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Existing Routing Protocols for Wireless Sensor Network – A study.

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ABSTRACT:
Wide usage of wireless sensor network (WSN) is the reason for development of many routing protocols. Recent advances in WSN observe the increased interest in the potential use in applications like Military, Environmental, Health, Vehicular, Mechanical stress levels on attached objects, disaster management etc. Wireless sensor networks are callously restricted by storage capacity, energy and computing power. So it is essential to design an energy efficient aware protocol in order to augment the network lifetime. WSN also has the influencing features to perform remote communication, it is also shrouded with various loopholes in its precise operation, where majority of the communication issues are raised from deployment of existing standards of routing protocols and algorithm. Sensors are expected to be remotely deployed in unnoticed environments. Routing as one key technologies of wireless sensor network has now become very important research work because the applications of WSN is everywhere, it is impractical that there is a routing protocol suitable for all applications. In this paper, a review on routing protocol in WSNs is carried out which are classified as data-centric, hierarchical and location based depending on the network structure. Then some of the multipath routing protocols which are widely used in WSNs like Multipath Multispeed Protocol (MMSPEED), Braided Multipath Routing Protocol, Energy-Aware Routing to improve network performance are also discussed. Massive research work has already been carried out in past to introduce some of the effective routing protocols to enable robust communication system in WSN. Advantages and disadvantages of each routing algorithm are discussed thereafter. This paper also discusses the critical open issues that are yet to be solved. This paper compares and summarizes the performances of routing protocols.

KEYWORDS- *Algorithms in WSN, Energy Effficiency, Hierarchical, Performance, Remote deployment, Routing Protocol, Wireless Sensor Network.*

I. INTRODUCTION.

Wireless Sensor networks consist of a large number of low-cost, , low powers and multifunctional wireless sensor devices with limited battery energy [1]. Wireless sensor network have been widely used in the industry, traffic, environmental protection, military and many other fields. Especially in the absence of the existence of the back bone of network, such as the dangerous region that man cannot get there, the battle field, and other destructive areas .These sensor nodes communicate over short distance via a wireless medium. A sensor network is a network of many tiny disposable low power devices, called nodes. The tiny sensor nodes, which consist of sensing, data processing and communicating components. Each node consists of four components: power unit and central processing unit (CPU), sensor unit and communication unit. They are assigned with different tasks. There are two factors that determine the sensor device lifetime: battery energy depletion and device failure. Energy consumption depends on the activities of each component in the sensor node device, which are mainly determined by the applications and network management schemes. Device reliability is affected by unexpected events. Device hardware and software components can fail due to either internal problems or external impacts. When thousands of sensor devices are deployed in an adversary environment, the normal function of a node cannot be guaranteed even before its battery energy get depleted. These individual node failures caused by either energy depletion or device failure result in a negative impact on network operations, including the sensing coverage of the area and the connectivity among nodes. The important requirements of WSN are: Use large number of sensors, Low energy consumption, Self organization capability, and Querying ability. Networking unattended sensor has effect on the efficiency of many military and civil applications such as distributed computing, weather monitoring and security. The areas of applications of WSNs vary from civil, healthcare, and environmental to military. Examples of applications include target tracking in battlefields, habitat monitoring, civil structure monitoring, forest fire detection and factory maintenance [2]. Different attributes, where it may contain delay sensitive and delay tolerant data. For example, the data generated by a sensor network that monitors the temperature in a normal weather monitoring station are not required to be received by the processing center or the sink node within certain time limits. On the other hand, for a sensor network that used for fire detection in a forest, any sensed data that carries an indication of a fire should be reported to the processing center within certain time limits. Furthermore, the introduction of multimedia sensor networks along with the increasing interest in real-time applications have made strict constraints on both delay and throughput in order to report the time-critical data (in such applications) to the processing center or sink within certain time limits and bandwidth requirements without any loss. These performance metrics (i.e. delay and bandwidth) are usually referred to as Quality of Service.

Hence, it is quite understood that routing protocols plays a critical role in the performance of wireless sensor network. Be it a problem of congestion, or security or quality of service, routing protocols are part and parcel of every issues. Therefore, this paper attempts to discuss various standard routing protocols that exists in operation of wireless sensor network and illustrates various pros and cons of different categories of all the standard routing protocols till date. The current paper mainly targets to review all the major work pertaining to routing: Section 2 of this paper discusses the fundamentals of routing protocols in WSN followed by design issues of routing protocols in WSN in Section 3. Section 4 discusses some of the recent studies conducted in the area of routing protocols in WSN along with description of open issues in it in Section 5. Finally Section 6 concludes the paper with its summary.

II. ROUTING PROTOCOLS IN WSN

The network layer is one of the most investigated research topics in WSNs [2]. Especially, many Routing algorithms and protocols have been proposed through the development of WSNs. The sensor nodes are constrained to limited resources itself, so the main target is to design an effective and energy aware protocol in order to enhance the network lifetime for specific application environment. Since sensor nodes are not given a unified ID for identification and much redundant data collected at destination nodes. So, energy efficiency, scalability, latency, fault-tolerance, accuracy and QOS are some aspects which must be kept in mind while designing the routing protocols in wireless sensor networks. Classically most routing protocols are classified as data-centric, hierarchical and location based protocols depending on the network structure and applications. All major routing protocols classified into main categories discussed below:

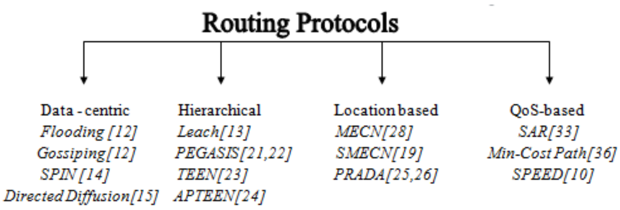

Figure 1: Overview of Routing Protocols

2.1 Challenges for Routing

Routing is one of the main problems in WSNs and many solutions have been developed to address this problem. Ensuring efficient routing faces many challenges due to both wireless communication effects and the peculiarities of sensor networks. These challenges preclude existing routing protocols developed for wireless ad hoc networks from being used in WSNs. Instead, novel routing protocols are required. The design of routing protocols for WSNs is challenging because of several network constraints. These constraints are imposed not only by the characteristics of individual sensors, the behavior of a network, and the nature of sensor fields, but also by the requirements of a sensing application in terms of some desirable metrics. These are the main challenges facing routing in WSNs.

2.1.1 Energy Consumption:

The main objective of the routing protocols is efficient delivery of information between sensors and the sink. To this end, energy consumption is the main concern in the development of any routing protocol for WSNs. Because of the limited energy resources of sensor nodes, data need to be delivered in the most energy-efficient manner without compromising the accuracy of the information content. Hence, many conventional routing metrics such as the shortest path algorithm may not be suitable. Instead, the reasons for energy consumption should be carefully investigated and new energy-efficient routing metrics developed for WSNs. The major reasons of energy consumption for routing in WSNs can be classified as follows:

2.1.1.1. Neighborhood discovery:

Many routing protocols require each node to exchange information between its neighbors. The information to be exchanged can vary according to the routing techniques. While most geographical routing protocols require knowledge of the locations of the neighbor nodes, a data-centric protocol may require the information content of the observed values of each sensor in its surrounding. In each case, nodes consume energy in exchanging this information through the wireless medium, which increases the overhead of the protocol. In order to improve the energy efficiency of the routing protocols, local information exchange should be minimized without hampering the routing accuracy.

2.1.1.2. Communication vs. computation:

It is well known that computation is much cheaper than communication in terms of energy consumption. Moreover, in WSNs, the goal is to deliver information instead of individual packets. Consequently, in addition to the conventional packet switching techniques, computation should also be integrated with routing to improve energy consumption. As an example, data from multiple nodes can be aggregated into a single packet to decrease the traffic volume without hampering the information content. Similarly, computation at each relay node can be used to suppress redundant routing information.

2.1.2 Scalability

WSNs usually consist of a large number of nodes. The need to observe physical phenomena in detail may also require a high-density deployment of these nodes. The large number of nodes prevents global knowledge of the network topology from being obtained at each node. Hence, fully distributed protocols, which operate with limited knowledge of the topology, need to be developed to provide scalability. In addition, since the density is high in the network, local information exchange should also be limited to improve the energy efficiency of the network. Furthermore, since high-level information is more important than individual pieces of information from each sensor node, the routing protocol should support in-network combination of the information from a large number of nodes without hampering energy consumption.

2.1.3 Addressing

The large number of sensor nodes in a network prevents unique addresses from being assigned to each node. While local addressing mechanisms can still be used to facilitate communication between neighbors, address-based routing protocols are not feasible because of the large overhead required to use unique addresses for each communication. Consequently, the majority of the ad hoc routing protocols cannot be adopted for WSNs since these solutions require unique addresses for each node in the network.
Furthermore, users are interested in collective information from multiple sensors regarding a physical phenomenon instead of information from individual sensors. Consequently, new addressing mechanisms or novel routing techniques that do not require unique IDs for each node are required.

2.1.4 Robustness

WSNs rely on the nodes inside the network to deliver data in a multi-hop manner. Hence, routing Protocols operate on these sensor nodes instead of dedicated routers such as in the Internet. The low-cost components used in sensor nodes, however, may result in unexpected failures to such an extent that the sensor node may be non-operational. As a result, routing protocols should provide robustness to node failures and prevent single point-of-failure situations, where the information is lost if a sensor node dies. Moreover, the wireless channel results in packets being lost during communication. In addition to robustness against node failures, the routing protocol should ensure that the effectiveness of the protocol does not rely on a single packet that can be lost. Even under very harsh conditions with frequent channel errors, the routing protocol should provide efficient delivery between the sensor and the sink.

2.1.5 Topology

The deployment of a WSN can be either predetermined or through a random strategy. While predetermined topology can be exploited to design more efficient routing protocols, this is usually not the case for WSNs. Consequently, individual nodes are usually unaware of the initial topology of the network. However, the relative locations of the neighbors of a node and the relative location of the nodes in the network significantly affect the routing performance. Therefore, routing protocols should provide topology-awareness such that the neighborhood of each node is discovered and the routing decisions are made accordingly. Furthermore, the network topology can change dynamically during the lifetime of the network. Since energy efficiency is crucial, nodes may switch off the transceiver circuitry, which, in effect, results in removing a node from the topology.

Whenever the node is active again, it joins the network. These changes between active and sleep states of nodes dynamically affect the neighborhood topology of a sensor node. WSN topology is usually assumed to be static. However, dynamic changes due to sink mobility or target mobility can affect the communication structure and, hence, the routes. Consequently, the routing protocol should also be adaptive to these changes in the network topology.

2.1.6 Application

The type of application is also important for the design of routing protocols. In monitoring applications, usually nodes communicate their observations to the sink in a periodic manner. As a result, static routes can be used to maintain efficient delivery of the observations throughout the lifetime of the network. In event-based applications, however, the sensor network is in sleep state most of the time. However, whenever an event occurs, routes should be generated to deliver the event information in a timely manner. Moreover, event location is not fixed since it is directly related to the event and, hence, new routes should be generated for each event. It can be seen that the routing technique is directly related to the application and significantly different techniques may be required for different kinds of applications.

2.2 Routing Protocols

2.2.1 Location Based Protocols:

The location information based routing protocol uses location information to guide routing discovery and maintenance as well as data forwarding, enabling directional transmission of the information and avoiding information flooding in the entire network. Location information is needed in order to calculate the distance between two particular nodes so that energy consumption can be estimated [3].

2.2.1.1: Geographical and Energy Aware Routing (GEAR):

The Geographic and Energy Aware Routing (GEAR) protocol (Yu *et al*. 2001) is an example of a geocasting protocol, where packets are forwarded to all nodes within a specific target region. GEAR consists of the two phases described above: (1) packets are forwarded toward the target region using a geographical and energy-aware neighbor selection algorithm and (2) packets are disseminated to nodes within the target region using a recursive geographic forwarding algorithm. Each node in the network maintains two types of costs of reaching a destination via its neighbors. The *estimated cost* $c(Ni,R)$ for each neighbor Ni and a target region R is defined as:

$$c(Ni,R) = \alpha d(Ni,R) + (1 - \alpha)e(Ni) \quad (7.2)$$

where α is a tunable weight, $d(Ni,R)$ is the distance from neighbor Ni to the centroid D of region R normalized by the largest such distance among all neighbors, and $e(Ni)$ is the consumed energy at node Ni, normalized by the largest consumed energy among all neighbors. That is, the estimated cost is a combination of both *residual energy and distance to the target region*. The *learned cost* $h(N,R)$ of a node N is then a refinement of the estimated cost that allows nodes to circumvent voids or holes in the network (if there are no holes, the learned cost and the estimated cost are identical)[52].

In this algorithm [4], each node keeps an estimated cost and a learning cost of reaching the destination through neighbors. The estimated cost is a combination of residual energy and distance to destination. Hole occurs when a node does not have any closer neighbors to the target. If there are no holes, the estimated cost equal to the estimated cost is equal to the learned cost. The learned cost is propagated one hop back every time a packet reaches the destination so that route set up for next packet will be adjusted.

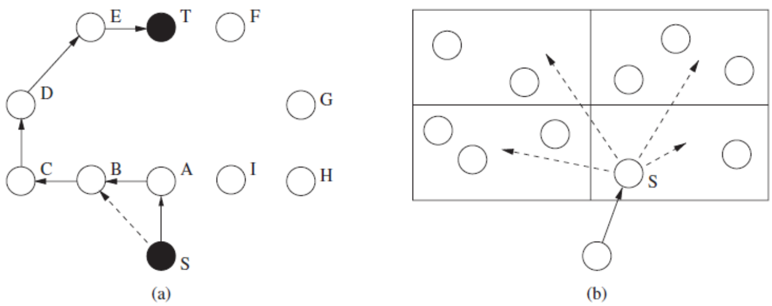

Figure 2: GEAR: (a) Learning routes around holes and (b) recursive geographic forwarding.

Figure 2(a) shows an example of this procedure, where T represents the centroid of the target region. Node S wishes to forward a packet toward the destination and it have three neighbors that are closer to the destination: B, A, and I. B's and I's learned and estimated costs are root 5 and A's learned and estimated costs are both 2. S will forward the packet to the lowest cost neighbor, which is A. Node A will find itself in a hole and it will forward the packet to the neighbor with the minimum learned cost, for example, node B. Additionally, it will update its own cost $h(A, T) = h(B, T) + C(A,B)$, that is, assuming a cost $(A,B) = 1$, the new learned cost of A will be $\sqrt{5} + 1$. The next time a packet for T arrives at node S, S will forward the packet directly to B instead of A to circumvent the hole. Once a packet reaches the target region *R*, a simple flooding with duplicate suppression scheme could be used to disseminate the packet to all nodes within *R*. However, due to the cost of flooding, GEAR relies on a process called *Recursive Geographic Forwarding*, as shown in **Figure 2b.**

2.2.1.2: Geographic Adaptive Fidelity (GAF):

GAF [5] is used for WSN because it favors energy conversation. The state transition diagram shown in Figure 2c has three stages, discovery, active and sleeping. When a sensor enters the sleeping state, it turns off radio for energy saving .In discovery state, a sensor exchange discovery messages to learn about other sensors in the grid. In active state, a sensor periodically broadcast its discovery message to inform equivalent sensors about its state.

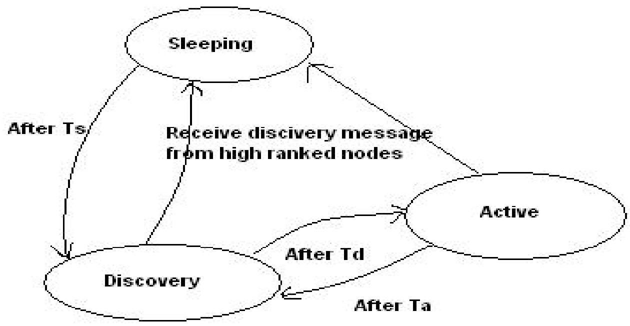

Figure 2c: State transition diagram of GAF

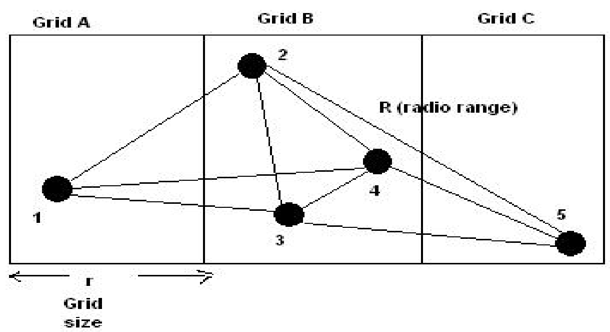

Figure 2d: Virtual grid structure in the GAF protocol

For example, nodes 2, 3 and 4 in the virtual grid B in Figure 2d are equivalent in the sense that one of them can forward packets between nodes 1 and 5 while the other two can sleep to conserve energy. Hence, GAF conserves energy by turning off unnecessary nodes in the network without affecting the level of routing fidelity. Each node uses its GPS-indicated location to associate itself with a point in the virtual grid.

2.2.1.3: MECN and SMECN:

Minimum energy communication network set ups and maintains a minimum energy network for wireless networks by utilizing low power GPS. This protocol has two phases: 1) It takes the positions of a two dimensional plane and constructs a sparse graph, which consists of all the enclosures of each transmit node in the graph. The enclose graph contains globally optimal links in terms of energy consumption. 2) Finds optimal links on the enclosure graph. It uses distributed shortest path algorithm with power consumption as a cost metric. The small minimum energy communication network (SMECN) is an extension to MECN. In SMECN protocol; every sensor discovers its immediate neighbors by broadcasting a discovery message using some initial power that is updated incrementally [6].

2.2.1.4: PRADA

Geographical routing protocols require neighborhood information to select the next hop according to distance, PRR, etc. However, collecting this neighborhood information is costly. Moreover, neighborhood information provides only a limited view of the network upon which the node has to make decisions. It can be argued that if a node has global knowledge of the network, the optimum path to the destination can be found. Accordingly, the next hop in this optimum route can be selected. However, in practice, global network knowledge is impossible to gather in WSNs due to the high density and associated high cost. Hence, geographical routing protocols aim to provide decision-making mechanisms using a limited view of the network, i.e., information about neighbors of a node.

2.2.2 Data Centric and Flat Architecture Routing Protocols:

The major differences between WSNs and ad hoc networks are that, because of the large number of sensor nodes, it is hard to assign specific IDs to each of the sensor nodes. Hence, address-based routing protocols are not preferred for WSNs. To overcome this, data centric routing protocols have been proposed. As an example, “the areas where the temperature is over 70 ◦F (21 ◦C)” is a more common query than “the temperature read by a certain node.” Attribute-based naming is used to carry out queries by using the attributes of the phenomenon. In data-centric routing, the sink sends queries to certain regions and waits for data from the sensors located in the selected regions. Since data is being requested through queries, attribute based naming is necessary to specify the properties of data. Here data is usually transmitted from every sensor node within the deployment region with significant redundancy.

An example for data-centric routing is illustrated in Figure 5. In this case, the sink is interested in areas where the temperature is higher than 70 ◦F. Consequently, the nodes with sensor readings matching this request are addressed. Note that data-centric routing provides routes according to the query content and, hence, the nodes that send information change for each query. Moreover, using a single data-centric query, multiple nodes in distant locations can be addressed as also shown in Figure below.

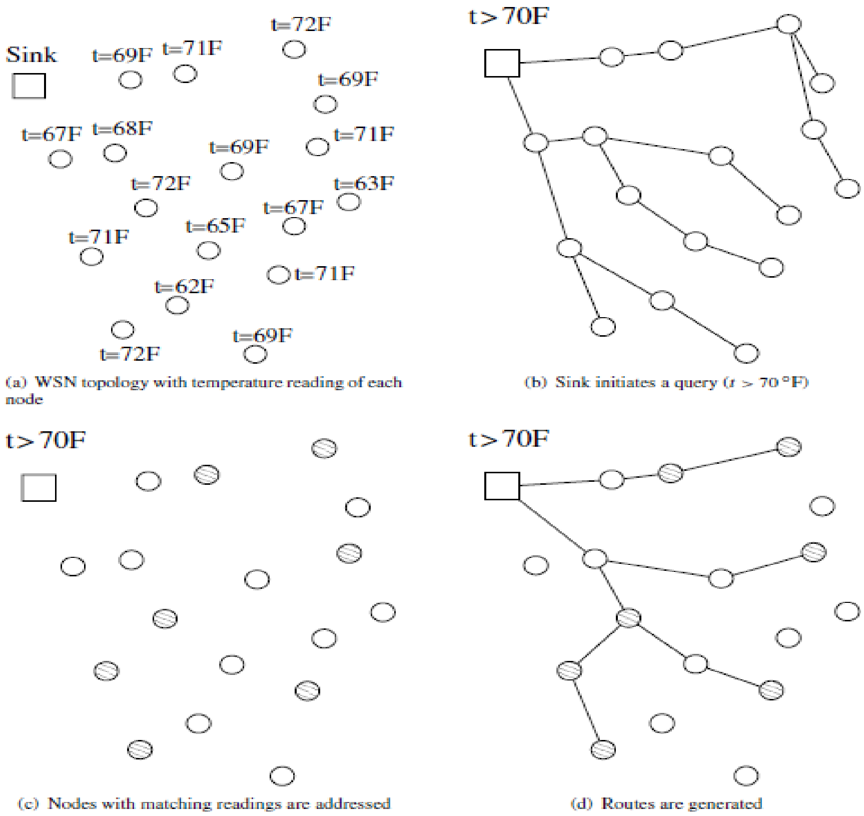

Figure 2(e): Illustration of data-centric routing

Flooding and Gossiping: Flooding and gossiping [7] are the most traditional network routing. They do not need to know the network topology or any routing algorithms.

2.2.2.1 Flooding:

The simplest routing algorithm, which has been developed for multi-hop networks, is the flooding technique. Accordingly, whenever a node receives a packet, it broadcasts this packet to all of its neighbors. This continues until all the nodes in the network receive the packet as shown in Figure 2(f). As a result, a packet can be *flooded* through the whole network. The flooding can be controlled by limiting the rebroadcast until the packet reaches the destination or the maximum number of hops is reached. Flooding is a reactive protocol and its implementation is fairly straightforward. The advantages of flooding are in its simplicity since a node does not require neighborhood information, and flooding does not require costly topology maintenance and complex route discovery algorithms. In flooding mechanism, each sensor receives a data packet and then broadcasts it to all neighboring nodes. When the packet arrives at the destination or the maximum number of hops is reached, the broadcasting process is stopped. On the other hand, gossiping is slightly enhanced version of flooding where the receiving node sends the packet to randomly selected neighbors, which pick another random neighbor to forward the packet to and so on.

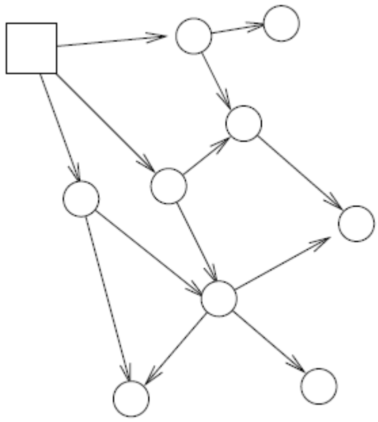

Figure 2(f): Flooding

However, flooding has several deficiencies as described below [13]:

- **Implosion:** The flooding mechanism does not restrict multiple nodes from broadcasting the same packet to the same destination. As a result, duplicated messages are usually sent to the same node. As shown in **Figure 2f (a)**, if node A shares *N* neighbor nodes with another node B, the sensor node B receives *N* copies of the message sent by node A.
- **Overlap:** The information sent by the sensor nodes is closely related to their sensing regions. As shown in **Figure 2f (b)**, if two nodes have overlapping sensing regions, then both of them may sense the same stimuli at the same time. As a result, neighbor nodes receive duplicated messages.
- **Resource blindness:** The most important resource in WSNs is the available energy, which should be efficiently consumed by networking protocols. However, the flooding protocol does not take into account the available energy resources. An energy resource-aware protocol must take into account the amount of energy available to it at all times.

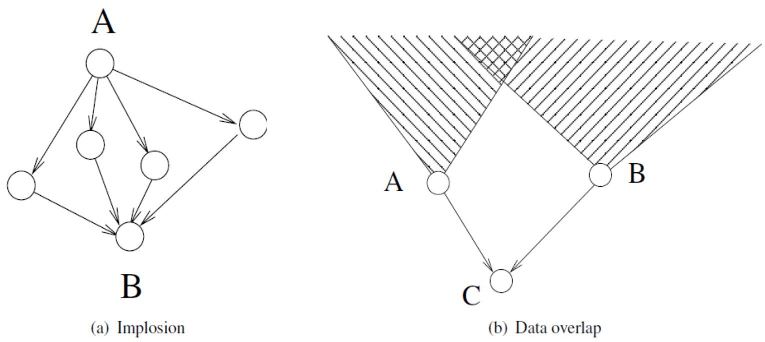

Fig 2(f) (a) Implosion, (b) Data Overlap

2.2.2.2 Gossiping:

One of the main inefficiencies of flooding is the implosion problem, where multiple copies of the same packet traverse the network. This can be avoided through gossiping, which is a derivation of flooding [11]. Gossiping avoids implosion by selecting a single node for packet relaying. As a result, whenever a node receives a packet it does not broadcast the packet but selects a random node among its neighbors and forwards the packet to that particular node. Once the neighbor node receives the packet, it randomly selects another sensor node.

Although gossiping avoids the implosion problem by just having one copy of a message at any node, it increases the latency in propagating the message to all sensor nodes. Since a single node at a time is informed about the packet, the information is distributed slowly. On the other hand, since multiple copies of a packet are prevented, the energy consumption of gossiping is lower than that of flooding. Although simple and inefficient, flooding and/or gossiping techniques can still be used by recent routing protocols for specific functions. As an example, during the deployment phase, the sink can use flooding or gossiping protocols to determine the active nodes. Similarly, during sensor network initialization, limited flooding can be used to gather information from neighbors in close proximity.

2.2.2.3 Sensor Protocol for Information via Negotiation (SPIN):

Joanna Kulik et al. in [8] proposed a family of adaptive protocol, called SPIN (Sensor Protocol for Information via Negotiation) that efficiently disseminate information among sensors in an energy-constrained wireless sensor network and overcome the problem of implosion and overlap occurred in classic flooding. Nodes running a SPIN communication protocol name their data using high-level data descriptors, called metadata. SPIN nodes negotiate with each other before transmitting data. Negotiation helps to ensure that the transmission of redundant data throughout the network is eliminated and only useful information will be transferred.

The negotiation mechanism of SPIN is performed through three types of messages, namely advertisement (ADV), request (REQ), and DATA, which are illustrated in **Figure 2(g).**

- Step 1.Before sending a DATA packet, a node advertises its intent by broadcasting an ADV packet
- Step 2. The ADV packet contains a description of the DATA packet to be sent, which is much smaller in size than the DATA packet. Then, if a neighbor is interested in the ADV packet, it replies back with a REQ message
- Step 3. Finally, the DATA packet is sent to the node that requests it (Step 3). Data propagation in WSNs is coordinated through this mechanism at each hop.
- Steps 4, 5, and 6 as shown in **Figure 2(g)**, multiple nodes can send REQ messages back to a node, which sends DATA to each node until all the nodes get a copy. As a result of the SPIN protocol, the sensor nodes in the entire sensor network which are interested in the data will get a copy.

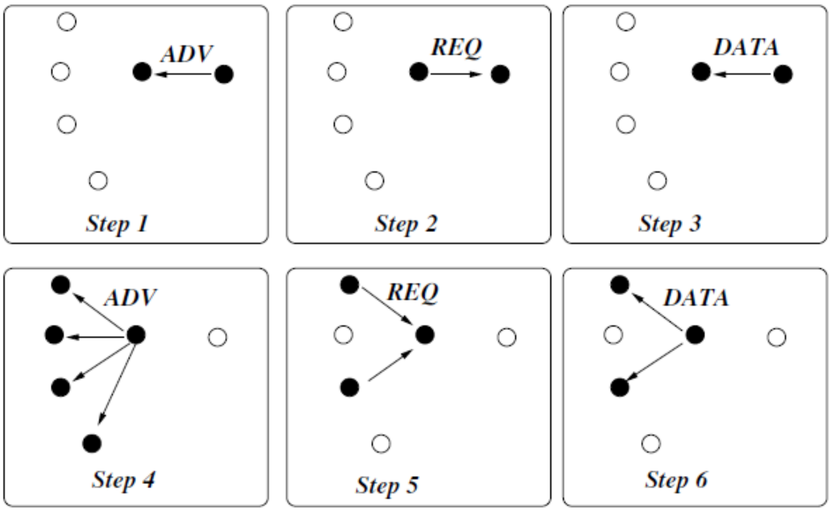

Figure 2(g): The SPIN protocol

The example in above figure is is referred to as the point-to-point SPIN protocol (SPINPP). In addition to SPIN-PP, several variations have been proposed to address some of the disadvantages of SPIN-PP i.e SPIN with energy consumption awareness (SPIN-EC), SPIN for broadcast networks (SPIN-BC), and SPIN with reliability (SPIN-RL).

SPIN-PP does not address the resource-blindness problem of conventional flooding or gossiping protocols. Although the DATA packet transmission is limited to nodes that provide interest, energy consumption is still a concern. SPIN-EC addresses this through a simple energy conservation heuristic such that whenever the residual energy of a node is lower than a threshold, the node does not participate in the protocol operation, i.e., it does not send a REQ packet if it does not have enough energy to transmit the REQ packet and receive a DATA packet. Since node participation is dependent on the residual energy, if a node has plenty of energy SPIN-EC behaves like SPIN-PP.

Another disadvantage of SPIN-PP is shown in Steps 5 and 6 of **Figure 2(g)** . Whenever there is more than one node that sends REQ packets, the DATA packet is sent to each node individually. Considering the broadcast nature of the wireless channel, this approach is a waste of resources since each neighbor of a node can receive the packet in each unicast. Furthermore, SPIN-PP does not provide any mechanism to prevent collisions when multiple REQ packets are send. This is addressed through SPIN-BC, which is developed for broadcast networks. In contrast to SPIN-PP, SPIN-BC introduces a randomized back off mechanism for the nodes before transmitting a REQ packet. As a result, if a node has an interest in a packet but hears a REQ packet related to that particular packet, it drops its REQ packet and waits for the DATA packet. Upon receiving a REQ packet, a transmitter node broadcasts a single DATA packet which can be received by all the interested neighbors. As a result, SPIN-BC decreases the energy consumption and overhead caused by multiple interested neighbors.

SPIN-RL provides a reliability mechanism to the SPIN-BC protocol such that if a node receives an ADV packet but does not receive a DATA packet followed by it (due to wireless channel errors), it requests the DATA packet from the neighbors that may have received the DATA packet. Moreover, SPIN-RL limits the retransmission period of the nodes such that they do not retransmit a DATA packet before a specified period.

SPIN is based on data-centric routing [13] where the sensor nodes broadcast an advertisement for the available data and wait for a request from interested sinks. Compared to flooding, SPIN-PP reduces energy consumption by 70% since redundant transmissions are prevented. SPIN-EC provides a further 10% increase in energy consumption, through energy-aware operation. Moreover, since local interactions are required for routing, SPIN is also scalable. However, compared to flooding, the latency in data dissemination is higher because of the overhead in the handshake mechanism.

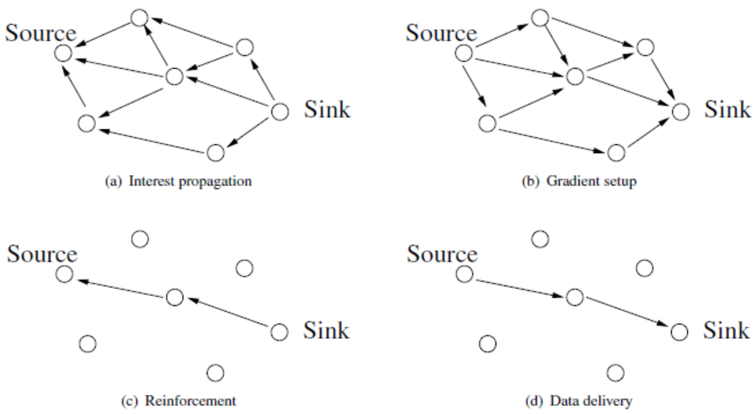

Figure 2(h): Operation of the directed diffusion protocol

2.2.2.4 Directed Diffusion:

Ramesh Govindan et al. in [9] proposed a popular data aggregation paradigm for wireless sensor networks called directed diffusion. Directed diffusion is data-centric and all nodes in a directed diffusion-based network are application-aware. This enables diffusion to achieve energy savings by selecting empirically good paths and by caching and processing data in network (e.g., data aggregation). The main advantages of directed diffusion are: 1) Since it is data centric, communication is neighbor-to-neighbor with no need for a node addressing mechanism. Each node can do aggregation and caching, in addition to sensing. Caching is a big advantage in term of energy efficiency and delay. 2) Direct Diffusion is highly energy efficient since it is on demand and there is no need for maintaining global network topology. **Figure 2(i)** shows the operation of directed diffusion protocol and **Figure 2(j)** shows the negative reinforcement in directed diffusion[53].

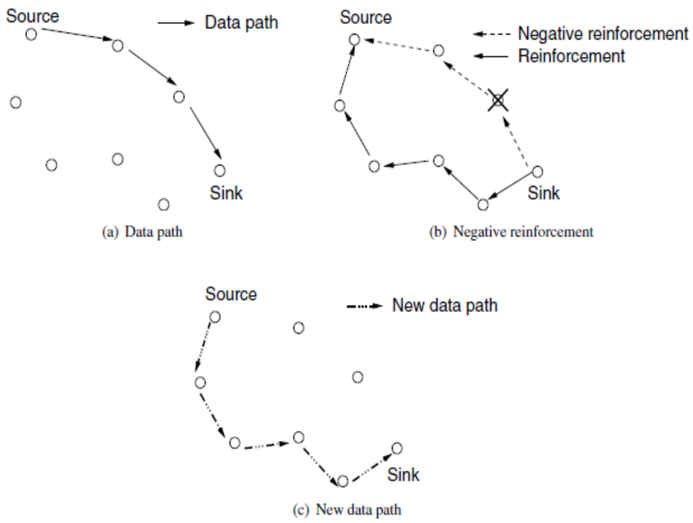

Figure 2(j): Negative reinforcement in directed diffusion

2.2.2.5 Rumor Routing:

Rumor routing is proposed in [10], which allows queries to be delivered to events in the network. It is mainly determined for context in which geographic routing criteria is not applicable. Rumor routing is a logical compromise between flooding queries and flooding events notification. Rumor routing is tunable and allows for tradeoff between setup overhead and delivery reliability.

2.2.2.6 Gradient-Based Routing:

The algorithm makes an improvement on Directed Diffusion, in order to get the total minimum hop other than the total shortest time. In the traditional gradient minimum hop count algorithm, hop count is the only metric, which measures the quality of route. Li Xia [11] gradient routing protocol which not only consider the hop count but also energy of each node while relaying data from source node to the sink. This scheme is helpful in handling the frequently change of the topology of the network due to node failure. A new gradient routing scheme also aims path from the source node to the sink.

2.2.3 Hierarchical protocols:

The data-centric and flat-architecture protocols result in the majority of the information generated at the sensors being concentrated near the sink. As a result, flat-architecture protocols suffer from data overload close to the sink as the density increases. The nodes which are located near the sink route more information than nodes in other parts of the network. As a result, these nodes die faster and produce a disconnection between the sink and the WSN. Consequently, flat-architecture protocols result in uneven energy consumption throughout the network and limit the scalability of the protocols.

The disadvantages of the flat-architecture protocols can be addressed by forming a hierarchical architecture, where the nodes are grouped in *clusters* and the local interactions between cluster members are controlled through a *cluster head* as shown in Figure 2(k). Based on this architecture, several hierarchical routing protocols have been developed to address the scalability and energy consumption challenges of WSNs.

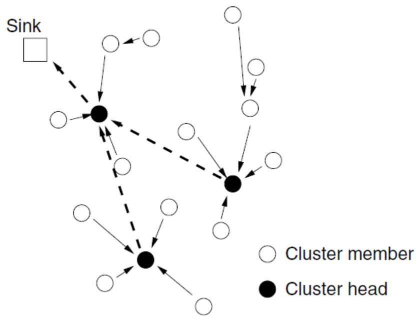

Figure 2(k): Hierarchical Cluster-based architecture in WSNs

Hierarchical clustering in WSN is an energy efficient protocol with three main elements: Sensor Nodes (SN), Base Station (BS) and Cluster Heads (CH). The SNs are sensors deployed in the environment to collect data. The main task of a SN in a sensor field is to detect events, perform quick local data processing, and transmit the data. The BS is the data processing point for the data received from the sensor nodes, and from where the data is accessed by the end-user. The CH acts as a gateway between the SNs and BS. The CH is the sink for the cluster nodes, and the BS is the sink for the cluster heads. This structure formed between the sensor nodes, the sink and the base station can be replicated many times, creating the different layers of the hierarchical WSN.

Some of the hierarchical protocols proposed for sensor networks are the Low-Energy Adaptive Clustering Hierarchy (LEACH), Power-Efficient Gathering in Sensor Information Systems (PEGASIS), Threshold-Sensitive Energy-Efficient Sensor Network (TEEN), and Adaptive Threshold-sensitive Energy-Efficient sensor Network (APTEEN).

2.2.3.1 Low Energy Adaptive Clustering Hierarchy (LEACH):

This is one of the most frequently studied routing protocols for any research work aiming at energy Efficiencies. The model was introduced in 2000 and has considered designing an effective radio and energy model, which is highly adopted even in current studies. LEACH [12][13] algorithm considers homogenous wireless sensor network where the base station is located in the center of the simulation area and surrounded by multiple clusters. The selection of the cluster head is always done depending on the highest residual energy. The cluster head uses TDMA scheduling to aggregate the physical data from the member nodes on one cluster. The entire operation of the LEACH is carried out using set up phase and steady phase. The energy depletion is controlled by reducing the cost of communication between the member node and cluster head using sleep scheduling algorithms. Hence, lifetime of the network is maximized in LEACH.

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

Just like HEED, it is also an enhanced version of LEACH routing protocol where the outcome shows that energy efficiencies capabilities are doubled up even compared to conventional LEACH [14]. The aggregated data are not forwarded to base station directly, inspite, the aggregated data are transmitted through a communication channel to the neighbor networks, which is finally forwarded to the base station. The phenomenon of cluster formation is evaded in PEGASIS and considers that all the sensor nodes have prior information about the wireless sensor network using greedy algorithm.

Figure 2(l) shows the chain construction is performed according to a greedy algorithm, where nodes select their closest neighbors as next hops in the chain. It is assumed that the nodes have a global knowledge of the network and the chain construction starts from the nodes that are farthest from the sink. As a result of chain operation, instead of maintaining cluster formation and membership, each node only keeps track of its previous and next neighbor in the chain.

Communication in the chain is performed sequentially such that each node within a chain aggregates data from its neighbor until all the data are aggregated at one of the sensor nodes, i.e., chain leader. The chain leader controls the communication order by passing a token among the nodes PEGASIS provides performance enhancement of 100–300% over LEACH in energy consumption. This improvement is due to the limited overhead in chain communication compared to cluster formation.

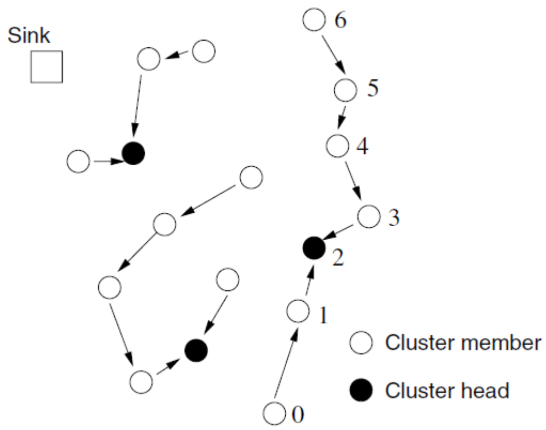

Figure 2(l). The Chain Structure of PEGASIS

However, PEGASIS results in significant delays since the data have to be sequentially transmitted in the chain and the chain leader waits until all the messages are received before communicating with the sink. Moreover, PEGASIS requires all the information in the chain to be aggregated into a single packet, which may cause inaccuracy in the information sent to the sink.

2.2.3.3 Threshold Sensitive Energy Efficient Sensor Network Protocol (TEEN):

The LEACH and PEGASIS protocols support applications where information from sensor nodes is periodically transmitted to the sink. Consequently, the information content from multiple nodes is decreased through aggregation techniques. However, these protocols may not be responsive to event-based applications, where information is generated only when certain events occur. The TEEN protocol aims to provide event-based delivery in the network.

The TEEN protocol organizes the sensor nodes into multiple levels of hierarchy as shown in Figure below. In this hierarchical architecture, data are transmitted first by sensor nodes to cluster heads, which collect, aggregate, and transmit these data to a higher level cluster head until the base station is reached. In order to evenly distribute the energy consumption, the cluster heads are periodically changed inside the cluster.

This protocol is mainly designed for mission critical requirements in any applications in reactive networks [15]. The aggregated data from the cluster head is forwarded to the upper level of cluster head and this phenomenon is continued for all the clusters until the forwarded data reaches base station. TEEN maintains energy conservation by occasionally using threshold base approach forwarding the unique data (although the member node spontaneously generates the data to the cluster head).

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

Since TEEN is based on fixed threshold limits, it is not suitable for periodic reports required by some applications. In order to provide periodic information retrieval, the adaptive threshold-sensitive energy efficient sensor network (APTEEN) protocol has been developed as an advancement of TEEN. APTEEN provides a TDMA-based structure for information transmission in each cluster. Consequently, each node transmits its information periodically to the cluster head. Moreover, the hard and soft threshold values control when and how frequently to send the data. As a result, both event-based and monitoring applications can be served.

It is an enhanced version of conventional TEEN protocol primarily targeting at periodic collection of physically sensed data from member node and promptly responding in mission / time critical applications [16]. The selection of the cluster head is almost like that of LEACH protocol. APTEEN also used enhanced TDMA scheduling thereby allocating a precise slot for transmission for preventing data redundancies. Figure 2(m) shows Hierarchical architecture of TEEN and APTEEN.

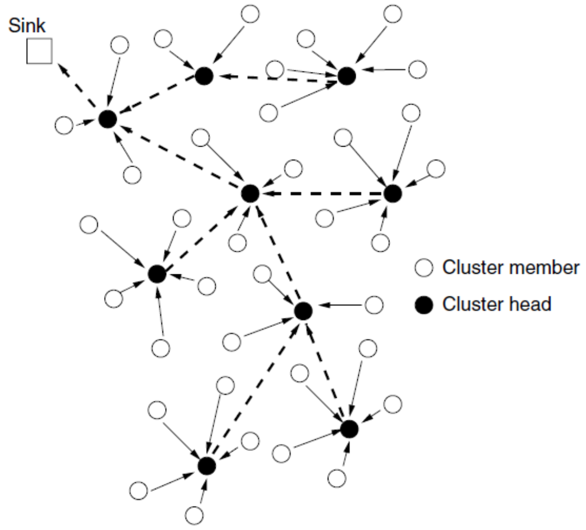

Figure 2(m): Hierarchical architecture of TEEN and APTEEN

2.2.3.5 Hybrid, Energy-Efficient Distributed Clustering (HEED):

It is an enhanced version of LEACH routing protocols that considers residual power as well as node density as a selection criteria of cluster head [17], [18]. The outcome of the HEED routing protocol is found with better energy efficiencies even compared to LEACH with better reduction in overhead and maximizing the network lifetime.

HEED protocol is the clustering protocol. It uses using residual energy as primary parameter and network topology features (e.g. node degree, distances to neighbors) are only used as secondary parameters to break tie between candidate cluster heads, as a metric for cluster selection to achieve load balancing. In this all nodes are assumed to be homogenous i.e. all sensor nodes are equipped with same initial energy. But, in this paper we study the impact of heterogeneity in terms of node energy. We assume that a percentage of the node population is equipped with more energy than the rest of the nodes in the same network - this is the case of heterogeneous sensor networks. As the lifetime of sensor networks is limited there is a need to re-energize the sensor network by adding more nodes. These nodes will be equipped with more energy than the nodes that are already in use, which creates heterogeneity in terms of node energy, leads to the introduction of H-HEED protocol.

2.2.3.6 Clustered Aggregation Technique (CAG):

Just like TEEN, CAG [19] is primarily designed for the reactive network. All the sensor nodes that sense equivalent physical data are formulated as one cluster and perform operation to check redundancies of data by filtering out unwanted elements thereby reducing the response time. CAG also addresses better storage efficiency and efficient cost of communication. Updated CAG Algorithm [20] is an improvement of CAG algorithm, where the clusters are still formed from nodes sensing similar values within a given threshold, but in this case, the clusters remain as long as the sensor values stay within a given threshold over time(temporal correlation). This ensures that the performance of CAG become independent of the magnitude of sensor readings and network topology. When used in the interactive mode, the protocol alternates query and response phases. Usually, energy Efficient Homogeneous Clustering Algorithm for Wireless Sensor Networks [21] is a algorithm that proposes homogeneous clustering for WSNs that save power and prolongs network life. The life span of the network is increased by homogeneous distribution of nodes in the clusters. A new CH is selected based on the residual energy of existing cluster heads, holdback value and nearest hop distance of the node. The cluster members are uniformly distributed, and thus, the life of the network is extended

III. DESIGN ISSUES IN ROUTING PROTOCOLS

3.1 Features of WSNs

There are several features of WSNs that distinguish them from more traditional wireless ad hoc networks.

- First, WSNs have specific traffic patterns in the form of multicast (one-to-many) and converge-cast (many-to-one) trees [22] (e.g., a sensing query is sent to all sensor nodes located in a specific area, an event is detected by multiple sensor nodes that all send the relevant information back to a monitor node).
- Second, WSNs are usually made up of small or tiny nodes equipped with little memory, limited non-rechargeable battery, low-end processors, and small bandwidth links. As a result, WSN protocol designers face strict constraints on the use and the availability of node resources.
- Third, the majority of target applications for WSNs require the deployment of the sensor nodes in large numbers, ranging from thousands to millions. Hence, the scalability of the used protocols is also a major concern [23].
- Fourth, individual sensor nodes can potentially generate huge amounts of data. The transmission of every data bit to a common sink node would make use of a large amount of energy, bandwidth, and processing power.

Therefore, possibly redundant information need to be detected, filtered out, and/or aggregated in order to reduce the in-network traffic. In the following subsections, these specific characteristics of WSNs are taken into account and a list of must-to-have features for WSN routing protocols in order to allow their use in real-world applications are identified. They are as follows,

3.1.1 Minimal computational and memory requirements:

Sensor nodes are typically equipped with a low-end CPU and have limited memory. For instance, Crossbow's XM2110 mote is equipped with ATMega 1281 processor running at 16 MHz [24]. Therefore, it is customary that the routing algorithm has minimal processing overhead to make its execution feasible and effective on such a low-end processor.

3.1.2 Autonomicity and self-organization:

A WSN is expected to remain operational for an extended period of time. During this time, new nodes might be added to the network, while other nodes might incur in failures or exhaust their batteries, becoming unoperational. A routing protocol must be resilient to such dynamic and generally unpredictable variations and must sustain the long-term availability of essential network services [23]. Therefore, the network protocols, and the routing protocols in particular, must be empowered with self-organizing and self-management properties, in order to let the network functioning as an autonomic system [25].

Table 1: Comparison of Standard routing protocols

	Routing Protocols	Power usage	Data aggregation	Multipath	Query based	QoS
Flat	SPIN	Ltd.	Yes	Yes	Yes	No
	Directed diffusion	Ltd.	Yes	Yes	Yes	No
	Rumor Routing	Low	Yes	No	Yes	No
	GBR	Low	Yes	No	Yes	No
	N-to-1 Multipath	Ltd.	Yes	Yes	No	No
	Braided Multipath	Ltd.	Yes	Yes	Yes	No
	Energy aware	N/A	No	No	Yes	No
Hierarchical	LEACH	High	Yes	No	No	No
	PEGASIS	Max.	No	No	No	No
	TEEN / APTEEN	High	Yes	No	No	No
	ECRA	Max.	Yes	No	No	No
	MECN /SMECN	Low	No	No	No	No
Location	GEAR	Ltd.	No	No	No	No
	GAF	Ltd.	No	No	No	No

Legend: Ltd: Limited, N/A: Not applicable, Max: Maximum

3.1.3 Energy efficiency:

Sensor nodes are equipped with small non-rechargeable batteries (usually less than 0.5 A h and 1.2 V) [23]. Therefore, the efficient battery utilization of a sensor node is a critical aspect to support the extended operational lifetime of the individual nodes and of the whole network.

A WSN routing protocol is expected to:

I. Minimize the total number of transmissions involved in route discovery and data delivery, and

II. Distribute the forwarding of the data packets across multiple paths, so that all nodes can deplete their batteries at a comparable rate. This will result in the overall increase of the network lifetime.

3.1.4 Scalability:

In a wide range of WSN applications, thousands or even millions of nodes are expected to be deployed [23]. A typical example is battle field surveillance, in which the criticality and the geographical extension of the scenarios require the deployment of large numbers of densely distributed sensors that have short communication ranges and high failure rates. Therefore, the routing protocol should be able to effectively cope with the challenges deriving from intensive radio interference, very long paths, and unpredictable failures. Moreover, it should be able to display scalable performance in face of these challenges.

3.1.5 Architecture matching the characteristics of traffic patterns:

One of the features that make WSNs clearly different from other types of networks (e.g., MANETs and wired networks for local/wide area connectivity), is the structure of the traffic patterns. The most common traffic patterns present in WSNs include: event-driven, query driven, continuous monitoring, and some hybrid combination of these [26]. An event-driven traffic is triggered when a sensor node detects an event of interest (e.g., the environment temperature goes above a certain threshold). In a similar way, a user may generate a query to a set of nodes which will respond with the required data. In continuous monitoring, data packets are sent back to the monitoring node(s) at regular intervals. The characteristics of the traffic patterns significantly affect the choice of a routing protocol. For instance, a proactive approach, which is based on the periodic gathering of routing information for all possible destination nodes, is suitable for continuous traffic models but might determine excessive energy expenditure for applications that only require sporadic data transmissions. In these cases, a reactive/on-demand approach might be more appropriate.

3.1.6 Support for in-network data aggregation:

Sensor networks can generate large amounts of locally redundant data. For instance, when a node detects that the temperature in its surroundings has exceeded a certain threshold value, it is likely that also its neighboring nodes will detect the same event. If all these sensor nodes notify the event to the monitor node, which then can aggregate the received information to assess the event with high statistical confidence? The downside of this way of proceeding lies in the excessive use of network resources. However, not every single piece of information needs to be communicated to the global sink. Information from a group of neighboring nodes can be partially aggregated and processed as close as possible to its origin. In this way, it is possible to significantly reduce the number of transmissions, saving on the limited available hardware resources and reducing the negative effects due to radio interference. A good routing protocol for WSNs must be able to effectively support the setup and the use of data paths for in-network data aggregation.

IV. RECENT STUDIES

The previous sections has presented all the standard routing protocols in WSN while this section presents some of the recent studies performed in 2014 for the purpose of mitigating the routing issues in WSN. Du et al. [27] analyzed some typical existing routing algorithms in WSN and proposed energy aware ladder direction diffuse routing algorithm.
There are three innovations about this algorithm as:

- ***First,*** a special packet head is defined to update nodes' information with transmitting message and special data structure is stored in every nodes to memorize its neighbor nodes information.
- ***Second,*** new ladder diffusion method is designed to activate the nodes in WSNs; third, an energy aware routes choosing method is designed to improve the energy efficiency of WSNs. Jiang and Sun [28] construct hybrid virtual potential field based on the hop of nodes to sinks and the residual energy of nodes and design a virtual potential field based multi-sink routing algorithm, according to the feature of concentric in data transmission. Khanbabapour and Mirvaziri [29] propose a protocol for intrusion detection in clustered wireless sensor networks implemented on network simulator "GloMoSim". Dymora and Mazurek [30] presented comparative analysis of existing solutions in a field of wireless fault tolerant self-adopting protocols. However, this approach to the problem of providing continuous availability is not without drawbacks because it does not reflect the capabilities of modern communication technology, in particular with regard to the use of multi-channel transmission.
- ***Third -*** the use of reconfiguration on a physical level for systems with large size usually does not produce the expected results, it is expensive and difficult to upgrade and providing only communication system coherence in many cases is insufficient.

Rahmatizadeh et al. [31] describe MS-DVCR, an extension of a state-of-the-art virtual coordinate routing protocol (DVCR) with the ability to route towards a mobile sink. An experimental study had shown that with respect to average path length the MS-DVCR protocol closely matches the performance of a simple extension of the DVCR protocol for mobile sinks, but with significantly lower energy consumption. Ghadimi et al. [32] introduce ORW, a practical opportunistic routing scheme for wireless sensor networks. ORW uses a novel opportunistic routing metric, Expected Number of Duty Cycled Wakeups (EDC) that reflects the expected number of duty-cycled wakeups that are required to successfully deliver a packet from source to destination. Our results show that Opportunistic Routing in Wireless sensor networks (ORW) reduces radio duty cycles on average by 50% (up to 90% on individual nodes) and delays by 30% to 90% when compared to the state of the art. He et al. [33] proposed a DCP3D (the degree of coplanarity three dimensional) algorithm which used the degree of coplanarity and multiple threshold constraint strategy to improve the accuracy by analyzing the beacon node topology. Simulation results show that the improved method has a good performance in accuracy, bad node control and stability.

The other recent studies explored for the purpose of energy efficiency in WSN using some of the unique techniques are tabulated below.

Table 2: Summary of Most recent studies in energy efficient routing techniques

Authors	Problem Focused	Techniques Applied	Inference
Xu et al.[34]-2014	Energy efficiency in routing	Density-based Energy-efficient Clustering Heterogeneous Algorithm	-The CH selection procedure is same as conventional
Lee et al.-[35]-2014	Energy efficiency in routing	Energy-Efficient QoS-aware Routing Algorithm	-No evidence of standard benchmarking with significant routing protocols
Zytoune-[36]-2014	Energy efficiency in routing	Time Based Clustering Technique	No evidence of standard benchmarking with significant routing protocols
Poostfroushan et al. –[37]-2014	Energy efficiency in routing	Particle Swarm Optimization Algorithm	-No evidence of standard benchmarking with significant routing protocols -Energy variation is not discussed
Haider et al.-[38]-2014	Energy efficiency in routing	-REECH-ME: Regional Energy Efficient Cluster Heads based on Maximum Energy Routing Protocol with Sink Mobility	-Better network lifetime achieved. --Energy variation is not discussed
Zhang et al.-[39]-2014	Energy efficiency in routing	-distributed energy-efficient unequal clustering routing protocol	- better balance energy consumption, improve energy efficiency and then prolong the network lifetime -Algorithm convergence behavior not discussed -Multiple hop not addressed

Shu & Wang-[40]-2013	Energy efficiency in routing	An Optimized Multi-hop Routing Algorithm Based on Clonal Selection	-Better performance compared to PEGASIS -No discussion on comparison with LEACH -possible control overheads are not discussed -Result achieved from less simulation rounds
Deng et al.-[41]-2013	Prolong the lifetime of the network.	Balancing Energy Consumption LEACH (BEC-LEACH) protocol	-Result achieved from less simulation rounds -Only 5 clusters are evaluated. -Energy variance is not discussed.
Alia-[42]-2013	Extending Wireless Sensor Network Lifetime	Harmony Search Algorithm	-Energy variance is not discussed. -Result achieved from less simulation rounds -Overheads not discussed
John & Ramson-[43]-2013	Efficient data collection	Energy-Aware Duty Cycle Scheduling	-Not compared with LEACH -doesn't address any optimization.
Zhao & Yang-[44]-2014	prolong the lifetime	LEACH-A	- performs better than the LEACH
Kim et al.-[45]-2014	Optimization	IC-ACO: Inter cluster Ant colony Optimization Algorithm	Selection of CH is just like LEACH
Zungeru et al.-[46] [2013]	Optimization of swarm approaches	-Comparative study of the routing performance of swarm based techniques	Energy aware routing objectives increases the network lifetime

4.1 Prime factors for Energy Consumption

From the elaborated discussion on the previous section, it can be seen that different approaches in majority stresses on a single factor for maintaining power efficiency and this is efficient selection of cluster head. Majority of the prior research also emphasized that if CH is selected properly, than cumulative network life time can be increased. Fig below shows that the protocol stack used by sensor nodes. Much research [47] has been done to design schemes for power conservation and power management in sensor nodes upon all layers of protocol stack, as studied in subsequent sections. Performance of such schemes can be evaluated through simulation tools for instance PAWiS [48]. PAWiS simulation framework supports capturing of features that are critical for WSN like power consumption.

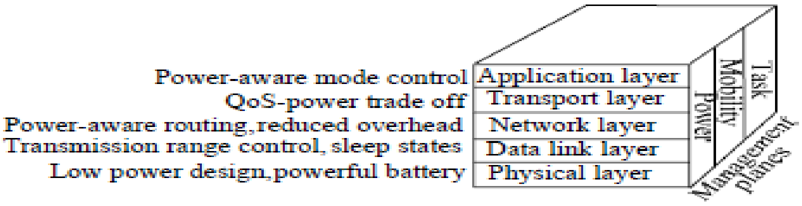

Figure 4: Energy aware protocol stack

The above protocol stack is considered almost in all the study where it can be seen that power aware mode control works in application layer and low power design is implemented on the physical later. Hence, because of this design, selection of cluster head is the only cost effective method for controlling energy drainage. Unfortunately, various energy mitigation routing techniques comes under hierarchical routing protocol, where LEACH is found higher in adoption. The frequently used LEACH protocol has some significant drawback in CH selection that has been consistently addressed by current studies as: i) Some very big clusters and very small clusters may exist in the network at the same time, ii) Unreasonable cluster head selection while the nodes have different energy, iii) Cluster member nodes deplete energy after cluster head was dead, iv) The algorithm does not take into account the location of nodes, v) Ignores residual energy, geographic location and other information, which may easily lead to cluster head node will rapidly fail. Hence, some of the significant studies pertaining to these issues are addressed in last few years. Ramesh and Somasundaram [49] have presented a study for evaluating comparative performance evaluation of cluster head selection procedure in WSN. The author has discussed deterministic scheme, Base Station Assisted Adaptive Schemes, Fixed parameter probabilistic schemes, Resource adaptive probabilistic schemes, and combined metric schemes. The parameters considered for the study are Node ID, number of CH range, Reference point, Residual energy, CH to SN and CH to BS Distances, Position information and energy level, Min distance between node to base station, optimal placement of CH, location aware, threshold, coverage rate. The use of these parameters for this comparison is justified by reasoning the effects of clusterhead selection and its role rotation on the energy efficiency of the network. Chen & Megarian [50] investigate the problem of cluster formation for data fusion by focusing on two aspects of the problem: (i) how does one estimate the number of clusters needed to efficiently utilize data correlation of sensors for a general sensor network, and (ii), given the number of clusters, how does one pick the cluster-heads (sinks of information) to cover the sensor network more efficiently. The energy parameters considered for the study is average power consumption. Chen et al. [51] presented efficient request-oriented coordinator methods for conserving energy in hierarchical sensor networks. The energy evaluation parameters selected were number of alive nodes and percentage of node death.

V. OPEN ISSUES/RESEARCH GAP

There are large numbers of open issues that can be explored from this paper. Flooding and Gossiping [7] is one of the prominent data centric routing protocol has several drawbacks e.g. implosion, overlap and resource blindness problem. Gossiping avoid the problem of implosion by sending information to a random neighbor instead of classic broadcasting mechanism which send packets to all neighbors. However, gossiping creates another problem of delay in a propagation of data among sensor nodes.. Similarly, SPIN [8] is highly uncertain about the data if it will certainly reach the target or not and it is also not good for high-density distribution of nodes. Other drawback is that if the nodes that are interested in the data are far away from the source node and the nodes between source and destination are not interested in that data, such data will not be delivered to the destination at all. Therefore, SPIN is not a good choice for applications. Third, Directed Diffusion [9] is not a good choice for the application such as environmental monitoring because it require continuous data delivery to the sink will not work efficiently with a query driven on demand data model.

Although there are standard hierarchical routing protocols in wireless sensor network, but it has been seen that majority of them are not without flaws. For an example, the most frequently studied LEACH routing protocol selects its clusterhead arbitrarily that doesn't ensure the effective distribution of clusterhead. The biggest flaw in technical consideration in LEACH is that it still considers a node with lowest residual energy as clusterhead resulting in faster rate of power depletion. Moreover, LEACH doesn't address the multi-hop communication requirements in large scale wireless sensor network. Similarly, the HEED protocol is also not much reliable as it prioritizes remnant energy and then topological attributes like node density, relative distances among the clusters etc. It is because all the nodes do posses same initial energy in start up in homogenous network thereby do not ensure better network lifetime. In PEGASIS, there is a massive need of adjustment of dynamic topology as the energy condition of the neighbor clusters are required to be known for routing purpose. This task requires lot of significant network overhead. In TEEN, which is basically dependent on threshold based technique; the sensor nodes may possibly not perform communication if the threshold is not reached. Problem starts appearing when the node starts depleting energy in TEEN. One of the limitations of CAG protocol is that it doesn't support proactive as well as reactive data collection based on real-time requirements of wireless sensor network. Although there are some of the significant research attempts in past, it can be seen that majority of the standard hierarchical routing protocols are found with limitations that act as an impediment towards maximizing the network lifetime of wireless sensor network. The next section discusses about the upcoming trend of using swarm intelligence for the purpose of optimizing the routing performance in wireless sensor network.

From section 2 and section 4, it can be seen that there exist various routing protocols that has been a subject of research in wireless routing protocols. Existing protocols provide different tradeoffs among the following desirable characteristics: fault tolerance, distributed computation, robustness, scalability, and reliability. The research issues that can be considered are different strategies to improve signal reception, design of low power, less cost sensors and processing units. Various schemes to conserve node power consumption and node optimization and simple modulation schemes may also be considered for sensor nodes. Various open issues explored from are:

- Energy efficiency is a very important criterion. Different techniques need to be discovered to eliminate energy inefficiencies that may shorten the lifetime of the network. At the network layer, various methods needs to be explored for discovering energy efficient routes and for relaying the data from the sensor nodes to the BS so that the lifetime of a network can be optimized.
- Routing Protocols should incorporate multi-path design technique. Multi-path is referred to those protocols which set up multiple paths so that a path among them can be used when the primary path fails.
- Path repair is desired in routing protocols whenever a path break is detected. Fault tolerance is another desirable property for routing protocols. Routing protocols should be able to find a new path at the network layer even if some nodes fail or blocked due to some environmental interference.

- Sensor networks collect information from the physical environment and are highly data centric. In the network layer in order to maximize energy savings we need to provide a flexible platform for performing routing and data management.
- The data traffic that is generated will have significant redundancy among individual sensor nodes since multiple sensors may generate same data within the vicinity of a phenomenon. The routing protocol should exploit such redundancy to improve energy and bandwidth utilization.
- As the nodes are scattered randomly resulting in an ad hoc routing infrastructure, a routing protocol should have the property of multiple wireless hops.
- Routing Protocols should take care of heterogeneous nature of the nodes i.e. each node will be different in terms of computation, communication and power.
- The QoS routing algorithms for wired networks cannot be directly applied to wireless sensor networks due to the following reasons: The performance of the most wired routing algorithms relies on the availability of the precise state information while the dynamic nature of sensor networks make availability of precise state information next to impossible. Nodes in the sensor network may join, leave and rejoin and links may be broken at any time. Hence maintaining and re-establishing the paths dynamically which is a problem in WSN is not a big issue in wired networks.

Sensor networks are still at an early stage in terms of technology as it is still not widely deployed in real world and this opens many doors for research. The current routing protocols need to be improved as they have their own set of problems. Much work is not reported on contention issues or high network traffic. Very little analytical work is done.

VI. CONCLUSION AND FUTURE SCOPE

Routing in sensor networks is not a new research area, with a limited but rapidly growing set of results. Routing in sensor networks has attracted a lot of attention in the recent years and introduced unique challenges compared to traditional data routing techniques. In this paper, recent research results on data routing in sensor networks are summarized and classified the approaches into four main categories, namely data-centric, hierarchical and location-based and Quality of Service based.. They have the common objective of trying to extend the lifetime of the sensor network.

It is also observed that there are some hybrid protocols that fit under more than one category as shown in Table 1. The table summarizes the classification of the protocols covered in this survey. The table mentions the parameters such as Power usage, Data Aggregation, Multipath, Query based and QoS, since these are important consideration for routing protocols in terms of energy saving and traffic optimization. Protocols, which name the data and query the nodes based on some attributes of the data are categorized as data-centric. Rumor routing discussed in the paper is tunable and allows for tradeoff between setup overhead and delivery reliability. In Gradient Based routing the back-off waiting scheme is quite effective for saving the energy consumption when establishing the network's routes. Hierarchical based techniques have special advantage of scalability and efficient communication. Hierarchical routing maintains the energy consumption of sensor nodes and performs data aggregation which helps in decreasing the number of transmitted messages to base station. Most of the routing protocols require location information for sensor nodes in wireless sensor networks to calculate the distance between two particular nodes on the basis of signal strength so that energy consumption can be estimated. Single-path routing approach is unable to provide efficient high data rate transmission in wireless sensor networks due to the limited capacity of a multi-hop path and the high dynamics of wireless links. This problem can be overcome by using multipath routing. Many routing protocols have been proposed which are not suitable for all applications in WSNs. Many issues and Challenges like Energy efficiency, Reliability, Scalability still exist that need to be solved in the sensor networks. In addition other mechanisms such as the ability of nodes to maintain membership in auxiliary clusters can reinforce the current state of energy efficiency and sensor network life time.

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