A Brief Overview about Energy-aware, Location-specific, and Topology adjustment routing protocols for Wireless Sensor Networks

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Abstract: The main objective of this work is to provide a brief overview on energy-aware, location-specific, and topology adjustment routing protocols for wireless sensor networks. Major attention is being given to the routing protocols because they usually differ based on the application and network architecture. This paper is to survey the recent routing protocols for sensor networks and it provides a classification for the various methods used. The three major divisions surveyed in this paper are data-centric, hierarchical and location-based. Each and every routing protocol is stated and explained under the suitable category. Also, protocols using current-day techniques such as network flow and quality of service modeling are also conferred.

I. INTRODUCTION

Present-day innovations in micro-mechanical systems and below power and more integrated digital electronics have led to the innovation of micro-sensors [1–5]. Such sensors are usually rigged with data processing and communication competence. The sensing circuitry allowance climate conditions analogues to the environment around the sensor and turns them into an electric signal. Processing such a signal exposes some chacteristics about objects positioned and/or events occurring in the vicinity of the sensor. The sensor delivers such collected data, generally via radio transmitter, to a sink either directly or by a data concentration gateway.

The diminishing size and cost of sensors, as a result of such technological improvements, has fired interest in the plausible use of big set of disposable unattended sensors. Such innovations has motivated intense research in the past few years in regards to the abeyant of collaboration among sensors in data collection, processing, coordination and management of sensing event and data flow to the destination. The most ubiquitous structure for such collective distributed sensors is a network with wireless links that can be assembled amongst the sensors in an ad hoc fashion. Networking connection-free sensor nodes have prominent influence on the efficacy of many military and civil applications like combat field surveillance, confidentiality and disaster administration.

These systems process data gathered from many sensors to administer the events in an area of interest. For instance, in a disaster management environment, much number of sensors could be dropped by a chopper. Networking these sensors can help rescue operations by finding survivors, identifying tricky areas and forming the rescue crew more cautious of the overall problem. Such application of sensor networks increase the efficacy of rescue operations and also ensures the safety of the rescue crew.

On the military field, usage of sensor networks is high. For instance, the use of networked set of sensors can diminish the want for personnel crisis in the generally alarming reconnaissance missions. Additionally, sensor networks may enable a civic use of landmines through making them manageable and target-specific to prevent endangering people and animals. Security utilizations of sensor networks have intrusion detection and criminal hunting. But, sensor nodes are restrained in energy and bandwidth. Such conditions together with a typical deployment of much number of sensor nodes pose much opposition to the design and management of sensor networks. These challenges make mandatory the energy awareness at all layers of networking protocol stack.

The problems related to physical and link layers are usually common for all kind of sensor uses, thus the research on these areas focuses on system-level power alertness like dynamic voltage escalate, radio connection hardware, low duty cycle issues. At the network layer, the major goal is to find methods for energy-efficacy route setup and trust relaying of data from the sensor nodes to the destination such that the lifetime of the network is increased. Routing in sensor networks is very assert due to many features that dissimilar them from ubiquitous communication and wireless ad hoc networks. First of all, it is not possible to form a world-wide addressing method for the deployment of erect number of sensor nodes. Therefore, regular IP-based protocols may not be applied to wireless sensor nodes. Secondly, in contrast to classic communication networks most of the applications of sensor networks need the flow of sensed data from multiple regions (sources) to an appropriate destination. Thirdly, generated data traffic has prominent replication in it because multiple sensors can create same data within the surroundings of phenomena. Such redundancy has to be used by the routing protocols to increase energy and bandwidth usage. Fourth, sensor nodes are closely restrained according to conveyance power, on-board energy, processing proficiency and storage.

Because of such differences, many new algorithms have been stated for the issue of routing data in wireless sensor networks. These routing techniques have considered the features of sensor node together with the application and architecture needs. Most of the routing protocols could be grouped as data-centric, hierarchical or location based although there are few distinct ones based on quality of service (QoS) awareness.

Data-centric protocols are query-based and dependent on the naming of required data, which supports in dispose of redundant transmissions. Hierarchical protocol's main aim is to cluster the nodes so that cluster heads can combine and reduce data to provide energy efficiency. Location based protocols use the location information to transmit the data to the desired destination than the entire. Another approach includes routing that is based on usual network-flow protocols that work for meeting some QoS requirements together with the routing needs.

In this paper, we will discuss the routing protocols for wireless sensor networks innovated in recent years. Each routing protocol is explored under the appropriate category. Our goal is to help provide better knowledge of the existing routing protocols for wireless sensor networks. The grouping of the paper is as follows, in the Section 2, data-centric routing approaches are discussed. Section 3 briefs hierarchical routing protocols. In Section 4, routing approaches that are based on network flow or QoS are discussed. Lastly, in section 5, the conclusion is made.

II. DATA-CENTRIC PROTOCOLS

In many uses of wireless sensor networks, it is not plausible to accredit global identifiers to each node because of the sheer number of nodes unfold. Hence, data is generally transmitted from every sensor node inside the deployment region with prominent redundancy. However, this is much disorganized according to energy usage; routing protocols that have the ability to select a group of sensor nodes and make use of data gathering during the transmission of data have been studied.

In data-centric wireless sensor routing, the destination sends queries to appropriate regions and waits for data from the sensor nodes located in the sent regions. Since data is being asked for through queries, attribute-based naming is mandatory to specify the characteristics of data. SPIN [12] was the first and foremost data-centric protocol, which considered data consultation among nodes in order to reduce redundant data and provide energy efficiency. Then, Directed Diffusion [18] has been innovated and it became a boost in data-centric routing. Later, many other protocols have been designed based on Directed Diffusion [13,15] or by following a related concept. This section will describe these protocols in a detailed manner.

2.1. Flooding and gossiping:

Flooding and gossiping [17] are two typical techniques to transmit data in sensor networks which does not have any need for routing algorithms and topology management. In flooding, each sensor which receives a data packet broadcasts it to all of its neighbouring nodes and this step is continued until the packet arrives at the sink or the limit for the maximum number of hops for the packet is reached. Gossiping is a minor enhanced version of flooding. Here, the intermediate receiving node transmits the packet to a random neighbour, which selects another random neighbour to send the packet to and so on. Even though, flooding is easy to deploy, it has many disadvantages from [12]. Gossiping reduces the issue of flooding by selecting any node as a random node to transmit the packet thus avoiding broadcasting. But, this can cause delay in transmission of data through the nodes in the network.

2.2. Sensor protocols for information via negotiation:

SPIN [12] is one of the early works done to pursue a data-centric routing technique. The main idea driving SPIN is to christen the data using high-level descriptors or metadata. Before transmission, data are exchanged amongst sensors through a data advertisement technique, which is the key property of SPIN. Each and every node on receiving new data sends it to its neighbours and interested neighbours. SPIN metadata negotiation provides a solution to the typical problems of flooding and hence providing a lot of energy efficiency. There is no standard format for metadata and it is said to be application definite. There are three kinds of messages described in SPIN to transfer of data between nodes. These are:

1. ADV: to allow a sensor to advertise a particular meta-data.
2. REQ: to request the specific data.
3. DATA: to carry the actual data.

2.3. Directed Diffusion:

Directed Diffusion [8,9] is a prominent milestone in the data-centric routing research of sensor networks. The idea is to diffuse the data via sensor nodes by using a naming method for the data. The main idea behind using such a method is to get rid of unwanted operations of network layer routing in order to provide energy efficacy. Direct Diffusion gives the suggestion to the use of attribute-value for the data. Also to create a query, an interest is stated through a list of attribute-value pairs like name of objects, duration, interval, and geographical area, etc. The interest is then broadcasted by the sink via its neighbours. Each node which receives the interest can do caching for later usage.

2.4. Energy-aware routing:

Shah and Rabaey[16] have given a proposal to use a set of sub-optimal paths periodically to enhance the lifetime of the network. The transmission paths are selected by the means of a probability function, which is dependent on the energy consumption of each and every path. Network survival ability is the main criteria that the approach is associated with. The technique argues that the usage of the minimum energy path during the time will decrease the energy of nodes present on that particular path. Instead, one of the many paths can be used with a particular probability so that the lifetime efficiency of the network is increased. The protocol makes an assumption that each node can be addressed through a class-based addressing. It also includes the location and types of the nodes. The energy aware routing protocol has three phases. They are:

1. Setup phase.
2. Data communication phase
3. Route maintenance phase.

2.5. Gradient-based routing:

Schurgers [14] have stated a lightly enhanced version of Directed Diffusion, named the Gradient-based routing (GBR). The main idea is to keep track of the number of hops when the interest is diffused throughout the network. Therefore, each node will be able to discover the minimum number of hops to the sink, called height of the node. The distance amongst a node's height and its neighbour is considered as the gradient on that particular link. A packet is then forwarded on a link with the highest gradient. Nodes enacting as a transmission line for multiple paths can create a data gathering entity to combine data. There are three different data spreading techniques which have been presented:

1. Stochastic scheme
2. Energy-based scheme
3. Stream-based scheme

III. HIERARCHICAL PROTOCOLS:

Related to other communication wireless sensor networks, scalability is one of the major design attributes of wireless sensor networks. A single-tiered network might cause the gateway to overload. Such overload can cause delay in communication and inadequate tracking of events. Additionally, the single-gateway architecture is not efficient for a wider set of sensors covering a larger area of interest because the sensors are classically not capable of long-hauled communication. In order to allow the system to manage with extra load and also to cover a large area of interest without degrading, networking clustering has been used in some routing techniques. The important aim of hierarchical routing is to efficiently manage the energy consumption of wireless sensor nodes by including them in a multi-hop communication inside a particular cluster and also by performing data combining and fusion to lower the number of transmitted messages to the destination.

3.1. LEACH:

Low-energy adaptive clustering hierarchy (LEACH) [6] is one of the most prominent hierarchical routing algorithms for wireless sensor networks. The main idea is to form clusters of the wireless sensor nodes based on the transmitted signal strength and the use of local cluster heads as routers to the destination. This will save energy because the transmissions will be done only by the cluster heads than all sensor nodes. Capital number of cluster heads is accounted to be 5% of the total number of nodes.

3.2. PEGASIS and Hierarchical-PEGASIS:

Power-efficient GAthering in Sensor Information Systems (PEGASIS) [10] is an enhancement of the before stated LEACH protocol. Here, rather than forming many number of clusters, PEGASIS forms a chain from sensor nodes such that each node transmits and receives from a neighbour and exactly one node is selected from that chain send data to the base station (destination). The data which has been gathered moves from one node to another node, aggregated and finally sent to the base station. The chain formation is performed in a greedy way.

Hierarchical-PEGASIS [11] is a slight enhancement to PEGASIS, whose main aim is to decrease the delay occurring for packets during transmission to the sink and it also proposes a solution to the data collecting problem by considering energy · delay metric. Also, to reduce the latency in PEGASIS, at the same time transmissions of data messages are done. To avoid collisions which occur and also the possible signal interference which can occur among the sensors, two approaches have been devised. The first approach makes use of signal coding, e.g. CDMA and in the second technique only the nodes which are spatially separated are allowed for simultaneous transmissions.

3.3. TEEN and APTEEN:

Threshold sensitive Energy Efficient sensor Network protocol (TEEN) [7] is stated to be an hierarchical protocol which is designed to be as a response to erratic changes in the attributes which are sensed using factors such as temperature. Responsiveness is another important feature for time-critical usages, also in that the network is operated in a reactive mode. TEEN follows a hierarchical approach which also uses a data-centric mechanism. The architecture of the sensor network is based on a hierarchical aggregation where nodes which are closer form clusters and this process continues onto the second level until base station (destination) is reached.

The Adaptive Threshold sensitive Energy Efficient sensor Network protocol (APTEEN) [18] is an enhancement of TEEN and its main aim is to provide both capturing soporific data collections and giving a reaction to time critical activities. The architecture is similar to that of TEEN. When the sink forms the clusters, the cluster heads then broadcast the attributes, the transmission schedule, and the threshold values to all nodes. The cluster heads are also used to perform data combination to save energy. APTEEN asserts three different query types:

1. Historical: to analyze past data values.
2. One-time: to take a snapshot view of the network.
3. Persistent: to monitor an event for a period of time.

IV. NETWORK FLOW AND QoS-AWARE PROTOCOLS

Even though most of the routing protocols stated for wireless sensor networks fit our classification perfectly, some continue somewhat different techniques such as QoS and network flow. In some techniques, route setup is first modeled and then it is solved as a network flow issue. End-to-end delay requirements are considered in QoS-aware routing protocols while the paths are being set up in the wireless sensor network. Some samples of these protocols are discussed in this section.

4.1. Maximum lifetime energy routing:

Chang and Tassiulas [19] represent an interesting answer to the issue of routing in wireless sensor networks which is based on a network flow approach. The prominent objective of the technique is to maximize the lifetime of the network through carefully defining link cost as an imminent function of required transmission energy and the node remaining energy using that link. Finding the traffic distribution in wireless sensor network is a possible solution to the routing problem and it is based on the name called ''maximum lifetime energy routing''. The answer to this problem helps maximize the plausible time the network exists. To find out which is the best link metric for the discussed maximization issue, two maximum residual energy path algorithms can be devised and simulated.

4.2. Maximum lifetime data gathering:

Kalpakis [20] is used to model the data routes setup in wireless sensor networks as the maximum lifetime data collection issue and it gives a polynomial time based algorithm. The lifetime ''T '' of the system can be defined as the periodic data readings from wireless sensors until the first sensor dies. The data-collection schedule defines for each round how to acquire and transmit the data to the destination. A schedule contains one tree for each round, which is directed from the destination and it spans to all the nodes in the entire system. The lifetime of the system depends on the duration for which the schedule will remain valid. The major objective is to maximize the lifetime of the schedule. For this purpose, Maximum lifetime Data Aggregation (MLDA) algorithm is devised.

4.3. SAR:

Sequential assignment routing (SAR) is the first and foremost protocol which was designed for wireless sensor networks that includes the techniques of QoS in its major routing decisions [1,2]. SAR is a table-driven multi-path approach striving to attain fault tolerance and energy efficacy in wireless sensor networks. The SAR protocol generates trees which are rooted at one-hop neighbours of the destination by taking QoS metric, priority level of each packet and energy resource on each path into consideration. By using the trees which have been created, multiple routes from destination to sensors are provided. One among these paths is selected relative to the QoS on the path and energy resources. By enforcing routing table consistency between downstream and upstream nodes on each path, failure recovery can be done. Any local failure which might occur can cause an automatic path restoration procedure locally. Using the simulation it can be shown that SAR offers low power consumption when compared to minimum-energy metric algorithm.

V. CONCLUSION

Routing protocols in wireless sensor networks have attracted a lot of attention during the recent times and this attention has introduced some unique challenges when compared to other traditional data routing in wired networks. This paper provides a summary of recent research results based on data routing in wireless sensor networks and then it has classified the approaches into three main divisions, called data-centric, hierarchical and location-based and QoS technologies. Thus, this paper provides a brief study over all the routing protocols available for wireless sensor networks.

PROTOCOL NAME	CATEGORY	ADVANTAGES	DIS ADVANTAGES	QoS PARAMETER
Flooding and Gossiping	Data Centric Protocol	No topology management needed	Flooding	Time Delay
SPIN	Data Centric Protocol	No flooding	No standard format for metadata	Anonymity
Directed Diffusion	Data Centric Protocol	No unwanted operations	Uses single attribute value	Energy
Energy Aware Routing	Data Centric Protocol	Network survival ability	Assumptions are made	Location
Gradient Based Routing	Data Centric Protocol	Discovers height of the node	High energy usage	Location
LEACH	Hierarchical protocol	Cluster head transmission	Uses single-hop routing	Energy
PEGASIS and HPEGASIS	Hierarchical protocol	Chain formation of sensor nodes	Dynamic topology	Topology Adjustment
TEEN and APTEEN	Hierarchical protocol	Hierarchical approach of clusters	Over-head and complexity of clusters	Topology adjustment
Maximum lifetime energy routing	QoS-aware protocols	Defines cost link as imminent function	High energy Consumption	Energy
Maximum lifetime data gathering	QoS-aware protocols	Presents a polynomial time algorithm	Computationally expensive	Energy
SAR	QoS-aware protocols	Energy efficiency and fault tolerance	Overhead of maintaining tables	Energy

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