Asian Journal of Information Technology 13 (4): 182-189, 2014
ISSN: 1682-3915

A Survey on Hierarchical and Hybrid Protocols for Wireless Sensor Network

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Abstract: Wireless Sensor Network, the name that explodes lot of crucial improvements in growing world technological impact. In WSN, clustering makes the vital role for the deployment of coverage, energy efficient, high localized communication between sensor nodes and its base station. To make the cluster process more effective various protocols are introduced especially in hierarchical protocol like LEACH, SEP, TEEN, PEGASIS protocols. In present scenario, the protocol's superior process characteristics are combined that produces the hybrid protocol for various purposes like energy conservation, prolonged network life time, improved localized process, reduced no of CH selection. Here, the research that made the survey of these hybrid protocols and their superior characteristics on the basis of no of nodes alive for defined round, stability period, energy dissipation under various conditions. Each protocol made the dominant characteristics in various aspects. Their advantages and their characteristics are discussed with their characteristics.

Key words: LEACH, SEP, TEEN, PEGASIS, localization, energy dissipation

INTRODUCTION

Wireless Sensor Network is a stream where it composed of wireless sensor nodes deployed in a region to sense various type of physical quantity information from the environment. The information gathered by these sensors is then processed and sent it to the base station using Sink architecture. WSN plays a enormous role for various applications like military surveillances, industrial environmental control, green-orbs monitoring, habitat monitoring, transport controlling, etc. The sensor nodes are wireless and nano-size level which can be deployed with ease in remote areas and hilly terrains. Even though they are compact, their dense properties make them difficult in monitoring of those. Particularly in the region where the physical intervene of the human being is not possible. Once the network established, their foremost task is sensing the defined physical quantity of information and processing it then send it to the base station. Whenever the sensor nodes performs their mission they have to spend their given energy for sensing those defined quantities and spend some more energy for transmitting those information to the base station.

When researchers are considering about the sensor nodes they have some problem in the sense of physical parameters. The one is ad hoc deployment, nothing but the deployed regions of sensor nodes where it can be tossed by the aeroplane. That means there is no intervention of human-beings. It is one of the most due of this sensor nodes where it identify its connectivity and distribution in the irregular infrastructure regions. The second one is they have the responsibility for reconfiguration incase of any environmental changes. The third one is unethered property of the sensor nodes. The last one is dynamic changes where the system must be adaptable to changing connectivity as well as modifying environmental stimuli. Before going to analyze the protocol, researchers have to look about the inner subsystem of the sensor node. It has four subsystems, one is computing subsystem where it consists of microprocessor that has the responsible for control of communication protocol and operates under various operating modes for power consumption. Second one is communication subsystem that takes the task of communication with neighbouring nodes with the four modes of transmit, receive, idle and sleep modes (Freris *et al*., 2010). Another subsystem deals with sensing subsystem that has the main factor of energy dissipation factor. The last thing is power supply subsystem that makes the heart of all system and also the leading factor to energy conservation process. Many routing protocols are already proposed to improve the performance of WSN. The routing protocol can be classified into flat, hierarchical, location based network routing protocols (Jiang *et al*., 2009). In flat routing protocol, the sensor nodes are assigned with equal task and equal role. SPIN (Sensor Protocol for Information via Negotiation) and DD (Directed Diffusion) are considered in this network. In Hierarchical routing, the network is partitioned into clusters to achieve efficiency. LEACH, TEEN, SEP are the main members of this network

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(Freris *et al*., 2010; Khan and Sampalli, 2012). The other one, location-based routing, the position of the node is the key factor for the determination of its optimal routing path. When compared with flat routing and location-based routing protocols in WSN, clustering routing protocols have enormous advantages such as scalability, data aggregation/fusion process, less load, less energy, more robustness, collision avoidance, latency reduction, load balancing and fault tolerance, etc. (Kashaf *et al*., 2012).

HIERARHICAL PROTOCOLS

Before going to analyze the hybrid protocol of various network, researchers have to analyze the basic types of protocol their advantages and disadvantages too. Thus, researchers can get the thing of purpose for which hybrid brings the advantages and which hybrid make the contribution to improve the network in terms of coverage, no of nodes alive in extended round of communication and also the prolonged lifetime of the network. Here in this study, researchers have to analyze the protocols of LEACH, TEEN, PEGASIS and SEP. This protocol made the combinations which produce the hybrid protocols to improve the performance in various aspects.

LEACH: LEACH means Low Energy Adaptive Clustering Hierarchy. It is the first hierarchical routing protocol in WSN (Khan and Sampalli, 2012). In this, there are two types of nodes are classified. One is normal sensor node and another one is Cluster Head (CH). Initially the normal nodes are formed and made the cluster group. Then, among all, one of the nodes is elected as CH. The selection process is based on the randomized procedure with assigned random value. The randomized value decides the CH with the comparison of threshold value T(n). When the random value is less than the T(n), the corresponding node leads the group as a CH. The threshold value is calculated by:

$$T(n) = \begin{cases} \dfrac{P}{1 - P \times \left(r \bmod \dfrac{1}{P} \right)} & \text{if } n \in G \\ 0 & \text{otherwise} \end{cases}$$

Where:

n = The number of nodes
p = The priori probability of a node to be elected as CH
r = The random number between 0 and 1 that is selected by a sensor node

If it is less than the threshold level then the node react as CH. The G portrays the set of nodes that has not elected as Cluster head. In each round, the process begins with a set-up phase, the time where the clusters are organized followed by a steady state phase; several frames of data are transferred from the nodes to CH and CH to base station (Fig. 1).

After the defined 1/p rounds, all nodes are again eligible to get CH. In LEACH, the optimal no of CH is estimated with 5% of the total no of nodes. The process made with the phase which at current node broadcasts an advertisement message to the rest of nodes. The remaining nodes that received the advertisement message, decide the cluster group which it belongs to this round (Fig. 2).

When CH receives all the messages from the nodes that are in the group, based on number of nodes in the cluster the CH creates a TDMA schedule and assigns each node with time slot when it can transmit. Leach protocol is a complete distributed network where it requires the global information about the network. There are lot of changes that has occurred in this protocol and made several modified advantages too. The most predominant advantages of leach is. Any node that act as CH in certain round can't be selected as a CH again. So, each node shared the load imposed. It prevents unnecessary collisions. The cluster can open or close the communication interface that avoid excessive energy dissipation with their allotted time slots. However, it has some disadvantages. LEACH performs the single hop inter cluster network communication which leads to direct routing between CH to BS thus it was made as the inability network in large-region networks. CH selection is based in terms of probabilities not in energy

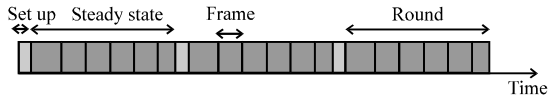

Fig. 1: Leach protocol phases

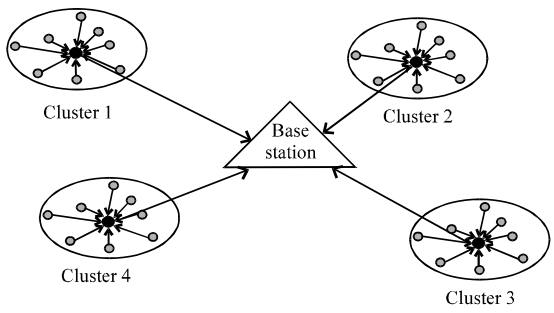

Fig. 2: Leach protocol cluster formation

considerations. May be the fact, the low energy node tend to act as a CH which holds lot of problems and in coverage. The dynamic clustering brings more overhead.

TEEN: Threshold sensitive Energy Efficient sensor Network protocol (TEEN) is a hierarchical protocol whose main aim is to cope with the sudden changes in the sensed attributes nothing but the physical quantity of the environment like temperature, pressure (Freris *et al*., 2010). It combines the hierarchical technique in line with a data-centric approach. In TEEN, a 2-tier clustering topology is used with two level of threshold is proposed. One is hard threshold and soft threshold is another one (Fig. 3). The threshold portrays about to the sensing value must switch on its transmitter and have to make the report with CH. The softer threshold in the sense that trigger the node to switch on its transmitter and transmit.

There is some task done by the hard and soft threshold values. The hard threshold tries to reduce data communications by making the nodes to transmit the data only when the physical attributes are with the range of interest. The soft threshold, further reduces the communication latency where it processed the task only by little or no change in the sensed attribute. Using those threshold values, users can make the trade off between energy efficiency and data accuracy by the parameter adjustment. If researchers discussed the advantages of TEEN, one is controlled data processed is done with the threshold values. It is applicable to the reactive scenes and time critical environmental applications. But, there is also some disadvantages too. It is not suitable for periodic reports applications. There may be wasted time slot and the BS may not be able to distinguish dead nodes from alive ones. If CHs are not in the communication range then the data will be lost.

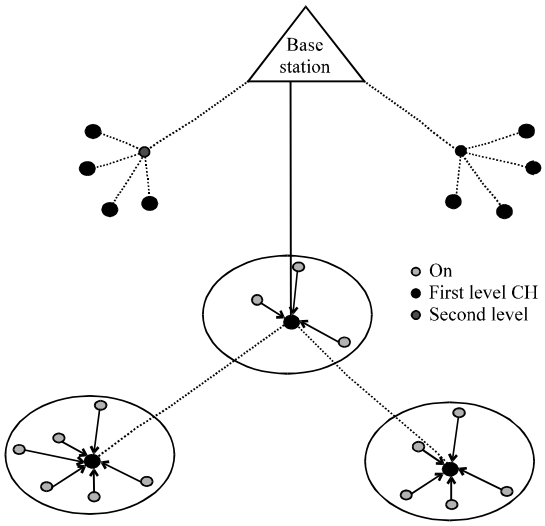

Fig. 3: Teen protocol cluster formation

PEGASIS: Power Efficient Gathering in Sensor Information Systems (PEGASIS) is an improved LEACH protocol (Ali and Refaay, 2011). The concept is for each node to only communicate with their close neighbours and take turns being the head for transmission to the sink. In this protocol, the locations of nodes are randomized and have the ability of data detection, data fusion and positioning. And also, energy loads are distributed evenly among the sensor nodes in the network.

The basic thing of communication is done by the formation of chain which can be either assigned by sink and broadcast to remaining nodes or done by the nodes themselves using Greedy algorithm. When the chain is formed by them, the first thing is they tend to get the location data of all nodes and compute the chain locally using the Greedy algorithm. In the process of chain formation, the assumption is made that all nodes have the global knowledge of the network. The chain construction is formed from the furthest node from the sink and the nearest neighbour which is closer to the sink will be the next node on the chain. When the node on the chain dies, the chain again reformed to bypass the dead node by the same manner.

Data gathering process is done through each round by chain formation where each node receives the data from one neighbour, fuses the data with its own then transmits to its neighbour node on the chain. Thus, the data is moved from one to another node at a random position on the chain. The data transmission at the end of the chain is processed by the token passing approach. In Fig. 4, the data from c0 is transmitted to c2 through c1. When the data is received by c2 it passes the token to c4 to transmit the data. Thus, it coverage the total transmit process through token passing approach. When researchers go for the advantages of PEGASIS, it reduces the problem of overhead arises in the dynamic cluster

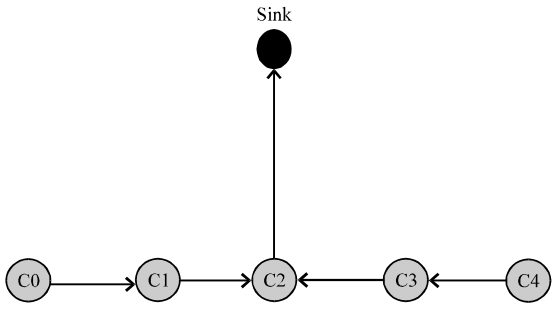

Fig. 4: PEGASIS protocol cluster formation

Table 1: Comparison of hierarchical protocol

Clustering routing protocols	LEACH	TEEN	SEP	PEGASIS
Cluster characteristics				
Variability of cluster count	variable	Fixed	variable	variable
Uniformity of cluster sizes	Even	Even	heterogeneity	Even
Intra-cluster routing	Single-hop	Single-hop	Multi-hop	Multi-hop
Inter-cluster routing	Single-hop	multi-hop	Multi-hop	Single-hop
Clustering process				
Control manners	Distributed	Distributed	Distributed	Distributed
Execution nature	Probabilistic	Probabilistic	Probabilistic	Probabilistic
Convergence time	Constant	Constant	Constant	Constant
Parameter for CH selection	Adaptive	Adaptive	Adaptive	Adaptive
Objective	Load balancing	Reactive scenes lifetime extension	Proactive reactive	Load balancing

formation which is main drawback of LEACH. The energy load is uniformly distributed in the network. However, the drawbacks are: it is not suitable for time varying topology network. The long range communications between node to sink consume lot of energy. Excessive delay caused by single chain and high probability of bottle neck made this protocol into more suffered. It is not very scalable because it if difficult to maintain the complete database about the location of all other nodes in the network.

SEP: Classical clustering protocols assume that all the nodes are equipped with the same amount of energy and as a result they cannot take full advantage of the presence of node heterogeneity (Jiang *et al*., 2009). SEP which is a heterogeneous based protocol to prolong the time interval before the death of the first node which is crucial for many applications where the feedback from the sensor network must be reliable. SEP is based on weighted election probabilities of each node to become cluster head according to the remaining energy in each node (Table 1). SEP always prolongs the stability period compared to (and that the average throughput is greater than) the one obtained using current clustering protocols. SEP protocol leads to heterogeneity parameters capturing energy imbalance in the network. SEP yields longer stability region for higher values of extra energy brought by more powerful nodes. Stable election protocol for clustered heterogeneous WSN is developed for two level heterogeneous networks. It includes two types of nodes, normal nodes and advanced nodes based on the initial energy. The probability of threshold which each node Si uses to determine the chance to become a cluster head in each round:

$$T(n)=\begin{cases}\dfrac{P}{1-P\times\left(r \bmod \dfrac{1}{P}\right)} & \text{if } n\in G\\ 0 & \text{otherwise}\end{cases}$$

Also, for two level heterogeneous networks, Pi is defined as:

$$P_i=\begin{cases}P_{nrm}=\dfrac{p_{opt}}{(1+am)} & \text{if } S_i \text{ is the normal node}\\ P_{adv}=\dfrac{p_{opt}(1+a)}{(1+am)} & \text{if } S_i \text{ is the advance node}\end{cases}$$

P_{opt} is the optimal probability of each node to become CH. In order to prolong the stable region, SEP attempts to maintain the constraint of well balanced energy consumption. Intuitively, advanced nodes have to become cluster heads more often than the normal nodes which is equivalent to a fairness constraint on energy consumption. Note that the new heterogeneous setting (with advanced and normal nodes) has no effect on the spatial density of the network so the a priori setting of P_{opt} SEP protocol could be triggered whenever a certain energy threshold is exceeded at one or more nodes. Non-cluster heads could periodically attach their remaining energy to the messages they sent during the handshaking process with their cluster heads and the cluster heads could send this information to the sink. The sink can check the heterogeneity in the field by examining whether one or a certain number of nodes reach this energy threshold. If so then the sink could broadcast to cluster heads in that round the values for p_{nrm} and p_{adv}, in turn cluster heads unicast these values to nodes in their clusters according to the energy each one has attached earlier during the handshaking process.

CHS election in SEP is done as randomized on the basis of probabilistic value which is presented in LEACH. By increasing m or researchers can improve the system further. So, SEP gives increased stability period and prolonged life time due to advanced nodes but at the same time two level heterogeneity made the increased throughput. Figure 5 portrays about the throughput rate of LEACH and SEP at m = 0.2 and n = 3. It clearly shows that in the basis of throughput SEP made a lag of form against LEACH protocol.

HYBRID PROTOCOLS

So, far researchers have seen the basic network protocol of hierarchical network. In order to overcome the

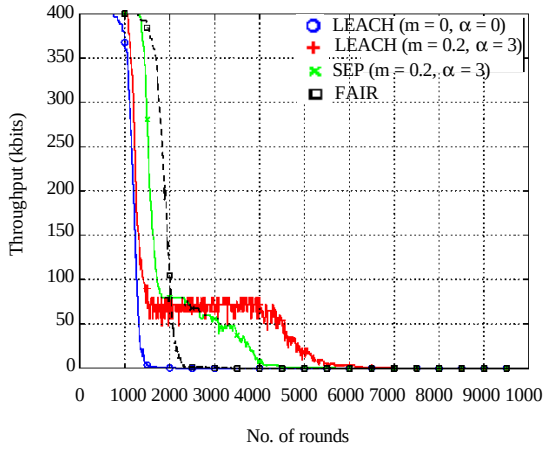

Fig. 5: Throughput of the Network for SEP and LEACH

disadvantages in the previous protocols in one with another, people produce their study research with combined effect of these protocols. They are nothing but the hybrid protocols. Here, some of the hybrid protocols which make the high impact on the energy efficient with prolonged life time of network and also good coverage too.

APTEEN: Adaptive Threshold sensitive Energy Efficient sensor Network protocol (APTEEN) is a extension to TEEN and make the goal of transmission of periodic data and reacting to critical events (Wei *et al*., 2011). It is based on the query system which employs 3 types of queries: historical, on-time and persistent. And also, QoS requirements are introduced in the process of on-time queries and overhead latency is reduced by the modified TDMA schedule with a special time slot assignment manner. In this protocol, the CH broadcast four parameters. Attributes-set of physical parameter that is interested in obtaining of data. Thresholds: consists of hard and soft threshold. Schedule: this portrays the modified TDMA schedule. Count Time (CT) maximum time period for the successive report made by a node. The superior feature of the APTEEN protocol is to switch between proactive and reactive modes to transmit data. All of the nodes in the network sense the environmental physical attributes continuously but the nodes which sense the data value more than the threshold value permit the transmitting. If the node failed to provide the data for a time period which is equal to count time, it must sense the attributes and transmit the data again. In APTEEN, CH aggregates and transmits the data within its clusters. On the process of data aggregation, the data must be sufficiently correlated. The modified TDMA schedule makes the nodes task with time slot for transmission.

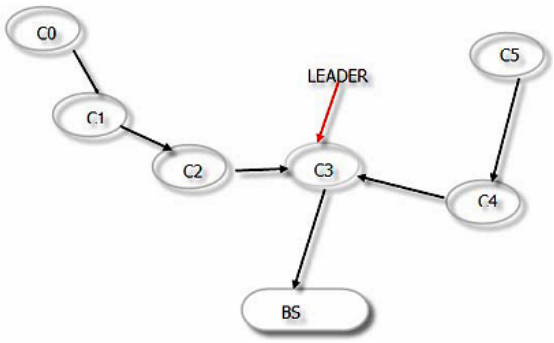

Fig. 6: Data transmission in chains

When researchers considering the advantages: it combines both proactive policies which is in LEACH and reactive policies which is in TEEN. It employs a lot of flexibility with setting of CT interval and threshold value of energy consumption.

CCBRP: The goal of Chain-Chain Based Routing Protocol (CCBRP) is to achieve both minimum energy consumption and minimum delay (Ali and Refaay, 2011). Researchers can say that PEGASIS protocol, the father of this protocol. The PEGASIS protocol is a near optimal based protocol to extend the WSN lifetime. This protocol operates based on the closest neighbours and leads communication in their turns until the processed data reached the BS. So, it leads to improved energy consumption over LEACH protocol. It is the one that starts with formation of chain using Greedy algorithm (Fig. 6). Then, it made the selection of leader by random basis and made the transmutation. The disadvantages of this protocol, more delay that make the transmutation. And it is recovered by the CCBRP.

It divides the WSN into a no of chains with Greedy algorithm to construct the chain. The no of sensor nodes in WSN decides the no of sensor chains and no of sensor nodes in the network. Consider an WSN with N sensor nodes distributed in a 2D with size of L(m)×L(m). If number of nodes is hundred then assume the chain counts are equal to ten percent of N.

In CCBRP, the partitioned chains are run in two phases. The first phase leads with randomized selection of a leader for each chain then each leader send their token message to the other end of chain simultaneously. Then each end node simultaneously sends the data to the closes neighbour nodes and the neighbour nodes receive the data, fuse that with received data and sends to the next node. In Fig. 7, the CCBRP cluster chain formation is shown where the nodes are grouped into 10 chains. In that C0 is the one of the node of initial chain and L5 is the

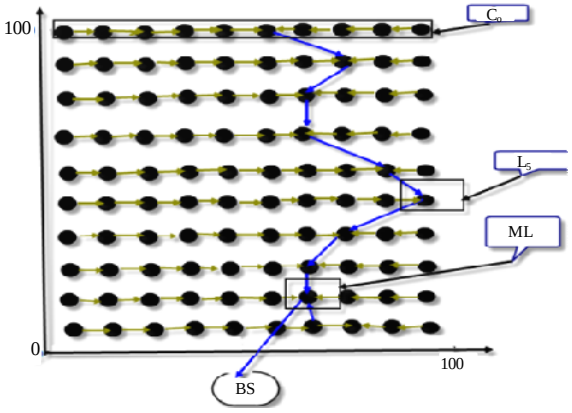

Fig. 7: CCBRP cluster formation

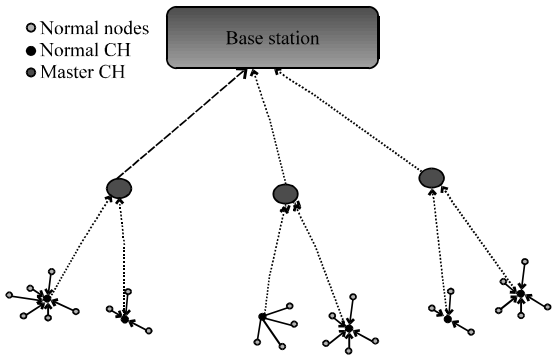

Fig. 8: EEE LEACH protocol cluster formation

chain leader of chain 5 and the ML is the main leader where it sends the data to BS. The CCBRP has the two phase of process. In first phase, randomly CH is selected in each chain. After that at the two ends, each node sends its data to its nearest neighbour node, the neighbour node fuse the data and send it to further nearest node. The processes are continued, till the leader receives the data and send the token to the end nodes. In second phase, after the all leader nodes from the various chains received the data then chain leader form new chain by Greedy algorithm. Then, the node simultaneously sends the data its nearest neighbour. This process is continued until the main leader receives the data. Main leader in the sense, it has the ability to send the data to BS. The average energy consumption is calculated by:

$$E = \sum_{i=1}^{N} \frac{E_i(r)}{r}$$

The main proposal of this protocol leads to the 60% of less energy consumption than LEACH protocol and 10% of less energy consumption than CCM protocol. When in the sense delay, CCBRP gives 75% less delay than PEGASIS which is same delay of LEACH protocol. When researchers go for the minimum delay with minimum energy consumption level network, CCBRP makes the good use of that. But the problem will arise when researchers go for larger area network with the bottleneck in the token passing and receiving the data from the neighbour nodes.

EEE LEACH: Energy Efficient Extended LEACH protocol is the further step of LEACH where it focused with multi-hop process (Sharma and Shaw, 2012). The main aim of this protocol is to increase the energy efficiency by reducing the distance for radio communication. It involves the modification of LEACH by introducing multi level cluster formation. First the normal cluster formation is done and the process the data with normal CH to transmit its own data (Fig. 8).

Then, here the secondary CH nothing but Master Cluster Head (MCH) are formed. After the formation of MCH, the normal CH search for nearest MCH by calculating the distance between them and transmit their aggregate data to the MCH. Then, MCH receives the data and made the aggregation process and send to the BS. The population of CH and MCH is decided by predetermined fractional value (p election probability) for CH and p_{opt} value for MCH.

In Fig. 9, it shows the matlab research and it compares with LEACH and DTx process where it gives about 35% of increased transmission time with 18% of reduced throughput rate. In this research, the focus of improved is on reducing the throughput rate thereby increasing the energy conservation process.

TSEP: Threshold sensitive Stable Election Protocol (TSEP) has made with two features (Kashaf *et al*., 2012. One is, it is reactive routing protocol and second is three level of heterogeneity. Thereby, it begins with three types of nodes:

- Normal nodes
- Intermediate nodes
- Advanced nodes

Advanced nodes had energy greater than all nodes where the intermediate has the energy between normal and advanced nodes. Intermediate node is chosen by the factor b, fraction of nodes which have the relation that energy of normal nodes μ times more than normal nodes. In SEP, the normal nodes have the energy value of E_0, for advanced node it has $E_{adv} = E_0 (1+\alpha)$ and intermediate nodes have $E_{int} = E_0 (1+\mu)$ where; $\mu = \alpha/2$. So, the total

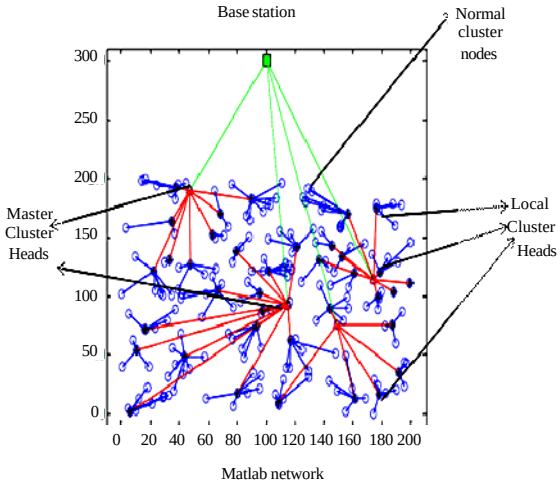

Fig. 9: EEE LEACH network in Matlab

energy of nodes will be nE_0 (1+mα+bμ) where n is number of nodes, m is proportion of advanced node to total no of nodes n and b is the proportion of intermediate nodes. The probability of node elected as normal, intermediate and advanced through optimal probability is portrayed as follows normal nodes:

$$P_{nrm} = \frac{p_{opt}}{1+m\alpha+b\mu}$$

Intermediate nodes:

$$P_{int} = \frac{p_{opt}(1+\mu)}{1+m\alpha+b\mu}$$

Advanced nodes:

$$P_{adv} = \frac{p_{opt}(1+\alpha)}{1+m\alpha+b\mu}$$

And at the same time, the threshold value of these nodes are separated one. These node values are calculated by follow methods:

$$T_{nrm} = \begin{cases} \dfrac{P_{nrm}}{1-P_{nrm}\times\left(r \bmod \dfrac{1}{P_{nrm}}\right)} & \text{if } n_{nrm} \in G' \\ 0 & \text{otherwise} \end{cases}$$

$$T_{int} = \begin{cases} \dfrac{P_{int}}{1-P_{int}\times\left(r \bmod \dfrac{1}{P_{int}}\right)} & \text{if } n_{int} \in G'' \\ 0 & \text{otherwise} \end{cases}$$

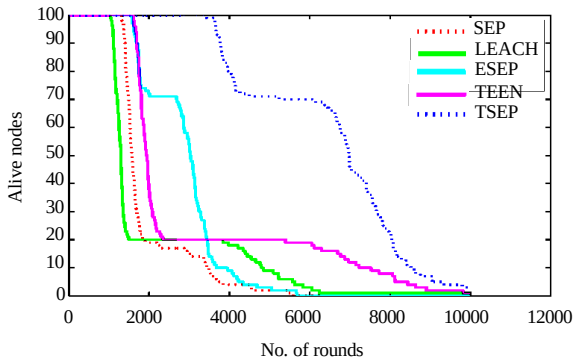

Fig. 10: Comparison of TSEP with other protocol in terms of no of alive nodes

$$T_{adv} = \begin{cases} \dfrac{P_{adv}}{1-P_{adv}\times\left(r \bmod \dfrac{1}{P_{adv}}\right)} & \text{if } n_{adv} \in G''' \\ 0 & \text{otherwise} \end{cases}$$

where, T_{nrm}, T_{int} and T_{adv} are the set of normal nodes, intermediate nodes and advanced nodes, respectively. Even though the average no of nodes are equal in LEACH, SEP, ESEP the good aspect of TSEP is, it leads to reduced energy dissipation due to its heterogeneity node formation Fig. 10. Before going for the CH selection process this protocol broadcast the four parameters:

- Report Time (TR): the period which reports are being sent by nodes successively
- Attributes (A): the physical environmental parameter to be sent
- Hard threshold: the value which the node will transmit the data to CH
- Soft threshold: the value to switch on their transmitter and transmit in each node

The most attractive features of TSEP are the time critical data reaches almost instantaneously. Node sensing is done continuously but transmission is not done in frequent manner so energy consumption is lesser than proactive networks. The user can change the attributes of network depending upon the requirements. By the parameter like stability period, number of alive nodes per round and throughput, the proposal made the superior characteristics among LEACH, SEP, TEEN, ESEP. of no of alive nodes.

CONCLUSION

The survey portrayed the clear view of hierarchical protocols and shows what are the modifications done in

this and how the hybrid protocols are made. And also, the advantages over other protocols are discussed with some experimental results. One of the major concerns to be notified is, researchers have to analyze the use of protocol. It is nothing but the area where researchers have to use like whether researchers have to reduce the throughput or whether researchers have to reduce the energy conservation on sensing process or with minimum delay with less energy consumption or non-periodical data transmission. These hybrid protocols are based on these approaches, mainly focused to increase the prolonged life time of the network with the trade off between the coverage and throughput.

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