision in SAR is dependent on three factors: energy resources, QoS on each path, and the priority level of each packet [6,14, 20]. SPEED [20] is another QoS routing protocol for sensor networks that provides soft real time end-to-end guarantees. The protocol requires each node to maintain information about its neighbours and uses geographic forwarding to find the paths. In addition, SPEED strive to ensure a certain speed for each packet in the network so that each application can estimate the end-to-end delay for the packets by dividing the distance to the sink by the speed of the packet before making the admission decision. Moreover, SPEED can provide congestion avoidance when the network is congested.

VIII. BIO ISPIRED ROUTING

In recent years insect sensory systems have been inspirational to new communications and computing paradigms, which have led to significant advances like bio inspired routing. The most popular ACO (Ant Colony Optimization) is a colony of artificial ants is used to construct solutions guided by the pheromone trails and heuristic information they are not strong or very intelligent; but they successfully make the colony a highly organized society[21,22]. Swarms are useful in many optimization problems. A swarm of agents is used in a stochastic algorithm to obtain near optimum solutions to complex, non-linear optimization problems. There are two popular swarm inspired methods: Ant Colony optimization (ACO) and Particle Swarm Optimization (PSO). Proposed by Marco Dorigo et al., ACO is based on foraging behaviour of ant colonies [23]. PSO, proposed by Eberhart Kennedy, is inspired by social behaviour of flocks of birds and schools of fish [24]. Currently, these nature inspired techniques are being used for finding better quality solutions in optimization problems and formulate better decision making mechanisms. Bacterial Foraging Optimization Algorithm (BFOA) proposed by Passino, is a newcomer in this field. BFO is inspired by social foraging behaviour of Escherichia coli bacteria [25].

IX. COHERENT AND NONCOHERENT PROCESSING

Data processing is a major component in the operation of wireless sensor networks. Hence, routing techniques employ different data processing techniques. In general, sensor nodes will cooperate with each other in processing different data flooded in the network area. Two examples of data processing techniques pro-posed in WSNs are coherent and non-coherent data processing-based routing[26].

In non-coherent data processing routing, nodes will locally process the raw data before being sent to other nodes for further processing. The nodes that perform further processing are called the aggregators. In coherent routing, the data is forwarded to aggregators after minimum processing. The minimum processing typically includes tasks like time stamping, duplicate suppression, etc. To perform energy-efficientrouting, coherent processing is normally selected [27]. Non-coherent functions have fairly low data traffic loading. On the other hand, since coherent processing generates long data streams, energy efficiency must be achieved by path optimality. In non-coherent processing, data processing incurs three phases: (1) Target detection, data collection, and pre-processing (2) Membership declaration, and (3) Central node election. During phase 1, a target is detected, its data collected and pre-processed. When a node decides to participate in a cooperative function, it will enter phase 2 and declare this intention to all neighbors. This should be done as soon as possible so that each sensor has a local understanding of the network topology. Phase 3 is the election of the central node. Since the central node is selected to perform more sophisticated information processing, it must have sufficient energy reserves and computational capability [28]. In [29], a single and multiple winner algorithms were proposed for non-coherent and coherent processing, respectively.

X. QUERY BASED ROUTING

In this kind of routing, the destination nodes propagate a query for data (sensing task) from a node through the network and a node having this data sends the data which matches the query back to the node, which initiates the query. Usually these queries are described in natural language, or in high-level query languages. Directed diffusion, Rumor routing protocol are examples of Query Based Routing.

A. Directed Diffusion:

In directed diffusion [30], the BS node sends out interest messages to sensors. As the interest is propagated throughout the sensor network, the gradients from the source back to the BS are set up. When the source has data for the interest, the source sends the data along the interests gradient path. To lower energyconsumption, data aggregation (e.g., duplicate suppression) is performed enroute.

XI. CONCLUSION AND OPEN ISSUES

In recent years, routing in WSN has gained tremendous attention leading to unique challenges and design issues whencompared to routing in traditional wired networks. This paper presents a comprehensive survey of the routing techniques for WSNs from the recent works.The main categories explored in this paper areflat Routing, Hierarchical Routing, Location based Routing, Data centric Routing, Multipath Routing, QoS based Routing, Bio-Inspired Routing, Coherent and Non-Coherent based Routing, Query based Routing.We have also listed some important protocols in each category along with their merits and demerits.As our study reveals, it is not possible to design a routing algorithm which will have good performance under all scenarios and for all applications. Although many routing protocols have been proposed for sensor networks, many issues still remain to be addressed. Another possible future research area for routing protocols isthe integration of internet with WSNs so that the data sensedin one part of the world can be sent to the server located inanother part of the world for further analysis.

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