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Review on Energy Efficient Using Clustering Algorithm for Wireless Sensor Networks

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***Abstract*--The area of wireless sensor networks (WSNs) is one of the emerging and fast growing fields in the scientific world. This has brought about developing low cost, low-power and multi-function sensor nodes. However, the major fact that sensor nodes run out of energy quickly has been an issue and many energy efficient routing protocols have been proposed to solve this problem and preserve the long life of the network. WSN consisting of a large number of sensor nodes is effective for gathering data in a variety of environments. Since the sensors operate on battery of limited power, it is a challenging task to design an efficient routing scheme which can minimize the delay while offering high energy efficiency and long network lifetime. Achieving both energy efficiency and scalability at the same time is a challenging task in wireless sensor networks. This is very crucial to ensure that the system operates at minimum energy with increasing scalability and network life-time.**

***Keywords:*--Wireless sensor networks (WSNs), energy efficiency, network lifetime, scalability, clustering algorithm, hierarchy.**

I. INTRODUCTION

In these days, wireless sensor network emerging as a promising and interesting area. Homogeneous and Heterogeneous nodes are used in wireless sensor network where a wireless medium is used by the nodes to communicate with each other. A hundred to thousands of nodes can be deployed in the sensing region to sense the environment. These nodes work cooperatively and send information to the sink. Figure 1 shows the basic architecture of WSN. Wireless sensor network can be categorized into two types first Unstructured WSN- The nodes are densely deployed and also the nodes can be deployed in ad-hoc manner in the sensing area or region. Second is Structured WSN – Sensor node developments of some or all nodes are preplanned. The nodes placement is also planned. So, the maintenance of structured WSN is much easy as compare to Unstructured WSN [1].

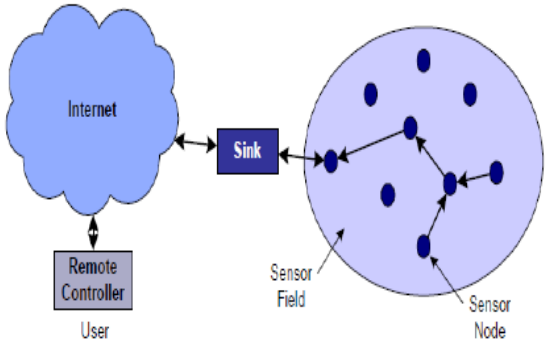
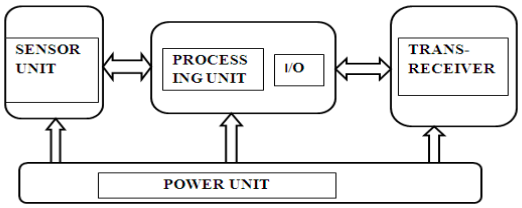


Figure1. Basic architecture of wireless sensor networks [2]

Sensor nodes work cooperatively to monitor environment conditions such as temperature, sound, vehicular movement, pressure and pollutants. The sensor nodes are deployed in the sensing area through wireless links which provide opportunities for many civilian and military applications, for example intrusion detection, battlefield monitoring and availability of equipments, environment observation and home intelligence.

Basically a sensor node is made by four components a sensing unit, a processing unit, a communication unit, a power unit. Figure 2 shows the sensor node. A sensing unit is made up of one or many sensors and analog to digital convertor. Where the sensor nodes sense the physical phenomenon and generate the analog signal. Than the ADC convert these analog signal in digital signals which are sensed by the sensors. After the conversion of the signals they are fed into processing unit. The processing unit has limited memory (storage) and processor (microprocessor) provides full control

to sensor nodes. A communication unit use radio for data transmission bandwidth nodes. The most important component or unit of a sensor node is power unit which supply power to the nodes. There can be more components or units can be added to the sensor node, depending on different applications.



Figure

Figure2. wireless sensor node

In some specific application where we need the location information, there we use global positioning system (GPS) in

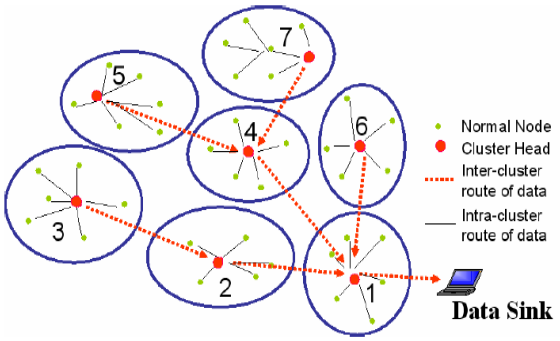


Figure 3. Clustering process in WSN[2]

II. ENERGY EFFICIENCY IN ROUTING

More research works have already been done in routing in WSN, since energy efficiency is more important for wireless sensor networks than any other networks. In wireless communication, data transmission consumes more power than data processing. The battery power of the node will be reduced whenever they transmit more number of data proportionately. In order to reduce the data size we can prefer techniques like data fusion or aggregation. Data fusion is that in which the sensed data are fused at certain point for transmitting data at reduced size. There are two types of aggregation in which the first type of data aggregation will data gathered from different sources will be fused and sent in reduced size. But the problem is, it lacks in precision and accuracy of data from various sensor nodes. In the second method both the data nodes. Some specific applications need to move the sensor nodes, than the motor can be used as a component or unit in a node. These units should be small so that power consumption will be less. The sensor nodes are grouped called clustering. When the sink is far away from the sensing region then the local aggregation is much better than direct communication. Thus clustering works efficiently in those conditions or environments which aggregates the nodes into clusters. There is only a one cluster head for a cluster. Cluster heads can be chosen by sink or members of the clusters. Cluster heads serve as relays for transmitting the data to the sink. The cluster head of the cluster have the same transmission capacity as the sensor nodes. Data aggregation at cluster head reduces the number of data transmission to the sink and improves energy efficiency and lifetime of the network. Figure 3 shows basic clustering process in wsn.

under the single header are combined together and forwarded to the base station. Here header packets consolidates and pass it to the base station without any modification to the original data from the sensors. Thus accuracy can be improved.[3]

In order to prolong the lifetime of the WSN, designing efficient routing protocols is critical. It has been established that most of the energy consumption in a WSN comes from data reception and transmission. A good routing protocol therefore can reduce the number and size of unnecessary transmissions that take place, thus helping alleviate the energy crisis in WSNs. Hierarchical routing algorithms are techniques with special advantages related to scalability and efficient communication. The main aim of hierarchical routing is to optimize energy consumption of sensor nodes by arranging the nodes into clusters. Data aggregation and fusion is performed within the cluster in order to decrease the number of transmitted messages.

III. ENERGY EFFICIENT HIERARCHICAL ROUTING

Among the issues in WSN the consumption of energy is one of the most important issues. Regarding energy efficiency Hierarchical routing protocols are found to be the best. By the use of a clustering technique they minimize the consumption of energy greatly in collecting and disseminating data. Hierarchical routing protocols minimize energy consumption by dividing nodes into clusters. In each cluster, a node with more processing power is selected as a cluster head, which aggregates the data sent by the low-powered sensor nodes.[4]

The primary motive of hierarchical routing is to maintain the consumption of energy by sensor nodes as an efficient one through multi-hop communication that too in a particular cluster, by doing fusion and data aggregation to decrease the number of transmitted messages to the sink. Formation of cluster is mainly based on the sensors energy reserve and proximity to the cluster head.[5]

The set of aspects that are used to differentiate all lustering based protocols are discussed below

A. Clustering Method

The three approaches are used for clustering process are centralized, distributed and hybrid. In centralized clustering, the clusters and cluster heads are made by an authority (centralized authority). In distributed clustering, all the nodes in the clusters can took the decision of becoming cluster head for the current round. Hybrid clustering is the mixture of both of above.

B. Cluster Properties

In clustering process, following properties are used in the structure of the cluster.

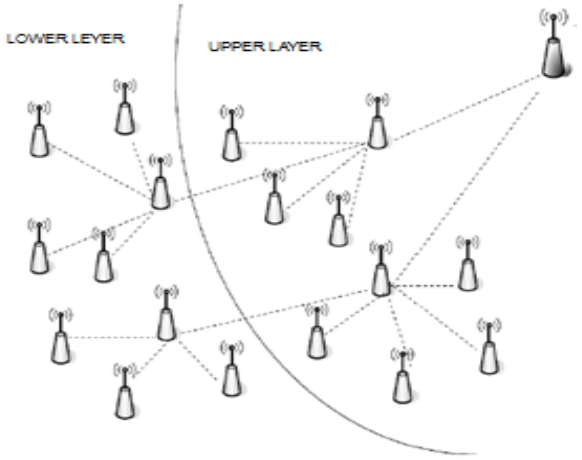


Figure 4. Hierachical routing scheme[2]

1) Cluster Count: Cluster heads can be pre assigned for fixed clusters or cluster heads can be elected by its cluster members for variable number of clusters. Cluster count can be defined as number of clusters formed in a round. Small size cluster distribution can be better to conserve energy in wireless sensor network.

2) Cluster Size: Cluster size is the maximum distance between the sensor (member) nodes and cluster head. Cluster size can be fixed for fixed clusters or it can be variable for each cluster. Large sized clusters are not good in term of energy consumption because it maximizes transmission distance.

3) Cluster density: Cluster density is proportion of number of cluster member in cluster and cluster area. In fixed clustering approach, there is density of cluster where as in dynamic clustering the cluster density is variable. So it is a big challenge to conserve energy of cluster heads in dense clusters.

4) Message count: The number of message transmissions is required for a cluster head selection is called as message count. The cluster heads are chosen using message transmission in many non probabilistic algorithms. If message transmission number is more for a cluster head than the energy consumption also increases.

5) Stability: During the clustering process if cluster counts are not varied than it is called fixed. But if the cluster counts varied during clustering process than that is called as adaptive. Fixed cluster count gives more stability to the WSN's.

6) Intra-cluster Topology: The communication between the cluster head and the sensor (member) nodes can be direct or multi-hop. This depends upon the sensor node's range of transmission. If the communication range of sensor node is very high than the node can direct communicate with cluster head (CH). But if the transmissions range of the node is low than the node can communicate with CH using multi-hop.

7) Inter-cluster head connectivity: The procedure indicates the communication between the CH and the base station (BS). CH has some range or capability to connect to the BS. But if CH have not that capability than clustering scheme has to ensure some intermediate provision of routing to base station.

C. Cluster-head Capabilities

The capabilities of cluster heads during clustering process play very important role. The capabilities of CH's can influence the clustering process in terms of stability and life time of sensor network. Following are some aspects for differentiating the clustering process.

1) Node Type: Some nodes are pre chosen as cluster heads at the time of sensor nodes deployment for that round only depends upon their energy and computation resources.

2) Mobility: Mobile CH can be used for balancing the cluster which gives the better network performance. Mobility

of CH's in the network cane assigned on the basis of objectives defined in clustering scheme. If there is any need in the network than mobile cluster heads can be re-locatable easily.

3) Role: The role of CH's in the network is to collect the information from sensor nodes, aggregate that information and send to the base station.

D. Cluster-head Selection

Cluster heads can be pre assigned or chosen randomly from deployed sensor network. Following are the two ways to select the cluster head.

1) Probability Based CH Selection: In probability based clustering algorithm, each sensor node in the network uses pre assigned probability to determine the initial cluster heads. Probability can be the maximum energy of the sensor nodes.

2) Non Probability Based CH Selection: In non probability based clustering algorithm, the cluster heads selection is based on sensor nodes proximity, connectivity and degree.

IV. DIFFERENT CLUSTERING ALGORITHM IN WSN

A. LEACH

W. R. Heinzelman, A. P. Chandrakasan and H. Balakrishnan [9] proposed Low Energy Adaptive Clustering Hierarchy (LEACH) protocol in 2000. It is one of the most popular hierarchical routing algorithms for sensor networks. The idea is to form clusters of the sensor nodes based on the received strength of the signal and use local cluster heads as routers to the BS. This will save energy since the transmissions will only be done by such cluster heads rather than all sensor nodes. Optimal number of cluster heads is estimated to be 10 percent of the total number of nodes. All the data processing such as data fusion and aggregation are local to the cluster

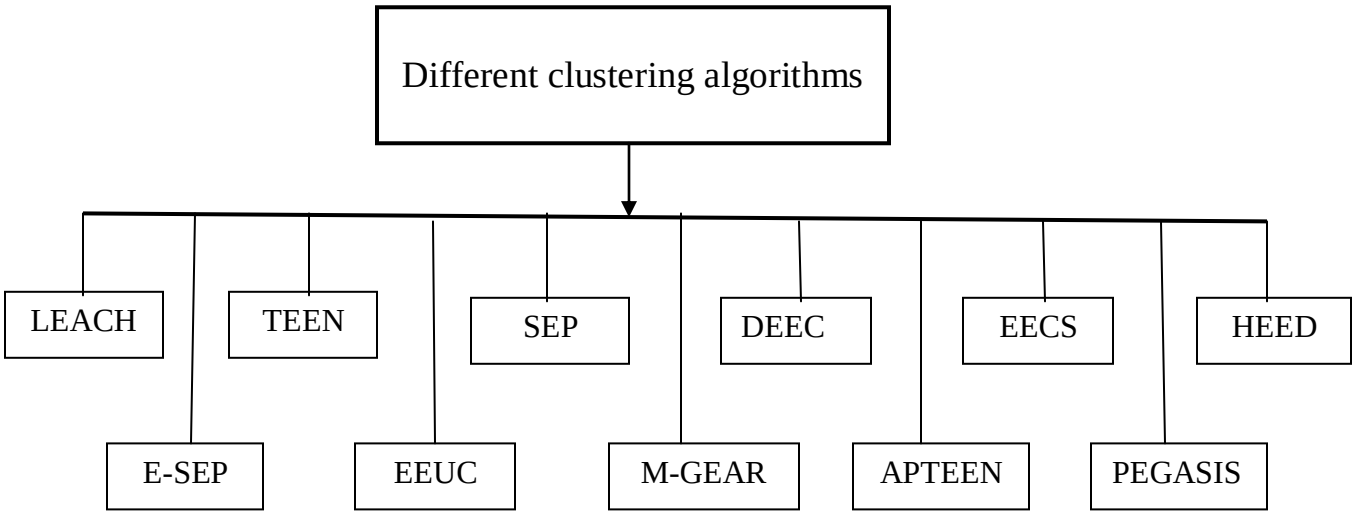
Cluster heads change randomly over time in order to balance the energy dissipation of nodes. This decision is made by the node choosing a random number between 0 and 1. The node becomes a cluster head for the current round if the number is less than the following threshold

$$T(n) = \frac{p}{1 - p * \left(\frac{1}{p}\right)}, \quad n \in G$$
$$= 0 \quad ; \text{Otherwise} \qquad (1)$$

Where p is the desired percentage of cluster heads (e.g. 0.1), r is the current round and G is the set of nodes that have not been cluster heads in the last 1/p

rounds. However the limitations of Leach protocol are that it uses single-hop routing within cluster and thus not applicable to networks deployed in large regions, dynamic clustering brings extra overhead, assumes all nodes can transmit with enough power to

reach BS, if necessary (e.g., elected as CHs), Each node should support both TDMA and CDMA, failure of cluster head is a problem and cluster head selection is a difficult problem to optimize. However LEACH is only effective for homogeneous network as it sets same probability of becoming cluster head to all sensor nodes.



Consequently, a number of enhancements to the conventional LEACH routing protocol have been proposed and is summarized. In Centralized LEACH (LEACH-C) [10] location of the nodes is sent to the BS, which then selects CHs for each round. No. of CHs is fixed to a predetermined value. The BS utilizes global knowledge of the network to produce better clusters that require less energy for data transmission.Balanced-LEACH protocol (LEACH-B) [11] a adaptive strategy is designed whereby each node chooses its CH evaluating the energy dissipated in the complete path between itself and the final receiver, passing by the CH. It performs well when the final receiver is closer to the sensors. In Two-Level LEACH (TL-LEACH) [12] two level hierarchy of CHs are formed. The secondary CH collects data from the cluster members and relays the data to the base station through a primary CH that lies between it and the BS. Here better distribution of the energy load among the sensors in dense networks. In Multi-hop low energy adaptive clustering hierarchy (MH-LEACH) [13] the CHs away from the sink, sends data to the sink using the other CHs as relay stations. It improved throughput. In Advanced-solar aware- Low energy adaptive clustering hierarchy protocol (A-s LEACH) [14] all nodes are considered to be solar powered having battery power as backup, where CHs initially selected by BS, chooses the next CHs after a certain time called round. Here enhanced data aggregation by FIFO priority scheme and collision minimized non-persistent Carrier Sense Multiple Access (CSMA).

B. PEGASIS

S. Lindsey and C. Raghavendra [15] introduced Power Efficient Gathering in Sensor Information Systems (PEGASIS) protocol in 2002. It is an improved version of LEACH protocol. Instead of forming clusters, it is based on forming chains of sensor nodes. One node is responsible for routing the aggregated data to the BS. Each node aggregates the collected data with its own data and then passes the aggregated data to the next ring. The difference from LEACH is to employ multi hop transmission and selecting only one node to transmit the data to the sink or base station. Since the overhead caused by dynamic cluster formation is eliminated, multi hop transmission and data aggregation is employed, PEGASIS outperforms the LEACH. However excessive delay is introduced for distant nodes, especially for large networks, where single leader can be a bottleneck.

C. TEEN

In 2001, A. Manjeshwar and D. P. Agarwal [16] proposed Threshold sensitive Energy Efficient sensor Network Protocol (TEEN) protocol. Closer nodes form clusters, with cluster heads to transmit the collected data to one upper layer. Forming the clusters, cluster heads broadcast two threshold values. First one is hard threshold; it is minimum possible value of an attribute to trigger a sensor node. Hard threshold allow the nodes to transmit the event, if the event occurs in the range of interest. Therefore a significant reduction of the transmission delay occurs. Unless a change of minimum soft threshold occurs, the nodes don't send a new packet of data. Employing soft threshold prevents from the redundant data transmission. Since the protocol is to be responsive to the sudden changes in the sensed attribute, it is suitable for time-critical applications.

D. APTEEN

A. Manjeshwar and D. P. Agarwal [17] proposed Adaptive Threshold sensitive Energy Efficient sensor Network Protocol (APTEEN) protocol in 2002. The protocol is an extension of TEEN aiming to capture both time-critical events and periodic data collections. The network architecture is same as TEEN. After forming clusters the cluster heads broadcast attributes, the threshold values along with the transmission schedule to all nodes. According to energy dissipation and network lifetime, TEEN gives better performance than LEACH and APTEEN, because of the decreased number of trans- missions. The main drawbacks of TEEN and APTEEN are overhead and complexity of forming clusters in multiple levels, implementing threshold-based functions and dealing with attribute based naming of queries.

E. SEP

In 2004, G. Smaragdakis, I. Matta and A. Bestavros proposed Stable Election Protocol (SEP) [18]. This protocol is an extension of LEACH. It is a heterogeneous aware protocol, based on weighted election probabilities of each node to become cluster head according to their respective energy. This approach ensures that the cluster head election is randomly selected and distribution is based upon the fraction of energy of each node, which assures a uniform use of the energy. In this protocol, two types of nodes (two tier in-clustering) and two level hierarchies were considered. CHs selecting probability for normal nodes is

$$p_{nrm} = \frac{p_{opt}}{(1+m.\alpha)} \quad (2)$$

and for advanced nodes

$$p_{nrm} = p_{opt} \cdot \frac{1+\alpha}{1+m.\alpha} \quad (3)$$

Where p_{opt} is the optimal probability of each node to become CH. The idea is that the advance nodes have to become the CHs more often than normal nodes. SEP gives better result as the value of α and m will increase.SEP maintains the constraints of well-balanced energy consumption.

As initially, advanced nodes have to become the CHs more often than normal nodes. Thus, SEP yields longer stability region by utilizing the extra energy of more powerful nodes. But the main drawback 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. SEP sets two probabilities based on only nodes initial energy. But the possibility in SEP is that after certain rounds an advanced node might become normal node due to more energy consumption. In such conditions, SEP selects low energy node as a maximum probability of being cluster heads SEP is only aware of nodes initial energy.

F. E-SEP

The extension of SEP, Femi A. Aderohunmu and Jeremiah D. Deng proposed E-SEP [19] in the year of 2009.E-SEP considers three types of nodes, normal nodes, intermediate nodes and advance nodes. Where, advance nodes are in a fraction of total nodes with an additional energy as in SEP and a fraction of nodes with some extra energy greater than normal nodes and less than advance nodes, called intermediate nodes, while rest of the nodes are normal nodes. As in SEP, the initial energy for normal nodes is E_o, and for advanced nodes is (1+α).E_o. E-SEP added another set of initial energy nodes i.e. E_{int} as (1+μ). E_o, where μ=α/2. Like SEP, in E-SEP CHs are selected depending on probability of each type of node. However, energy dissipation is controlled to some extent due to three levels of heterogeneity. ESEP has same drawbacks as SEP. For selecting CHs it also set the probability based on nodes initial energy. E-SEP also does not consider residual energy of nodes.

Other extension of SEP protocols is ASEP-E [20], Z-SEP [21], T-SEP [22] and H-SEP [23]. In ASEP-E, four types of nodes have been considered for assigning the probability of each type of nodes.. Z-SEP is zone based clustering algorithm where the advance nodes only have the probability to become a cluster head.. T-SEP is threshold based SEP, uses three level of heterogeneity. As in T-SEP the CHs selection is done based on threshold value, it decreases the throughput due to threshold sensitivity. H-SEP is heterogeneous aware protocol to minimize transmission cost between CH and BS. In H-SEP selection of cluster heads cannot be done in a distributive way.

G. DEEC

In 2006, Q. Li, Z. Qingxin and W. Mingwen [24] proposed Distributed Energy Efficient Clustering Protocol (DEEC) protocol. This protocol is a cluster based scheme for multi level and two level energy heterogeneous wireless sensor networks. In this scheme, the cluster heads are selected using the probability based on the ratio between residual energy of each node and the average energy of the network. The epochs of being cluster- heads for nodes are different according to their initial and residual energy. The nodes with high initial and residual energy have more chances to become the cluster heads as compared to nodes having low energy. The main disadvantage of DEEC is advanced nodes are always penalized, particularly when their residual energy reduced and become in the range of the normal nodes. In this position, the advanced nodes die rapidly than the others.

H. EECS

In 2005, M. Ye, C. Li, G. Chen and J. Wu [25] proposed Energy Efficient Clustering Scheme (EECS) protocol. It is novel clustering scheme for periodical data gathering applications for wireless sensor networks. It elects cluster heads with more residual energy through local radio communication. In the cluster head election phase, a constant number of candidate nodes are elected and compete for cluster heads according to the node residual energy. The competition process is localized without iteration. Further in the cluster formation phase, a novel approach is introduced to balance the load among all cluster heads. But on the other hand, it increases the requirement of global knowledge about the distances between the cluster-heads and the base station.

I. HEED

In 2004,O Younis, S Fahmy proposed HEED: A hybrid, energy-Efficient, distributed clustering approach [26]. HEED is a multi-hop clustering algorithm for wireless sensor networks, with a focus on efficient clustering by proper selection of cluster-heads based on the physical distance between nodes. Cluster construction in HEED Reference2is performed based on two parameters- the node's residual energy, and intra-cluster communication cost. In HEED, elected CHs have relatively high average residual energy. Moreover HEED aims to provide evenly distributed CHs throughout the network. CHs send the aggregated data to the

BS in a multi-hop fashion rather than single-hop fashion of LEACH. Similar to LEACH, the performing of clustering in each round imposes significant overhead in the network. This overhead causes noticeable energy dissipation which results in decreasing the network lifetime. As per HEED implementation, these nodes are forced to become a CH and these forced CHs may be in range of other CHs or may not have any member associated with them. As a result, more CHs are generated than the expected number and this also accounts for unbalanced energy consumption in the network .

J. EEUC

In 2005, C. Li, M. Ye, G. Chen and J. Wu proposed An energy-Efficient unequal clustering mechanism for wireless sensor networks [27].EEUC is designed for periodic data gathering applications in WSN. According to this scheme the nodes in one region compete to become CH in such a way that the node's competition range decreases as its distance to the base station decreasing. Thus the nodes closer to the BS consume less energy for intra cluster routing and can utilize it for inter-cluster routing. Energy consumed by cluster heads per round in EEUC much lower than that of LEACH standard but similar to HEED protocol.

V. COMPARATIVE STUDY

In this section, we compare between routing protocols covered in this survey. Table 1 summarizes the classification of the hierarchical cluster-based routing protocols by stating its strength points and limitations. It is obvious that there are wide number of researches were conducted for homogeneous networks where all nodes consume energy at same level, while there are few researches were developed for some heterogeneous networks where some nodes are supported with more capabilities and are assigned with more responsibilities such as data gathering and forwarding. Hence the consumed energy level is not equal among all nodes. The main advantage of homogeneous over heterogeneous protocols is the formulation of approximately balanced clusters partition in network, while heterogeneous overcomes homogeneous protocols in terms of increasing reliability, lifetime, and decreasing network latency. Since real world applications may require different capability-supported sensors to develop network reliability and prolong network lifetime, researches should be oriented towards heterogeneous networks. In the homogeneous WSNs, most of proposed single-hop protocols are based on LEACH protocol and have sought to overcome the drawbacks that it suffers from, such as wasting energy during CH-selection phase, unbalanced clusters, and consuming a large amount of energy if the CHs are located far away of the sink. Many of protocols that have been suggested to improve LEACH protocol suffer from the same problems in addition to an extra overhead of forming clusters and then selecting CHs.

On the other hand, multi-hop routing protocols were suggested to improve LEACH protocol by reducing the energy consumption due to long-distance direct transmission. However, many of these specified protocols suffer from hotspots, delay, overhead, in addition to limited scalability. Single-hop heterogeneous protocols achieve more reliability and less delay compared to multi-hop heterogeneous protocols. This can be explored by the number of hops required to reach the sink.

Hence from above discussion we found that the hierarchical clustering based algorithm provide better results in its higher energy efficiency, network scalability, and lower data retransmission.

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TABLE 1. COMPARISION OF SELECTED PROTOCOLS

Protocol Name	Cluster Stability	Delivery Delay	Scalability	Load Balancing	Advantages
LEACH	Medium	Very Small	Very low	Medium	Energy saving
TEEN	High	Small	Low	Good	Energy saving
SEP	Medium	Very small	Medium	Good	Network lifetime
DEEC	High	Very small	High	Good	Energy saving
HEED	High	Medium	Medium	Medium	Energy saving

APTEEN	Very low	Small	Low	Medium	Network lifetime
PEGASIS	Low	Very large	Very low	Medium	Energy saving , network lifetime

VI. PROBLEM STATETMENT

There is a situation of clustering where each node sends data to the CH and then the CH performs aggregation on the received raw data and then sends it to the BS. This approach consumes a substantial amount of energy which needs to be improved upon. Thus, the problem can be formulated as: How can we improve network-lifetime & energy efficiency in Wireless Sensor Network using the hierarchical routing technique ?

VII. CONCLUSION

Hierarchical cluster-based routing protocols are considered as one of the most efficient routing protocols in wireless sensor networks (WSN) due to its higher energy efficiency, network scalability, and lower data retransmission.

In this paper we have surveyed the past research works which mainly focuses on energy efficient clustering based routing protocols for wireless sensor networks and we have Systematically analyzed a few classical WSN clustering routing protocols in deep, and compared these different approaches based some primary metrics. Hence we finding better performance in it higher energy efficiency, better scalability and lower data retransmission using the hierarchical clustering algorithm. We have also discussed the fundamental concept of wireless sensor network, clustering, clustering type, clusters property and cluster- heads capabilities.

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