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Categorical Analysis of Routing Protocols

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Abstract

Increased potential in the use of wireless sensor networks in many applications as disaster management, border protection etc., In recent advances wireless sensor networks have let too many new protocols and it has been especially designed for sensor networks and where energy efficient is considered essential. However most of the attention has been given on routing protocols they might differ according to the application and network architecture. The survey is about recent routing protocols with main categories explored are data-centric, hierarchical and location-based. The routing protocols are mainly responsible for maintaining the routes in network and to ensure reliability. Therefore it is a survey of routing protocols for wireless sensor network with energy efficiency.

Keywords: Wireless sensor networks, routing protocols, classification of protocols, energy-efficient.

I. Introduction

Wireless sensor network has been considered as one of the most important technologies for twenty first century. Nowadays it has received tremendous attention in both all over the world. A wireless sensor network typically consists of a large number of low-cost, low-power, wireless communication and computation capabilities [1-2].

These sensor nodes communicate and accomplish a common task. For example, environment monitoring, industrial process [3].

Sensor nodes are battery-powered and also considered to be energy efficient and expected to operate without any loss and relatively work for long period of time. Thus the unique characteristics present in wireless sensor network provide many new challenges. Routing in sensor network is considered

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to be challenging due to the characteristics present in them. Almost all of the routing protocols can be given as data-centric, hierarchical or location-based and few distinct ones also based on the QOS.The basic philosophy that has been behind wireless sensor network is that, when the capability of each and every sensor node has been limited, the aggregate power of the whole network is been sufficient for the particular required mission.

In wireless sensor network applications the deployment of the sensor nodes has been considered in an ad-hoc fashion without any careful planning and organizing. And once when it is deployed, the sensor nodes must be able to autonomously organize themselves in a wireless communication network.

Due to the severe energy constraint of large number of densely deployed sensor nodes it requires to have a suite of network protocols to implement various network control and to manage functions such as synchronization, node localization and network security.

A large number of research activities have been carried out to explore and overcome the constraint of wireless sensor network and to solve and design with its application and issues.

This paper is organized as follows. In the balance of this section 2, we will briefly summarize the system architecture design issues for sensor network and the implementation in data routing. In section 3, network design objectives. In section 4, network design challenges and its routing issues. In section 5, hierarchical based protocols and their approaches are covered. In section 6, summarizes location based protocols in sensor network. In section 7, data centric protocols are discussed. . In section 8, we describe quality of service (QOS) based protocol. Finally, section 9 concludes with a survey of routing protocols in wireless sensor networks.

II. System Architecture and Design Issues

Depending on the application, the architecture and the design goals also have been considered with the sensor network. Since the routing protocols are been closely related with the system architectural model, we highlight the implication.

A. Network Dynamics

There are three main components in a sensor network. They are the *sensor nodes, sink and monitored event*. Routing messages from or to moving nodes is more challenging since route stability becomes an important optimization factor with energy and bandwidth [5].

B. Node Deployment

Another consideration is the deployment of nodes. It is an application dependent and also it affects the routing protocol. The deployment is either *deterministic or self-organizing*. In deterministic situation the sensors have been placed manually. Whereas in self-organizing the sensor nodes have been scattered randomly.

C. Energy Consideration

In creating an infrastructure, the process of setting up the routes is influenced only by the energy consideration. Most of the time sensors are scattered randomly, over an area of interest and it becomes unavoidable.

D. Data Delivery Models

Depending on the application of the sensor network, the data delivery model can be *continuous event-driven, query-driven and hybrid*. In continuous delivery model each sensor takes place periodically. In event-driven and query-driven models, the transmission of data is triggered and finally in hybrid models it uses a combination of both continuous and event-driven.

E. Node Capabilities

In a sensor network much functionality can be associated with sensor nodes and all the sensor nodes are assumed to be with terms as computations, communication and power. By encaging the three functionalities together at the same time on a node there might be a loss and drain in the energy of the node. Therefore by a heterogeneous environment routing becomes more challenging even.

F. Data Aggregation/Fusion

Data aggregation is a combination of data from different sources by using function such as suppression (eliminating duplicates), min, max and average. Data aggregation technique has been used to achieve energy efficiency and data transfer optimization in a number of routing protocols.

III. Network Design Objectives

Most sensor network is application specific and has different requirements. Thus the main objectives in design of sensor network are as follows:

A. Small Node Size

This small node size will reduce the power and consumption with cost of sensor nodes.

B. Low Node Cost

The sensor nodes have been usually used large in numbers and so it cannot be reused, and in reduction of cost and totally it will result in cost reduction.

C. Low Power Consumption

Since all the sensor networks are powered by battery it becomes often difficult or impossible to consumption with the batteries. So that the lifetime of sensor nodes as the whole network is prolonged.

D. Scalability

Since the sensor nodes in sensor network are been ordered as tens, hundreds, thousands it should be given with a scalable unit according to the different network sizes.

E. Reliability

The network protocols present in the sensor network should provide an error control with a correction mechanisms to ensure the reliability over-noisy, error-prone and time-varying wireless channels.

F. Self-Configurability

In sensor networks the sensor nodes should be able to organize themselves in the communication in the event of topology and failure of nodes.

G. Adaptability

In sensor networks any node may be suddenly failed, joined or moved which may result in changes in node density and network topology. Thus the network protocols designed for sensor network must be adaptive to such density and changes.

H. Channel Utilization

Since sensor networks have limited bandwidth resources, communication protocols designed for sensor networks must be efficiently used to improve channel utilization.

I. Fault Tolerance

Sensor networks are fault tolerant and have the ability of self-testing, self-calibrating and self-repairing.

J. Security

Sensor networks introduce effective security mechanisms to prevent the data information in the network or a sensor node from any other unauthorized access or malicious attacks.

K. *QOS support*

In sensor networks, different applications may have different quality of service requirements in terms of delivery latency and packet loss.

IV. Network Design Challenges and Routing Issues

The design challenges in sensor networks involve in the following main aspects [7]

A. Limited Energy Capacity

Since the sensor nodes are been battery powered, they have limited energy capacity. Thus the routing protocols designed for sensors which should be as energy efficient and thus prolongs the network lifetime.

B. Sensor Locations

Another important challenge that has been found in the routing protocols is by managing the location of sensors.

C. Limited Hardware Resources

This hardware presents many challenges in design for sensor networks which must be considered not only the energy constraint but also the storage capacities in sensor nodes.

D. Massive and Random Node Deployment

Sensor node deployment in wireless sensor networks has been application dependent (i.e.); it can be either manual or random which affects the performance in routing protocol.

E. Network Characteristics and Unreliable Environment

A sensor network generally works on the dynamic and its unreliable environment. Therefore the routing paths must be considered with limited energy and sensor mobility and also increasing in size with coverage and connectivity.

F. Data Aggregation

This data aggregation technique has been used to achieve the energy with efficiency and data transfer optimization in a number of routing protocols.

G. Diverse Sensing Application Requirements

The sensor network has a wide range in diverse applications. Therefore the routing protocols guarantee its accuracy about the physical phenomenon on time.

H. Scalability

The routing protocol must be able to scale network size. Hence the communication links between sensors must be symmetric.

V. Hierarchical Based Protocols

Many research projects have explored hierarchical clustering in wireless sensor network from different aspects [1]. Clustering is energy-efficient communication protocol that has been used by sensors to sensor the data.

In this section we give an example of layered protocols in which an network has been composed of several clumps (or clusters) of sensors. Each clump has been managed by a special node called as cluster head, that has been responsible for all the data transmission.

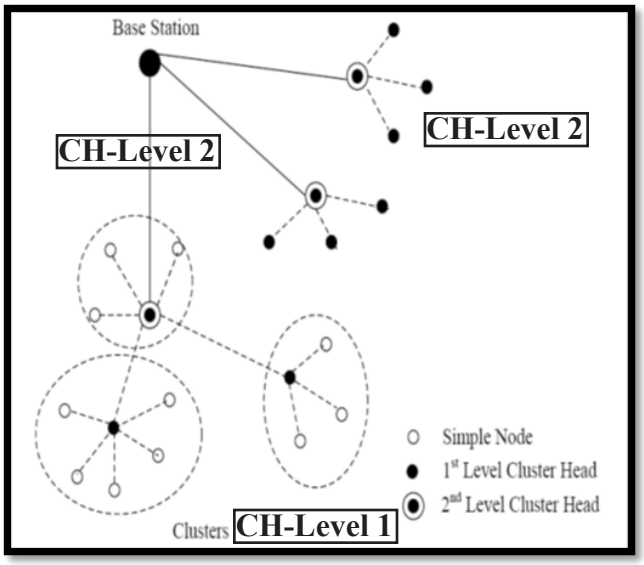

Figure: 1 Cluster Based Hierarchical Model

As shown in figure1 a hierarchical approach breaks the network into cluster layers. Nodes have been grouped into clusters with a cluster head which has the responsibility of routing from cluster to other cluster heads. Data generally travel from lower clustered layer to the higher one. Although it moves from one node to another, but which it moves from one layer to the other and it covers generally larger distances [11]. By this way it moves data faster. Clustering provides the inherent optimization capabilities at cluster heads. In this section, we review a sample of hierarchical-based routing produces for wireless sensor networks.

Low-Energy Adaptive Clustering Hierarchy (LEACH)

LEACH is a first and most popular energy-efficient clustering algorithm proposed for reducing power consumption in wireless sensor networks. The idea used in it is to form clusters of the sensor nodes based on the received signal strength and use local cluster heads as routers to the sink. By doing this we will save energy since transmissions has been done by cluster heads rather than all sensor nodes.

LEACH is based on the aggregation technique that combines on aggregation the original data into a smaller size of data that carry only meaningful information.

The operation of LEACH is been divided into two phases namely i.) A setup phase to organize the network into clusters, CH advertisement and transmission schedule creation and ii.) A steady state-phase for data aggregation, compression and transmission to sink.

LEACH is complete knowledge of network that reduces energy consumption by (a) minimizing the communication cost between sensors and their clusters heads and (b) turning off non-head nodes as much as possible [9].

And also LEACH terminates in a finite number of iterations; but does not guarantee for good CH distribution and also assumes uniform energy consumption for CHs.

Power-Efficient Gathering in Sensor Information System (PEGASIS)

PEGASIS is an extension of LEACH protocol, which forms a chain from sensor nodes so that each node transmits and receives from a neighbor's and only one node has been selected from that chain to transmit to the base station [10]. Gathered data moves from node to node aggregated and eventually sent to the base station .The chain construction is performed in a greedy way. As shown in Figure 2 node c0 passes its data to node c1. Node c1 aggregates node c0's data with its own and then transmits to the leader. After node c2 passes the token to node c4, node c4 transmits its data to node c3. Node c3 aggregates node c4's data with its own and then transmits to the leader. Node c2 waits to receive data from both neighbor's and then aggregates its data with its neighbor's data. Finally, node c2 transmits one message to the base station.

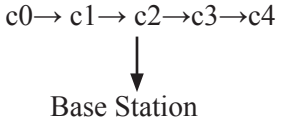

Figure: 2 Chaining in PEGASIS

Such a topology adjustment can introduce significant overhead especially for highly utilized network.

Hybrid-Energy Efficient Distributed Clustering (HEED)

HEED extends the basic scheme of LEACH by using residual energy for cluster selection to achieve power balancing [11]. HEED has been proposed with *four primary goals* namely (i) prolonging network lifetime by distributing energy consumption, (ii) terminating the clustering process within a constant number of iterations, (iii) minimizing control overhead, and (iv) producing well-distributed CHs and compact clusters.

In HEED the proposed algorithm periodically selects CHs according to a combination of two clustering parameters. The primary parameter is their residual energy of each sensor node (used in calculating probability of becoming a CH) and the secondary parameter is the intra-cluster communication cost as a function of cluster density or node degree (i.e. number of neighbors). The primary parameter is used to probabilistically select an initial set of CHs while the secondary parameter is used for breaking ties. However the cluster selection deals with only a subset of parameters, which are possibly constraint on system.

Threshold Sensitive Energy Efficient Sensor Network Protocol (TEEN)

TEEN is a hierarchical clustering protocol, which groups sensors with each led by a CH. The sensors within a cluster report to their CH.TEEN has been useful for applications where the users can control a trade-off between energy efficiency, data accuracy, and response time dynamically. However TEEN is not suitable for sensing application which is needed since the user may not get any data at all if the threshold is not reached.

Adaptive Periodic Threshold Sensitive Energy Efficient Sensor Network Protocol (APTEEN)

APTEEN is an improvement to TEEN and to overcome its shortcomings and aims at both capturing periodic data collections and reacting with time-critical events. The architecture of APTEEN is same as TEEN, which uses the concept hierarchical clustering for energy efficient communication between source sensors and sink.

It supports three different query types namely (i) historical query to analyze past data values, (ii) one-time query, to take a snapshot view of the network; and (iii) persistent queries, to monitor an event for a period of time.

VI. Location Based Protocols

In this location based protocol, sensor nodes are addressed by their locations. In this section, we present a sample of location-aware routing protocols proposed for wireless sensor networks.

Geographic and Energy-Aware Routing (GEAR)

GEAR is an energy-efficient routing protocol proposed for routing queries to target regions in a sensor field; GEAR uses energy aware heuristics that are based on geographical information to select sensors to route a packet to towards its destination region. Then GEAR uses a recursive geographic forwarding algorithm to disseminate the packet inside the target region.

Minimum Energy Communication Network (MECN)

MECN is a location- based protocol for a minimum energy for randomly deployed ad-hoc network, which attempts to set up and maintain a minimum energy network with mobile sensors.

In the first phase (encloses graph construction), MECN constructs a sparse graph, called an *enclosure graph,* based on the immediate locality of the sensors. An enclosure graph is a directed graph that includes all the sensors as its vertex set and whose edge set is the union of all edges between the sensors and the neighbors located in their enclosure regions. In other words, a sensor will not consider the sensors located in its relay regions as potential candidate forwarders of its sensed data to the sink. In the second phase (*cost distribution*), non-optimal links of the enclosure graph are simply eliminated and the resulting graph is a *minimum power topology.* This graph has a directed path from each sensor to the sink and consumes the least total power among all graphs having directed paths from each sensor to the sink.

To address this problem the enclosure graph and thus the minimum power topology should be dynamic based on the residual energy of the sensors.

Small Minimum-Energy Communication Network (SMECN)

SMECN is an routing protocol proposed to improve MECN, in which a minimal graph is characterized with regard to the minimum energy property. In SMECN protocol every sensor discovers its immediate neighbours by broadcasting a message with initial power that is updated incrementally. Specifically the immediate neighbors of a given sensor are computed analytically. Otherwise, it increments and rebroadcasts its neighbor's discovery message.

VII. Data Centric Protocols

Data centric protocols differ from traditional address-centric protocol in the manner that the data is sent from source sensors to the sink. In data-centric protocol when the source sensors send their data to the sink they can perform some form of aggregation on the data originating from multiple and send the aggregated data toward the sink.

Rumour Routing

Rumour routing is a logical compromise between query flooding and event flooding application schemes. Rumour routing is an efficient protocol if the number of queries is between two intersection points of the curve of rumor routing with those of query flooding and event flooding.

Rumour routing is based on the concept of agent, which is a long-lived packet that traverses a network and informs each sensor its network traverse. It also maintains and updates the event to maintain the shortest paths to the events that occur in the network.

COUGAR

The COUGAR routing protocol is a database approach to tasking sensor network. The COUGAR approach uses a query layer where every sensor is associated with a query proxy that lies between the network layer and application layer of the sensor. Since the COUGAR is a database approach it faces few challenges.

Active Query Forwarding in Sensor Network (ACQUIRE)

ACQUIRE is another data centric mechanism used for querying named data. It provides superior query optimization to answer very specific queries called one-shot complex queries for replicated data. ACQUIRE allows the queries to inject a complex query into the network and been forwarded through a sequence of sensors.

VIII. QOS Based Protocols

QOS protocols consider end-end delay requirements while setting up the paths in sensor network [12].

Sequential Assignment Routing (SAR)

It is the first protocol for sensor network that includes the notion of QOS in its routing decisions. This is also a multi-path approach [9]. The objective of SAR algorithm is to minimize the average weighted QoS metric throughout the lifetime of the network.

If topology changes due to node failures, a path re-computation is needed. As a preventive measure, a periodic re-computation of paths is triggered by the base-station to account for any changes in the topology.

SPEED

It is another QoS routing protocol for sensor networks that provides soft real-time end-to-end guarantees. SPEED does not consider any further energy metric in its routing protocol. Therefore, for more realistic understanding of SPEED's energy consumption, there is a need for comparing it to a routing protocol, which is energy-aware.

Energy-Aware QoS Routing Protocol

In this QoS aware protocol for sensor networks, real-time traffic is generated by imaging sensors. The proposed protocol extends the routing approach in and finds a least cost and energy efficient path that meets certain end-to-end delay during the connection. However, it does not provide flexible adjusting of bandwidth sharing for different links.

Conclusion

One of the main challenges in the design of routing protocols for WSNs is energy efficiency due to the scarce energy resources of sensors. In this paper, we have summarized recent research results on data routing in sensor networks and classified the approaches into three main categories, namely data-centric, hierarchical and location-based.

The factors affecting cluster formation and cluster-head communication are open issues for future research.

Moreover, the process of data aggregation and fusion among clusters is also an interesting problem to explore. We highlighted with the energy efficiency and the network challenges and its routing issues.

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