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A Study of Hierarchical Routing Protocol for Wireless Sensor Networks

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Abstract— Wireless sensor networks consist of miniaturized battery powered spatially distributed autonomous sensor nodes with constrained computational capability. The routing protocol in sensor network must ensure uniform energy distribution across the network, quickly converge irrespective of the network node density, and be flexible in terms of the routing framework and route computation metric. The growing interest and the continual emergence of new architectural techniques inspired for surveying the characteristics, applications and communication protocols of sensor networks. In this survey, we have reviewed the significant topology control algorithms of hierarchical networks, to provide insights how energy efficiency has been achieved by design and present a comprehensive study of different topology control techniques for sensor networks. For this protocol family, we have provided a didactic presentation of the basic concept, a discussion on the enhancements and variants on that concept and a detailed description with emphasis on their advantages and disadvantages of those latest state-of-the-art protocols. Depending on the outcomes of our literature survey, we have identified open research issues for achieving energy efficiency in the development of hierarchical routing protocols for wireless sensor networks.

Index Terms— Wireless sensor networks, multi-hop, routing, hierarchical, energy efficiency;

1 Introduction

Wireless sensor networks are formed by small sensor nodes with sensing, computation, and wireless communications capabilities. The potential applications of sensor networks are highly varied, such as natural phenomena, environmental changes, controlling security, estimating traffic flows, monitoring military application, and tracking friendly forces in the battlefields, vehicular movement, mechanical stress levels on attached objects etc.

Wireless sensor networks consist of sinks and sensors. Sinks play a role of collecting data, transmitted by sensors. Sensor nodes sense the desirable physical phenomenon and locally do the data aggregation to avoid communication of redundant data. Using routing protocol sensor nodes determine the path for sending data to sink. A sensor node is comprised of four basic components: sensing unit, processing unit, radio unit and power unit. The sensing unit is used to measures a certain physical condition. Processing unit is responsible for collecting and processing signals. The radio unit transfers signals from the sensor to the user through the gateway. All previous units are supported by the power unit to supply the required energy in order to perform the mentioned tasks.

Due to the restricted communication range and high density of sensor nodes, packet forwarding in sensor networks is usually performed through multi-hop data transmission. Many power management, and data dissemination routing protocols have been specifically designed for sensor networks where energy awareness is an essential design issue. Multipath routing approach is widely used in wireless sensor networks to improve network performance through efficient utilization of available network resources.

Hierarchical network structure is a well-known technique with special advantages related to scalability and efficient communication, and is also utilized to perform energy efficient routing in wireless sensor networks. The main aim of hierarchical routing algorithms are to efficiently maintain the energy consumption of sensor nodes by involving them in multi-hop communication within a particular region and by performing data aggregation and fusion in order to decrease the number of transmitted messages to the sink.

The rest of the paper is organized as follows. In section 2, routing challenges and issues have been presented. A comprehensive survey of different existing hierarchical energy efficient routing approaches for wireless sensor networks has been pursued in section 3. This classification provides a deep analysis on the most well-known energy efficient routing, highlighting their advantages and disadvantages. In section 4, this paper concludes and identifies some of the future directions with open research issues for achieving energy efficient routing protocol for wireless sensor networks.

2 Routing Challenges and Issues

Despite the tremendous and numerous advantages like distributed localized computing, wide area coverage, extreme environment area monitoring, wireless sensor networks pose various challenges to the research community. This section identified some of the major challenges faced while designing the hierarchical WSNs and here we strive to capture architectural issues as; Network Dynamics in Nature; Network Scalability; Node Deployment; Node deployment ; Node Capabilities; Energy Consumptions; Data Aggregation; Data Delivery Models ; Fault Tolerance ; Quality of Service;

Compared with the traditional network algorithm, routing protocols of wireless sensor networks have different characteristics and requirements. Each and every individual node has limited energy; it is an important goal to design energy efficient routing protocol to extend the network lifetime. Minimize data transmission, reduce information redundancy through data aggregation are highly important in designing sensor network. In order to minimize energy consumption, multi-hop communication modes are highly required in the network. Routing protocol can't be too complicated calculation, routing mechanism must be simple and efficient in technique, able to adapt to the dynamic topology change, reduce communication costs and improve the transmission efficiency. As node failure causes, routing mechanism must have some fault tolerance mechanism.

Described aboves are mainly based on hierarchical routing protocols which are relevant to different applications. While limiting it by some pre assigned minimum distance can be effective in some cases but this is an open research issue. Cluster head selection can either be centralized or decentralized and number of clusters might be fixed or dynamic in the sensor network. Fixed number of clusters cause less overhead and in terms of scalability the fix clustering scheme is not feasible.
Wireless sensor network routing protocols can be classified in different ways, according to the way of routing paths are established, according to the network structure, according to the protocol operation and according to the initiator of communications. In the next section we will present an extensive summery of different hierarchical cluster based routing protocol for wireless sensor networks.

3 Related Works

In this section, we have presented a comprehensive and fine grained survey on hierarchical clustering routing for wireless sensor networks. We have analyzed different clustering routing algorithms in detail based on the classification of different algorithm stages, and highlight their characteristics with advantages and disadvantages.

Clustering is a network management technique, which creates a hierarchical structure over a flat network and provides scalability and robustness for that network. This technique allows spatial reuse of the bandwidth, simpler routing decisions, and results in decreased energy dissipation of the whole system by minimizing the number of nodes that take part in long distance communication. A cluster is a group of linked nodes working together closely for same purposes and belongs to same topological structure. A cluster head is responsible of resource allocation to all nodes belonging to its cluster and directly associated to its neighbor clusters for performing various task of inter and intra cluster communication. Sensor network used to be designed as hierarchical clustering structure to minimize transmission costs and energy usage to prolong the network lifetime. In clustering networks, the imbalanced energy consumption among nodes is the key factor affecting the network lifetime.

Heinzelman et.al. proposed Low Energy Adaptive Clustering Hierarchy [1] algorithm for sensor networks, which is a hierarchical cluster based routing scheme with random rotation of the cluster heads for evenly distribute energy among sensor nodes within the network. Two layers of architecture were introduced in LEACH [1], one used for communication within the clusters and the other used between the cluster heads and sink. In [1],due to the random selection, there exists the probability of unbalanced cluster head selection and selected cluster head may be present in one part of the network, making other portion of the network unreachable. In [1], utilization of TDMA scheduling prevents cluster heads from unnecessary collisions. LEACH [1], performs the single hop inter cluster routing, which is not applicable to large networks. LEACH [1] cannot ensure real load balancing in the case of sensor nodes with different amounts of initial energy; as cluster head election is performed depends upon the probability, it is hard for the predetermined cluster head to be uniformly distributed throughout the network.

LEACH-Centralized [2] is an extension of the LEACH [1] routing protocol uses the centralized cluster formation technique for the network. In LEACH-C [2], the presence of cluster heads are limited and randomly cluster head selection procedure executed depending upon the energy of the sensor node. LEACH-C [2] is not feasible for larger networks, as nodes are far away from the base station unable to send their states to the base station. In [2], cluster remains fixed and only rotates the cluster head within the cluster and this will save energy and increase the system throughput. No setup overhead at the beginning of each round. LEACH-F [2], has lack of scalability within the network and requires more transmit power from nodes and increases energy dissipation of non-cluster head node and inter-cluster interference. This protocol doesn't handle node mobility.

O.Younis et.al. [9] Hybrid Energy Efficient Distributed Routing Algorithm [9] for prolonging network lifetime by distributing energy consumption, terminating the clustering process within a constant number of iterations, minimizing control overhead. In [9], the initial probability for each node to become a tentative cluster head depends on its residual energy, and final heads are selected according to the intra cluster communication cost. HEED [9], is a fully distributed clustering method and in [9], communications in a multi-hop fashion between cluster heads and the base station manages more energy conservation. Some limitations of HEED [9] have been presented as: Similar to LEACH [1], performing of clustering in each round imposes significant overhead in the network and as well as decrease the network lifetime; HEED [9] suffers from a consequent overhead, as it have required several iterations to form clusters.

In [15], Mao et.al. introduced a cluster head competitive algorithm without message exchange iterations, which is an extension of LEACH [1] and HEED [9]. In EECS [15] nodes having more residual energy selected as cluster head and achieves a well distribution of cluster heads. In [15], a distance based cluster formation method is proposed to produce clusters of unequal sizes. EECS [15] finds the lowest energy route and use that path for all communication between the pair of source and destination. Using such a path continually will result in energy depletion of the nodes along that path and may lead to network partition. Based on energy and distance, EECS [15] has been generated balancing point between intra-cluster energy consumption and inter-cluster communication load; Dynamic size clustering has been performed based on cluster distance from the base station. As single hop communications have been performed in EECS [15], it is not suitable for large range networks. EECS [15] required much more global knowledge and control overhead complexity.

Threshold Sensitive Energy Efficient Protocol [4] proposed by Agrawal et.al. to pursue a hierarchical clustering approach along with the use of a data centric mechanism. In TEEN [4] cluster head uses hard threshold & soft threshold values. By adjusting these thresholds, it is possible to achieve energy saving by decreasing the number of transmissions. TEEN [4] is designed for time critical applications to respond to sudden changes in the sensed data and not suitable for periodic reports based applications. In [4], based on the two thresholds, data transmission can be controlled commendably; TEEN [4] is complement for reacting to large changes in the sensed attributes and it is not suitable for periodic reports applications.

A. Manjeshwar et.al. presented Adaptive Threshold Sensitive Energy Efficient Sensor Network Protocol [5] is an extension of TEEN [4] and aims at capturing periodic data collections and reacting to time critical events. APTEEN [5] supports three different query types: historical is used to analyze past data values; one-time is used to take a snapshot view of the network; and persistent is used to monitor an event for a period of time. Both proactive and reactive policies are described in APTEEN [5], and the additional complexity required implementing the threshold functions. APTEEN [5] combines proactive policies as LEACH [1], and reactive policies alike that of TEEN [4]. APTEEN [5] offers a lot of flexibility by allowing the user to set the count time interval and the threshold values for energy consumption can be controlled by changing the count time as well as the threshold values. In [5], there exist additional complexity required to implement the threshold functions and the count time.

Lindsey et.al. proposed a Power Efficient Gathering in Sensor Information Systems [6], which is a chain based routing protocol. PEGASIS [6] has two main objectives, it increases the lifetime of each node by using collaborative techniques and as a result the network lifetime will be increased. Secondly allow only local coordination between nodes that are close together, so that less bandwidth has been consumed in communication. In PEGASIS [6] the greedy algorithm can keep the minimum distance of each hop while cannot achieve the optimal outing in the whole network. PEGASIS [6] introduces excessive delay for distant node on the chain and in addition the single leader can become a bottleneck. PEGASIS [6] is able to outperform LEACH [1] for different network sizes and topologies, as this protocol reduces the overhead of dynamic cluster formation in LEACH [1] and decreases the number of data transmission volume through the chain of data aggregation; the energy load is dispersed uniformly in the network. In [6], long range communications directly from the node to the sink can breed too much energy consumption.

In [7], Huseyin Ozgur et.al. presented Power Efficient Data Gathering and Aggregation in wireless sensor networks protocol which is extended from PEGASIS [6] protocol. In PEDAP [7] all nodes are constructed into a minimum spanning tree and only need to receive the routing information from base station. According to PEDAP [7], the base station knows the location information of all sensor nodes and can predict the remaining energy of any node based on some energy dissipation model. PEDAP [7] achieves less communication time to forward packets to destination and could be used and for reliable communication with high bandwidth utilization. The major drawback of PEDAP [7] to improve the reliability of the system as edge weight assignment is calculated with only transmitters' residual energy.

Sh. Lee et al. proposed clustering algorithm CODA [10] in order to relieve the unbalance of energy depletion caused by different distance from the sink. CODA [10] divides the whole network into a few group based on the distance from the base station and the strategy of routing. CODA [10] differentiates the number of cluster in terms of the distance from the base station. The farther the distance from the base station, the more clusters are formed in case of single hop with clustering. CODA [10] relies on global information of node position, and that is not scalable.

An Energy Efficient Unequal Clustering [13] routing protocol was proposed by Hee Yong Youn et.al. EEUC [13] is a distributed competitive algorithm, where cluster heads are elected by locally and clusters closer to the base station are expected to have smaller cluster sizes. EEUC [13] successfully balances the energy consumption over the network and achieves a remarkable network lifetime improvement. In EEUC [13] the network topology varies frequently in routing technique, which may cost much more energy than others. To address the hot spots problem, EEUC [13] introduces an unequal clustering mechanism to balance the energy consumption among Cluster heads. Based on communication cost, EEUC [13] can save more energy via inter cluster multi-hop routing mechanism. In [13], clustering mechanism in each round imposes significant overhead and global data aggregation can result in much overhead for all nodes and deteriorate the network performance.

Zhe Zang et.al. proposed Hop Based Robust Routing Protocol [32] for wireless sensor networks. In HBRRP [32] network work cycle divided into gradient phase and data transmission phase. In gradient phase, nodes delay in sending gradient packets to avoid redundancy and reduce cost of establishing gradient in data transmission phase. In [32], nodes make parents and siblings as forward selection and a trigger update mechanism was introduced to guarantee real time dynamic network topology.

Proxy Enabled Adaptive Clustering Hierarchy proposed by Kim et.al, where proxy node selection has executed to assume the role of cluster head in place of weak cluster head during one round of communication. In PEACH [11], the cluster based scheme avoids long range communication, data fusion saves energy by compressing the data, and rotation of cluster heads allows even depletion of the energy and prolongs the lifetime of every node. The location-aware PEACH [11] operates when the localization mechanism is available on sensor nodes. In order to reduce the communication cost and utilize the advantages of the PEACH [11] protocol, the farthest node from the sink node must initiate the packet transmission.

Kyung Tae Kim et.al. proposed an Energy Driven Adaptive Clustering Hierarchy for wireless sensor networks [12] to increase the lifetime of sensor networks. This is achieved by forming different number of clusters in each region of the network according to the relative distance to the base station. The EDACH [12] protocol is based on the partitioning of the network for assigning different probability of cluster head to each node. EDACH [12] outperforms the LEACH [1] more significantly when the initial energy is relatively high. The residual energy is well balanced among all the sensors because it selects the most capable node to be a proxy when facing problematic cluster head. In [12], the dead nodes are well dispersed.

A centralized protocol [14] with the base station being an important component with complex computational capabilities makes the sensor node very effective. Base-station Controlled Dynamic Clustering Protocol [14] operates in two major phases; first is the setup phase and the second is data communication. Cluster formation, cluster head selection, and scheduling for each cluster has been executed in the setup phase. The data communication phase consists of data gathering, data fusion, data routing phases. BCDCP [14] resolves the cluster head distribution problem and ensures similar power dissipation of cluster heads. BCDCP [14] needs information about all the nodes in a network before the selection of cluster heads and in a larger network this approach would not provide better performance. As BCDCP [14] is the single-hop routing scheme, it is not adaptive to applications in large range of networks.

The Clustering Periodic Event Driven and Query Based Routing Protocol [16] was designed based on the PEQ [16] mechanism. CPEQ [16] protocol consists of four steps: selection mechanism, cluster configuration, data transmission to the cluster head, data forwarding to the sink. The CPEQ [16] protocol configures the dissemination tree using the PEQ's [16] with a simple modification; an additional field contains the percentage of nodes that can become cluster heads. CPEQ [16] employs an energy aware cluster head selection mechanism in which the sensor nodes with more residual energy are selected to become cluster heads and increases the network lifetime and provides a better distribution of the energy consumption among the sensor nodes. CPEQ [16] performs data aggregation to reduce repetitive data transmission and as well as minimize energy consumption. In a highly dense network scenario, high amount of energy will be wasted in the transmission of and listening to unwanted packets.

In [17] A. Martirosyan et al. proposed an Energy Efficient Inter Cluster Communication based routing protocol for wireless sensor networks. ICE [17] uses acknowledgement based approach to faulty paths discovery and provides QoS by finding a path with the least cost for high priority event notification messages. ICE [17] protocol has the benefits of both CPEQ [16] and PEQ [16] as; data aggregation, support for reliability, simplicity and support for low latency. The advantages of ICE [17] are as follows: Load balancing, network longevity and fault tolerance is ensured through the use of multi path routing. Energy optimization has been executed in ICE [17]. Redundant data transmission and reception of packets are highly likely to occur. The management and maintenance of the entire network can be costly. This protocol is not suitable for large network and difficult in a scenario where the sensor nodes are mobile in nature in the wireless sensor network.

In [22], Elshakankiri et.al. presented a new routing protocol for WSNs namely Pairs Energy Efficient Routing protocol. PEER [22] is based on grouping the sensor nodes into pairs, each two nodes forming a pair should be chosen to be close to each other to ensure minimum energy consumption required for transmission between both nodes. In PEER [22] one node sends at low power level and the other uses high power level and used dual power management and focuses on minimizing both the energy dissipated and the delay cost.

Sethares et.al. [19] proposed an Adaptive Decentralized Re-clustering Protocol for wireless sensor networks. In ADRP [19], network operations are divided into two phases; initial phase and data cycle phase. At initial phase all the nodes send their information to the sink that forms the cluster. ADRP [19] reduces the energy wastage due to cluster formation for each round by electing the next eligible cluster head for each cluster. ADRP [19] incurs high overhead in forming clusters due to the information exchanged between the nodes and the sink.

In [29], Asif U. Khattak et.al. presented a Two Tier Cluster Based Routing Protocol for wireless sensor networks. TTCRP [29] configures the nodes in the form of clusters at two levels. TTCRP [29] introduced a power control algorithm to allow the isolated sensor nodes as well as cluster heads to dynamically change their transmission power for connecting sensor nodes with unreachable clusters and provides network robustness. TTCRP [29] is efficient in both uniform and non-uniform sensor node deployment.

Ming Zhang et.al. presented a Novel Energy Efficient Minimum Routing Algorithm [23], in wireless sensor networks, which employs the minimum angle of source node and goal node to prolong network lifetime. EEMR [23] improves energy utility by changing the activity of wireless communication module, energy models and state transition of sensor nodes.

Mei Lin et al. proposed Double Cluster heads Routing Policy Based on the Weights of Energy Efficient for wireless sensor networks [30]. DCWE [30] algorithm is composed of four phases; first cluster head and second cluster head selection, data transmission and next round cluster heads selections. Cluster heads are responsible for data collection and transmission respectively. In DCWE [30] weights of cluster head selection algorithm reduces the energy consumption of data transmission effectively.

Qiang Wang et.al. presented Maximum Degree and Negotiation Strategy Based Clustering Algorithm for wireless sensor networks [33]. MAXD-N [33] selects candidate based maximum degree and determines the cluster head according to the negotiation strategy. MAXD-N [33] is divided into two phases; one is communication and computation of node degree and other is cluster head election and cluster formation. In the cluster head selection phase, the promotion from candidate to cluster needs to obtain all neighbors information.

In HCBQRP [34] the main objective was design a cluster based routing algorithm for sensor networks to find route from source to destination. In this routing scheme designed based on the query-driven approach and provides the real time communication between sensor nodes.

In WHCBR [35], authors presented weight based cluster head selection mechanism along with the cost estimation techniques for achieving real time communication and high energy efficiency. In HRP [36], author presented modified weight based cluster head selection and cluster formation mechanism.

Babar Nazir et.al. proposed Mobile Sink Based Routing Protocol [27] for prolonging network lifetime in clustered wireless sensor network. In MSRP [27] mobile sink moves within cluster area to collect sensed data from cluster heads. During data gathering mobile sink also maintains information about the residual energy of the cluster heads. In MSRP [27] authors have combined two different approaches and address the hotspot problem in clustered WSN by employing mobile sink approach as a results in a balanced use of WSN energy and improves network life time.

In [25], Awwad et.al. presented adaptive time division multiple access scheduling and round free cluster head protocol called Cluster Based Routing Protocol for Mobile Nodes in Wireless Sensor Network [25]. CBR Mobile-WSN [25] is cluster based routing protocol used to handle packet loss and efficiently use energy resources. This protocol is query based routing protocol in which sensor node choose minimal power to transmit the message and send data back to cluster head after receiving the message of data request from cluster heads. It is energy aware scheme and reduces the energy consumption by transmitting with low transmission with minimal amount of energy power based on the received signal strength of data request message. CBR Mobile-WSN [25] ensures efficient bandwidth utilization by avoiding wastage of time. There is an unnecessary broadcast due to the selection of same node within the same transmission range in CBR Mobile-WSN [25].

Zhongbo et.al. proposed an Energy Level Based Routing Algorithm of Multi sink Sensor Networks [20]. In ECR [20] two different hierarchy structure of the network topology are presented. The operation of ECR [20] can be divided into three steps, cluster-formation phase, cluster head selection phase and steady state phase. ECR [20] protocol is designed based on LEACH [1] and it is applied to the network to continuously send the monitored messages to the sink and highly correlated data among the neighbor nodes.

Energy Aware Routing for Cluster Based Sensor Network [8] presents multi gateway architecture to cover a large area and balances the load among different clusters. The algorithm balances the load among different clusters at clustering time to keep the density of the cluster uniform. The disadvantage of this routing scheme [8] is that, if the network is deployed randomly then there is a probability that the resultant distribution of the cluster heads is unbalanced.

Lu Cheng et.al. proposed an Energy Efficient Weight Clustering Algorithm [21] in wireless sensor networks to reduce energy consumption by perfecting cluster formation procedure. The main objectives of EWC [21] are forming distributed cluster to extend lifetime and data delivery guaranties. In EWC [21] residual cluster energy, location and node degree and coefficients are takes an important role in cluster head selection stage and nodes' having minimal combined weight becomes cluster head.

Wenjun Liu et.al. proposed Energy Efficient Clustering and Routing scheme for wireless sensor networks [26], which includes three phases: distributed nodes clustering, dynamic cluster head rotation and inter cluster routing selection. The main motive of dynamic cluster head rotation mechanism is to evenly distribute the energy load among all the sensor nodes. Routing selection takes advantage of base station's energy and the communication overhead and network lifetime of EECR [26] are also desirable.

Tian Ying et.al. proposed Energy Efficient Chain Cluster routing protocol [28], which is divided into backbone setup phase, cluster formation phase and steady communication phase. ECRM [28] includes efficient cluster head selection mechanism to prolong the lifetime of the first fixed node in the network to improve the energy efficiency.

Energy Efficient Hierarchical Routing Protocol [31] is effective for wide range communication in the wireless networks. In EEHRP [31] the number of gateway nodes is usually larger than that of the cluster heads by setting the transmission power of the sink node and it guarantees that each cluster head can connect a gateway node. In EEHRP [31], cluster head can preserve some energy in data forwarding and gateway nodes can ease their burden and not taking participation in cluster formation.

Energy Residue Aware [18] is a LEACH [1] based routing protocol, where each non cluster head node selects its cluster head. ERA [18] enables each sensor to associate its cluster head to find a path with maximum energy residue sum instead of a path with the minimum energy consumption. ERA [18] enables each sensor to select a best route from possible candidate return paths. In ERA [18] all nodes need to store the location information concerning with other nodes and may introduce an unacceptable level on node's memory overhead. ERA [18] algorithm can balance the energy consumption of entire network and thus prolong the network lifetime at a very small cost of increasing the average energy consumption.

Hierarchical Power Aware Routing [3] divides the network into groups of sensors and each group of sensors in geographic proximity is clustered together as a zone. A single node in each zone is periodically selected to estimate the power levels of each node in its zone. Nodes from other zones can infer the path that can reliably relay information using the minimum amount of energy. The motivation is that using nodes with high residual power may be expensive as compared to the path with the minimal power consumption.

LU Li fang et.al proposed Weight Based Clustering Routing Protocol for wireless sensor network [24], which is used to reduce the energy dissipation of nodes for routing data to the base station and prolong the network lifetime. In WCR [24] cluster head selection algorithm is designed for periodically select cluster heads, based on the node position information and residual energy of node and in order to minimize the energy dissipation of intra cluster and inter cluster data transmission. In WCR [24] the residual energy of node can distribute the energy among sensor nodes by rotating the role of cluster heads.

In [1], according to free space model, the propagation loss is modeled as inversely proportional to d^i (where i=2, if $d < d_0$). In the multi-path fading channel model [1], the propagation loss is modeled as inversely proportional to d^i (where i=4, if $d \geq d_0$). At the time of transmitting message, the amount of energy dissipated by sensor node has been defined as;

$EP_{tx}(p, d) = EP_{elec} * p + \varepsilon_{fs} * p * d^i$, To receive this p-bit message the energy dissipated; $EP_{rx}(p) = EP_{elec} * p$, Where p is the size of message, d is the distance between source and destination node, EP_{elec} is the circuit energy cost for transmitting or receiving purposes, ε_{fs} is the amplifier parameter. In [1], the first order radio model is used, which consists of three main models: the transmitter, the power amplifier, and the receiver. The amount of energy consumed by each sensor node while transmitting message, is defined as: $EP_{tx}(p, d) = EP_{elec} * p + EP_{amp} * p * d^2$, where EP_{amp} is the amplifier coefficient.

4 CONCLUSIONS

Recent years have witnessed a lot of attention on routing for wireless sensor networks and introduced unique challenges compared to traditional data routing in wired networks and can be employed in a wide spectrum of applications in both civilian and military scenarios. Severe resource constraints in the form of limited computation, memory and power make the problem of routing interesting and challenging. Hierarchical cluster based routing protocols hold a great potential toward energy efficiency in WSNs. Clustering algorithms have been a hot research area in the last few years. Cluster based routing group sensor nodes to efficiently relay the sensed data to the sink. Cluster head performs aggregation of data and sends it to the sink on behalf of the nodes within its cluster. Clustering techniques have to provide low overhead cluster head rotation as well as optimal traffic distribution among cluster heads while keeping network connectivity and coverage. In this paper we have presented a comprehensive survey on hierarchical clustering routing protocols in wireless sensor networks. Here we have systematically analyzed a few classical clustering routing protocols and outlined their key features and compared these different approaches based on taxonomy and some primary metrics. The routing protocols have been classified into distinct categories and their advantages and disadvantages have been discussed. From the above discussion, it is clearly seen so far that, significant efforts have been made in addressing the techniques to design effective and efficient clustering routing protocols for WSNs in the past few years. The most interesting research issue regarding such protocols is how to form the clusters so that the energy consumption and contemporary communication metrics are optimized. The factors affecting cluster formation and cluster-head communication are open issues for future research. The process of data aggregation and fusion among clusters is also an interesting problem to explore. As our study reveals, it is not possible that a routing algorithm is suitable for all scenarios and for all applications. Although many routing protocols have been proposed in WSNs, many issues still exist and there are still many challenges that need to be solved in the sensor networks. The future vision of WSNs is to embed numerous distributed devices to monitor and interact with physical world phenomena, and to exploit spatially and temporally dense sensing and actuation capabilities of those sensing devices.

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