A Survey on Energy Efficient Routing Protocols for Wireless Sensor Networks

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ABSTRACT
Wireless Sensor Networks (WSN) have gained wide popularity and have increased tremendously in recent time due to growth in Micro-Electro-Mechanical Systems (MEMS) technology. WSN has the potentiality to connect the physical world with the virtual world by forming a network of sensor nodes. Energy saving of sensor nodes is a major design issue since sensor nodes are usually battery-operated devices. Sensor network's lifetime can be prolonged by minimizing the energy consumption at all layers of the network protocol stack starting from the physical to the application layer including cross-layer optimization. In this paper, clustering based routing protocols for WSNs have been discussed. In cluster-based routing, special nodes called cluster heads form a wireless backbone to the sink. Each cluster heads collects data from the sensors belonging to its cluster and forwards it to the sink. In heterogeneous networks, cluster heads have powerful energy devices in contrast to homogeneous networks where all nodes have uniform and limited resource energy. Hence it is essential to avoid quick depletion of cluster heads. This is done by the cluster head role rotation, i.e., each node works as a cluster head for a limited period of time. Energy saving in these approaches can be obtained by cluster formation, cluster-head election, data aggregation at the cluster-head nodes to reduce data redundancy and thus save energy.

General terms: Wireless Sensor Networks, Wireless Network Protocols

Keywords: Routing protocols, Energy efficiency, WSN

1. INTRODUCTION
Wireless Sensor Networks(WSN***)*** have gained world-wide attention in recent years due to the advances made in wireless communication, information technologies and electronics field [**1**,**2**,**3**,**4**].The concept of wireless sensor networks is based on a simple equation: Sensing + CPU + Radio = Thousands of potential applications [**5**] . This sensing technology deploys tiny, autonomous and compact devices called sensor nodes or motes in a remote area to detect phenomena, collect and process data and transmit sensed information to users. The development of low-cost, low-power, a multifunctional sensor has received increasing attention from various industries. Sensor nodes or motes in WSNs are small sized and are capable of sensing, gathering and processing data while communicating with other connected nodes in the network, via radio frequency (RF) channel.

The basic block diagram of a wireless sensor node is presented in Figure 1. It is made up four basic components: a sensing unit, a processing unit, a transceiver unit and a power unit. There can be application dependent additional components such as a location finding system, a power generator and a mobilizer.

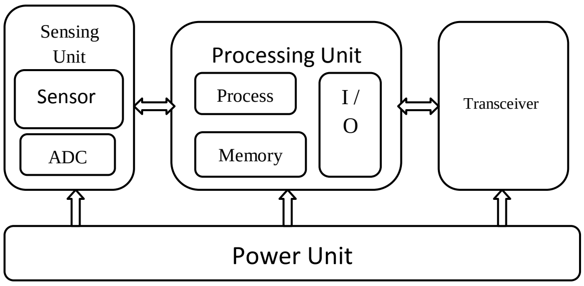

Figure1: Architecture of a WSN Node

1.1 Sensing Unit
Sensing units are usually composed of two subunits: sensors and analog to digital converters (ADCs). Sensor is a device which is used to convert physical phenomena to electrical signals. Sensors can be classified as either analog or digital devices. The analog signals produced by the sensors based on the observed phenomenon are converted to digital signals by the ADC and then fed into the processing unit.

1.2 Processing Unit
The processing unit consists of a microprocessor, which is responsible for control of the sensors, execution of communication protocols and signal processing algorithms on the gathered sensor data. The processing unit mainly provides intelligence to the sensor node. There are four main processor states that can be identified in a microprocessor*: off, sleep, idle and active*. In sleep mode, the CPU and most internal peripherals are turned on, and can only be activated by an external event (interrupt). In idle mode, the CPU is still inactive, but other peripherals are active.

1.3 Transceiver Unit
The radio enables wireless communication with neighboring nodes and the outside world. There are several factors that affect the power consumption characteristics of a radio, which includes the type of modulation scheme used, data rate, transmit power and the operational duty cycle. Similar to microcontrollers, transceivers can operate in *Transmit, Receive, Idle and Sleep* modes. An important observation in the case of most radios is that, operating in *Idle* mode results in significantly high power consumption, almost equal to the power consumed in the *Receive* mode. Thus, it is important to completely shut down the radio rather than set it in the *idle* mode when it is not transmitting or receiving due to the high power consumed. Another influencing factor is that, as the radio's operating mode changes, the transient activity in the radio electronics causes a significant amount of power

dissipation. The sleep mode is a very important energy saving feature in WSNs.

1.4 Power Unit
As an untethered computing platform, wireless sensor nodes must be supported by a power unit which is typically some form of storage (a battery) but may be supported by power scavenging components (solar cells). Energy from power scavenging techniques may only be stored in rechargeable (secondary) batteries and this can be a useful combination in wireless sensor node environments where maintenance operations like battery changing are impractical. To conserve energy a power unit may additionally support power conservation techniques such as dynamic voltage scaling. This causes energy consumption to be the most important factor in determining sensor node lifetime.

2. ROUTING CHALLENGES AND DESIGN ISSUES IN WSNS
Despite wide numerous applications of WSN, these networks have several restrictions, like limited energy supply, computing power, and bandwidth of the wireless links connecting sensor nodes. One of the main design goals of WSN is to carry out data communication while trying to prolong the lifetime of the network and prevent connectivity degradation by employing aggressive energy management techniques. In order to design an energy efficient routing protocol, several challenging factors should be addressed meticulously. The following factors are discussed below:

2.1 Node deployment
Node deployment in WSN is application dependent and affects the performance of the routing protocol. The deployment can be either deterministic or randomized. In deterministic deployment, the sensors are manually placed and data is routed through pre-determined paths; but in random node deployment, the sensor nodes are scattered randomly creating an infrastructure in an ad-hoc manner. Hence random deployment raises several issues as coverage, optimal clustering etc. which need to be addressed.

2.2 Energy consumption without losing accuracy
Sensor nodes use their limited battery power to perform computations and transmit information in a wireless environment. The processes of communication and computation are bound to consume optimal power so as to increase the lifetime. Sensor node lifetime shows a strong dependence on the battery lifetime. In a multihop WSN, each node plays a dual role as data sender and data router. The malfunctioning of some sensor nodes due to power failure can cause significant topological changes and might require rerouting of packets and reorganization of the network.

2.3 Node/Link Heterogeneity
Some applications of sensor networks might require a diverse mixture of sensor nodes with different types and capabilities to be deployed. Data from different sensors, can be generated at different rates, network can follow different data reporting models and can be subjected to different quality of service constraints. Such a heterogeneous environment makes routing more complex.

2.4 Fault Tolerance
Some sensor nodes may fail or be blocked due to lack of power, physical damage, or environmental interference. The failure of sensor nodes should not affect the overall task of the sensor network. If many nodes fail, MAC and routing protocols must accommodate formation of new links and routes to the data collection base stations. This require actively adjusting transmit powers and signaling rates on the existing links to reduce energy consumption, or rerouting packets through regions of the network where more energy is available. Therefore, multiple levels of redundancy may be needed in a fault-tolerant sensor network.

2.5 Scalability
The number of sensor nodes deployed in the sensing area may be in the order of hundreds or thousands, or more. Any routing scheme must be able to work with this huge number of sensor nodes. In addition, sensor network routing protocols should be scalable enough to respond to events in the environment. Until an event occurs, most of the sensors can remain in the sleep state, with data from the few remaining sensors providing a coarse quality.

2.6 Network Dynamics
Most of the network architectures assume that sensor nodes are stationary. However, mobility of both Base Stations (BS) and sensor nodes is necessary in many applications. Routing messages from or to the moving nodes is more challenging since route stability becomes an important issue, besides energy, bandwidth etc. Moreover, the sensing phenomenon can be either dynamic or static depending on the application: it is dynamic in a target detection/tracking application, while it is static in forest monitoring for early fire prevention. Monitoring static events allows the network to work in a reactive mode, simply generating traffic when reporting. Dynamic events in most applications require periodic reporting and consequently generate significant traffic to be routed to the BS.

2.7 Transmission Media
In a multi-hop sensor network, communicating nodes are linked by a wireless medium. The traditional problems associated with a wireless channel (fading, high error rate) may also affect the operation of the sensor network. As the transmission energy varies directly with the square of distance therefore a multi-hop network is suitable for conserving energy. But a multi-hop network raises several issues regarding topology management and media access control. One approach of MAC design for sensor networks is to use CSMA-CA based protocols of IEEE 802.15.4 that conserve more energy compared to contention based protocols like CSMA (IEEE 802.11). So, Zigbee which is based upon IEEE 802.15.4 LWPAN technology is introduced to meet the challenges.

2.8 Connectivity
The connectivity of WSN depends on the radio coverage. If there is a continuous coverage between any two nodes in a multi-hop connection, the network is connected. The connectivity is *intermittent* if WSN is partitioned occasionally, and *sporadic* if the nodes are only occasionally in the communication range of other nodes.

2.9 Coverage

The coverage of a WSN node means either sensing coverage or communication coverage. Typically with radio communications, the communication coverage is significantly larger than sensing coverage. For applications, the sensing coverage defines how to reliably guarantee that an event can be detected. The coverage of a network is either sparse, if only parts of the area of interest are covered or dense when the area is almost completely covered. In case of a redundant coverage, multiple sensor nodes are in the same area.

2.10 Data Aggregation

Sensor nodes usually generate significant redundant data. So, to reduce the number of transmission, similar packets from multiple nodes can be aggregated. Data aggregation is the combination of data from different sources according to a certain aggregation function, like duplicate suppression, minima, maxima and average. It is incorporated in routing protocols to reduce the amount of data coming from various node sources and thus to achieve energy efficiency. But it adds to the complexity and makes the incorporation of security techniques in the protocol nearly impossible.

2.11 Data Reporting Model

Data sensing and reporting in WSNs is dependent on the application and the time criticality of the data reporting. In wireless sensor networks data reporting can be continuous, query-driven or event-driven. The data-delivery model affects the design of network layer, ex., continuous data reporting generates a huge amount of data therefore, the routing protocol should be aware of data-aggregation

2.12 Quality of Service

In some critical applications, data should be delivered within a certain period of time from the moment it is sensed; otherwise the data will be useless. Therefore bounded latency for data delivery is another condition for time-constrained applications. However, in many applications, conservation of energy, which is directly related to network lifetime, is considered relatively more important than the quality of data sent. As the energy gets depleted, the network may be required to reduce the quality of the results in order to reduce the energy dissipation in the nodes and hence lengthen the total network lifetime. Hence, energy-aware routing protocols are required to capture this requirement.

3. ROUTING PROTOCOLS IN WSNS

Routing in wireless sensor networks differs from conventional routing in fixed networks in various ways. There is no infrastructure, wireless links are unreliable, sensor nodes may fail, and routing protocols have to meet strict energy saving requirements [6]. Many routing algorithms were developed for wireless networks. In general, routing in WSNs can be broadly divided into two categories namely protocol based routing and network structure based routing as shown in Figure 2.

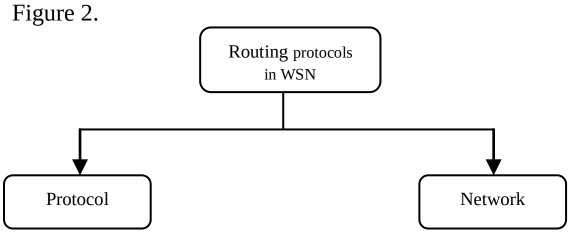

Figure 2: Taxonomy of Routing protocols in WSN

In addition to the above, routing protocols can be classified into three categories, namely, proactive, reactive, and hybrid protocols depending on how the source sends a route to the destination. In proactive protocols, all routes are computed before they are really needed, while in reactive protocols, routes are computed on demand. Hybrid protocols use a combination of these two approaches. When sensor nodes are static, it is preferable to have proactive routing protocols rather than using reactive protocols. A significant amount of energy is used in route discovery and setup of reactive protocols. Another class of routing protocols is called the cooperative routing protocols. In cooperative routing, nodes send data to a central node where data can be aggregated and may be subject to further processing, hence reducing route cost in terms of energy usage.

3.1 Routing protocols for protocol operation

Routing protocols based on protocol operation can be further classified into negotiation-based, multipath-based, query-based, QoS-based as shown in Figure 3.

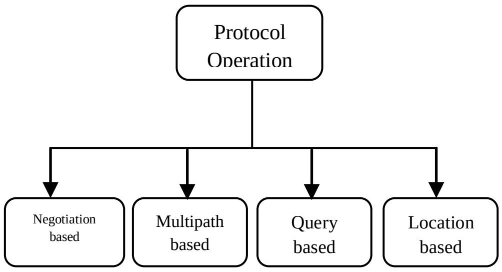

Figure 3. Routing protocols for protocol operation

3.1.1 Negotiation based routing

These protocols use high-level data descriptors called meta data in order to eliminate redundant data transmission through negotiations. The necessary decisions are based on available resources and local interactions. Sensor Protocols for Information via Negotiation (SPIN) [**7**] is one of well known Negotiation based routing protocol for WSN. The SPIN protocol is designed to disseminate the data of one sensor to all other sensors assuming these sensors are potential base-stations. Hence, the main idea of negotiation based routing in WSN is to suppress duplicate information and prevent redundant data from being sent to the next sensor or the base-station by conducting a series of negotiation messages before the real data transmission begins.

3.1.2 Multipath based routing

These protocols offer fault tolerance by having at least one alternate path (from source to sink) and thus, increasing energy consumption and traffic generation. These paths are kept alive by sending periodic messages. Maximum Lifetime Routing in Wireless Sensor Networks [**8**] is a protocol that routes data through a path whose nodes have the largest residual energy. The path is switched whenever a better path is discovered. The primary path will be used until its energy is below the energy of the backup path. By means of this approach, the nodes in the primary path will not deplete their energy resources through continual use of the same route, thus achieving longer lifetime. A disadvantage for applications that require mobility on the nodes, is that the protocol is oriented to solve routing problem in static wireless networks. Hierarchical Power-aware Routing in Sensor Networks [**9**] protocol enhances the reliability of WSN by using multipath routing. It is useful for delivering data in unreliable environments. The idea is to define many paths from source to sink and send through them the same subpackets. This implies that the traffic will increase significantly (not energy aware), but increasing the reliability of the network. The idea is to split the original data packet into subpackets through each path. This can offer at the end, even with the loss of subpackets, the reconstruction of the original message.

3.1.3 Query based routing

In these protocols, the destination nodes propagate a query for data (sensing task or interest) from the node through the network. The nodes containing this data send it back to the node that has initiated the query. Rumor routing protocol [**10**] is one of the routing protocol used in the context of event notification. The approach does not flood the network with information about an event occurrence but only installs few paths in the network by sending out one or several agents. The agents propagate through the network installing routing information about the event in each node that is visited. When the agents come across shorter paths or more efficient paths, they optimize the paths in the routing tables accordingly. Each node can also generate an agent in a probabilistic fashion.

3.1.4 Location based routing

In the protocols, the nodes are addressed by their location. Distances to next neighboring nodes can be estimated by signal strengths or by GPS receivers. Location based routing protocols are: .Small Minimum Energy Communication Network (SMECN) [**11**] protocol sets up and maintains a minimum energy network for wireless networks by utilizing low power GPS. Although, the protocol assumes a mobile network, it is best applicable to sensor networks, which are not mobile.

3.2 Routing protocols for network structure

In general, routing protocols in WSNs based on network structure can be divided into flat-based routing, cluster-based routing, and location-based routing depending on the network structure as shown in Figure 4. In flat-based routing, all nodes are typically assigned equal roles or functionality. In cluster-based routing, however, nodes will play different roles in the network. In location-based routing, sensor nodes' positions are exploited to route data in the network. A routing protocol is considered adaptive if certain system parameters can be controlled in order to adapt to the current network conditions and available energy levels.

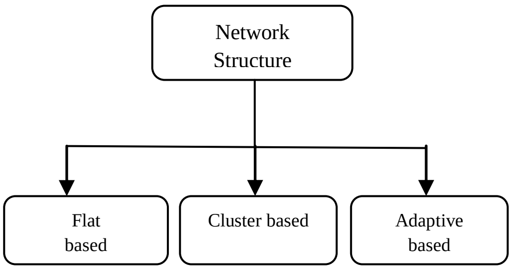

Figure 4: Routing protocols for network structure

3.2.1 Flat based routing

In these protocols, all nodes are assigned equal roles in the network. The well known protocols considered in flat based routing are: Sequential Assignment Routing (SAR), Directed Diffusion, Energy Aware Routing (EAR) etc. Sequential Assignment Routing [**12**] proposed was one of the first protocols for WSN that considered QoS issues for routing decisions. The objective of SAR algorithm is to minimize the average weighted QoS metric throughout the lifetime of the network .SAR makes a routing decision based on three factors: energy resources, QoS planned for each path, and the packet‘s traffic type, which is implemented by a priority mechanism. To resolve reliability problems, SAR uses two systems consisting of a multipath approach and localized path restoration done by communicating with neighboring nodes. The multipath tree is defined by avoiding nodes with low-energy or QoS guarantees while taking into account that the root tree is located in the source node and its ends in the sink nodes set. In other words, SAR creates a multipath table whose main objective is to obtain energy efficiency and fault tolerance. Although this ensures fault tolerance and easy recovery, the protocol suffers certain overhead when tables and node states must be maintained or refreshed. This problem increases especially when there are a large number of nodes. Directed Diffusion (DD) [**13**] is a data-centric and application aware paradigm since all data generated by sensor nodes are named by attribute value pairs. The objective of the DD paradigm is to aggregate the data coming from different sources by deleting redundancy, which drastically reduces the number of transmissions. This has two main consequences: First, the network saves energy and extends its life. Secondly, it counts on a higher bandwidth in the links near the sink node. The latter factor could be quite persuasive in deciding to provide QoS in real-time applications. The DD paradigm is based on a query-driven model, which means that the sink node requests data by broadcasting interests. Requests can originate from humans or systems and are defined as pair values, which describe a task to be done by the network. The interests are then disseminated through the network. This dissemination sets up gradients to create data that will satisfy queries to the requesting node. When the events begin to appear, they start to flow toward the originators of interest along multiple paths. This behavior provides reliability for data transmissions in the network. Another feature of directed diffusion is that it caches network data, generally the attribute-value pair‘s interests. Caching can increase efficiency, robustness, and the scalability of coordination between sensor nodes, which is the essence of the directed diffusion paradigm. A new energy-aware WSN routing protocol, Reliable and Energy Efficient Protocol (REEP) is proposed in [**14**]. REEP is also a fault tolerant. REEP has been motivated by the existing network layer data-centric routing protocol directed diffusion. REEP makes sensor nodes establish more reliable and energy-efficient paths for data transmission. In addition, the energy conservation heuristic of SPIN-2 has been used to maintain an energy threshold value in each REEP node in order to make the sensor nodes energy-aware. REEP consists of five important elements namely sense event, information event, request event, energy threshold value and Request Priority Queue (RPQ). A sense event is a kind of query, which is generated at the sink node and is supported by the sensor network for acquiring information. The response of this query is the information event, which is generated at the source node. It specifies the detected object type and the location information of the source node. After receiving this information, request events are generated at the sink node and are used for path setup to retrieve the real data. The real data in any sensor network are the collected or processed information regarding any physical phenomenon. Each node in REEP uses an energy threshold value by checking which node agrees or denies for participating in path setup with adequate energy for data transmission. It gives more reliable transmission of any event information or real data. RPQ is a kind of first-in-first-out (FIFO) queue, which is used in each node to track over the sequence of _information event reception from different neighbours. It is used to select a neighbour with highest priority in order to request for path setup in case of failed path, without invoking periodic flooding. The performance metrics like average packet transmission, average data loss ratio, average delay and average energy consumption were used to analyze and compare the performance of both protocols DD and REEP. The performance of REEP has been found to be superior to directed-diffusion routing protocol. Energy Aware Routing [1**5**] is a reactive protocol to increase the lifetime of the network. This protocol maintains a set of paths instead of maintaining or reinforcing one optimal path. The maintenance and selection depends on a certain probability, which relays on how low the energy consumption of each path can be achieved. The protocol creates routing tables about the paths according to the costs. Localized flooding is performed by the destination node to maintain the paths alive.

3.2.2 Cluster based routing

It is also known as hierarchical -based routing. In these protocols, the nodes can play different roles in the network and normally the protocol includes the creation of clusters. Additionally, designations of tasks for the sensor nodes with different characteristics are also performed. Low Energy Adaptive Clustering Hierarchy (LEACH) is one of the most popular clustering algorithms with distributed cluster formation for WSNs [16,**17**]. The algorithm randomly selects cluster heads and rotates the role to distribute the consumption of energy. LEACH uses TDMA/CDMA MAC to reduce inter-cluster and intra-cluster collisions and data collection is centralized with defined periods. It forms clusters based on the received signal strength and uses the CH nodes as routers to the base-station. All the data processing such as data fusion and aggregation are local to the cluster. LEACH forms clusters by using a distributed algorithm, where nodes make autonomous decisions without any centralized control. Initially a node decides to be a CH with a probability P and broadcasts its decision. Each non-CH node determines its cluster by choosing the CH that can be reached using the least communication energy. The role of being a CH is rotated periodically among the nodes of the cluster in order to balance the load. Since the decision to change the CH is probabilistic, there is a good chance that a node with very low energy gets selected as a CH. When this node dies, the whole cell becomes dysfunctional. Also, the CH is assumed to have a long communication range so that the data can reach the base-station from the CH directly. This is not always a realistic assumption since the CHs are regular sensors and the base-station is often not directly reachable to all nodes due to signal propagation problems, e.g., due to the presence of obstacles. LEACH also forms one-hop intra and inter cluster topology where each node can transmit directly to the CH and thereafter to the base-station. Consequently, it is not applicable to networks deployed in large regions. The HEED protocol [**18,19**] is an energy-efficient clustering protocol designed for WSNs. The aim of HEED is to prolong the lifetime of a WSN. In HEED cluster-head selection is based on two different parameters. The primary parameter is the residual energy of each node, while the second parameter measures the intracluster communication cost, i.e., the number of neighbours. The idea is to use the primary parameter to perform a probabilistic choice of an initial set of cluster heads, and the second parameter to break ties between them, e.g., when a node is within the range of multiple cluster heads. HEED is an iterative algorithm in which nodes change their probability of becoming cluster-head CHprob at each iteration. When nodes elect themselves to become cluster heads, they send an announcement message and then go into tentative_CH status if their CHprob is less than or otherwise into final_CH status. Nodes that receive an announcement consider themselves covered. At each iteration, each uncovered node elects itself as a cluster head with a probability CHprob, and then every node doubles its CHprob value. Each node selects the least-cost candidate as its cluster head. Nodes that complete the HEED execution without selecting a cluster head in final_CH status consider themselves uncovered and elect themselves cluster heads with final_CH status. A tentative_CH can also become a non-cluster-head node if it finds a lower-cost cluster head. This algorithm is proved to guarantee a bounded number of iterations before converging. The selection of cluster heads is energy-aware (so it selects better cluster heads than LEACH) and the clusters obtained are balanced. However, HEED requires multiple iterations, so the overhead and power consumption due to network management is greater than in LEACH. Nevertheless, simulation results show that the higher overhead is compensated for by the better cluster-head selection mechanism and the final result is an increased network lifetime. Power-Efficient Gathering in Sensor Information Systems (PEGASIS) [**20**] protocol is a LEACH-inspired protocol. PEGASIS is not exactly a cluster-based protocol, as nodes are not explicitly grouped into clusters. PEGASIS is instead a chain based approach, in which each node only communicates with a close neighbour and takes turns to transmit to the BS, thus reducing the amount of energy spent per round. This approach distributes the energy load evenly among the sensor nodes in the network. The PEGASIS protocol is designed for a WSN containing homogeneous and energy-constrained nodes, with no mobility. The BS (sink) is fixed and far away from nodes. The radio model adopted is the first-order radio model, same as the LEACH protocol. Using this model, energy efficiency can be improved by minimizing the amount of direct transmissions to the sink node. This idea is common to the LEACH protocol, in which clustering is used to reduce both the duty cycle of the nodes and direct transmissions to the BS. A way in which energy efficiency can be further improved is to decrease the number of nodes that perform long-range direct transmissions. So the basic idea of PEGASIS is to have only one designated node that directly transmits to the BS in each round. This can be achieved with a linear chain-based approach, where sensor nodes form a chain, in which gathered data moves from node to node, gets fused, and eventually a designated node will transmit it to the BS. As nodes take turns to transmit to the BS and transmissions are between close neighbours, the average energy spent by each node per round is reduced.

Threshold sensitive Energy Efficient sensor Network protocol (TEEN) [**21**] is a hierarchical protocol. It is useful for time-critical applications in which the network operates in a reactive way. Closer nodes form clusters and elect a cluster head. Each cluster head is responsible for directly sending the data to the sink. After the clusters are formed, the cluster head broadcasts two thresholds to the nodes. These are hard and soft thresholds for sensed attributes. Hard threshold is the minimum possible value of an attribute to trigger a sensor node to switch on its transmitter and transmit to the cluster head. Thus, the hard threshold allows the nodes to transmit only when the sensed attribute is in the range of interest. Hence, the number of transmissions significantly reduced. Once a node senses a value at or beyond the hard threshold, it transmits data only when the value of that attributes changes by an amount equal to or greater than the soft threshold. As a result, soft threshold will further reduce the number of transmissions if there is little or no change in the value of sensed attribute. However, TEEN is not good for applications where periodic reports are needed since the user may not get any data at all if the thresholds are not reached Adaptive Periodic Threshold-sensitive Energy Efficient sensor Network protocol (APTEEN) is an extension to TEEN [**22**]. The main features of this protocol are that it combines proactive and reactive policies and modification of parameters that allow better control in the cluster heads. Virtual Grid Architecture (VGA) [**23**] is based on the concept of data aggregation and in-network processing. This routing paradigm considers an extremely low mobility of sensor nodes. Therefore, this protocol arranges the nodes in a fixed topology forming clusters that are fixed, equal, adjacent and non-overlapping with symmetric shapes. One node per zone is considered as cluster head which is in charge of aggregating and transmitting data. It is possible to implement specific strategies for aggregation of data.

3.2.3 Adaptive based routing

In these protocols, the system parameters are controlled to be adapted to the actual network conditions by means of acquired information of the network and negotiation between nodes (e.g. the available energy on the node or QoS of the path). Adaptive based routing is based on the family of protocols called Sensor Protocols for Information via Negotiation (SPIN) which is described in Negotiation based routing. The SPIN protocols are designed based on two basic ideas:

1. Sensor nodes operate more efficiently and conserve energy by sending metadata instead of sending all the data.
2. Flooding technique wastes energy and bandwidth when sending extra and unnecessary copies of data by sensors covering overlapping areas.

The protocols disseminate all the information at each node to every node in the network assuming that all nodes in network are potential base-stations. With this, the user can query any node and get the needed information immediately. The protocols use data negotiation and resource-adaptive algorithms. The nodes assign a high-level name to describe completely their collected data; this is called meta-data. Then are preformed negotiations before any data is transmitted to avoid redundant data to be transmitted. These protocols distribute the information all over the network, even when the user does not request any data.

3.2.4 Bio-inspired routing

In recent years insect sensory systems have been inspirational to new communications and computing paradigms, which have lead to significant advances like bio inspired routing [**24**]. The most popular ACO (Ant Colony Optimization) metaheuristic, a novel population based approach was proposed in 1992 by Marco Dorigo et al. to solve several discrete optimization problems. Research shows that ants have the ability to select the shortest path among few possible paths connecting their nest to a food site. The pheromone, a volatile chemical substance laid on the ground by the ants while walking and affecting in turn their moving decisions according to its local intensity, is the mediator of this behavior. 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 [**25**]. Minimum Ant-based Data Fusion Tree (MADFT) [**26**] is a sink selection heuristic routing algorithm .It is based on ACO for gathering correlated data in WSN. It first assigns ants to source nodes. Then, the route is constructed by one of the ants in which other ants search the nearest point of previous discovered route. The chosen formula is Probability function composed of pheromones and costs in order to find the minimum total cost path. MADFT not only optimizes over both the transmission and fusion costs, but also adopts ant colony system to achieve the optimal solution. The Many-to-One-Improved Adaptive Routing protocol [**27**] is an ant colony-based routing protocol. It is specifically designed to route many-to-one sensory data in a multi-hop WSNs. Actually, in a many-to-one routing paradigm generates lots of traffic in a multihop WSN that results in greater energy wastage, higher end-to-end delay and packet loss. So, to mitigate the collision, it comes with a lightweight congestion control algorithm. It has the capability of handling both event- based and periodic upstream sensory data flow to the base station. The protocol works in two-phases. During the first phase, the protocol uses ant colony optimization and swarm intelligence to find the shortest and the optimal route within a multi-hop WSN. Here, each node is aware of its location and location of its destination. The ant-routing algorithm is used by each forward ant to find the best next-hop neighbour node, closer to itself and closest to the sink using probabilistic theory. The following nodes use the binary exponential back off algorithm to calculate their channel access time. In the second phase, when the actual many to-one sensory data transmission takes place, the protocol combines the knowledge gained during the first phase with the congestion control mechanism to avoid packet loss and traffic while routing the sensory data. The algorithm outperforms in terms of finding shortest path within least amount of time. The algorithm can be extended considering shortest path by not only distance but also residual energy of nodes. Swarm Intelligence Optimization Based Routing Algorithm [**28**] works with the objective to balance global energy consumption and avoiding some node‘s premature energy exhausting. The algorithm chooses the nodes with less pheromone as next hop, taking less hop numbers into consideration. The algorithm is different from traditional ant colony algorithms. It is better than the directed diffusion routing protocol both in end-to-end delay and global energy balance. It can effectively balance the global energy consumption and prolong the network lifetime.

4. CONCLUSION

Routing in wireless sensor networks has attracted a lot of attention to the researchers in the recent years. 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 ultimate objective behind the routing protocol design is to keep the sensors operating for as long as possible, thus extending the network lifetime. 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. In this paper, we have surveyed a sample of routing protocols by taking into account several classification criteria, including location information, network layering and in-network processing, data centricity, path redundancy, network dynamics, QoS requirements, and network heterogeneity. For each of these categories, we have discussed a few example protocols. The scarce energy resources of sensors, has made energy efficiency as one of the main challenges in the design of protocols for WSNs. The ultimate objective behind the protocol design is to keep the sensors operating for as long as possible, thus extending the network lifetime. Spatial queries and databases using distributed sensor nodes and interacting with the location-based routing protocol are open issues for further research. Future research issues should focus on security, QoS and node mobility. Routing techniques for WSNs should address application-dependent security issues such as reliability, authentication, confidentiality etc. and examined.

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