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A Study of Power and Energy Efficient Clustering Protocols in Wireless Sensor Networks

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Abstract: ***Clustering plays a vital role in any wireless sensor network (WSN). By adapting clustering in WSN the performance of the WSN can be improved. Performance is related to amount of power and energy consumed in any WSN. These two parameters are interlinked with the lifetime of the WSN. If a WSN consumes less power means, the energy stored in the sensor node (SN) has been maintained for longer time. Clusters create hierarchical WSN, which incorporate efficient utilization of limited resources of sensor nodes thus extends network life time. The energy that is stored in the battery of the SN decreases when more amount of power is consumed by the SN. So care has to be taken by considering these parameters while designing the WSN. In this paper, power and energy efficient clustering protocols are discussed***

Keywords: Wireless sensor Network (WSN), Sensor Node (SN), Cluster Head (CH), Clustering algorithms (CA), Life time (LT), LEACH, PEDAP, PEGASIS, HEED, EECS.

I. INTRODUCTION – SENSOR NETWORK

Sensor networks are collection of sensor nodes which co-operatively send sensed data to base station [2]. A sensor network is composed of a large number of sensor nodes which are densely deployed either inside the location where the operation is being performed or very close to it [3]. A WSN is also called as intelligent distributed sensor system, which consists of small sensor nodes that act as information collectors and one or more processing centres connected via wireless links [5]. WSN have limited computational power and limited memory and battery power. Because of these characteristics more care has to be taken by the developers to develop a particular sensor network [2]. Each cluster contains a cluster-head and several non-cluster head nodes [11]. Power consumed by the WSN is mainly due to network dynamics, node capabilities, data delivery model, energy consideration, data aggregation and network deployment [19]. Basically the WSNs are classified into two types as Homogeneous WSN and Heterogeneous WSN. This classification is based on the characteristics of sensor nodes present in the cluster. The nodes present in the homogeneous WSN have identical characteristics and they are identical in nature. Due to this nature, all the nodes perform same type of functions. Heterogeneous WSN are the networks which consists of sensor nodes (SN) having two or more types of nodes and characteristics. The operation of the individual nodes differs depending on the nature of the characteristics of SNs. Some nodes perform sensing operation; some performs filtering operation, while others perform fusion of data and transfer of data to the base station [29]. In single –hop sensor network, the sensor nodes use single hopping in order to reach cluster head]. In multi-hopping, the sensor nodes use multi-hopping in order to reach cluster head [14]. In the multi-hopping sensor network, because of the relaying operation of passing the information from the far away sensor nodes to the nodes that are very close to the cluster head more energy has to be spend.

The lifetime of the network is extended in terms of rounds. A round is defined as the process of gathering all the data from sensor nodes to the base station regardless of how much time it makes [18]. Two desirable characteristics are there in any WSN.

They are uniform energy drainage and lower hardware cost. Uniform energy drainage is being achieved by homogeneous WSN, and the lower hardware cost is being achieved by heterogeneous WSN.

Energy usage is an important issue in the design of WSNs which typically depends on portable energy sources like batteries for power [10]. Energy consumption in the clustering is measured as a fraction of total energy dissipated in the network [9]. Two types of energy consumptions are there in WSN. They are due to useful sources and wasteful sources. The useful energy consumption is due to transfer of data between source and destination, attending the queries made by other nodes, conveying the information/data to nearby nodes. Wasteful energy consumption is due to collision of data between the nodes. When collision of data between the nodes occurs, unnecessarily the packets have to be retransmitted to the destination once again [27]. Energy efficiency and hardware complexity plays a vital role in designing the WSN [14]. Energy efficiency in the WSN can be achieved by considering energy conservation mechanism, power conservation mechanism, energy harvesting mechanism, and energy efficient routing [10].

The power source of the sensor node is battery (<0.5 Ah, 1.2V). Two types of functions have been done by each sensor node. They are data generation function and transferring the data from the sensor nodes to the base station. During the transfer of data from one node to another, when one or more nodes are not performing properly, then the rest of the nodes have to select the new route topology. Due to this selection of new route, more amount of power has been consumed. Therefore power management plays a vital role in any WSN. The power consumed by the SNs can be analysed under three major areas. They are sensing the information, transferring the sensed information to the processing centre and finally the data that is present in the centre has been analysed for further processes. The amount of power consumed by the SN depends on the nature of that application [3]. The rest of the paper is organized as follows. The sensor nodes, their types and characteristics are discussed in section II. A type of clustering and cluster head selection is discussed in Section III. In section IV classification of clustering algorithms and power and Energy efficient protocols like PEGASIS, LEACH, TL-LEACH, FZ-LEACH, HEED, EECS are described. In section V observations of the above said protocols are discussed. In Section VI concluding remarks are given.

II. SENSOR NODES

Wireless sensors are small in size. The processing and computing resources are also small. The sensor nodes are randomly deployed [3]. It is possible for these nodes to sense, measure and collect information from environment and they transmit the sensed data to the user. In order to reduce the number of messages that can be transferred to the base station data aggregation has been adopted. The network performance is improved when the nodes that are present in that particular network are grouped in the form of clusters. Sensor nodes are small in size and it consists of sensing, data processing and communicating components [3]. The data being sensed by the nodes in the network must be transmitted to a control centre or base station where end user can access the data [7]. The base station is fixed and located far from the sensors [7]. Communication capability and energy storage capability of the sensor nodes are very limited because of limited power supply [11]. Sensor nodes are prone to failure [4].A sensor node is resource constraint [5]. Power in each node will be depleted very quickly if each node in that cluster sends its data or information directly to the base station [13].

The parameters to estimate the location of node are Angle of Arrival (AOA), Time of arrival (TOA) Difference of arrival (DOA), time difference of arrival (TDOA) and received signal strength indicator (RSSI). The purpose of angle of arrival is to identify the direction from which the signal is received. The purpose of the TOA is to identify at what time the signal reaches the cluster head, whether the signal reaches in time or delayed. The RSSI indicate the location of the node in the cluster. If the node is very close to the cluster head then, the signal strength of that node is very strong. And if that node is far away from the cluster head then, the signal that reaches the cluster head is very weak in nature [16]. The Clustering improves the lifetime of the sensor nodes that are deployed randomly [15].The efficient reuse of the shared channel has been done with the help of clustering [20].

III. CLUSTERS

Purpose of clustering is to reduce the central coordination between the nodes. Clusters are the organization unit for Wireless sensor networks (WSN). The dense nature of these networks requires the need for them to be broken down into clusters to simplify tasks such as communication [9]. Clustering can be done in order to enhance the network life time. WSN are deployed in an Ad-Hoc manner and have large number of nodes [15]. Communication bandwidth can be conserved due to clustering; the size of the routing table can be reduced with the help of clustering. Topology maintenance can be cut because of clustering. The energy consumption can be reduced due to scheduling activities in the cluster, The battery life of the individual sensors and network can be extended due to clustering [21].The design attributes to be considered for clustering are number of clusters, intra-cluster communication, nodes and CH mobility, node types and roles, cluster head selection, multiple levels, overlapping [22].The issues in clustering the sensor networks are connectivity, rotating the role of cluster heads, MAC layer design, node duty cycle, optimal cluster size, node synchronization [15]. The collected data is fused each time when it travels from one node to another node [18]. The cluster density is defined as the expected number of cluster per unit area [17]. Performance parameters for evaluating clustering protocols are, Network life time, number of cluster heads per round, number of nodes per round, throughput [21].The life time(LT) is limited by the battery energy. Because of this lifetime variation, the quality of the sensor nodes has also varied [18]. LT of the WSN can be maximized if the total energy consumed along the path is minimized.

The LT of the nodes can be extended when the nodes are grouped as clusters. Each cluster has a coordinator referred to as cluster head and the number of nodes. The cluster head acts as a local coordinator for that particular cluster [20]. The cluster heads then form another group of nodes. In that group, the cluster heads from various clusters elect one cluster head. This new cluster head receive the information from the cluster heads in all the clusters. Finally only one cluster head send the information to the base station. These nodes are typically unaware of their locations [15]. Cluster order is the number of nodes that belongs to a cluster [17]. The cluster may be homogeneous if all the nodes forming the cluster possess same characteristics, and if the nodes have different characteristics then that type of clusters are said to be heterogeneous clusters. The information gathered by the cluster head in the clustering is communicated to the data processing centre [12]. Two nodes are denoted as neighbours if they have a direct wireless link between each other. The number of neighbours of a node is denoted as its degree d [17]. The processing centre then analyses the information passed by the cluster head [12]. Several WSN applications require only an aggregate value to be reported to the observer. With the help of data aggregation, the life time of the WSN can be increased [15]. The consumption of power in a cluster depends on the distance between the two nodes. If the nodes are nearby, then less power is consumed. But at the same time, if the distance between the nodes is large, then more power has to be consumed by the respective node. In order to overcome this drawback, individual nodes are requested to pass the information gathered by that node to the nearby node in a relay manner [24].

Based on the selection of cluster head two types of clustering are there. They are static clustering and dynamic clustering. In static clustering once the selection of cluster head (CH) is over, then there is no change in the cluster head. That CH continues till it is alive. But in dynamic clustering the selection of cluster head takes place in every round. There are two phases in clustering. They are clustering set up and clustering maintenance. During the cluster set up phase, the nodes present in that group do not move from one location to another location. Reorganization of the clusters is done periodically due to the mobile nature of the node present in that cluster. Whenever reorganization of cluster process is going on, it is not possible for the network to rely on the cluster organization [20]. Cluster heads are the organization leader of a cluster [9]. They often are required to organize activities in the cluster. These tasks include but not limited to data aggregation and organizing the communication schedule of the cluster [9]. Large constraint is placed on the cluster head, because it is acting as a communication centre. Due to this, battery power of the cluster head is reduced very fast [19]. The cluster head is selected by the normal nodes present in the cluster, and then the cluster head directly communicates with the base station after collecting or

gathering the information from the normal cluster nodes. Selection of cluster head is based on the received signal intensity. It does not consider the distance from the node itself to the base station [11]. Two methods are there for conveying the information to the cluster head. They are aggregating method and non aggregating method. In aggregating method, the cluster head coordinator has to collect the information passed by the cluster heads, and then finally a consolidated data has been sent to the base station. Weather forecasting is an example for aggregation method. But in the non aggregating method, the information gathered by the sensor nodes is passed to the cluster heads. The cluster heads then convey the information to the base station immediately without consolidating the information. Disaster management sensor networks come under this non aggregation method category, because the information from the disaster area has to reach the base station immediately. Then only it is possible for the base station to take immediate steps to the corresponding situations. Selection of cluster head is important in order to reduce the power consumption and to improve the performance of a particular cluster. The nodes in the cluster convey the information when data arrives, to its nearby neighbour nodes, rest of the time the nodes may be in passive state. Thereby power consumed by the particular node may be reduced. In each round, one node is acting as cluster head (CH). Therefore, selection of the cluster head for every round may reduce the life time of that cluster [24].The cluster heads in the clusters send a strong beacon signal to all nodes in the cluster and nearby cluster also, now sensor nodes have to decide on which cluster the node has to be joined. This cluster selection by the node is done based on the received signal strength from the cluster head [13]. The purpose of cluster head is to act as a fusion points for aggregation of data. By doing this data aggregation, the data has to be reached to the base station is reduced [14]. The energy consumed by cluster head is more when compared to the non-cluster head nodes [11]. The parameters like remaining energy node degree are dynamic in nature. Due to this periodic clustering is needed [15]. There are several key attributes that designers must carefully consider they are, cost of clustering, selection of cluster heads, real time operation, synchronization, data aggregation, repair mechanisms, quality of service.

Care must be taken to design an algorithm in order to organize sensors in the clusters; thereby it is possible for us to reduce the energy consumed by the clusters. Clustering algorithms can be broadly classified as centralized and distributed clustering algorithms. Distributed clustering algorithm (DCA) uses weights associated with nodes to elect cluster heads .Weighted clustering algorithms (WCA) elects a node as a cluster head based on the number of neighbours, transmission power, battery life and mobility of the node [12]. Two types of clustering techniques are available. They are iterative clustering techniques and probabilistic clustering techniques [15].

Advantages of clustering are (i) with the help of clustering it is possible to reuse the resources. The system capacity will be increased by using these reuse characteristics, (ii) energy efficient routing protocols have been introduced by sharing the routing information to cluster heads or cluster gateways. The main purpose is to reduce the number of data transmissions between the sensor nodes and base stations [32].

A. Centralized clustering method

Clustering can be managed by the BS with the help of vector quantization (VQ) technique. In VQ techniques, two sets of vectors have been considered. They are large set of vectors (X) and small set of Vectors (W). The large set of vectors are represented by X = {x1, x2,….xv}, small set of vectors are represented by W = { w1,w2,…….wk} (in general the value of v>>k). xεX is represented as input vector and wεW is represented as weight vectors [37].

Centralized Clustering Algorithm (CCA)

Step 1: Active nodes convey the information about the battery level and its corresponding coordinates to the BS.
Step 2: VQ procedure is performed.
Step 3: Based on the weight and the battery level the CH has been determined.
Step 4: The nodes corresponding to the CHs have been assigned.
Step 5: Now BS has to convey the operation and other assignments to be performed to the corresponding CHs.

B. Distributed Clustering Method

In this method, the BS has to receive the information collected by the CHs. Here the each sensor node (SN) broadcasts its availability within its surroundings (nearby nodes) based on the information conveyed by the SN (the battery level, availability of the node to the nearby node, node ID) the CHs and other nodes belongs to that particular clusters have been determined autonomously [37].

DISTRIBUTED CLUSTERING ALGORITHM (DCA)

Four phases are there in DCA.
Phase 1: Broadcasting is being done by active nodes (ANs).
Phase 2: Nomination for CH is being done.
Phase 3: CH has been elected from the nominees given by the ANs.
Phase 4: Now a TDMA schedule has been prepared by the corresponding CHs and the same has been passed to the ANs in the appropriate clusters.

IV. CLASSIFICATION OF CLUSTERING ALGORITHM

Clustering algorithms can be classified under three types of schemes. They are heuristic schemes, weighted schemes, hierarchical schemes, grid schemes. The purpose of the Heuristic algorithm is to create a reasonable runtime for setting the cluster. This algorithm functions based on the performance of the particular cluster . Weighted scheme algorithm is based on the selection of the cluster head. This is a fully distributed algorithm. The selection of the cluster head is based on the combined weight of the individual nodes. According to this, the node with smallest combined weight is selected as cluster head. The performance of the hierarchical schemes is analysed in stage by stage manner. That is, the nodes transfer the information to the respective cluster heads; the respective cluster heads then passes the information to the cluster head coordinator. The cluster head coordinator then passes the fused information to the base station for further processing the information. By adapting this grid scheme, it is possible for us to improve the power, energy efficiencies of the particular clusters. Algorithms in heuristic schemes are further classified into linked cluster algorithm (LCA), linked cluster algorithm 2(LCA2), highest connectivity cluster algorithm, Max-Min D- cluster algorithm [9].In weighted schemes we have weighted clustering algorithm, cluster head election procedure, complexity due to distributiveness. In hierarchical schemes we have low energy adaptive clustering Hierarchy (LEACH), two level- low energy adaptive clustering Hierarchy TL-LEACH, Energy efficient clustering scheme (EECS), Hybrid- energy efficient distributed clustering (HEED) . In grid schemes we have power efficient gathering in sensor information systems (PEGASIS), Group [9].

Clustering algorithms can also be classified based on the functions performed in that clustering. They are probabilistic clustering algorithms, unequal clustering algorithms and fuzzy clustering algorithms. LEACH, PEGASIS comes under probabilistic clustering algorithms. The purpose of the probabilistic clustering algorithm is to elect the cluster head based on the probability (Random selection). Unequal clustering algorithms are adopted in order to reduce the drainage of the energy in the nodes that are very close to the base station. The size of the cluster plays a vital role in these algorithms. Energy efficient unequal clustering (EEUC) algorithm is a best example for this approach. In fuzzy clustering algorithms two types of clustering approaches are adopted. They are centralized approach and distributed approach. Some of the power and energy efficient clustering algorithms have been discussed below.

A. LOW ENERGY ADAPTIVE CLUSTERING HIERARCHY (LEACH) PROTOCOL

Low energy adaptive clustering hierarchy (LEACH) is a clustering based protocol that minimizes energy dissipation in sensor network. The purpose of the LEACH is to randomly select sensor nodes as cluster heads, due to this the high energy dissipation in communicating with the base station is spread to all sensor nodes in the sensor network [3]. Number of nodes that communicates directly with the base station has been reduced with the help of LEACH protocol [18]. In LEACH clusters are formed dynamically in each round and cluster head gather the data locally and then transmit to the BS [13]. The cluster head in LEACH is randomly rotated in every round. In LEACH, clusters are formed in a self-organized manner, in each round of data collections these clusters are formed to fuse data before transmitting to the base station [13]. Two phases are there in the

LEACH protocol. They are set-up phase and the transmission phase. The lifetime of the node in the LEACH protocol can be extended by reducing the load that is available on the cluster head [19]. The reason for reducing the load in the cluster head is the power available in the cluster head drains very fast due to Radio transmission of the data to the base station.

Fig.1 shows LEACH. The algorithm utilized in LEACH is distributed clustering formation algorithm. In order to improve the energy efficiency of LEACH is improved by two types of clustering algorithms. They are LEACH- C and saving energy clustering algorithm (SECA). In LEACH- C centralized approach is adopted. In SECA, the cluster head selection is based on the amount of residual energy present in the node. When the node is having high residual energy means, then that node can compete with other high residual energy nodes for becoming cluster head. The residual energy of the node in SECA is high when compared with LEACH, LEACH- C, and HEED [36]. The flow chart representation of LEACH protocol is shown in fig.2.

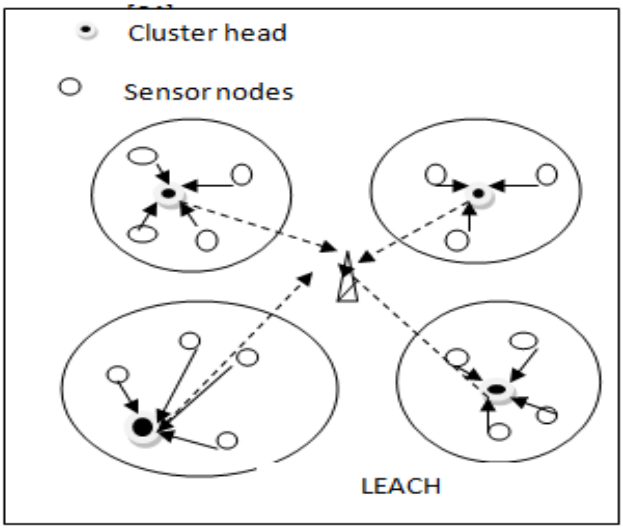

Fig.1. LEACH

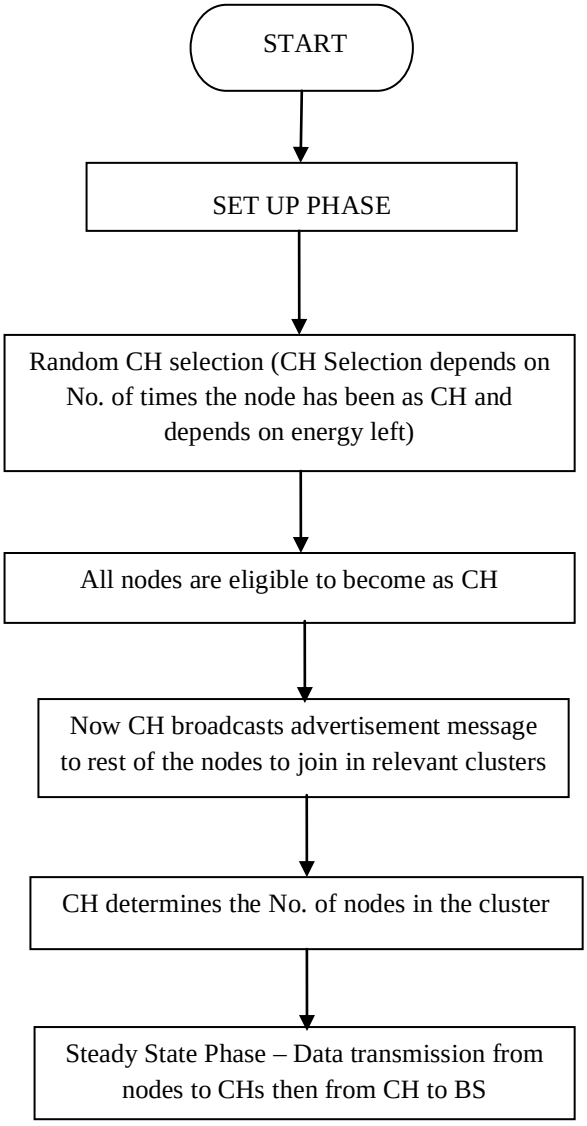

Fig. 2 FLOW CHART REPRESENTING LEACH PROTOCOL

B. TWO LEVEL LOW ENERGY ADAPTIVE CLUSTERING HIERARCHY (TL-LEACH) PROTOCOL

Data have been overloaded in traditional LEACH protocol. To overcome this limitation TL-LEACH has been adopted. Data fusion concept is utilized in TL –LEACH. Four phases are there in TL-LEACH. They are, advertisement phase, cluster set –up phase, schedule creation phase, and data transmission phase. Two types of CHs are there in TL- LEACH, they are Primary cluster head (PCH), secondary cluster head (SCH). PCH is present in the top level, SCH are present in the next level. In the advertisement phase, the SCH conveys a message to the simple nodes (SN), two sub phases are there in advertisement phase of TL-LEACH. In the first sub phase, decision has to be taken by the SCH that, to which PCH it has to join. In the second sub phase, the other SNs have to select the SCH. The set –up phase in TL –LEACH is different from traditional LEACH. i.e. in TL –LEACH, the nodes are autonomous in nature. Due to this, the distance covered by the nodes (to pass information) in TL- LEACH is less when compared to the traditional LEACH. In the schedule creation phase, a schedule has to be created by the PCH with the help of TDMA schedule. Based on this schedule, particular time slot has to be allotted to each SN for data transmission to the SCH. SCH conveys the information to the PCH. During the data transmission phase, data transfer takes place between SNs to SCH. From SCH information has been passed to PCH. From PCH information has been conveyed to BS [34]. Fig 3 shows TL –LEACH.

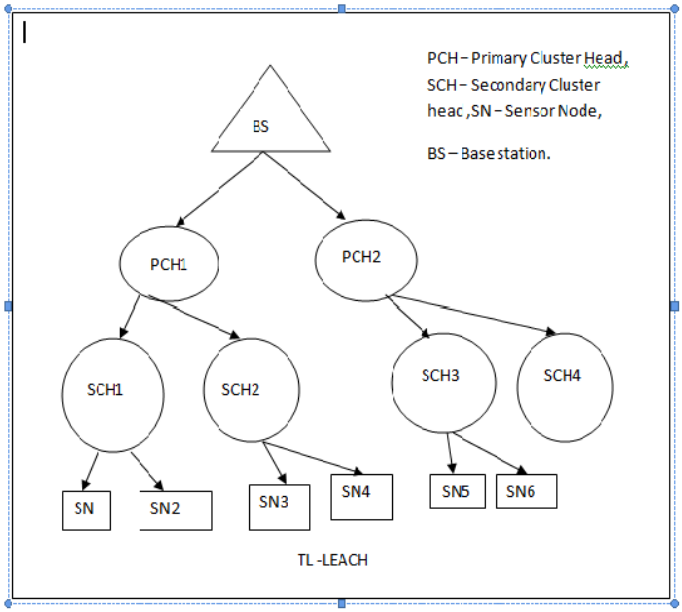

Fig.3. TL-LEACH

C. FAR ZONE LOW ENERGY ADAPTIVE CLUSTERING HIERARCHY (FL-LEACH)PROTOCOL

Major drawbacks in traditional LEACH protocols are (i) whenever CH is dead, the energy present in the other nodes are depleted, (ii) there is no reason given for the selection of CH (random selection) in traditional LEACH, (iii) Size of the clusters vary from small to big, in order to overcome these drawbacks another advanced LEACH protocols (FZ – LEACH) has been considered. In FZ-LEACH (far zone LEACH), a zone has been constructed in the cluster called far zone (FZ). This FZ has been created based on the minimum reachable power. As soon as the construction of FZ is over, within the FZ zone head (ZH) has been elected. The energy present in the ZH is highest when compared to other nodes. Generally FZ- LEACH has been adopted if the size of the cluster is large. ZHs convey the information to the BS [35]. Fig.4. shows FZ-LEACH

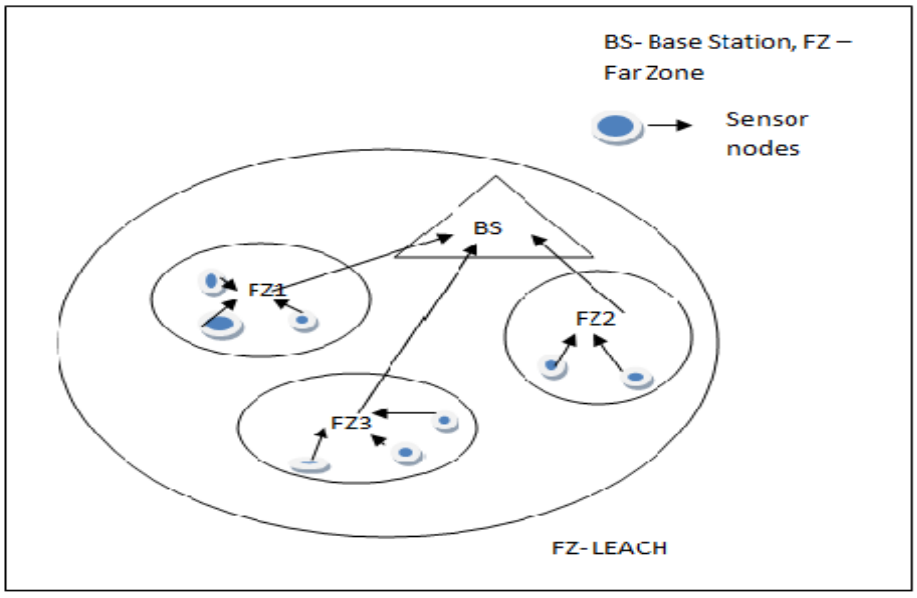

Fig.4. FZ-LEACH

D. POWER EFFICIENT GATHERING IN SENSOR INFORMATION SYSTEMS (PEGASIS) PROTOCOL

The purpose of the LEACH is to minimize the nodes that are directly communicating with the base station (i.e. sink) . But in Power Efficient Gathering in Sensor information systems (PEGASIS), only one node can be able to communicate with the base station. That is, the cluster head coordinator only conveys the information to the base station. The cluster heads from

various clusters convey the information to the cluster head coordinator in a chain manner [24]. The information collected from each and every node is combined by the other nodes and finally the

Cluster head node only transmits the collected information to the base station. Advantages of PEGASIS are: (i) the distance between the base station and CH has been reduced when compared to LEACH, (ii) the messages conveyed to each node are 2 (at the maximum)when compared to LEACH, (iii) the energy consumption is uniform in PEGASIS, (iv)the number of transmitting and receiving information is limited. The drawbacks of the PEGASIS are (i) the energy level of the cluster head has not been considered,(ii) the data transmission to the base station may be redundant in nature, because the CH alone convey the message to the base station [31].

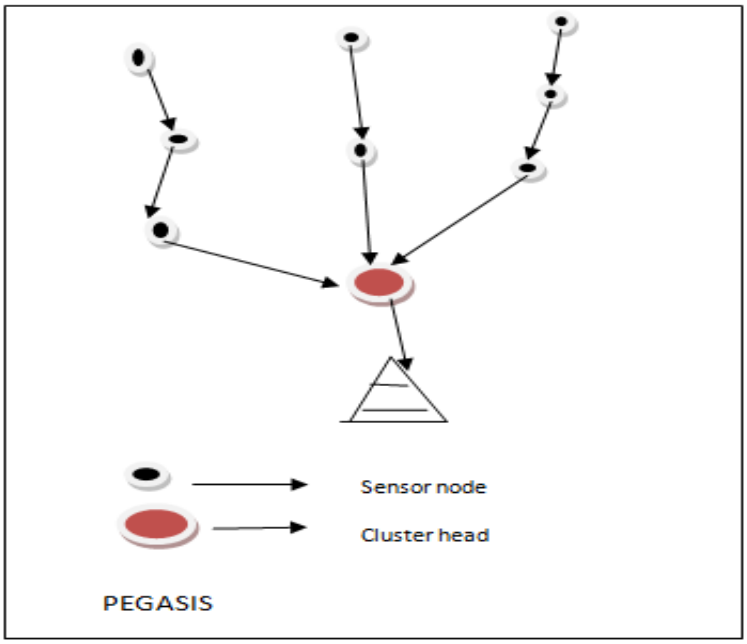

Fig.5. PEGASIS

E. POWER EFFICIENT DATA GATHERING AND AGGREGATION (PEDAP) PROTOCOL

The PEDAP (Power Efficient Data Gathering and Aggregation) protocol is applicable only when the sensor nodes are homogeneous in nature (nodes having identical properties) and also the sensor nodes and the base station are not movable (i.e. stationary in nature). Energy distribution is uniform in a particular cluster because, the CH has to be activated throughout that round (alive nature).

Due to this property more energy consumption is needed for CH. But at the same time, the nodes in the cluster needs less energy because, they may be active during data transfer only. Rest of the times, the other nodes may go to sleep mode [24].

F. ENERGY EFFICIENT CLUSTERING SCHEME (EECS)

The purpose of energy efficient clustering scheme (EECS)[25] is to improve the data gathering scheme in a periodical manner. Two phases are there in EECS, they are clustering phase and data transmission phase. In the clustering phase, the first phase is cluster head election phase and cluster formation phase. In the cluster head election phase, based on the node's residual energy some nodes have been elected for competition. Then competition takes place between the elected nodes. COMPETE _Head Messages have been passed by the nodes who are in the competition. The node who won the competition sends the HEAD _ AD message to all other nodes. This HEAD _AD message passing takes place in cluster formation phase. All other nodes except the cluster head node acts as plain nodes. The cluster formation takes place based on the received signal strength between the cluster head and the plain nodes. The flow chart representation of EECS is shown in fig.6.

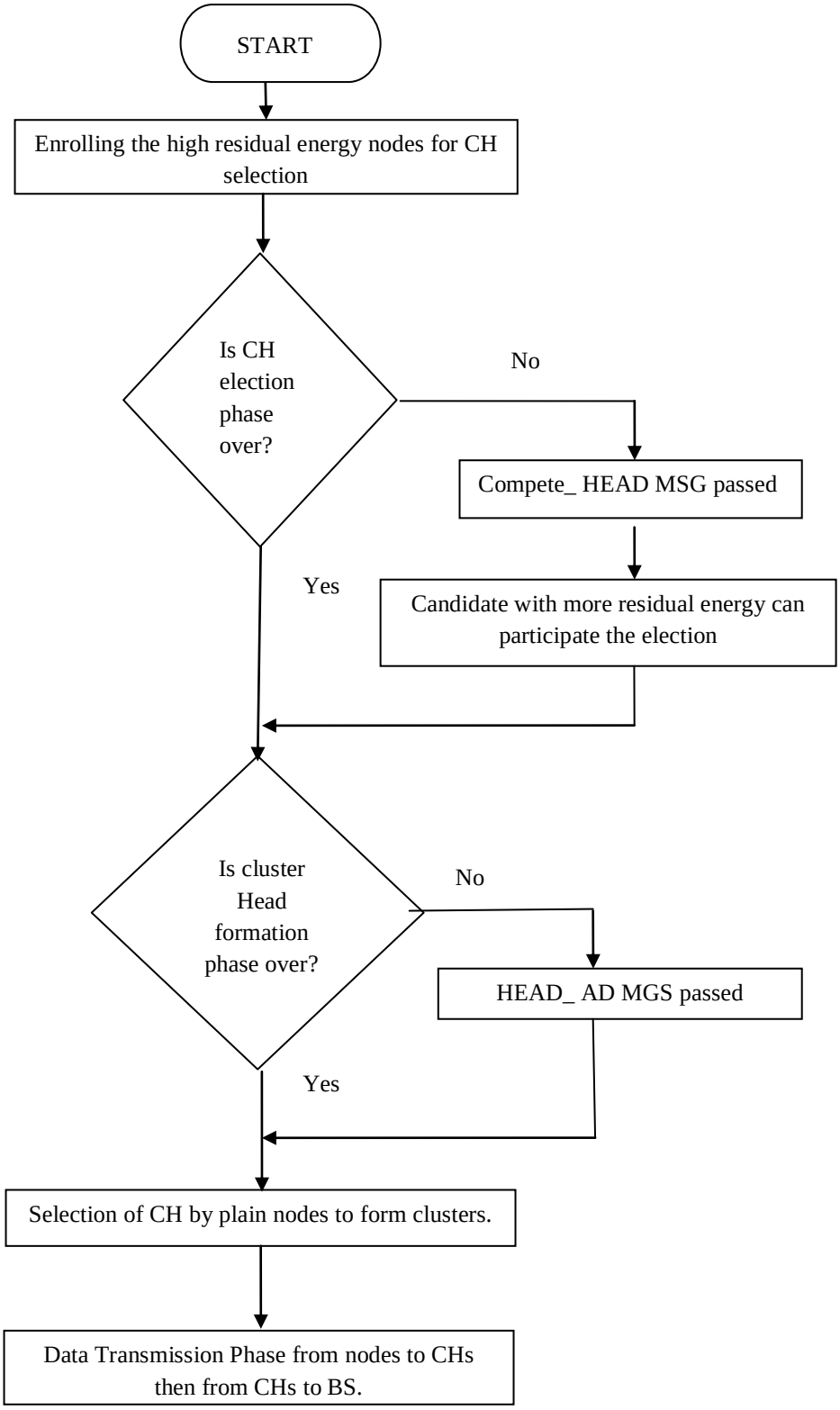

Fig.6. The flow chart for Cluster head selection in EECS protocol

As soon as the cluster formation phase completes, then the data transmission phase takes place.

G. HYBRID ENERGY EFFICIENT DISTRIBUTED CLUSTERING (HEED) PROTOCOL

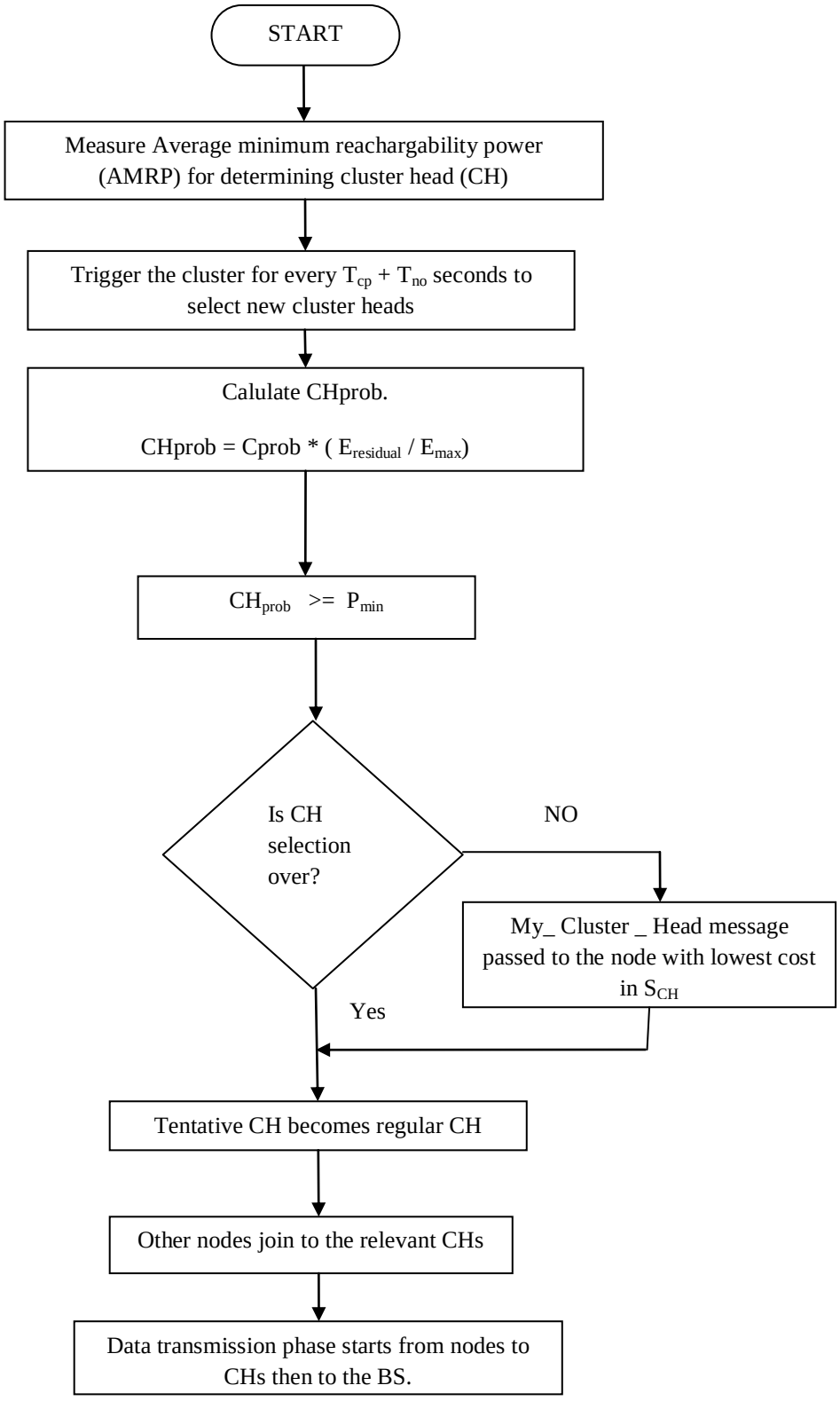

Fig.7.Flow chart representing HEED Protocol

HEED means Hybrid Energy Efficient Distributed clustering. The purpose of the HEED is to increase the network lifetime. This can be achieved by distributing energy consumption of the cluster head. The clustering process can be terminated within a scheduled number of iterations. The cluster heads are well distributed. The control overhead can be minimized. Two types of clustering parameters are there to select the cluster head in HEED. The first clustering parameter is measuring the amount of residual energy present in each node. Residual energy is, the energy present in the node after the consumption of energy for

sensing, processing and communication. The second clustering parameter is intra-cluster communication. The cluster power level indicates the number of clusters in the particular WSN. The intra cluster communication cost is due to the size of the cluster, variable permissible power level for inter cluster communication, cost. Clustering process duration is denoted by Tcp. This Tcp is the time taken by the clustering protocol to create a cluster.

Tno is denoted as network operation time. New cluster is formed every Tcp + Tno seconds. The cluster radius plays an important role for selecting the number of cluster heads. Large number of cluster heads is required when the radius of the cluster is small. The selection of the cluster head is better when compared to LEACH. The lifetime of the HEED is better when compared with LEACH. The energy consumed in HEED is less when compared with LEACH. Advantages of HEED protocols are (i) prolonged life time of the WSN due to even distribution of energy consumption between the nodes, (ii) fast selection of cluster heads, (iii) Minimized control overhead; (iv) selection of CH is based on the amount of residual energy. Table 1 shows the comparisons of the LEACH, PEGASIS, HEED, EECS protocols.

V. OBSERVATION

TABLE I
Comparison of the Protocols

Parameter	LEACH	PEGASIS	HEED	EECS
Expansion	Low energy adaptive clustering hierarchy	Power Efficient Gathering in Sensor Information Systems	Hybrid Energy Efficient Distributed Protocol	Energy Efficient Clustering Scheme
Role of the Protocol	Relaying	Relaying	Aggregation and Relaying	Aggregation and Relaying
Objective	To save energy	To save Power	To save energy	To save energy
Designed for	For Homogeneous wireless sensor network	For Homogeneous wireless sensor network	For Heterogeneous wireless sensor network	For Heterogeneous wireless sensor network
Algorithm used	Distributed clustering formation algorithm	Greedy algorithm for chain formation	Distributed clustering formation algorithm	Distributed randomized clustering algorithm
Clustering Process – Methodology	Distributed	Distributed	Distributed	Distributed
Clustering techniques	Clustering approach	Tree based Approach	Clustering approach	Clustering approach
Hopping	Single hop clustering	Multi hop clustering	Single hop clustering	Single hop clustering
Communication with base station	Cluster heads can communicate with base station	Only one node (the node which is very close to the base station) can communicate with base station	Cluster heads can communicate with base station.	Cluster heads can communicate with base station.
Data gathering Method	Aggregation method	Non aggregation method	Aggregation Method	Aggregation method
Data Transmission type	Indirect type	Indirect type	Indirect type	Direct type
Phases	Setup phase, steady state phase.	Chain formation phase, broadcasting phase	Initialization phase, setup phase, steady phase	Cluster head election phase, cluster head formation phase
Life time	When compared to the conventional method of clustering,, the life time of LEACH gives 8 times better results in terms of first node death.	PEGASIS provides 100% to 300 % increase in lifetime when compared with LEACH	Better lifetime when compared with LEACH protocol	Better lifetime when compared with LEACH protocol
Energy Utilization rate	53%	The performance of the PEGASIS is improved due to the energy saving parameter at several stages	Energy utilization in HEED is less when compared to EECS	93%
Applications	For continuous monitoring and conveying the information to the base station like weather forecasting	In Disaster management Scenarios	In environmental monitoring applications	In Homogeneous and Heterogeneous Scenarios.

The energy efficient clustering algorithms like LEACH, HEED, assume that, the base station is static in nature. The nodes present nearer to the base station have to convey the information from other nodes. Due to this, there is an active participation of the sensor nodes which are very nearer to the base station. The data traffic nearer to the base region increases heavily. Because of this situation the energy presents in those nodes decreases very fast when compared to other nodes. Under these circumstances the amount of energy consumption is in the form of wasteful nature. This affects the lifetime of that network

[28]. Two desirable characteristics are there in any WSN. They are uniform energy drainage and lower hardware cost. Uniform energy drainage is being achieved by homogeneous WSN, and the lower hardware cost is being achieved by heterogeneous WSN [30]. Depending on the operations performed by these nodes we have three types of heterogeneous characteristics. They are computational, link, and energy heterogeneous characteristics. By deploying these heterogeneous nodes to the WSN, it is possible for us to improve the response time of the SN (with the help of computational heterogeneity and link heterogeneity) and the life time of the WSN can be improved (with the help of energy heterogeneity) [29]. The nodes in WSN are usually battery operated sensing devices with limited energy resources and replacing and replenishing the batteries is usually not an option. Specific functions can be obtained through cooperation between these nodes [6]. Sensor nodes are fitted with an onboard processor instead of sending raw data to the nodes responsible for fusion, they use their processing abilities to locally carry out simple computations and transmit only the required and partially processed data .Sensor nodes mainly use a broadcast communication paradigm, and they may not have global identification. The topology of the sensor network changes very frequently [4]. Power supply for the sensor node is provided by a small battery which when replaced or recharges frequently for the sensor nodes because the size is small. As a sensor node in WSN is a small, its power supply units should support all its operations without degrading the performance [8].

The performance of these algorithms is analysed based on the power and energy consumption of the corresponding clusters. For analysing the performance of the clustering algorithms we have to consider two major areas. They are power, energy and network life time, quality and reliability of the links [9].Uniform energy drainage characteristics are achieved in heterogeneous sensor network [14].When compared to the conventional methods, the lifetime of the LEACH gives 8 times better results in terms of first node death. Between TL-LEACH and LEACH, the lifetime of the TL-LEACH has been extended up to 35%. PEGASIS, PEGASIS provides 100% to 300 % increase in lifetime than LEACH. The lifetime of the HEED algorithm is better when compared with LEACH because, in LEACH, the cluster head is selected randomly. Due this random type of cluster head selection, the death rate of the sensor nodes is fast when compared with HEED. But in HEED, the selection of cluster head is in distributed manner. Due to this reason, the lifetime of the HEED is extended. The comparison of these protocols is shown in table I.

VI. CONCLUSION

In this paper various energy efficient protocols have been analysed and compared. The comparison has been made on the parameters life time, hopping, data gathering method, and type of data transmission. With the observation we conclude that for disaster management area, and then the information has to be reached to the base station for processing immediately PEGASIS protocol is preferred. In other applications, like measuring and analysing the information for weather forecasting, continuous Environment monitoring etc. protocols like LEACH, HEED and EECS are useful.

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