3.1.2 Hierarchical Routing

Hierarchical or cluster-based routing, originally suggested for wireless sensor networks, are well-known techniques with special advantages related to scalability, energy efficiency and efficient routing. In a hierarchical routing, higher energy nodes can be used to process and send the information to BS while low energy nodes can be used to perform the sensing task in the desired region. This means that formation of clusters and assigning special tasks to cluster heads can greatly contribute to overall system scalability, lifetime, and energy efficiency. Hierarchical routing is an effective way to lower energy consumption within a cluster and by performing data aggregation in order to decrease the number of transmitted messages to the BS. Hierarchical routing is mainly two-layer architecture where one layer is used to select cluster heads and the other layer is used for routing. In this two approaches are used

a) Clustering approach
b) Tree approach

3.1.3 Clustering approach

LEACH protocol:

Heinzelman, et. al. [1] proposed a hierarchical clustering algorithm for sensor networks, called Low Energy Adaptive Clustering Hierarchy (LEACH). LEACH is a cluster formation based protocol. LEACH randomly selects a few sensor nodes as cluster heads (CHs) and rotate this role to evenly distribute the energy load among the sensors in the network. In LEACH, the cluster head (CH) nodes gather the data from nodes that belongs to the respective cluster called cluster members, 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. In LEACH TDMA/CDMA MAC technique is used to reduce inter-cluster and intra-cluster collisions. In LEACH data collection is centralized and is performed periodically. Therefore, this protocol is most appropriate for an application where there is a need for constant monitoring is required. 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 from cluster members to the base station takes place. The duration of the steady state phase is more than the duration of the setup phase in order to minimize overhead. During the setup phase, a predetermined fraction of nodes p, elect themselves as CHs . A sensor node chooses a random number r, between 0 and 1. If this random number is less than a threshold value, T(n), the node becomes a cluster-head for the current round. The threshold value is calculated based on an equation that incorporates the desired percentage to become a cluster-head, the current round, and the set of nodes that have not been selected as a cluster-head in the last (1/P) rounds, denoted by G. It is given by:

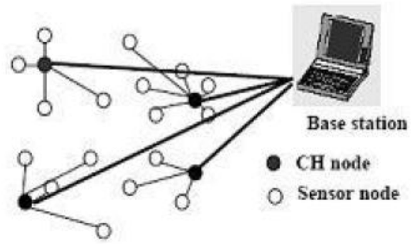

Figure 4: LEACH

$$T(n) = \frac{p}{1 - p(r \bmod (1/p))} \quad if\ n \in G$$

Where G is the set of nodes that are involved in the CH election.

3.1.4 Tree approach

Power-Efficient Gathering in Sensor Information Systems (PEGASIS)

In [17], an enhancement over LEACH protocol was suggested. The protocol, called Power Efficient Gathering in Sensor Information Systems (PEGASIS), is a chain-based algorithm. The main idea of the protocol is that in order to prolong network lifetime, nodes need only communicate with their closest neighbors and they take turns in communicating with the base-station. This helps in reducing the power required to transmit data per round as the power consumption is distributed evenly over all nodes. Thus, PEGASIS has two main objectives. First is to increase the lifetime of each node by using collaborative techniques. Second is to reduce the bandwidth requirement by allowing only local coordination between nodes that are close to each other .Unlike LEACH, PEGASIS there is no cluster formation. Instead of using multiple nodes only one node in a chain is selected to transmit data to the BS.

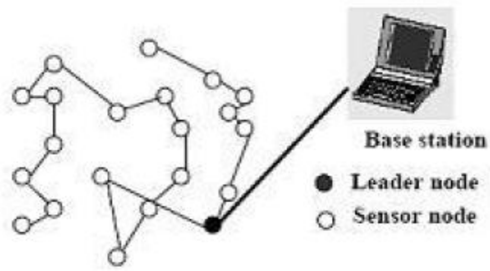

Figure 5: Chain construction using greedy algorithm

Threshold-sensitive Energy Efficient Protocols (TEEN and APTEEN):

Two hierarchical routing protocols called TEEN (Threshold-sensitive Energy Efficient sensor Network protocol), and APTEEN (Adaptive Periodic Threshold-sensitive Energy efficient sensor Network protocol) are suggested in [8] and [9], respectively. These protocols were proposed for time-constrained applications. In TEEN, sensor nodes sense the medium continuously, but the data transmission takes place periodically. A cluster head sensor sends its members a hard threshold limit, which is the threshold value of the sensed attribute and a soft threshold limit, which is a small change in the value of the sensed attribute that triggers the node to switch on its transmitter. Thus the hard threshold tries to reduce the number of transmissions by allowing the nodes to transmit only when the sensed attribute is in the region of interest. The soft threshold further reduces the number of transmissions that might have otherwise occurred when there is small or no change in the sensed attribute. The major disadvantage of this scheme is that, communication will not occur if the thresholds are not received, and the user will not get any data from the network at all.

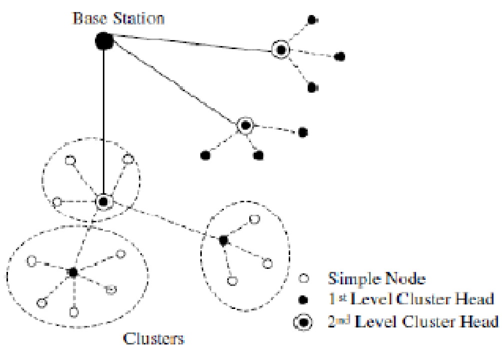

Figure 6: Clustering in TEEN and APTEEN

3.2 Communication based Model

3.2.1 Negotiation Based

Sensor Protocols for Information via Negotiation (SPIN): Heinzelman et.al. in [3] and [7] suggested a family of adaptive protocols called Sensor Protocols for Information via Negotiation (SPIN) that disseminate all the information at each node to every node in the network assuming that all nodes in the network are potential base-stations. This enables a user to query about any node and get the required data immediately. The SPIN family of protocols uses resource-adaptive and data negotiation algorithms.

3.2.2 Query Based

Directed Diffusion

In [2], C. Intanagonwiwat et. al. suggested a popular data aggregation for WSNs, called directed diffusion. Directed diffusion is a data-centric (DC) and application- aware approach. In this all data generated by sensor nodes is named by attribute-value pairs. The main idea of the DC approach is to combine the data coming from different sources that is performing in-network aggregation for eliminating redundancy, minimizing the number of transmissions, thus leads to saving network energy and prolonging the network lifetime. Unlike traditional end-to-end routing, DC routing finds routes from multiple sources to a single destination that enables in-network consolidation of redundant data.

3.2.3 Coherent and non coherent routing

Coherent Data Processing-Based Routing: This category is an energy efficient approach where each sensor node performs the minimum processing. By employing time stamping, duplicate suppression minimum processing can be done. After the minimum processing, the data is forwarded to the aggregators.

Non Coherent Data processing-based routing: In this data is processed locally and then send it to the other nodes for further processing. The nodes that perform further processing are called the aggregators. The phases of data processing in non-coherent routing are (a) Target detection, data collection, and preprocessing (b) Membership declaration and (c) Central-node election. In target detection stage, an event is detected; its information is collected and pre-processed. In the membership declaration phase, the sensor node chooses to participate in a coordinate fashion and declare this intention to all neighbors. In the central node election stage, a central node is chosen to perform more refined information processing.

3.3 Topology based

3.3.1Location based routing protocol

Geographic and Energy Aware Routing (GEAR):

Yu et al. [42] discussed the use of geographic information while disseminating queries to selected regions since data queries often include geographic attributes. The protocol, called Geographic and Energy Aware Routing (GEAR), uses energy aware and geographically-informed neighbor selection methods to route a packet towards the desired destination region. The basic idea is to limit the number of transmission overheads in directed diffusion by only considering a certain region rather than sending the queries to the whole network. By using this technique, more energy can be saved than directed diffusion. Each node in GEAR keeps an estimated cost and a learning cost of reaching the destination through its neighbors.

3.4 Reliable Routing

3.4.1 Multipath routing protocols

The multipath routing protocols multiple paths are taken rather than a single path to increase the network performance. The fault tolerance of a protocol is estimated with presence of an alternate path exists between a source and a destination when the primary path fails. This can be increased by maintaining multiple paths between the source and the destination at the expense of an increased energy consumption and traffic generation. In this alternate paths are kept alive by using periodic messages.

3.4.2 QoS-based routing

In QoS-based routing protocols, the network has tendency to balance between energy consumption and data quality. In particular, the network has to satisfy certain QoS metrics, e.g., energy, delay, bandwidth, etc. when sending data to the BS. Sequential Assignment Routing (SAR) proposed in [11] is one of the first routing protocols for WSNs that introduces the QoS in the routing procedure decision. Routing decision in SAR is based on three factors: QoS on each path, energy resources and the priority of each packet. To avoid single route failure, a multi-path approach is utilized and localized path restoration methods are used. In order to create multiple paths from a source node, a tree rooted at the source node to the destination nodes (i.e., the set of base-stations (BSs)) is built. The paths of the tree are built while avoiding nodes with low energy or QoS guarantees.

4. Conclusions

The routing techniques can be classified based on the network structure, communication model, topology and reliability. In this paper the design tradeoffs between energy, power, communication overhead savings as well as the merits and demerits of each routing technique are presented. Although many of these routing techniques look promising, there are still many challenges in design and communication need to be solved in the future.

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