A Study of Energy Efficient Routing Protocols for Wireless Sensor Networks

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Abstract— Wireless sensor networks consist of miniaturized battery powered sensor nodes with constrained computational capability. Packet forwarding in sensor networks is usually performed through multi-hop data transmission due to the limitation of the communication range and an optimal choice of the routing path has been significantly increased the performance of the sensor networks. The application of topology control methods in wireless sensor networks will have a profound impact on energy efficiency and the limited and constrained resources have driven research towards primarily reducing energy consumption, energy minimization, memory requirements and complexity of routing functionalities. In this paper the routing protocols have been classified into two different categories based on the underlying network structure; as: flat and location based techniques. For all of these protocol families, we have provided a didactic presentation and a detailed description with emphasis on the advantages and disadvantages of those latest state-of-the-art protocols. Depending on the outcomes of the literature survey, a number of open research issues have been identified for achieving energy efficiency in the development of routing protocols for wireless sensor networks.

Index Terms— Wireless sensor networks, flat, location based, energy efficiency, routing;

1 INTRODUCTION

Recent advancement in sensor networks have been growing interest on understanding and optimizing in network routing protocols where the limited and constrained resources have driven research towards primarily reducing energy consumption, memory requirements and complexity of routing functionalities and the potential use in applications like military, environmental, health, space exploration, vehicular movement, disaster management, combat field reconnaissance etc. To reduce deployment budge, sensor networks are expected to have minimized overall energy consumption and balanced energy usage among individual sensors.

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 transmission 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.

Routing in wireless sensor network is very challenging due to several inherent characteristics that distinguish them from contemporary communication and wireless ad hoc networks. Multipath routing approach is widely used in wireless sensor networks to improve network performance through efficient utilization of available network resources. Many power management, and data dissemination routing protocols have been specifically designed for sensor networks where energy awareness is an essential design issue.

Flat routing protocols are similar to the conventional multi-hop ad hoc routing protocols and nodes are typically equal and perform the same function. Each node not only can collect the data from the interesting events, but also can relay the information data by serving as a relay node. In flat based routing, data is being requested through queries, attribute based naming is necessary to specify the properties of data. According to the establishment and maintenance of routing table is initially sponsored by the sink nodes, flat based routing can be classified into three different modes. In traditional flooding mode, sensor nodes transmit the received messages to their neighbor nodes by broadcasting until the messages reach the sink nodes. In event driven mode sensor nodes actively broadcast the sensed data messages to sink nodes and choose the next hop according to routing table. In query driven mode, sink node broadcasts an application specified request to its neighbor nodes by flooding the entire network and requested nodes then choose an appropriate path to answer this query. Flat based routing demonstrates several advantages, as the low overhead of topology maintenance and the ability of multipath discovery and all the nodes can reach the base station irrespective of their position.

Location based routing has emerged as one of the most significant, efficient and scalable routing scheme for wireless sensor networks. In location based protocols sensor nodes are addressed by means of their locations and this location information have been required to calculate the distance between two particular nodes, so that energy consumption can be estimated. Location based protocols utilize position information to relay the data to the desired regions rather than the whole network. The key advantage of location based routing solu-

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tions is that there is no requirement for recognizing the topology of the network. In location based routing, sensor nodes' positions are exploited to route data in the network. Location based routing represents the algorithmic process of determining the paths on which to send traffic in a network, using position information only about source, neighbors and destination. In location based routing, all nodes are involved in the routing process contribute to making routing decisions by using localization methods and computing the best forwarding options.

The rest of the paper is organized as follows. A comprehensive survey of different existing routing approaches for wireless sensor networks have been pursued in section 2. This classification provides a deep analysis on the most well-known energy efficient routing, highlighting their advantages and disadvantages. In section 3, 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 Related Works

Different works on the sensor networks have been executed in the development of the routing protocols, applications and systems with vastly varying requirements and characteristics. In this section, we have presented a comprehensive and fine grained exhaustive survey on energy efficient routing protocols for wireless sensor networks. We have focused on the techniques of different flat based, and location based protocols in order to route messages and also taking into consideration the energy consumptions and how they have achieved the energy minimization to extend the lifetime of the network.

2.1 Flat Routing Protocol

Flat routing protocols are designed for networks with homogenous nodes, i.e., all the network nodes have the same processing and data transmission capabilities while their packet forwarding role is also similar. Flat routing protocols can be classified according to the centrality of their theme. In this subsection we have presented the state-of-the-art flat based routing protocol for wireless sensor networks and highlighted of their characteristics with advantages and disadvantages.

Heinzelman et.al. proposed Sensor Protocols for Information via Negotiation that uses data negotiation techniques [2]. The main idea of SPIN [2] is to name the data using high level descriptors called meta-data, to reduce redundant transmissions in the network. Three different messages defined in SPIN [2] to exchange data between nodes as: ADV message has been used to allow a sensor to advertise a particular meta-data, REQ message has been used to request the specific data and DATA message that carry the actual data. SPIN [2] works in a time driven fashion and distribute the information all over the network and also estimates energy level of each node. SPIN [2] family has been designed to address the deficiencies of classic flooding by negotiation and resource adaptation. SPIN [2] protocols maintain only local information about their neighboring nodes. SPIN [2] comprises a family of protocols: SPIN-PP [2] and SPIN-EC [2] for point-to-point communication networks and SPIN-BC [2] and SPIN-RL [2] for broadcast networks. SPIN-PP [2] assumes that each node can communicate with another node without interfering with any other nodes. SPIN-EC [2] is the energy conserving version of the basic SPIN-PP [2] protocol. The broadcast protocols SPIN-BC [2] and SPIN-RL [2] exploit the one-to-many transmission phenomenon of broadcast networks. SPIN-l [2] and SPIN-2 [2] are simple protocols that efficiently disseminate data, while maintaining no per-neighbor state. SPIN-PP [2], SPIN-EC [2], SPIN-BC [2] and SPIN-RL [2] are applicable for mobility of the nodes, while all of these protocols communicate with their neighbors only in case that they have data to send, minimizing the energy spent on periodic messages. All these protocols are scalable and robust and their performance is in depended of the network size. The advantages of SPIN [2] are that topological changes are localized since each node needs to know only its single hop neighbors. SPIN [2] gives a factor less than flooding in terms of energy dissipation and meta-data negotiation almost halves the redundant data. SPIN's [2] data advertisement mechanism cannot guarantee the delivery of data. SPIN [2] is not a good choice for applications as intrusion detection, which requires reliable delivery of data packets over regular intervals.

Intanagonwiwat et.al. proposed a data centric communication and application aware paradigm for wireless sensor networks called Directed Diffusion[6], where all data generated by sensor nodes are named by attribute value pairs protocol. Directed Diffusion [6] is based on query driven data delivery model and selects empirically good paths and uses the techniques of caching and processing data in network in order to achieve the minimization of energy consumption. In Directed Diffusion based network all sensor nodes are application aware, enables diffusion to achieve energy efficiency and there is no need for maintaining global network topology. Directed Diffusion [6] has been used to spontaneously propagate an important event to some sections of the sensor network. In Directed Diffusion [6], data can be routed through multiple paths at low rates and it is not a good choice as a routing protocol for the environmental monitoring applications. The naming schemes used in Directed Diffusion [6] are applications dependent and each time should be defined a priori and the matching process for data and queries might require some extra overhead at the sensors.

Schurgers et.al. [9] proposed another variant of Directed Diffusion [6], named as Gradient Based Routing. The key idea of GBR [9] is to memorize the number of hops at the time of interest diffusion through the whole network. Auxiliary techniques have been used in GBR [9] like data aggregation, traffic spreading and in order to obtain a balanced distribution of the traffic in the network. In GBR [9] nodes act as a relay for multiple paths and can create a data combining entity in order to aggregate data. Three different data dissemination techniques have been presented in GBR [9]. In stochastic scheme, a node picks one gradient at random when there are two or more next hops that have the same gradient. In energy based Scheme, node increases their heights when its energy drops below a certain threshold, so that other sensors are discouraged from sending data to that node. In stream based scheme, new streams are not routed through nodes that are currently part of the path of other streams.

Braginsky et.al. proposed Rumor Routing [13], a variant of Directed Diffusion [6] and compromises between flooding queries and flooding event notifications. The key idea of Rumor Routing [13] is to route the queries to the nodes that have observed a particular event rather than flooding. Rumor Routing [13] maintains only one path between source and destination as opposed to Directed Diffusion [6]. Rumor Routing [13] is applicable for delivering queries to events in large networks according to a wide range of conditions. Rumor Routing [13] has been adjusted to support different query to event ratios, successful delivery rates, and route repair. This [13] routing protocol has been used to handle node failure gracefully, degrading its delivery rate linearly with the number of failed nodes. The overhead associated with Rumor Routing [13] is controlled by different parameters used in the algorithm, as time-to-live pertaining to queries and agents.

Rabaey et.al. [17] proposed a destination initiated reactive protocol is used to increase the network lifetime. Energy Aware Routing [17] is similar to Directed Diffusion [6] and maintains a set of paths instead of maintaining or enforcing one optimal path at higher rates. Energy Aware Routing [17] achieves longer network lifetime as energy is dissipated more equally among all nodes. Network survivability is the main metric of this routing algorithm. Energy Aware Routing [17] approach requires gathering the location information and setting up the addressing mechanism for the nodes, which complicate route setup compared to the Directed Diffusion [6].

In [14] Haussecker et.al. proposed Constrained Anisotropic Diffusion Routing, which is a general form of Directed Diffusion [6]. The key idea of CADR [14] is to query sensors and route data in the network, such that the information gain is maximized while latency and bandwidth are minimized. CADR [14] uses a set of information criteria to select which sensors can get the data. In CADR [14], each node evaluates an information/cost objective and routes data based on the local information/cost gradient and end user requirements. Estimation theory was used to model information to utility measure. In [14], author presented Information Driven Sensor Querying algorithm, where the querying node can determine which node can provide the most useful information with the balancing of the energy cost. IDSQ [14] does not specifically define how the query and the information are routed between sensors and the base station. IDSQ [14] has been used as a complementary optimization procedure.

Yao et.al. presented a data centric protocol, which is used to declarative queries in order to abstract query processing from the network layer functions and data aggregation technique have been used for energy efficiency. COUGAR [15] architecture for the sensor database system has been used to provide in-network computation ability to obtain more energy savings. The main advantage of the COUGAR [15] is that it provides energy efficiency when generated data is huge. Few drawbacks of COUGAR [15] have been summarized as follows: The additional query layer of sensor node provides extra overhead memory storage. The leader nodes should be dynamically maintained to prevent from hot spots problem.

In [20], authors have proposed a technique for querying sensor networks called Active Query Forwarding in Sensor Networks is similar to COUGAR [15] and considered network as a distributed database where complex queries can be further divided into several sub queries. ACQUIRE [20] is ideal for one-shot and complex queries for response. In ACQUIRE [20], Directed Diffusion [6] mechanism has not be used for complex queries to minimize energy consumption. ACQUIRE [20] provides efficient querying by adjusting the value of the look ahead parameter. For forwarding the query, ACQUIRE [20] selects the next node either randomly or based on maximum potential of query satisfaction.

Servetto et.al. [16] presented random walks based routing technique is to achieve load balancing in a statistical sense and by making use of multi-path routing in wireless sensor networks. This routing algorithm is applicable for large scale networks with limited node mobility. In [16], each node has a unique identifier but no location information has been required. This routing algorithm is simple as nodes are required to maintain little state information and different routes are chosen at different times even for the same pair of source and destination nodes. The main concern of this protocol is that the topology of the network may not be practical.

Ye et.al. presented Minimum Cost Forwarding Algorithm [8] which exploits that the direction of routing is always known. In MCFA [8], each node should know the least cost path estimate from itself to the base station. MCFA [8] was modified to run a back off algorithm at the setup phase. In MCFA [8], each node maintains the least cost estimate from itself to the sink and each message to be forwarded by the sensor node, which is broadcast to its neighbors.

In [27], Awerbuch et.al. proposed Pulse protocol to address of routing, energy consumption and time synchronization in sensor networks. This routing uses a periodic pulse signal generated and flooded by a pulse source providing routing paths and synchronization to the network. For achieving energy efficiency, Pulse protocol [27] has been modified to incorporate intermediate wake up periods. Pulse protocol [27] has been provided a path deactivation feature to allow nodes to deactivate paths and conserve energy.

Ye et.al. proposed a robust data delivery protocol for large scale sensor networks namely Gradient Broadcast routing protocol [32]. In GRAB [32], node with sufficient power level and minimum cost path reach its next hop neighbor. The credit assignment in the GRAB [32] packets are made adaptive to the local network conditions. Here nodes having lesser cost than the sender are allowed to forward packets. GRAB [32] employs event driven refreshing of the cost field that can ensure that the information about link failures spreads throughout the network and avoids the counting to infinity problem.

In [21], Deng et.al proposed Intrusion Tolerant routing protocol for sensor networks, ensures that a single compromised node can only affect a limited portion of the network without disrupting the functioning of the rest of the network. INSENS [21] consists of two phases: the route discovery phase and the data forwarding phase. The route discovery phase is divided into three rounds: route request, route feedback and computation and propagation of multipath routing tables. INSENS [21] is a simple routing protocol in that the routing computations are performed by the central base station rather than the resource constrained sensor nodes. To maintain network connectivity, INSENS [21] would have to run the route discovery phase frequently which may not be feasible in practice.

Karlof et.al. [18] presented a probabilistic algorithm to avoid packet loss by sending multiple packets corresponding to a single sensor. Algorithm for Robust Routing in Volatile Environments [18] ensures that different links are chosen for each of the packets by selecting outgoing links probabilistically based on link reliability and node reputation. ARRIVE [18] decides to forward an incoming packet to a parent or a peer neighbor. The limitations of ARRIVE [18] are that there may not be multiple alternate routes between the source and the sink in sparse sensor networks, and hence path diversity may not be feasible. In ARRIVE [18] paths followed by packets are not optimal due to the probabilistic nature of the algorithm.

Cerpa et.al. proposed an Adaptive Self Configuring Sensor Networks Topologies system [28], where subset of the nodes is actually required to establish connectivity in a dense network. In ASCENT [28], each node determines its connectivity and follows a reactive algorithm that responds to changes in the network characteristics. ASCENT [28] operates in between the MAC and network layers and only determines which nodes join the routing infrastructure and does not utilize or modify state maintained by the routing protocol. ASCENT [28] does not detect network partitions nor does it attempt to repair them.

Sohrabi et.al. [7] proposed, a table driven multipath routing algorithm to improve the resilience of the network to node failures. The objective of Sequential Assignment Routing algorithm [7] is to optimize the average weighted QoS metric in the network. Routing decision in SAR [7] depends on three factors: energy resources, QoS on each path, and the priority level of each packet. To avoid single route failure, a multi path approach and localized path restoration schemes has been used. In SAR [7], the counting to infinity problem is avoided by hastening the convergence to infinity whenever the path metric reaches an upper threshold.

Deng et.al. [29] described a mechanism to discover alternate routes from a node to the base station. The path repair algorithm [29] works in four stages. First stage called failure detection, second stage termed as failure information propagation, third step is called new parent detection and the final step is known as new parent selection. This algorithm [29] works when nodes fail randomly in the network as well as when a certain portion of the network fails entirely. In [29] the path repair algorithm is capable of eliminating loops resulting from inconsistencies.

Niculescu et.al proposed Trajectory Based Forwarding [22] routing protocol, views a route as a continuous function. TBF [22] is basically a greedy algorithm where in each intermediate node attempts to forward packets along an optimal path with respect to the intended trajectory. TBF [22] paradigm has been applied as a low cost solution to many applications including unicast routing, resource and topology discovery, broadcasting, multicasting and multipath routing. The main advantage of TBF [22] is that the actual intermediate nodes are not explicitly named by the path. There are several problems with TBF [22] are as; specifying and modifying the trajectory, whether to use curve fitting techniques or simply a list of points. In TBF [22], a number of interesting problems arise if the target node becomes mobile.

2.2 Location Based Routing Protocol

Location information is required to calculate the distance between two nodes and optimized the routing in an energy efficient way. Two techniques are used to find location; relative coordinates of neighboring nodes can be obtained by exchanging information between neighbors, through location information can be obtained directly through Global Positioning System devices. In location based technique, the query can be diffused only to that particular region which will eliminate the number of transmission significantly. In order to stay with the theme of the survey, we limit the scope of coverage to only energy aware location based routing protocols for wireless sensor networks.

Heidemann et.al. [12] proposed an energy aware location based routing algorithm for mobile ad hoc networks and also applicable to sensor networks, is named as Geographic Adaptive Fidelity. In GAF [12], the network area is divided into fixed zones and forms a virtual grid and inside each zone, nodes collaborate with each other to play different roles. GAF

[12] conserves energy by turning off unnecessary nodes in the network without affecting the level of routing fidelity.There are three states defined in GAF [12], discovery for determining the neighbors in the grid, active for reflecting participation in routing and sleep when the radio is turned off. GAF [12] has been implemented for both non-mobility (GAF-basic) and mobility (GAF-mobility adaptation) of nodes. In GAF [12], as the numbers of nodes are increased, the network lifetime has been also increased.

Yu et.al.[11] proposed Geographic and Energy Aware Routing, it uses energy aware and geographically informed neighbor selection heuristics to route a packet toward the destination region. GEAR [11] is used to restrict the number of interests in Directed Diffusion [6] by only considering a certain region rather than sending the interests to the whole network. GEAR [11] can conserve more energy than Directed Diffusion [6]. Each node in GEAR [11] keeps an estimated cost and a learning cost of reaching the destination through its neighbors. There are two phases in the GEAR [11] algorithm: Forwarding packets toward the target region, and forwarding packets within the region. Researches explained that GEAR [11] not only reduces energy consumption for route setup, but also performs better than GPSR [xxx] in terms of packet delivery.

Stojmenovic et.al. proposed Geographic Distance Routing [4] scheme based on geographic distance and a failure criterion. GEDIR [4] is a loop free algorithm, which always moves the packet to the neighbor of the current vertex whose distance to the destination is minimized. GEDIR [4] drops the message if the best forwarding choice of the current node is to return the message to the originating node. GEDIR [4] algorithm has been proposed with different forwarding methods: one-hop GEDIR (GEDIR), 2-hop GEDIR (GEDIR-2), flooding GEDIR (GEDIR-f) and 2 hop flooding GEDIR (2-f-GEDIR). The hybrid single-path/flooding GEDIR [4] was designed for mobility issues and to provide guaranteed delivery for the static case.

Zorzi et.al. proposed a Geographic Random Forwarding [25], is a forwarding strategy for achieving a good tradeoff between location progress and delay for WSNs with random sleep scheduling. The design goal of GeRaF [25] is to deliver each packet to sink via as few hops as possible. In GeRaF [25], the next hop candidates are those nodes whose positions are closer to the destination than the node currently holding the message. In GeRaF [25], sensor node acts as relay is not known a priori by a sender and there is no guarantee that a sender will always be able to forward the message toward its ultimate destination. Best-effort forwarding RTS/ a CTS message mechanism are employed in GeRaF [25] and back-off time increases the reliability.

Chen et.al. proposed an Energy Efficient Algorithm for Topology Maintenance [19] protocol, operates under the routing layer and above the MAC layers and is designed to conserve energy and increase network lifetime. In SPAN [19], each node decides by itself whether to sleep or join the forwarding backbone. SPAN [19] is a position based algorithm, which select some nodes as coordinators based on their positions. SPAN [19] improves routing throughput and packet delivery latency and for mobility, it uses random waypoint model.

Rodoplu et.al. [3] proposed a localized and position based algorithm, Minimum Energy Communication Network protocol [3] is based on identifying a relay region for each node and minimize the communication energy consumption. MECN [3] is used to find a sub network, which will have less number of nodes and require less power for transmission between any two particular nodes. MECN [3] consists of two phases: first one is the construction of a sparse graph, and the second phase consists in finding the optimal links through Bellman-Ford shortest path algorithm and power consumption metric. MECN [3] is self-reconfiguring and can dynamically adapt to nodes failure or the deployment of new sensor nodes.

Halpern et.al.proposed Small Minimum Energy Communication Network [24], is an extension of MECN [3]. The sub network constructed by SMECN [24] for minimum energy relaying is provably smaller than the one constructed in MECN [3].The goal of SMECN [24] is to determine the enclosure graph for minimum energy paths and it is less complex, more realistic and more power efficient technique. In SMECN [24] the trade-off however is the overhead which exceeds the MECN [3].

Champ et.al. proposed a geographic routing algorithm named Energy Efficient Geographic Routing [33], which takes into account sensor position error. In EEGR [33], node's location is estimated with a certain error ε. The EEGR [33] algorithm uses a metric which defines communication costs between neighbors. It sends messages along paths having the best trade-off between communication probability, progress and energy consumption. In EEGR [33], shortest path, from sensor to base station, can be computed with Dijkstra algorithm.

Wang et.al. proposed an energy efficient algorithm named as Energy Aware Geographic Routing [37], which is designed for mobile environments and makes use of residual energy information in greedy and recovery mode alike. In EGR [37], both basic mode as well as when handling voids, the forwarding node is chosen to balance energy consumption by maximizing a weight function which takes into account distance progress (for greedy routing) or angle progress (for face routing) and residual energy.

Seada et.al. proposed Energy Efficient Forwarding Strategies for Geographic Routing [30] which assumes a positioning system to account for the location knowledge. In EEFS [30] nodes are randomly distributed in the network and aims to improve energy efficiency considering distance and reception rate in the routing decisions. In EEFS [30] neighbors are classified based on link reliability and neighbor selection has been used.

Elrahim et.al. proposed a geographic routing algorithm based on greedy forwarding named as Energy Aware Geographic Routing Protocol [40] . The objective of EAGPR [40] is to prolong the lifetime of the sensors and hence the network lifetime In EAGPR [40], nodes have only local knowledge of neighbors' position and energy levels and the location of the destination. The packet is forwarded to the neighbor closest to destination and with the highest energy level, by first adjusting the transmission power.

Zhang et.al. proposed an Energy Efficient Beaconless Geographic Routing [31], which is designed for highly dynamic scenarios with changing topology in which location information, is known. EBGR [31] algorithm aims to provide loop-free, energy-efficient sensor to sink routing at low communication overhead. The EBGR [31] algorithm tries to provide energy efficient routing in the presence of unreliable communication links by employing blacklisting and a discrete delay function. The performance of EBGR [31] is analyzed in three scenarios: a mobile scenario (in which a random walk mobility model is used for simulation), a random sleeping scenario (static case) and a high variant link quality scenario (for a static, active network with changing link quality).

In [38], Ding et.al. proposed a hybrid routing algorithm which combines a reactive mechanism and geographic routing which aims to find the shortest path and reduce communication overhead. Reactive Geographic Routing Protocol [38] is a reactive position-based protocol that aims to improve communication cost by not using beaconing or table maintenance and benefiting from two types of route discovery packets RREQ and RREP with multiple functions. In RGRP [38], the shortest path to destination is calculated by coordinator nodes in two steps, both in the forwarding of the RREQ and of the RREP. In this routing scheme route information and neighbor tables are not kept for a long time as they are created every time a new message needs to be forwarded.

Salhieh et.al. proposed Directional Source Aware Routing Protocol [31], consists of two algorithms, one to find the destination and one to route the packet. After collecting the information from distributed multiple sensors based on the information, the routing protocol forwards the packet in the direction of the destination via the nearest neighbor. The aim of this routing scheme is to increase power efficiency and network lifetime.

Haddad et.al.proposed a modified version of DSAP [31] and makes a compromise between the shortest path and the maximum power. MDSAP [34] consists of two types of nodes: fixed beacon nodes (B-nodes) and mobile nodes (M-nodes). In MDASP [34], messages are assigned different levels of priority and different routing to each, high priority messages can take the path with the maximum power, low priority can take the shortest path, and medium priority can take the shortest path, but having a certain energy threshold.

In [23], Widmer et.al. proposed Contention Based Forwarding is a beacon less algorithm consists of two forwarding phases: the contention process and the suppression phase. In the contention process, the node is determined as next hop through a timer based function. During the contention process, candidate neighbors compete for becoming the next relay by setting timers related to their actual positions. The suppression phase is used to reduce the selecting more than one node as the next hop, as well as to reduce the overhead of the protocol. The basic scheme consists only of canceling timers after hearing a transmission from another neighbor. The suppression process can be implemented through area based forwarding, using either a circle or Releaux triangle or through active selection. The drawbacks of this algorithm are the lack of a recovery method when forwarding in greedy mode in an empty area and the packet overhead created by broadcasts.

Takagi et.al [1] proposed a progress based algorithm, in which data forwarding to the neighbor has been executed with the greatest progress. The objective of Most Forward within Radius [1] is to maximize obtainable expectable progress in a certain direction MFR [1] minimizes the number of hops, but doesn't minimize energy consumption. MFR [1] is a variant of greedy algorithms and a loop free scheme. In inhomogeneous node density, MFR [1] recommended for short range transmission due to low possibility of packet collision.

Stojmenovic et.al.proposed DIR [10] algorithm, where the sending node uses the destination node information to calculate the message forwarding direction. DIR [10] is named as Compass routing as it minimizes the angle between the computed direction and the direction source destination. In DIR [10] method, the best neighbor has the closest direction toward the destination, i.e. the neighbor with the minimum angular distance from the imaginary line joining the current node and the destination is selected.

Sidhik et.al.proposed Optimal Range Forward [35] and Optimal Forward with Energy Balance [35], two routing protocols to prolong network lifetime by optimizing energy consumption and balancing traffic load. ORF [35] is based on the derivation of the optimal node transmission range which results in minimization of the total energy consumed by the transmission in all hops. OFEB [35] achieves energy balance by making use of the principle in ORF [35] and in addition, considering the residual energy of each node in finding the optimal next forwarding node.

Peng et.al. proposed a Least Expected Distance Routing Algorithm [36], takes into account the inevitable presence of location errors in the localization process inherent to geographic routing. By incorporating location errors into the routing objective function, the algorithm maximizes the probability to achieve minimum power consumption from source to destination. By determining the optimal next forwarding position which optimizes the energy consumption over a single hop, the optimization of the energy over the total path is achieved. The algorithm's consideration for location errors makes it very valuable for further research.

3 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. Flat routing protocols are similar to the conventional multi-hop routing protocols; attempt to find routes from source nodes to sink nodes by some form of flooding. The preceding sections have described several flat routing protocols for sensor networks. In flat based routing scheme, routing algorithms have to operate based only on local knowledge. The advantage of this approach is that all the nodes can reach the base station irrespective of their position. Location based routing represents the algorithmic process of determining the routing paths, using position information/geographic location only about network nodes. In location based routing, all nodes involved in the routing process and contribute to making routing decisions by using localization methods and computing the best forwarding options. It is considered substantially better from an energetic point of view due to the use of solely local information in the routing process. The need to design efficient, scalable protocols make location based routing and especially geographic routing attractive, which facilitates stateless, energy efficient, scalable routing for sensor networks. This routing survey helps in the design of location based routing protocols for highly demanding network applications and which aspects still require a lot of attention. 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 routing protocols for WSNs in the past few years. 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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