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The Energy-Efficient Hierarchical Routing Protocols for WSN: A Review

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Abstract : A WSN is a specialized wireless network made up of a large number of sensors and at least one base station. The foremost difference between the WSN and the traditional wireless networks is that sensors are extremely sensitive to energy consumption. Energy saving is the crucial issue in designing the wireless sensor networks[1].. Since the radio transmission and reception consumes a lot of energy, one of the important issues in wireless sensor network is the inherent limited battery power within network sensor nodes. In order to maximize the lifetime of sensor nodes, it is preferable to distribute the energy dissipated throughout the wireless sensor network.So it is essential to design effective and energy aware protocols in order to enhance the network lifetime.A WSN can have network structure based or protocol operation based routing protocol .In this paper, a review on network structure based routing protocol in WSNs is carried out.Energy consumption and network life time has been considered as the major issues .

Keywords: Energy-Consumption,Wireless,Sensor Network, Routing Protocols, LEACH, lifetime Chain based routing, Cluster head.

I. INTRODUCTION

A WSN is a specialized wireless network made up of a large number of sensors and at least one base station. The sensor nodes are small devices that consists of four basic components 1) sensing subsystem , 2) processing subsystem, 3) wireless communication subsystem 4) energy supply subsystem. The sensor nodes have limited battery power, communication range and memory etc. In
most cases, the sensors forming these networks are deployed randomly and left unattended to and are expected to perform their mission properly and efficiently. Sensor networks are also energy constrained since the individual sensors are extremely energy-constrained .

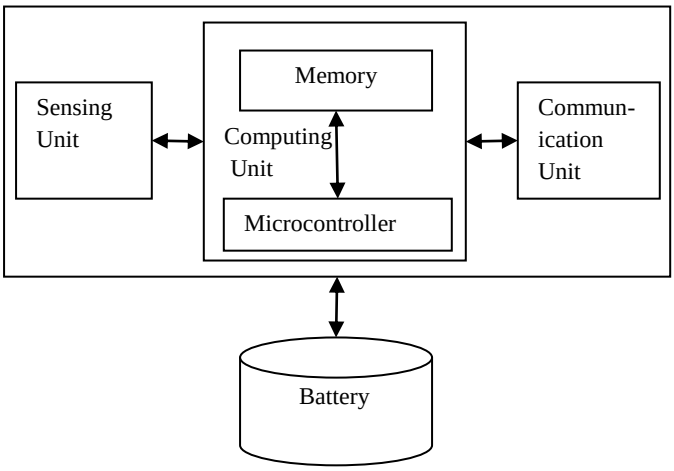

Fig.1 Components of a sensor node

A real and appropriate solution for this problem is to implement routing protocols that perform efficiently and utilizing the less amount of energy as possible for the communication among nodes. Sensor devices in WSNs monitor the same event and

report on them to the base station. Therefore, one good approach is to consider that sensors located in the same region of the network will transmit similar values of the attributes. This fact notices inherent redundancy in the node transmissions that may be used by the routing protocol.Sensor networks need protocols, which are specific, data centric, capable of aggregating data and optimizing energy consumption . sensor nodes deployed in a specified area monitors environmental conditions such as temperature, air pressure, humidity, light, motion or vibration, and so on. The sensor nodes are usually programmed to monitor or collect data from surrounding environment and pass the information to the base station for remote user access through various communication technologies.

II. ROUTING PROTOCOLS

A WSN can have network structure based or protocol operation based routing protocol .Routing protocols inWSNs might differ depending on the application (Protocol-Operation-based) and network architecture (Network-Structure-based) as shown in Fig. 2. Based on the underlying network there are three protocol categories:

A.Flat Routing

Each node plays the same role and sensor nodes collaborate to perform the sensing task.

B. Hierarchical Routing

Higher-energy nodes are used to process and send the information, while low-energy nodes are used to perform the sensing in the proximity of the target. The creation of clusters and assigning special tasks to cluster heads can greatly contribute to overall system scalability, lifetime, and energy efficiency. Hierarchical routing is an efficient way to lower energy consumption within a cluster, performing data aggregation and fusion in order to decrease the number of transmitted messages to the sink node.

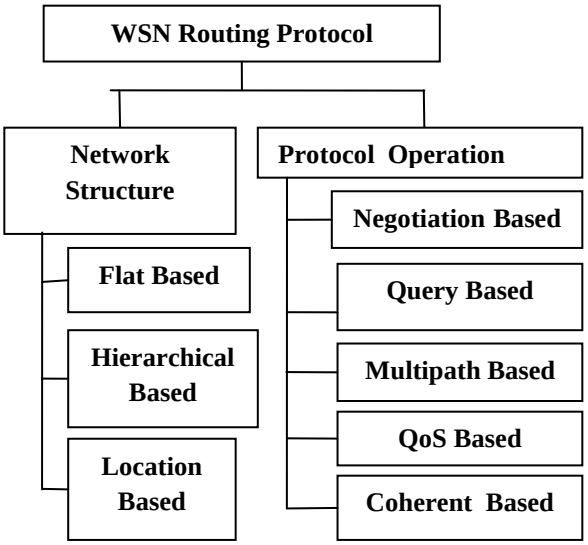

Fig.2 classification of WSN Routing Protocols

C. Location-based

Sensor nodes are addressed by means of their locations. The distance between neighboring nodes can be estimated on the basis of incoming signal strengths. Relative coordinates of neighboring nodes can be obtained by exchanging such information between neighbors or by communicating with a satellite using GPS. To save energy, some location-based schemes demand that nodes should go to sleep if there is no activity.

Depending on the ***Protocol Operation*** we can divide routing protocols in:

Multipath-based

They use multiple paths rather than a single path in order to enhance network performance. For instance the fault tolerance can be increased by maintaining multiple paths between the source and destination at the expense of increased energy consumption and traffic
generation.

Query-based

The destination nodes propagate a query for data from a node through the network, a node with this data sends the data that matches the query back to the node that initiated it.

Negotiation-based

Use negotiation in order to eliminate redundant data transmissions. Communication decisions are also made based on the resources available.

QoS-based

When delivering data, the network balances between energy consumption and data quality through certain QoS metrics as delay, energy or bandwidth.

Coherent-based

The entity of local data processing on the nodes distinguish between coherent (minimum processing) and non-coherent (full processing) routing protocols.

III. HIERARCHICAL PROTOCOLS

In this paper various hierarchical based routing protocols has been reviewed.Many researchers carried out their research in the hierarchical routing. A hierarchical approach breaks the network into clustered layers. Nodes are grouped into clusters with a cluster head that has the responsibility of routing from the cluster to the other cluster heads or base stations. Data travel from a lower clustered layer to a higher one. Although, it hops from one node to another, but as it hops from one layer to another it covers larger distances. This moves the data faster to the base station Clustering provides inherent optimization capabilities at the cluster heads.

Low-energy adaptive clustering hierarchy (LEACH) LEACH [4]is the first and most popular energy-efficient hierarchical clustering algorithm for WSNs that was proposed for reducing power consumption. LEACH is based on an *aggregation* technique that combines the original data into a smaller size of data that carry only meaningful information to all individual sensors. LEACH divides the a network into several cluster of sensors, which are constructed by using localized coordination and control not only to reduce the amount of data that are transmitted to the sink, but also to make routing and data dissemination more scalable and robust.LEACH uses a randomize rotation of high-energy CH position rather than selecting in static manner, to give a chance to all sensors to act as CHs and avoid the battery depletion of an individual sensor and die quickly. LEACH uses single-hop routing where each node can transmit directly to the cluster-head and the sink. Therefore, it is not applicable to networks deployed in large regions. While LEACH helps the sensors within their cluster dissipate their energy slowly, the CHs consume a larger amount of energy when they are located farther away from the sink.

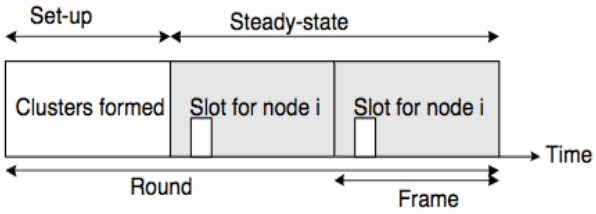

Fig. 3 LEACH operations

The major characteristics of this Protocol are as follow:

- It rotates the cluster heads in a randomized fashion to achieve balanced energy consumption,
- Sensors have synchronized clocks so that they know the beginning of a new cycle,
- Sensors do not need to know location or distance information.

There are some drawbacks of this protocol such as:

- LEACH uses single-hop routing where each node can transmit directly to the cluster-head and the sink. Therefore, it is not applicable to networks deployed in large regions.
- The idea of dynamic clustering brings extra overhead, e.g. head changes, advertisements etc., which may decrease the gain in energy consumption.
- Random election of CH, hence there is Possibility that all CHs will be concentrated in same area.
- The protocol assumes that all nodes begin with the same amount of energy capacity in each election round, assuming that being a CH consumes approximately the same amount of energy for each node.

This protocol is most suited for constant monitoring such as monitor machinery for fault detection and diagnosis.

Enhanced Low-energy Adaptive Clustering Hierarchy (E-LEACH):

E-LEACH proposes a cluster head selection algorithm for sensor networks that have non-uniform starting energy level among the sensors. It also determines that the required number of cluster heads has to scale as the square root of the total number of sensor nodes to minimize the total energy consumption.

LEACH-Centralized (LEACH-C):

LEACH-C uses a centralized clustering algorithm and same steady-state protocol. During the set-up phase of LEACH-C, each node sends information about

current location and energy level to base station (BS). The BS will determine clusters, CH and non-CHs of each cluster. The BS utilizes its global information of the network to produce better clusters that require less energy for data transmission. The number of CHs in each round of LEACH-C equals a predetermined optimal value.

Multi-hop LEACH (M-LEACH):

M-LEACH modifies LEACH allowing sensor nodes to use multi-hop communication within the cluster in order to increase the energy efficiency of the protocol. This work extends the existing solutions by allowing multi-hop inter-cluster

communication in sparse WSNs in which the direct communication between CHs or the sink is not possible due to the distance between them. Thus, the main innovation of the solution proposed here is that the multi-hop approach is followed inside the cluster and outside the cluster. CHs can also perform data fusion to the data receive, allowing a reduction in the total transmitted and forwarded data in the network.

Power-Efficient Gathering in Sensor Information Systems (PEGASIS):

PEGASIS is an extension of the LEACH protocol, which forms chains from sensor nodes so that each node transmits and receives from a neighbor and only one node is selected from that chain to transmit to the base station (sink). The data is gathered and moves from node to node, aggregated and eventually sent to the base station. The chain construction is performed in a greedy way. PEGASIS[8] avoids cluster formation and uses only one node in a chain to transmit to the BS (sink) instead of using multiple nodes. A sensor transmits to its local neighbors in the data fusion phase instead of sending directly to its CH as in the case of LEACH. When a sensor fails or dies due to low battery power, the chain is constructed using the same greedy approach by bypassing the failed sensor.

Hierarchical PEGASIS:

An extension to PEGASIS, called Hierarchical-PEGASIS was introduced with the objective of decreasing the delay incurred for packets during transmission to

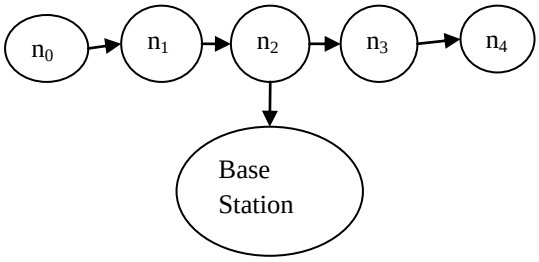

Fig.4 Chaining in PEGASIS

the BS. H-PEGASIS proposes a solution to the data gathering problem by considering energy x delay metric.

Energy Balancing PEGASIS (EB-PEGASIS): EBPEGASIS is an energy efficient chaining algorithm in which a node will consider average distance of formed chain. If the distance from closest node to its upstream node is longer than distance-threshold, the closest node is a far node. If the closest node joins the chain, it will emerge a long chain. In this condition, the far node will search a nearer node on formed chain. Through this method, the new protocol EB-PEGASIS can avoid long chain effectively. It not only saves energy on sensors, but also balances the energy consumption of all sensor nodes.

Hybrid, Energy-Efficient Distributed Clustering (HEED):

HEED extends the basic scheme of LEACH by using residual energy and node degree as a metric for cluster selection to achieve power balancing. It operates in multi-hop networks, using an adaptive transmission power in the inter-clustering communication. HEED was 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 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 select an initial set of CHs while the secondary parameter is used for breaking ties. The HEED clustering improves network lifetime over LEACH clustering because LEACH randomly selects CHs, which may result in faster death of some nodes.

The important features of this protocol are as follows:

- HEED distribution of energy extends the lifetime of the nodes within the network thus stabilizing the neighboring node.
- HEED does not require special node capabilities, such as location-awareness
- HEED does not make assumptions about node distribution . The nodes also automatically update their neighbour sets in multi-hop networks by periodically sending and receiving messages. It operates correctly even when nodes are not synchronized.
- The nodes only require local (neighborhood) information to form the clusters .

Threshold Sensitive Energy Efficient Sensor Network Protocol (TEEN):

TEEN is a hierarchical clustering protocol, which groups sensors into clusters with each led by a CH. The sensors within a cluster report their sensed data to their CH. The CH sends aggregated data to higher level CH until the data reaches the sink. Thus, the sensor network architecture in TEEN is based on a hierarchical grouping where closer nodes form clusters and this process goes on the second level until the BS (sink) is reached. TEEN uses a data-centric method with hierarchical approach.

The main features of this protocol are as follows:

- Time critical data reaches the user almost instantaneously.
- The soft threshold can be varied, depending on the criticality of the sensed attribute and the target application.
- A smaller value of the soft threshold gives a more accurate picture of the network, at the expense of increased energy consumption.
- At every cluster change time, the attributes are broadcast afresh and so, the user can change them as required

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

APTEEN aims at both capturing periodic data collections (LEACH) and reacting to time-critical events (TEEN). Thus, APTEEN is a hybrid clustering-based routing protocol that allows the sensor to send their sensed data periodically and react to any sudden change in the value of the sensed attribute by reporting the corresponding values to their CHs. CHs also perform data aggregation in order to save energy. APTEEN 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 (iii) persistent queries, to monitor an event for a period of time. Energy dissipation will be lower and a large number of sensors alive in APTEEN.

COSEN: Chain Oriented Sensor Network

COSEN [9]operates in two phases - chain formation phase followed by data transmission phase. In the chain formation phase, chains of different levels are formed and in data transmission phase, information is transmitted along with the designated paths. One higher level chain and several lower level chains are formed with the deployed sensors. In each chain, one node is elected as a leader. In every kind of chains, the chain-leader is elected based on some criteria or measures. Lower level leader nodes are responsible to collect information from lower level chains and send the information towards higher level leader. Higher level leader sends the information to BS.

Chain Based Hierarchical Routing Protocol (CHIRON)

Chain-based routing is one of most significant routing mechanisms. In such routing scheme, sensor nodes are linked into a single or multiple chains in advance. In data dissemination phase, each node communicates only with its closest neighbours, and takes turns to be the chain leader for transmitting the aggregated data to the BS. Even the chain-based routing protocols can effectively balance the node's energy dissipation, and thus significantly extend the network life-time; they would be easy to cause serious transmission delays and redundant paths, particularly for large sensing areas.Based on the Beam Star [10]concept, the main idea of CHIRON is to split the sensing field into a number of smaller areas, so that it can create multiple shorter chains to reduce the data transmission delay and redundant path, and therefore effectively conserve the node energy and prolong the network lifetime. In CHIRON, the technique of Beam Star is first used to divide the sensing area into several fan-shaped groups. The sensor nodes within each group are then self organized into a chain for data dissemination. Unlike traditional approaches, instead of taking turns, we consider the node with a maximum residual energy as chain leader candidate.

IV. 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. The energy consumption of the sensors is dominated by data transmission and reception. Therefore, routing protocols designed for WSNs should be as energy efficient as possible to prolong the lifetime of individual sensors, and hence the network lifetime. The protocols discussed have individual advantages and pitfalls. Based on the topology, the protocol and routing strategies can be applied. For realization of sensor networks, it is needed to satisfy the constraints introduced by factors such as fault tolerance, scalability, cost, topology change, environment, and power consumption.

Routing in sensor networks is a new research area, with a limited but rapidly growing set of results. In this paper, hierarchical based routing protocols are discussed on the basis of network structure. They have the common objective of trying to extend the lifetime by reducing the energy consumption of the sensor network.

Hierarchical based techniques have special advantage of scalability and efficient communication. Hierarchical routing maintains the energy consumption of sensor nodes and performs data aggregation which helps in decreasing the number of transmitted messages to base station. Most of the routing protocols require location information for sensor nodes in wireless sensor networks to calculate the distance between two particular nodes on the basis of signal strength so that energy consumption can be estimated.

Many issues and challenges still exist that need to be solved in the sensor networks.

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