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A Comparative Study on Energy - Efficient Routing Protocols in Wireless Sensor Networks

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Abstract**: The recent advances and the convergence of micro electro-mechanical systems technology, integrated circuit technologies, microprocessor hardware and nano technology, wireless communications, Ad-hoc networking routing protocols, distributed signal processing, and embedded systems have made the concept of Wireless Sensor Networks (WSNs). Sensor network nodes are limited with respect to energy supply, restricted computational capacity and communication bandwidth. More attention has been given to the routing protocols since they might differ depending on the application and network architecture. To improve the lifetime of the sensor nodes, designing efficient routing protocols is critical. Though sensor networks are primarily designed for monitoring and reporting events, as they are application dependent, a single routing protocol cannot be efficient for sensor networks across all applications. In this paper, the design issues of sensor networks are analysed and present a classification and comparison of routing protocols. This comparison reveals the important features that need to be taken into consideration while designing and evaluating new routing protocols for sensor networks.

Keywords: Sensor networks, Design issues, Routing protocols, Applications.

I. INTRODUCTION

In the today's market of rapid growth of computers, the processing power is increased unexpectedly but the price and size of computers have greatly reduced which encourages the use of computers. The latest and improved technologies have made vast advancements in computers era and also enhance the use of computers in our daily activities. In recent years, from the economic point of view, the single-purpose desktop computers having sensors embedded in them are highly used due to reduction in price and size of computers. Wireless Sensor Network is a recently increasing in demand by all people who involve in many applications because of their substantial applicability to improve their lives. They help us by extending our ability to accurately monitor, study, and control objects and environments of various scales and conditions such as human bodies, geological surveys, habitats, and security surveillance.

Sensor nodes in WSNs can autonomously process and cooperatively analyze sensed data inside networks so that they can reduce the redundant data observed inside a network and deliver only necessary data to the user through sinks. Furthermore, WSNs can dynamically adapt its topology. As soon as the deployment of sensor nodes gets completed, all the sensor nodes autonomously find the neighbour nodes and start communicating with each other in various ways, normally using multihop communications. In wireless communication and embedded micro-sensing technologies, the advancements encourage the use of WSN today in many environments to detect and monitoring sensitive information. In agriculture, WSN is used to detect monitor the condition of crops which favours crop-harvesting very much by decreasing their cost value in cropping also helps in improving crops quality. In military, WSN is used to detect and track the boundary areas for any kind of event. In forest, WSN is used to detect the rains and bad weather conditions. WSNs are here to detect and track the on a battlefield, tracking the personnel in a building, measure the traffic percentage on a road, monitor environmental pollutants, detect fire and rain. Sensors contribute to electricity production, and also used in collecting the solar energy where WSN tracks the sun rays to detect the power.

All these characteristics of WSNs are totally opposite from wired networks because in wired network energy consumption is not an issue. Moreover, the cost of transmission is very low, and the sensor nodes in WSN can process largely. The energy is an important characteristic of WSN upon which the lifetime of network nodes, maintenance cost and performance depends. Distribution of energy throughout WSN is correctly debauched so that the lifetime of the sensor node enhances and hence, it decrease maintenance cost and increase the overall performance of system. In WSN, protocols used for setting-up communication among network nodes incur some overhead for the process of synchronization. So, in this survey paper, we will look into various energy-efficient routing algorithms and also give an eye on comparison part. Various authors have been introduced many clustering algorithms in [4-9]. These algorithms are by nature heuristic, aiming to generate the minimum number of clusters so that in a cluster any node is at most d hops away from CH. Time complexity of most protocols is O(n) , where n is the total number of nodes. Time synchronization is also a factor upon which these protocols depend and these protocols are suitable for small network having small

number of sensors. During the deployment of network, the frequency of activities of nodes is not distributed uniformly because of unspecified identification of definite observation points at deployment time. Transmission and reception consume almost 70 percent of total energy used for all node activities. Therefore energy reduction for transmission and reception activities has significant impact for extending the lifetime of sensor nodes. The set of actively sensing nodes, as sources of data origination, consume extensive energy. Thus, the residual energy of actively sensing nodes should be considered more precious than the residual energy of the node which does not perform sensing activities; however, no means are investigated to preserve actively sensing node in the literature. The scope of this comprehensive survey is briefing the clustering routing techniques in WSNs.

II. ROUTING CHALLENGES IN WIRELESS SENSOR NETWORKS

Due to reduced computing, radio and battery resources of sensors, routing protocols in wireless sensor network are expected to fulfill the following requirements:

a) **Data delivery model**: Data delivery model solves the problem of fault tolerance domain by providing the alternative path to save its data packets from nodes or link failures [8]. It affect the routing protocol severely in wireless sensor network, especially with regard to use the limited energy of the node, security purpose [7], energy consumption and route immobility.

b) **Scalability:** A system is scalable if its effectiveness increases when the hardware is put-on and proportional to the capacity added [23]. Routing schemes make efforts with the vast collection of motes in WSNs which should be scalable enough to talk back to the events take place in the environment.

c) **Resilience:** Sometimes, because of environment problem or battery consumption sensors erratically stop working [9]. This problem is overcome by finding the alternate path when current-in use nodes stop operating.

d) **Production cost:** The cost of single node is enough to measure the overall cost of the sensor network. So the cost of each sensor node should be low.

e) **Operating environment:** Sensor network can be installed inside large machinery, at the base of the ocean, in a biologically or chemically contaminated field, in the battle field behind enemy line, in big building or warehouse etc.

f) **Power consumption:** Long life time of sensor networks and restricted storage capacity of sensor nodes requirements has directed to search a new scope to alleviate power consumption. Sidra Aslam discussed several schemes such as power aware protocol, cross-layer optimization, and harvesting technologies which aid in reducing power consumption constraint in WSNs [26]. In multi-hop sensor networks, the multi-functioning of some nodes such as data sender and data router can cause topology change due to power failure which need new path for data transfer and restructure the network.

g) **Data aggression/fusion:** The main goal of data aggregation algorithms is to collect and aggregate data from different sources by using different functions such as suppression, min, max and average to achieve energy efficient and traffic optimization in routing protocols so that network lifetime is enhanced [30].

III. ENERGY EFFICIENT ROUTING PROTOCOL IN WSN

The main goal of any Energy Efficient Routing (EER) protocol for WSN is to maximize network lifetime by minimizing energy consumption in end-to-end transmission. WSNs are largely application-specific which implies that routing protocols are also dependent on applications. Generalizing the classification given in [3], the EER protocols for WSN are categorized in this paper as follows:

- Hierarchical or Clustering-based Protocols
- Location-based or Geographical Protocols
- Mobility-based Protocols

A. Hierarchical or Clustering-based Protocols

A single-tier flat sensor network cannot scale well when large number of sensor nodes increases, simply because it will cause the single gateway to overload with huge amount of data. Therefore, the whole WSN is broken into some clusters having multiple gateways where nodes within a cluster communicate in multi-hop fashion efficiently consuming the energy. Every cluster has a cluster head that performs data aggregation and/or data fusion before forwarding them to the sink and the cluster head selection is dominated by the energy reserve of the nodes within a cluster. Among many hierarchical protocols, LEACH [7] is the pioneering one with its different versions like E-LEACH [26], M-LEACH [30],LEACH-C [9], VLEACH [29] etc. Other remarkable hierarchical protocols include PEGASIS [14], TEEN [15] and APTEEN. These protocols are briefly discussed below.

1. LEACH – LEACH is mostly called as Low Energy Adaptive Clustering Hierarchy protocol.

W.R. Heinzelman, A.P Chandrakasan and H. Balakrishnan [12] projected LEACH protocol in the year 2000. It is one of the widely used hierarchical routing algorithms in the sensor networks. The main plan of LEACH protocol is to divide the total wireless sensor network into many clusters. The cluster head node is randomly selected; the chance of every node to be selected as cluster head is equally attributable to which energy consumption of whole network is averaged. Thus LEACH will extend the network life cycle. Leach algorithm is cyclical; it provides a conception of round. Leach protocol runs with several rounds. Every round contains two states: cluster setup state and steady state. Within the cluster setup state cluster is formed within the self-adaptive mode whereas in steady state it transfers the information. The selection of cluster head depends on decision made 0 and 1. If number is smaller than the threshold value, the node becomes a cluster head for the current round.

Advantages in the LEACH protocol are:

1. It is one of the mostly used hierarchical routing algorithms in sensor networks.
2. LEACH protocol erstwhile divides the total wireless sensor network into many clusters. Any node that act as a CH in present round cannot be selected as the CH again; therefore each node can share the load equally which is imposed on Cluster heads.
3. The cluster head node is selected randomly and chance of every node to be selected as cluster head is equally attributable to which energy consumption of whole network is averaged. Thus LEACH will extend the network life cycle.

Problems within the LEACH protocol are:

1) The cluster head node is randomly selected in LEACH protocol. There are some drawbacks attributable to the likelihood of every node to be selected as cluster head is same. After numerous rounds, the node with greater remaining energy and the node with smaller remaining energy have same probability to be chosen as cluster head. If the node which has smaller remaining energy is chosen as cluster head, it'll run out of the energy and die more quickly, due to which network's robustness can be affected and life of the network become short.
2) The standard LEACH Protocol divides clusters randomly, additionally results in uneven distribution of clusters simply. Finally the divided clusters might not be the simplest or best. As an example some clusters have large number of nodes than others whereas some clusters have fewer nodes. Some cluster heads may be within the relatively central of clusters whereas some clusters heads may be in the edge of clusters far away from members. These phenomena will enhance the energy consumption and make harsh impact on the total performance of the network.
3) In steady state, cluster head usually transmit information to the sink or base station directly. Cluster head that is farther from the sink communicate with the sink directly mostly spend a plenty of energy. Thus it'll crash earlier as a result of it runs out of energy. Particularly in the midst of the enlargement of the dimensions of the network, these effects have an impact on the network life seriously.

2. E-LEACH: Energy-LEACH (E-LEACH) [26]improves over LEACH by considering the residual energy of each node during the second round of the cluster head selection process thereby making it more energy efficient than LEACH.

3. M-LEACH: Multi-hop-LEACH [M-LEACH] [30] improves on LEACH by relaying cluster head data to the sink through multiple intermediate cluster heads which serve as relay stations. This solves the problem of LEACH effectively or earlier versions of LEACH where a cluster head is located far away from the sink in which case huge energy is consumed for direct or single-hop transmission between cluster head and the sink.

4. V-LEACH: The new Version LEACH (V-LEACH)protocol proposed in [29] keeps the provision of a vice cluster head that plays the role of the cluster head in case the cluster head dies.

5. PEGASIS : S. Lindsey and C. Raghavendra [15] introduced Power Efficient Gathering in Sensor Information Systems (PEGASIS) protocol in 2002. It is an improved and revised version of LEACH. Instead of forming clusters, it is based on forming chains of sensor nodes. One node is mainly held responsible for routing the aggregated information to the sink. Every node aggregates the collected information with its own information, and then passes the aggregated data to the next ring. The difference from LEACH is to employ or use multi hop transmission and choosing or selecting only one node to transmit to the sink or base station. Since the overhead caused by dynamic cluster formation is eliminated, multi hop transmission and data or information aggregation is employed or used, PEGASIS outperforms the LEACH.

Advantages in the PEGASIS protocol are:

1. It is an revised and improved version of LEACH.
2. This protocol is in position to outgo LEACH for different or various network sizes and topologies cluster formation in LEACH, and reduces the number or quantity of data/information transmission volume through the chain of information aggregation.
3. The energy load is uniformly distributed within the network. All sensor nodes act as leader successively, to prevent the subsequent early death of sensor node,

Problems in PEGASIS protocol are:

1. Sensor nodes usually or probably die early in PEGASIS protocol.
2. It is assumed that every sensor node are often able to communicate with sink directly, however nodes typically use multi-hop communication with the sink in practical cases. Moreover, long-range communication directly from the node to the sink will increase the amount of energy consumption.
3. The communication mode suffers from excessive delays caused by the one or single chain for distant nodes and there arises a high chance for any node to become a bottleneck.
4. It is a difficult task for all nodes to maintain a complete database about the location of all other nodes within the network. Moreover the network is not very scalable as all nodes should have global knowledge of the network and use the greedy rule or algorithm.

5. TEEN : In 2001, A. Manjeshwar and D. P. Agarwal [17] projected Threshold sensitive Energy Efficient sensor Network Protocol (TEEN) protocol. Nearer nodes form clusters, with a cluster heads to transmit the collected information to one higher layer. Forming the clusters, cluster heads broadcast 2 threshold values. First one is hard threshold; it is minimum possible value of an attribute to trigger a sensor node. Hard threshold permits nodes transmit the event, if the event happens within the range of interest. Thus a reduction of the transmission delay happens. Unless an

amendment of minimum soft threshold happens, the node doesn't send a new data packet. Second one is soft threshold. Using soft threshold prevents from the redundant information/data transmission. Since the protocol is to be attentive to the rapid changes in the perceived attribute, it is appropriate for time-critical applications.

Advantages in TEEN protocol are:

1. Supported by the thresholds, data transmission are often controlled commendable, i.e. , only the sensitive data have a tendency to demand are often transmitted, thus reduces the energy transmission consumption and improves the effectiveness and utility of the receiving data.
2. TEEN is complement for reacting to huge changes in the sensed attributes that is appropriate for reactive scenes and time decisive applications.

Disadvantages in TEEN protocol are:

1. It is not appropriate for periodic reports applications since the user might not get any data if the values of the attributes may not arrive at the threshold.
2. If CHs is not within the communication range of each other, the data may be vanished, because information transmission is done only at CHs.

6. APTEEN : A. Manjeshwar and D. P. Agarwal [18] projected Adaptive Threshold sensitive Energy Efficient sensor Network Protocol (APTEEN) protocol in 2002. The protocol is a modification of TEEN aiming to capture time critical events and periodic data collections together. The network architecture is same as TEEN. While forming clusters, the cluster heads circulate attributes, the threshold values, and therefore the transmission schedule to any or all nodes. Cluster heads are also responsible for data aggregation so as to reduce the size of data transmitted and the energy consumed. According to energy dissipation and network lifetime, TEEN provides better performance than LEACH and APTEEN because of the minimal number of transmissions. The main drawbacks of TEEN and APTEEN are overhead and complexity of forming clusters in multiple levels, implementing threshold-based function etc. APTEEN is based on query system which permits 3 types of queries: historical, on-time, and persistent which can be employed in hybrid network.

Advantages:

1. APTEEN merges both proactive policies and reactive policies, which are similar to that of LEACH and TEEN. Subsequently, it is appropriate in each proactive and reactive application.
2. It embodies number of flexibilities and set the count-time interval and the threshold values for the energy consumption by changing both the count as well as the threshold values.

Disadvantages:

1. Supplementary complexity is existed which is required to implement threshold functions and the count time.
2. Actually, each TEEN and APTEEN has the similar drawbacks of additional overhead and complexity of cluster construction in multiple levels.

7.SEP : In 2004, G. Smaragdakis, I. Matta and A. Bestavros [25] projected Stable Election Protocol (SEP) protocol. This protocol is also a further modification to the LEACH protocol. It's heterogeneous aware protocol, supported weighted election probabilities of every node to become cluster head according to their specific energy. This approach certifies that the cluster head election is arbitrarily selected and distributed based on the fraction of energy of every node assuring a uniform use of the nodes energy. In this protocol, 2 types of nodes (two tier inclustering) and 2levelhierarchies were considered.

Advantage of SEP:

1. SEP does not require any universal knowledge of energy at each election round.

Disadvantages of SEP:

1. The shortcoming of SEP method is that the election of the cluster heads among the two type of nodes is not dynamic, which results that the nodes that are far away from the powerful nodes will die first.

9. EECS : In 2005, M. Ye, C. Li, G. Chen and J. Wu [31] projected Energy Efficient Clustering Scheme (EECS) protocol. It is a novel clustering scheme for periodical data collecting applications for wireless sensor networks. It elects cluster heads with more remaining energy through local radio communication. In the cluster head election phase, a stable number of candidate nodes are elected and compete for cluster heads according to the node residual energy. The competition method is localized and without iteration. The process also produces a near uniform distribution of cluster heads. Moreover in the cluster formation phase, a unique approach is introduced to balance the load among cluster heads. However, on the other hand, it will increase the necessity of global knowledge regarding the distances between the cluster-heads and the base station.

Advantages

1. EECS builds balancing point between intra-cluster energy consumption and inter-cluster communication load based on energy and distance

2. Clustering is performed by dynamic sizing based on cluster distance from the BS. This addresses the problem that the clusters with a large distance to the BS require more energy for transmission than those with a shorter distance, and produce low message overhead and uniform distribution of CHs compared to LEACH.

Disadvantages

1. On account of single-hop communication in EECS, long-range transmissions directly from CHs to the BS may lead to huge energy consumption. Thus, it is not suitable for large-range networks.
2. EECS needs huge global knowledge about the distances between the CHs and BS, and therefore the task of the global data aggregation adds overheads to all sensor nodes.
3. EECS produces rather more control overhead complexity because all nodes must compete for becoming CHs.

10. DEEC : In 2006, Q. Li, Z. Qingxin and W. Mingwen [11] projected Distributed Energy Efficient Clustering Protocol (DEEC) protocol. DEEC protocol is a cluster based method for multi level and 2 level energy heterogeneous wireless sensor networks. In this scheme, the cluster heads are chosen using the probability based on the ratio between residual energy of every node and the average energy of the network. The era of being cluster-heads for nodes are entirely different according to their initial and residual energy. The nodes with more initial and
remaining energy have greater chances of the becoming cluster heads compared to nodes with low energy.

Advantages of DEEC:

1. DEEC doesn't need any universal knowledge of energy at each election round.
2. In contrast to SEP and LEACH, DEEC will perform well in multi-level heterogeneous wireless network

Disadvantages of DEEC:

1. Advanced nodes always punish in the DEEC, particularly when their residual energy reduced and when they come in the range of the normal nodes. During this position, the advanced nodes die rapidly than the others.

11. HEED : O. Younis and S. Fahmy projected [4] Hybrid Energy Efficient Distributed clustering Protocol (HEED) protocol in 2004. It extends the fundamental or the basic scheme of LEACH by using residual energy as primary parameter and network topology features such as node degree, distances to neighbours are only used as secondary parameters to shatter the tie between the candidate cluster heads, as a metric for cluster choice to attain power balancing. The clustering process is divided into a number of iterations, and in every iteration nodes that are not covered by any cluster head doubles their probability of becoming a cluster head. As these energy efficient clustering protocols further enables each node to probabilistically and independently decide its role in the clustered network. Moreover they cannot guarantee optimal elected set of cluster heads.

Advantages of HEED protocol are:

1. It is a distributed clustering method that takes the advantage of the use of the two important parameters for CH election.
2. Low power levels of clusters endorse an increase in spatial reuse while high power levels of clusters are needed for inter-cluster communication. This imparts uniform CH distribution across the network and load balancing.
3. In a multi-hop fashion, communication between CHs and BS provides more energy conservation and scalability in contrast with the single-hop fashion, i.e long range communication directly from CHs to the sink, as within the LEACH protocol.

Limitations with HEED protocol:

1. Tentative CHs that do not become final CHs leave some uncovered nodes. Based on implementation of HEED, these nodes are forced to become a CH and these forced CHs may not have any member associated with them or may be in range of other CHs. As a result, more CHs are generated than the expected number and this also responsible for unbalanced energy consumption in the network.
2. Similar to LEACH, the clustering in each round imposes significant overhead in the network. This overhead causes remarkable energy dissipation which results in reducing the network lifetime.
3. HEED suffers from a subsequent overhead since it needs several iterations to form the clusters. Therefore at iteration, a lot of packets are broadcasted.
4. Some CHs, particularly near the sink, have huge workload and might die earlier

12. H-HEED : Harneet Kour and Ajay K. Sharma, 2010 discuss about the H-HEED protocol. This protocol is basically used in heterogeneous wireless sensor network. H-HEED protocol is employed to enhance the network life [2]. The impact of heterogeneity in terms of node energy in wireless sensor network has been stated. HHEED (Heterogeneous Hybrid Energy Efficient Distributed) is the revised and improved version of the HEED protocol in terms of non-homogeneity. Here the cluster head is chosen based on the fraction of residual energy to the utmost energy possessed by the sensor nodes. Head to head communication takes place and unlike energy leveled networks have been formed. The energy efficiency has been verified in terms of the energy needed for the transmission and reception of the data. Here the node substitution takes place in order to reenergize the network and to enhance the network life.

Advantages:

1. H-HEED protocol is superior and improved version of HEED protocol in terms of heterogeneous wireless sensor network

2. It is used to extend the network lifetime; network is re-energized by node replacement technique.

Disadvantages:

1. H-HEED can't work or out perform well in the homogenous environment as DEC protocol can do so.

B. Location-based or Geographical Protocols

Location based or geographical protocols is based on the location information of the sensor nodes to find out the most energy efficient path between a source node and the sink or the cluster head. Location information is usually made available to the nodes by the use of GPS devices as it gives very accurate information about location but imposes an additional cost per node.

1. GAF: Geographic Adaptive Fidelity (GAF) [18]proposed by Y. Xu et. al. forms a virtual grid where each node is associated with a point on the virtual grid by exploiting its GPS-indicated position information. GAF tries to reduce energy consumption by switching some nodes to their sleeping states provided that some equivalent nodes are kept active. Figure 4, which is redrawn from [18], depicts the idea. Here, node 2, 3 and 4 are considered to be equivalent as node1 can reach all of them which all can reach node 5.

2. GEAR: Geographical and Energy Aware Routing(GEAR) [19] complements the Directed Diffusion (DD)protocol by restricting the dissemination of interest messages to only a certain region rather than to the whole network as is the case with DD. This is possible in GEAR since it enables every node to possess the location information and remaining energy level of itself and its neighbors.

3. LEAR: Location Based Energy-Efficient Reliable Routing Protocol (LEAR) [20] proposed by Alasem et al. is based on the geographical positioning and clustering of the nodes. In LEAR, each node constructs a routing table based on the distances to its neighbors where distance is computed from the location information whiczis made available by GPS devices and published by each node to its neighbors. The core of the LEAR protocol is Enhanced Greedy Forwarding(EGF) algorithm which, unlike the greedy approach used by most other geographic routing protocols, selects the nearest node to the active node based on its distance which is a good attempt to minimize energy consumption. EGF is implemented by selecting only **the forward** nodes in the routing path on the way to the destination while pruning gall the nodes in the backward routine path which ultimately minimizes the number of hops to reach the sink thereby, significantly reducing energy consumption. Simulation result shows that LEAR significantly enhances network lifetime and through put over other reference protocols like LEACH or EGF [20]. But it bears the common drawbacks of geographical routing; i.e. extra cost for GPS devices.

C. Mobility-based Protocols

WSN, in most applications, consists of sensor nodes that are static. But in some cases, in order to have better connectivity, wider coverage or to support multiple missions, it is beneficial to equip the nodes with mobility feature having restricted movement within a few meters which in turn, causes the topology of the network to change frequently. Nevertheless, the sink in a WSN may also be mobile putting much more challenges to the problem of data routing. Therefore, the mobility-based protocols should be designed taking into consideration the mobility characteristic of the nodes as well as the sink. Popular mobility-based protocols like EAGRP [21] and LBDD [22] are discussed below.

1. EAGRP: Energy Aware Geographic Routing Protocol[21] first calculates the average distance between the source node and all its neighbors based on the location information of the nodes and then checks their energy levels. Finally, it selects the neighbor having energy level above a set threshold, having the maximum energy plus whose distance equal to or less than the calculated average distance among its entire neighbors.

2. LBDD: Line-based Data Dissemination (LBDD)protocol [21] addresses the fact that in a WSN there may be multiple sink moving randomly in the sensor field. LBDD, like other geographical protocols, assumes that each node has its own location information available to it either through the use of GPS devices or by some virtual coordinate system. Then it defines a virtual vertical line of a certain width intersecting the sensor field at them idle thereby, dividing the whole sensor field into two parts. The line itself is divided into groups. The nodes lying closer to the boundary of the line are termed as in-line nodes while the other nodes are referred to as ordinary nodes. LBDD forwards data towards sink in two phases [21]. When an ordinary sensor node generates some new data, it forwards the data to the nearest inline node. Whenever a sink wishes to retrieve a specific data, it sends a query towards the line in a perpendicular fashion. The first in-line node receiving the query propagates it in both directions along the perpendicular line until the inline node that owns the data is reached.

V. COMPARATIVE STUDY

LEACH, TEEN, APTEEN and PEGASIS have identical features and their architectures are to some extent similar. They have fixed infrastructure. LEACH, TEEN, APTEEN are cluster based routing protocols, whereas PEGASIS is a chain-based protocol. The performance of APTEEN lies between TEEN and LEACH with respect to energy consumption and longevity of the network. TEEN only transmits time-critical data, while APTEEN performs periodic data transmissions. In this respect APTEEN is also better than LEACH because APTEEN transmits data based on a threshold value whereas LEACH transmits data continuously. Again PEGASIS avoids the formation of clustering overhead of LEACH, but it requires dynamic topology adjustment since sensor energy is not tracked. PEGASIS introduces excessive delay for distant nodes on the chain. The single leader can become bottleneck in PEGASIS. PEGASIS increases network lifetime two-fold compared to the LEACH protocol.

GEAR limits the number of interests in Directed Diffusion by considering only a certain region rather than sending the interests to the whole network. GEAR thus complements Directed Diffusion and conserves more energy. GAF performs at least as well as a normal *ad hoc* routing protocol in terms of latency and packet loss and increases the lifetime of the network by saving energy. Since the sensor networks are application specific, we can't say a particular protocol is better than other.

VI. CONCLUSIONS AND FUTURE RESEARCH

The main goal of a routing protocol design is to provide energy efficiency and extend network lifetime. Sensor nodes are susceptible to a number of routing attacks depending on the nature of the WSNs, the limited memory resources and energy constraints. In order to provide security in WSNs and mitigate the security threats to routing protocols, secure routing protocols to be used. In this paper, some secure cluster based routing protocols are reviewed and analysed. The comparative study show that some selected schemes can well balance between security level and the associated energy consumption overhead. An informative overview of protocols is given and their advantages and disadvantages are listed. A detailed comparison based upon various criteria is also analysed in the analysis section. Further, research would be needed to address issues related to secure routing under the mobility for resource constrained WSN. The study may help to orient the development of future proposals well adapted in the area of security issues in routing protocols for WSNs.

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