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Automated Remote Monitoring Systems with Energy Efficient Routing Scheme

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***Abstract*—Automated Remote Monitoring Systems with Energy Efficient Routing Scheme (ARMSEERS) are being implemented in in a wide range of applications in a variety offields, like Telecom., medicine, environmental-study, robotics, battlefield, sensitive areas, and security, etc. Wireless sensor networks (WSNs) have been the center of attention lately. The main limitation is that in its tiny size and harsh installation-environments, the energy resource is limited, it cannot be recharged. This research work puts forward a routing scheme that assigns a discrete role to every node in the network usingits heterogeneity, residual energy of the nodes, distance between inter nodes and distance between sink and nodes. The proposed cluster-based hierarchical scheme selects the most optimal path, with a fair count of the node- BS links for transmitting data tothe sink in every round trip, saving not only the network energy and prolonging the network life but also making sure that energy-dissipation is uniform in the network and most of the sensing area is kept alive during the network lifetime. To evaluate the proposed scheme, several simulations were performed to compare it with the existing network protocols and the results clearly showed much improvement in terms of efficiency of energy and stability of the network. The life span of the network was also increased.**

Index Terms*—Wireless Sensor Network (WSN), Cluster, Heterogeneity, Base Station, Sink, Round, Inter-nodal, Node-BS, Residual Energy

I. INTRODUCTION

WSNs are networks of a substantial number of interconnected micro-sensors aimed to extract the sensing information from the subjected area. The WSNs blend sensing, information processing, and communication/transmission techniques together. Sensors are also known as motes or nodes and the subjected environment is called the sensor field. Motes collect the readings, convert them in the form of signals, perform the processing on them, and then accelerative them towards the Base Station (BS). Forwarding can one or the other be done through the other nodes. The base station gives a access to data by connecting to the Internet or other communication mediums. The user can have access to real-time information about the data at any location and time [1]. WSNs have a wideIdentify applicable funding agency here. If none, delete this.

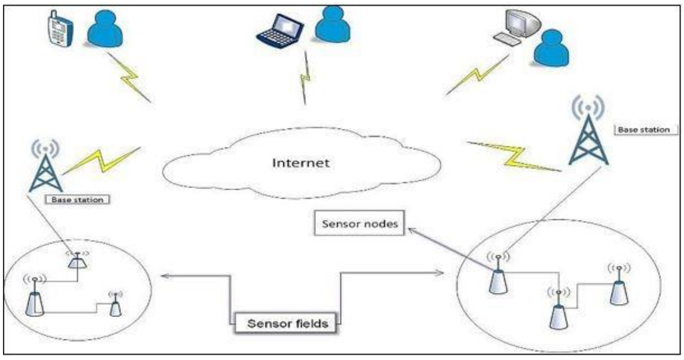

Fig. 1. A wireless sensor network

range of application in many fields both civil and military. To rescue in a disaster like condition, the sensor in huge numbers may be dropped from helicopters. The sensors then interconnect with each other to form a network. The networks then can convey vital information about the rescue operation for instance presence of survivors etc. The WSNs have made it possible to reduce direct human involvement in reconnaissance activities. Landmines can be controlled better to make sure civilian loss is prevented. Intrusion detection is an example of WSNs use in security matters. Other applications of WSNs include environmental-study, patient-monitoring, agriculture, smart buildings and robotics etc. Micro-Electro-Mechanical System (MEMS) technology has made it possible to de- velop tiny sensors with limited power, computational, and communication capabilities [1]. The sensors can detect and measure various phenomena like temperature, light, pressure, sound, vibrations, etc. The sensors often deployed in hostile environments self-organize themselves to make the network and act as a frontline interface for the user.

Small sensor nodes are not good for harsh environments as they have Un-rechargeable batteries and when all the battery is consumed the nodes become useless. Hence, it is critical to develop such strategies that efficiently make use of power resources. One of the methods is to turn the sensors ON, only

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when required for example when data has to be sensed and transmitted.

Data aggregation and fusion reduce the data size by re- moving the redundant data and hence network overhead and transmission costs are reduced and network energy is saved. Routing schemes such as implementing clustering and finding the shortest path from source to destination are also critical in terms of energy consumption. Clustering provides scalability of the network and sharing of resources thereby saving energy. However, it is important to choose the optimal number of clusters as a large number of small- sized clusters will cause congestion and conversely, too few clusters with a large number of members will overload the cluster head. A good routing protocol is the one in which energy conservation, the prolonged life span of a network,self-configuration, delays (latency), and fault tolerance can be anticipated. Routing protocols in WSNs are often application-dependent. A general protocol fulfilling requirements for all applications is not possible. However, mostly the common point is nodes collect data from the sensing field and covey it directly or indirectly to the BS. The transmission energy required is distance-dependent therefore it is critical to reducing the number of long-distance communications to save energy.

II. LITERATURE REVIEW

Low-cost sensors are available now with significant com- putation and communication capabilities [2]. By deploying a network of sensors in an area valuable information can be collected, for instance, in difficult-to-access environments.The sensor nodes gather temperature, motion, noise, seismic and many other sorts of data and in collaboration can accomplish a high-level task. As noticed in [3], the direct transmission

or DTS approach is most suited if the sink is located in closed proximity to the sensors or the receiving-cost higher

than the transmitting-cost. In case the Base station is placed farther from the nodes, the nodes will die quickly after consuming excessive energy for the data-delivery. The nodes must consume energy as low as possible for transmitting and receiving the data as a significant amount of energy

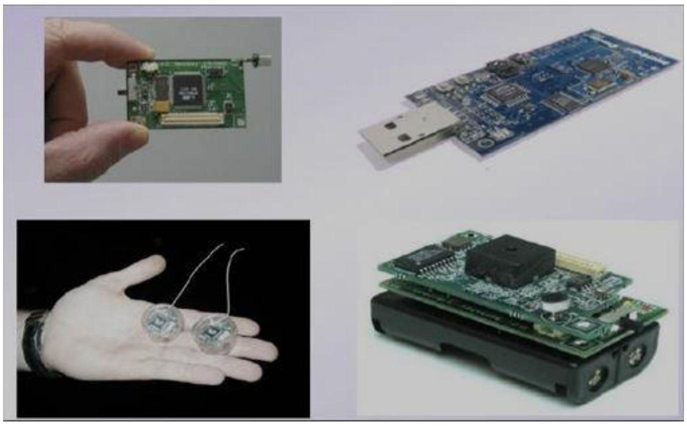

Fig. 2. Various commonly used MEMS Sensors (Courtesy of ICTP, Italy)

dissipation occurs during the wireless communication. It is a requirement from the protocols used in WSN communication to extend the lifetime of the nodes, save bandwiDTSh by collaborating locally between the nodes, and provide tolerance against failures [4].

Let's consider LEACH (Low Energy Adaptive Clustering Hierarchy), a hierarchically clustered sensor network. Leach provides balanced load spreading between nodes in the net- work. It produces new clusters in every round. Each cluster has a cluster head (CH). Every member of the cluster chooses the CH that is nearest to it, for communication. This reduces the communication cost up-to the Base station (BS). Now onlythe cluster head for specific member has to communicate with the base station and will consume the energy accordingly. In LEACH, the optimal probability P_{opt} makes sure that every node in the network plays the role of cluster head after a definite no. of rounds. I.e. $1/P_{opt}$, Also called epoch. Theaforesaid case is true for homogeneous structured network, which means that all the nodes have same amount of initial energy. In the start, the probability of every node Popt toturn out to be cluster head is equal. In every round/epoch,n P_{opt} Nodes that are already selected as CHs in previous rounds cannot participate again. The remaining candidate nodes belong to set G. To maintain a fixed number of cluster heads in every round, the probability for the remaining non- elected nodes increases after every round in the same epoch. Each node n G Every node selects a value between 0 1 randomly and if the value is less than the threshold $T(n)$ then the node is made the CH head in the round r. The thresholdis calculated as follows:

$$T(n) = \begin{cases} \frac{T_{opt}}{1 - T_{opt}[r mod] P_{opt}} & n \in G \\ 0 & Otherwise \end{cases} \quad (1)$$

The probability of a node becoming a CH increases after each round in that ePoch and in the final session of the epoch the probability turn out to be one. The session means the trip time when all the members have to transmit once to their cluster heads. In [5], author shows the heterogeneous scenario where the energies among the nodes are unequal and the CH election process is dependent on the initial energy values of nodes in order to prolong the network life span.

The optimal probability of a node to be elected as a cluster head, spatial density function has been studied for uniformly distributed nodes in a sensing area [6], [7]. Optimum clustering means that energy dissipation is distributed among the nodes in a well– balanced manner and the network energy consumption is minimal. Now ruminate the following model and analysis as suggested [8]. While sending the bit date L on the distance d to attain admissible SNR, the radio consumes energy that is given by:

The optimal number of formed clusters can be found as follows [8]:

Interestingly the optimal number of formed clusters does not depend upon the field dimensions and only depends upon

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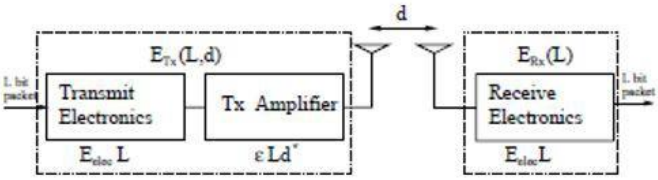

Fig. 3. Radio Energy Intemperance Model

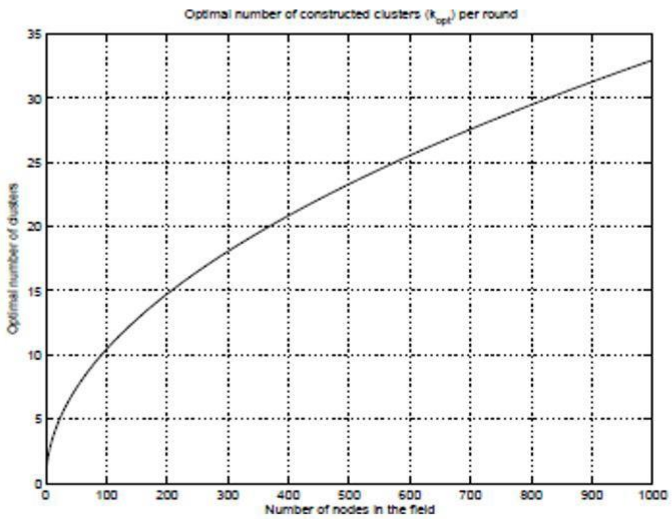

Fig. 4. Optimal number of clusters [8]

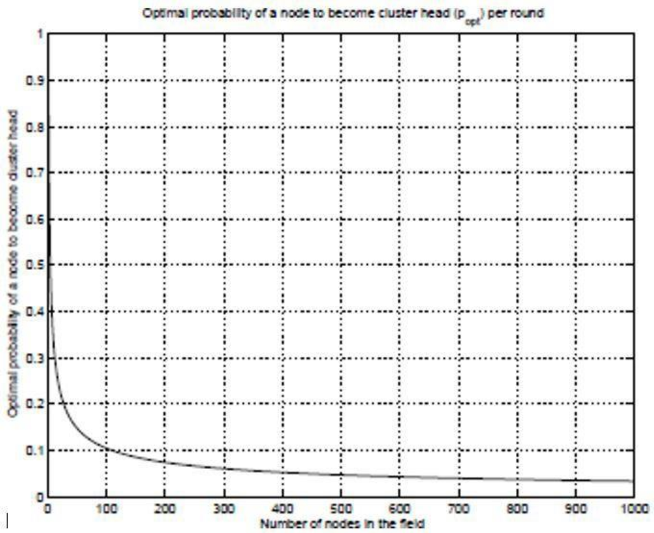

Fig. 5. Optimal probability of a node to become a cluster head [8]

n (the number of nodes) The optimal probability of a node to become a CH, P_{opt}, can be found as under:

$$P_{opt} = K_{opt}/n \qquad (2)$$

Figure 4 and 5 gives the values of K_{opt} and P_{opt} as equation related to n, the total no. of nodes in a 100m × 100m sensing field. It is critical to construct the clusters in optimal number or equivalently using the optimal probability for a node to become a cluster head. In [6], it has been shown that if the construction of clusters is not optimal, the consumption of network- energy increases exponentially either for too many clusters or in particular when the constructed clusters are fewer than the optimal number.

It provides a great motivation that certain applications can take advantage of the presence of heterogeneity in a wireless sensor network when it comes to node energies as sensors are ten times costlier than the batteries, hence it is important to analyze the network-life while simply through the distribution of extra-energy, without introducing new nodes, to certain existing nodes [9]. As we have seen earlier that LEACH operates in two phases: Set up phase where cluster formation is done and cluster head is elected and steady-state or data transmission phase, where data is collected from the member nodes and aggregated and finally sent to BS. Clustering is done for better energy-management in WSNs [8]. LEACH uses rotation of cluster heads for communicating data to BSto evenly distribute the energy dissipation in the network. The rotation of CH provides an added advantage of fault tolerance [10]. The nodes using a probability method elect themselves as cluster head on turns in an epoch. However In homogenous structure of LEACH the nodes consume their energies very fast as compared to the heterogeneity structure. Thus, the nodes cannot maintain the balance of energy. Leach does not consider the energy level of a node while electing it as a cluster head hence the elected CH with low energy has to transmit data to the Base station that reduces the life span of the network.

Power-Efficient Gathering in Sensor Information Systems (PEGASIS) [11] make a chain between sensor nodes in the network and for each node can send data to its neighbor node. The data moves from one node to another node, combined and then the node leader of the chain transfers data to the BS. This node tot node transmission helps in balancing energy dissipation. PEGASIS provides up to 300 percent Improvement in life span of network as compared to LEACH .Delays occur due to the length of the chain structure. Fault tolerance in PEGASIS is also reduced because of only single nodelink to base station. In HEARP [12] several clusters, eachwith a cluster head are formed. A higher-level chain is built among the cluster heads. Then from the cluster heads a nodeis randomly chosen to collect data from other cluster headsand then send to BS. Each cluster head gathers data from its cluster member nodes and then aggregates it. The aggregated data is then sent to the designated chain leader cluster head for onward transmission to BS. Using only a single long communication link to BS saves energy and reduces delay. However too much aggregation of data reduces the accuracy in

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the sensed data conveyed to the BS. Further, only a single link to the BS may render the protocol to data transmission failures due to lack of redundancy. Cluster Based Hierarchical Routing Protocol (CBHRP) [13] is an extension of LEACH protocol. It is a double-layer protocol. A concept of head set is introduced in this protocol instead of using only one cluster head. At a time, one cluster head in the set is active while the other is in sleep mode. The cluster head duties are distributed uniformly in cluster head set members, which has a positive impacton network. Being the extension of homogeneous LEACH it inherits the issues like not being able to make use of variance in energy levels of the nodes to extend the network life.

In [14], cluster head is selected on the basis of remaining energy in the node .Cluster heads are almost uniformly distributed and load is balanced among cluster heads. Again like LEACH too many single-hop communication links from CH to BS squander the energy that could have been managed better using fewer such transmissions. In [15], author proposes a new method for cluster heads-election. Stable Election Protocol (SEP) is a Heterogeneity based protocol. It consumes weighted possibilities to select Cluster heads for motes with non-identical initial energies. Therefore the stability of the network is improved. Stability means the time before the first node dies in the network. In many applications, it is crucial, especially where reliable feedback from the sensor network is desired. It used two kinds of motes/nodes concerning the initial energies and two-level hierarchical network. This protocol does not make efficient use of energies because every cluster head sends data to the BS and wastes energy.

In [16], SEP was expanded by by means of 03 kinds of nodes instead of two. Am intermediate node is also added that acts as a bridge between the other two nodes. This protocolhas the same energy-wasting overhead as SEP and LEACH because of many long-distance links to the BS.

Multihop Energy Efficient Heterogeneous Clustering (MEEHC) [17] which is path with multiple hops to bringdata from motes to BS. However, the network overhead is increased because of too many hops in the network and also the delay can occur in transmitting data from node to the B.

III. PROPOSED METHODOLOGY OF ENERGY EFFICIENTROUTING (EER)

The research work puts forward a innovative routing scheme, Energy Efficient Routing (EER). The proposed scheme saves network energy efficiently, which in turns pro- longs the Network Life. The suggested protocol takes care of

health of the individual sensor nodes too which is the key to a stable network. It is critical to maintain good number of

alive-nodes especially healthy ones i.e. with sufficient residual energy, over most of the time through network life cycle. ARMSEERS uses a robust routing approach. It has no chain-like fixed structure. Hence, if a certain node dies, it would not affect others nodes' communication with the sink.

A. Architecture and Working

This protocol uses energy efficiency by implementing the heterogeneous scheme in the network. Three kind of nodes are used in context of energy consumption: Normal, Intermediate and advance nodes. The total preliminary energy of the system will be equal to :

$$E_{total} = nE_0(1- m- x)+nmE_0(1+\alpha)+nxE_0(1+\beta) \quad (3)$$

$$E_{t}otal = nE_0(1 + m\alpha + x\beta) \quad (4)$$

where x shows the concentration of intermediate nodes in total n count of nodes in the network. β be the additional energy and fraction of E of intermediate node. E_0 be the initial energy.And α is the extra energy.

When the nodes are installed in the subjected geographical area, the BS transmits a message with certain signal power at the sender. When the message is received, each node updates its register with the value of its space from the BS. Using the known transmitted and the actual received signal strengths, the sensor nodes can calculate their distances from the BS. This protocol uses the same-clustered structure as LEACH. The whole field is divided this way into segments or clustersof closely spaced sensor nodes. The hierarchical structure balances the distribution of energy dissipation at its best. As discussed previously, it is critical to choose the optimum number of clusters for a given number of nodes deployed. ARMSEERS takes care of this important aspect and only the best suitable number of clusters would be formed for any given number-of-nodes.

Like in LEACH, there is a setup phase in ARMSEERS after the deployment of nodes, which is the beginning of first round and then same procedure is repeated subsequently at the start of every new round. Cluster formation takes place in this step.In the setup phase, every sensor node first choses a random number from a range determined by the optimum probability of CH election. For instance for a $n = 100$ node network, the optimum probability is 0.1, which means 10% of the nodes will be elected as CHs in every round or in other words 10 clusters will be formed in a 100 node network. Inthis example, every node will randomly choose a value from 0to 1. The node then performs a computation to decide whether to declare itself as a Cluster Head (CH) in that round. For that, the chosen random value for every node will be compared with a threshold value, which is also based on optimum probability for the number of Cluster Heads or clusters for a given number of nodes. The threshold value $T(n)$ is obtained using the equation 1 reproduced as below:

$$T(n) = \begin{cases} \frac{P_{opt}}{1-P_{opt}[r \bmod(\frac{1}{P_{opt}})]} & \text{if } n \in G \\ 0 & Otherwise \end{cases} \quad (5)$$

Where, P_{opt} is the optimum probability for CH election and the current number of round is represented by r. G is the set ofnodes that have not been so far elected as CH in the current epoch. Epoch is the numbers of rounds, after which every node would become eligible again for CH election. $1/P_{opt}$. represents the size of the epoch.

Now for a particular node if the chosen random value is smaller than the threshold value, the node declares itself as CH in that round. In LEACH exactly the above-mentioned procedure is followed.

The threshold value has different calculation method in heterogeneous ARMSEERS. ARMSEERS uses heterogeneity by giving weighted probability to the nodes. The probability of advanced nodes to become CH is the highest, then the immediate nodes and the probability of Normal nodes is the least to become CH. The three different probabilities are given as under:

$$P_{nrm} = \frac{P_{opt}}{1 + m\alpha + x\beta} \quad (6)$$

$$P_{int} = \frac{P_{opt}(1 + \beta)}{1 + m\alpha + x\beta} \quad (7)$$

$$P_{int} = \frac{P_{opt}(1 + \alpha)}{1 + m\alpha + x\beta} \quad (8)$$

where, P_{opt} is the optimum probability as nP_{opt}. no. of clusters

P_{nrm} = weighted probability
P_{int} = weighted probability for intermediate nodes
P_{adv} = weighted probability of advanced node

Therefore, for these three main forms of nodes, a new thresholds $T(n)$ are defined as follows: For normal nodes:

$$T(n_{nrm}) = \begin{cases} \frac{P_{nrm}}{1-P_{nrm}[r \bmod (\frac{1}{P_{nrm}})]} & n_{nrm} \in G' \\ 0 & Otherwise \end{cases} \quad (9)$$

$$T(n_{nrm}) = \begin{cases} \frac{P_{adv}}{1-P_{adv}[r \bmod (\frac{1}{P_{adv}})]} & n_{adv} \in G'' \\ 0 & Otherwise \end{cases} \quad (10)$$

The weighted probabilities for the nodes with different energy levels guarantee that more energetic nodes would have greater chance of being elected as CH.

Once the Cluster Heads are elected, they broadcast an advertisement message with a given low power signal strength as the message is meant for only the closely located sensor nodes. The message contains the source address of the CH. The nodes receive the CH advertisement messages and based on strongest signal received decide the CH they have to joinas cluster member. Every non cluster head node then sends an acknowledgement or joining message to its CH using CSMA MAC protocol. During this phase all CHs keep their receivers on. When the acknowledgments are received at all CHs from the associated nodes, every CH creates and communicates a TDMA schedule to its members, which decides once a particular node will transmit the data to CH.

After the clusters are created and TDMA scheduling has been done, the data-transmission phase begins. The sensornodes sense the data and after processing sends it to theirCH on their turn in the decided TDMA schedule. The radioof a member node is turned off, until it gets its time-slot to transmit the data, to save energy. As the sensors within a cluster are closely spaced hence chances of data duplication are high. The CH after collecting the data reduces its size by removing the redundant information and places it into a single packet. The action is called data aggregation and it saves the energy that would be consumed in sending this data to the BS. The aggregated data is then sent to the BS using the routing strategy given by ARMSEERS. In LEACH every CH transmits data individually to the BS. The BS is normally locate at very, long distances are involved which leads to the wastage of energy. As a result, long distanced CH BS hop will require a greater amount of energy dissipation as the consumption of energy in the RF model depends on the distance: The energy expended to attain Optimal SNR by transmitting L-bit data over distance d is rewritten as:

$$E_{tx}(L,d) = \begin{cases} L.E_{elec} + L.\epsilon_{fs} d^2 & d < d_0 \\ L.E_{elec} + L.\epsilon_{mp} d^4 & d \le d_0 \end{cases} \quad (11)$$

$$d_0 = \sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}} \quad (12)$$

where L is no. of bits. E_{elec} is energy dissipated per bit to run transmitter or reciever.

d is the distance between sender and reiever.
ϵ_{fs} free space coefficient constant.
ϵ_{mp} is multipath coefficient constant.

CH-to-BS links usually employ distances above d_0. Hence it is critical to reducing the number of such links to save energy.

The proposed scheme assumes that all the nodes in the network have radios. These radios to optimal transmitting power levels according to the requirement of the node. For example, for shorter distance communications they would not unnecessarily transmit the high power signals. The transmitter power would be enhanced only when required for example for long-distance BS communications.

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IV. 3.2.6 THE NETWORK HEADS (NHS) IN ARMSEERS ARMSEERS implements a procedure that reduces the num- ber of communication between Cluster Heads and Base station.In ARMSEERS only a chosen set of Cluster Heads (not all CHs) termed as Network heads transmit data to the B. The remaining Cluster heads send message only to their nearest network head.

These points are taken into account whereas selecting Net- work Heads (NHs):

- 1) The number of NHs should be optimal and every CH has a small distance from its nearest NH. This will decrease the communication cost.
- 2) CHs that have the least distance from the BS are selected as Network Heads in order to save energy .The energy saving ultimately leads to a longer network life.
- 3) To stabilize the network, ARMSEERS also considers the energy level of the node and elects CH as NH if the energy level is higher even if the CH is located farther from the BS. Taking in account both the communication cost and the residual energy level makes ASMEERS

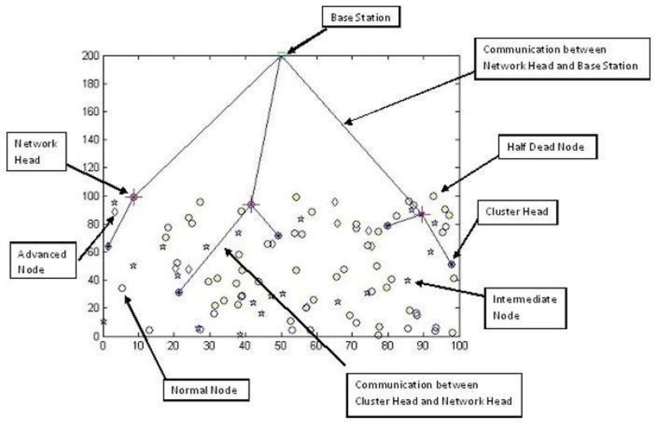

Fig 3.1: Routing in ARMSEERS using Network Heads (NHs)

Fig. 6. Routing in ARMSEERS using Network Heads (NHs)

flexible to the trade-off between the life span of network and the stability of the network.

- The nodes begin expiring, the no. of CHs reduces and eventually the number of NHs reduces too. This saves energy and increases the life span of the network. For illustration, in $n = 100$, $CHs = 10$, $NHs = 3$, when the CHs decrease to 3, the NH decreases to only one.

V. Routing in ARMSEERS

When the cluster Heads are selected and the process of cluster formation is in process , every CH multicasts a low cost message to other CHs in the network at a signal power known by all the CHs. This message consists of the source address and the distance of each CH from the BS. Hence, every CH knows this information about all other CHs in the network. This information is sorted in a sending order by everyCH and is sent to the three CHs that are nearest to the BS. Then every CH selects one these CHs as its NH based on the signal strength.

The acknowledgments are sent by every CH to its NH. When the NH receives the acknowledgments from its mem- bers, it generates the TDMA scheduling for communication just Like Cluster heads did for their cluster members. In the communication route, the data is first sent from cluster member to Cluster head, then from CH to NH and then NH transmits the packet to the Base Station. Data reduction is not performed by NH. It just receives all the packets from its members, place them in a single packet and forward it to the BS. It is because the data has very low correlation between various CHs.

VI. The Network Stability Problem

This scheme is useful in the start but when it is repeated over and over again for a multiple number of initial rounds,at some stage it becomes useless to persist. The health or the energy level of individual nodes is not taken into account when the shortest path between NH and BS is used .if a weak node is selected it will deplete all its energy after becoming NH

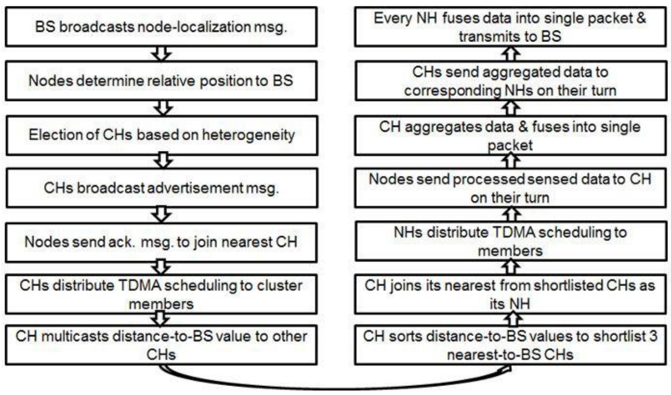

Fig. 7. Flow chart of ARMSEERS without stability window

which will lead to nodal death. This decreases the stability of the network.

A. The Solution proposed in ARMSEERS

It is therefore the time for some maintenance activity. So far, the information sent to CHs for NH selection was onlythe distance of CH from the BS. To avoid nodal death, the criteria of choosing NH is transformed for a particular number of rounds when the first node energy is consumed to half. ARMSEERS makes each CH to send a low cost message to BS when its energy is consumed to half viz. the initial energy of a normal node. The event is termed as half death of the particular node. BS broadcasts the half death of node to the network Every node receives the message to and increments the counterof the number of half death nodes and when the counter reaches the threshold value say ten the nodes stop transfertheir half death message to BS so that they can conserveenergy .This ends the intermediate stage of maintenance ofthe network. When the stage had reached, all nodes calculate the amount of energy required for becoming NH and then subtracts it from its remaining energy to regulate how much next residual energy it will have after becoming NH. Now, instead of distance from the BS, the next residual energyis joint with further CHs. The CHs sort this information in plunging order to discover the top three fittest nodes with highest next residual energy levels and elect them as NHS. Again, every CH chooses its NH based on the strength ofthe signal and data is transmitted to BS in the equal way as before. Almost 10% of the nodes are partially dead after the intermediate stage and the nodes go back to their real strategy of selecting NH by using shortest distance in order to save energy.

The figures 9 below show how the changing stability affects the energy level and network stability trade-off.

To save energy in later stages, each CH receives packet only from two other CHs, and only 1 NH with the smallest distance from BS is chosen to extend the life of the network. All CHs send their data to this NH for transmission to BS.

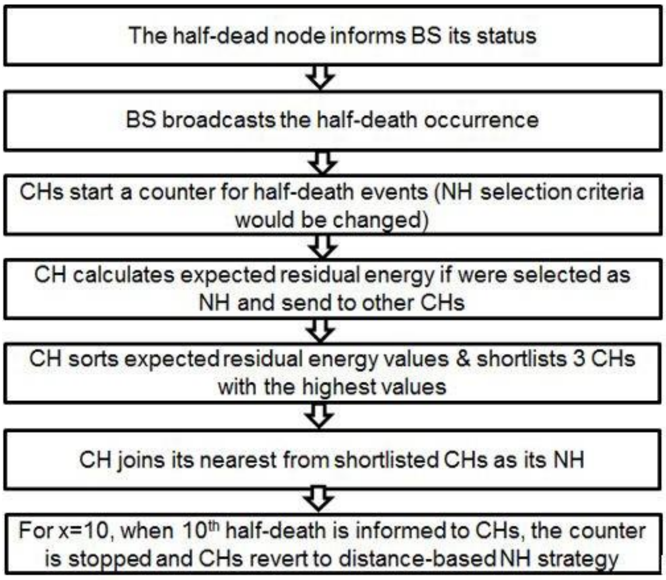

Fig. 8. Flow chart of using stability window in ARMSEERS

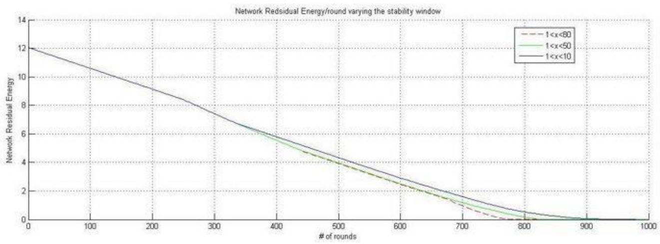

Fig. 9. Network Residual Energy (in Joules)/round changing stability window x in ARMSEERS

VII. 3.4 Energy Dissipation Equations in ARMSEERS

VIII. Simulation Results

ARMSEERS also employs a similar type of heterogeneous structure at the cluster level as do the SEP and SEP-E protocols.However, like LEACH, in SEP and SEP-E, All the cluster heads send data straight to the Base station. Whereas, ARMSEERS take on an additional hop scheme. Therefore it is relevant to compare ASMEERS with SEPE, which is already an improved version of SEP. Some performance parameters are given below.

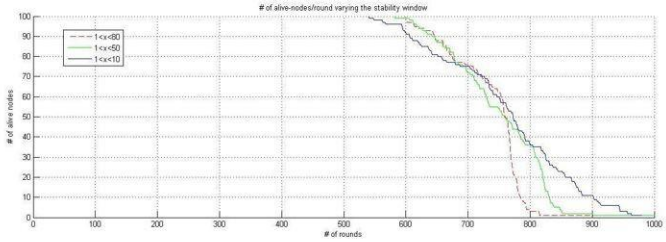

Fig. 10. Number of alive nodes /round changing stability window x in ARMSEERS

A. Network Quality

Life of network is defined as the number of the roundin which the last node of the network expires or when the network is completely depleted of the energy, but it is more of a subjective nature. For If most of the nodes in the network die speedily and only a few weak nodes are left that are prolonging the life of the network, the life despite being longer will not be useful because very short portion of the network will be accessible for detecting the data. Therefore, it is mandatory to sustain a optimized energy level of the network for the major portion of the network life span. In other words, networkquality is also worth taking care of besides the time for which a network exists. Therefore, examining the network for the number of alive or dead nodes after a significant number of rounds would provide an insight into the quality of the network for both types of competing protocols.

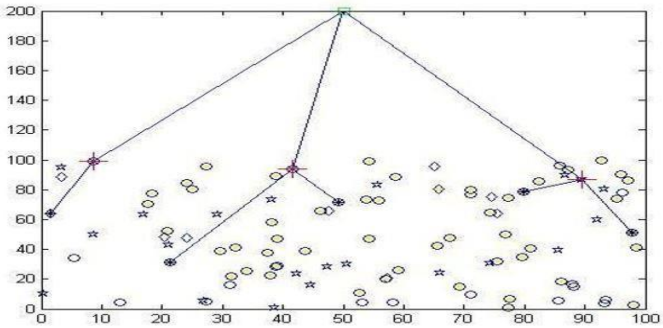

Fig. 11. Snapshot of ARMSEERS after 500 rounds, for n=100 heterogeneous WSN in 100m x 100m area

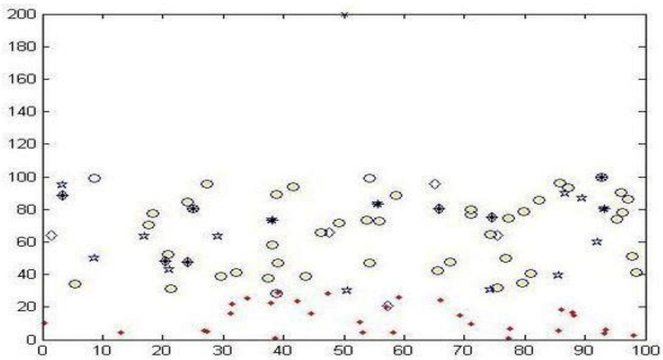

Fig. 12. Snapshot of SEP-E after 500 rounds, display nearly one third of nodes as dead (depicted as) for n=100 heterogeneous WSN in 100m x 100m area

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B. Network Stability

The number of the round in which the first node dies determines stability of a network. The number of alive and dead nodes after each round are designed. The well along the first node dies, the more stable is the network as shown in figure 13 and figure 14.

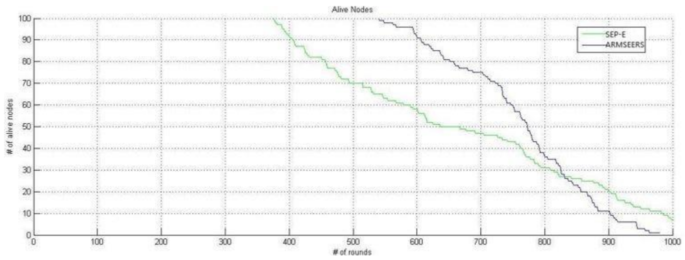

Fig. 13. No. of alive-nodes/round for ARMSEERS and SEP-E

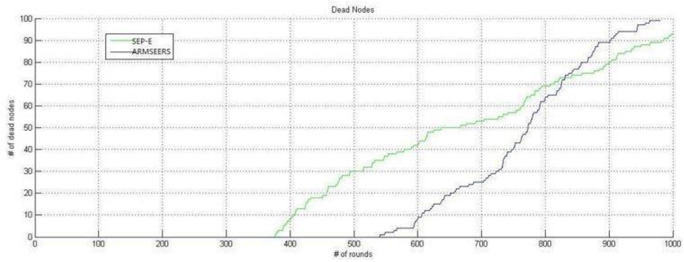

Fig. 14. No. of dead-nodes/round for ARMSEERS and SEP-E

C. Residual Energy

The length of the network and the quality of the network life can be determined by the residual energy vs number of rounds graph. The same has also been plotted for comparing ARMSEERS with SEP-E. If the network energy level is high for long then it means that the network has very highly energetic nodes in it. In addition to plotting the network residual energy against the number of rounds, another interesting parameter to look into is the presence of high energy nodes after every round. In this work, the alive-nodes that possess energy greater than partial of a reference energy value are termed as the energetic nodes. The energetic nodes can easily perform special tasks requiring high energy, making the network more potent as evident from figure 15 and figure 16.

D. Energy Dissipation Pattern

It is also important to gauge a network for the balance with which energy dissipation is distributed among the nodes. For a network dissipating the energy in a balanced way, the nodes would expend energy at similar rates. The number of half dead nodes after every round is a useful parameter to gauge the balance of energy dissipation. A half-dead node is one that has used up its Energy sufficient to touch half of the original value of energy. More nodes entering the half-dead status within fewer numbers of rounds would mean they were consuming their energy at optimum rates maintaining the network energy

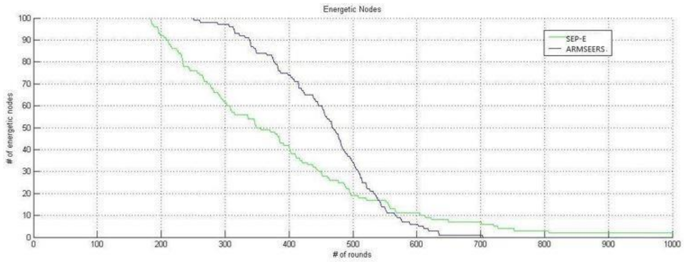

Fig. 15. No. of nodes possessing energy greater than half of E0/round for ARMSEERS SEP-E

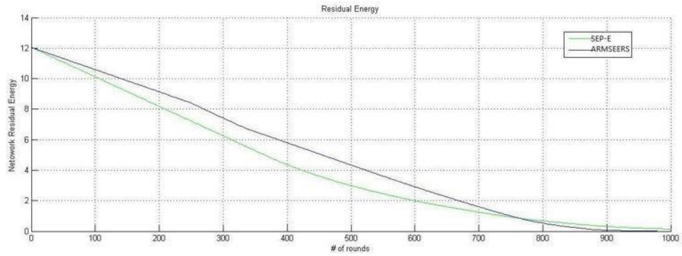

Fig. 16. Residual Energy (in Joules) of network/round for ARMSEERS and SEP-E

balance. Additionally achieving a maximum number of half-dead nodes and then maintaining the plateau for a significant number of rounds would mean that least number of nodes had reached their full death by that time as when the nodes started dying it would reduce the number of half-dead nodes as clearly shown in figure 17.

Fig. 17. No. of half-dead nodes/round for ARMSEERS and SEP-E

E. ARMSEERS v/s LEACH

ARMSEERS is a more stable routing scheme than LEACH. The first node expired 100 rounds behind schedule than in LEACH. ARMSEERS increased the life span of network by 73% more rounds than that of LEACH.

The simulation model parameters that was used are in table I.

The result obtained after simulations are in table II.

F. ARMSEERS v/s PEGASIS

G. Discussion

In terms of network life and stability, ARMSEERS surpassed PEGASIS. There was a marginal improvement in

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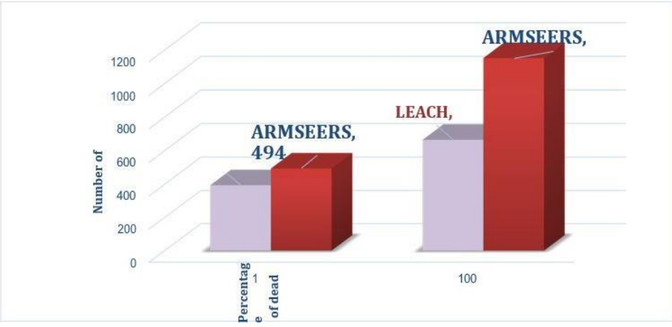

Fig. 18. Stability and Lifetime comparison between ARMSEERS and LEACH

M x N m2	100x100
n	100
BS (x,y)	0, -100
Avg. E_0	0.25 J
E_{elect}	50 nJ
EDA	5 nJ
ϵfs	100 pJ
mp	0.0003pJ
L	2000

TABLE I
SIMULATION MODEL TO COMPARE ARMSEERS WITH LEACH

Energy (J/node)	Protocol	Round first node dies	Round last node dies
0.25	LEACH	394	665
0.25	ARMSEEI	S494	1152

TABLE II
STABILITY LIFETIME (ARMSEERS V/S LEACH)

M x N m2	50 x 50
n	100
BS (x,y)	25, 150
Avg. E_0	0.25 J
E_{elect}	50 nJ
EDA	5 nJ
ϵfs	100 pJ
mp	0.0003pJ
L	2000

TABLE III
SIMULATION MODEL TO COMPARE ARMSEERS WITH PEGASIS

stability .first node expired 36 rounds later and the network life span was increased by 44% more rounds than that of PEGASIS. PEGASIS using a long chain structure may cause too much latency for far end nodes in data delivery to BS however in ARMSEERS every node has to traverse only a few hops to get to the sink. Also PEGASIS uses only single link for communication of all the data to BS every round, which may become bottleneck. ARMSEERS uses multiple links to BS and thus more robust against faults.

H. ARMSEERS v/s HEARP (Hierarchical Energy Aware Routing Protocol)

The results show that though ARMSEERS lagged behind HEARP slightly i.e. just by 18 rounds when it came to first node death but the network-life has been improved in ARMSEERS as compared to HEARP. The point when 90% nodes are dead comes later in ARMSEERS than in HEARP. Further, last node in ARMSEERS also dies much later than in HEARP. HEARP however like PEGASIS relies only on a single communication link to BS to conserve energy but it reduces its fault tolerance capability as clearly shown in figure 20.

I. ARMSEERS v/s MEEHC (Multi-hop Energy Efficient Heterogeneous Clustered scheme)

ARMSEERS outperformed MEEHC completely during the network life cycle. A Significant improvement in the stability as the first node dies 200 rounds later and the network life span is also increased. MEEHC performs closer to ARMSEERS in the later stage of network life when there remain only a very few nodes and only a small area can be sensed, however during most of the time in the network life cycle it is way behind ARMSEERS as shown in figure 21.

IX. THE SIMULATION MODEL

The important parameters and their values have been tabulated as under:

X. FUTURE WORK

This research paper proposed a heterogeneity based protocol for Wireless Sensor Networks (WSNs) that is highly efficient and stable in terms of energy and life span of the network. This protocol assigns various roles to various nodes / motes in the network depending on the energy of the node. The protocol uses the multi hop topology for communication.

Currently, the simulation has been done on NS-3, which is the open source network simulator LINUX based. The future research work might be done by developing viable and robust Machine Learning Algorithms to predict the health of the network and optimize the energy of the nodes in WSNs without the need of programming again and again. WSNs come with

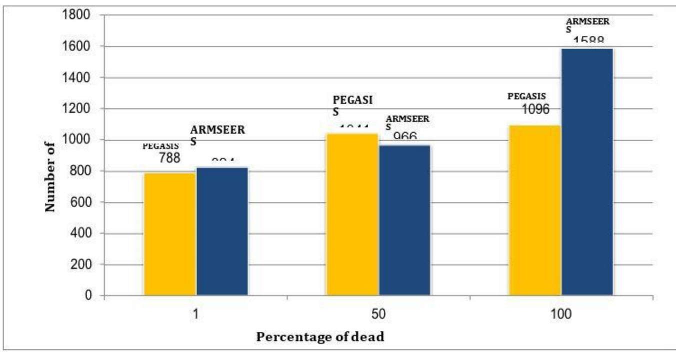

Fig. 19. Comparison of ARMSEERS with PEGASIS for number of rounds with 1%, 50% and 100% dead nodes

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Parameter	Value
Dimensions of the sensing region (M x N sq. m)	100 m x 100 m
Number of nodes deployed in the network (n)	100
Percentage of advanced nodes among the nodes n (m)	10%
Percentage of intermediate nodes among the nodes n (x)	20%
Normal nodes commencing energy (E_0)	$0.1J$
Additional level of energy in advanced nodes E0 ()	1
Additional level of energy in intermediate nodes of $E_0(\beta)$	0.5
Position of base station or sink in terms of x and y coordinate (x, y)	(50, 200)
Energy required to function the electronics of Tx/Rx (E_elect)	$50nJ/bit$
Energy required for data collection (EDA)	5nJ/bit/message
Size of the packet (L) $E_0(\beta)$	1000
Ideal probability for the selection of Cluster head (CH) (P_{opt})	0.1
Energy required for the amplification of the idel space if $d < d_0(fs)$	10pJ/bit/m2
Energy required for the amplification of the compound- path if d d0 (mp)	0.0013pJ/bit/m4
Crossover distance	87.7M

TABLE IV
MODEL OF SIMULATION TO IMPLEMENT ARMSEERS IN MATLAB

multiple challenges like data routing, clustering, localization, neighbor selection, security and fault detection. Different algorithms of Machine learning can help in enhancing the performance of WSNs from multiple aspects. Such as, the supervised learning K Nearest Neighbors (K-NN) algorithm of ML can help to find the nearest nodes by calculating their Euclidean distance and also it can predict the missing readings of the motes / nodes using the readings of the neighboring

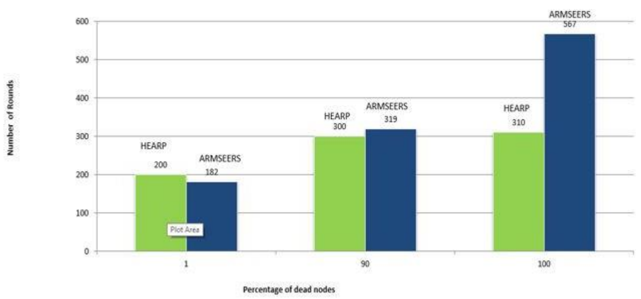

Fig. 20. Extended lifetime for ARMSEERS at the expense of little reduction in stability as compared to HEARP

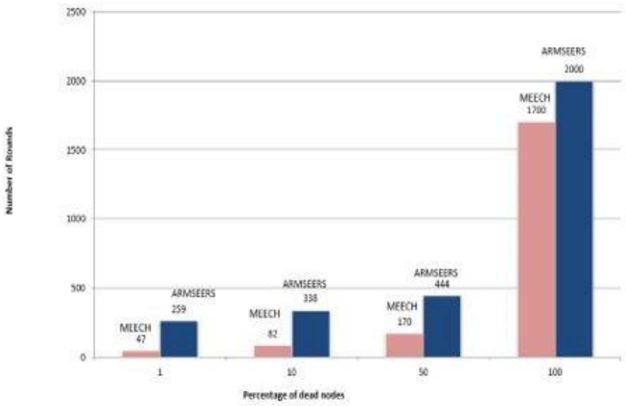

Fig. 21. : Enactment results for ARMSEERS whereas associating with multi-hop heterogeneous MEEHC

nodes. The decision trees Algorithm of ML can help to analyze the current status of a particular node in the network such as time failure rate of the node from which we can easily determine the health of the node. The unsupervised K Means algorithm of ML can help in choosing the cluster heads. PCA helps to reduce the amount of data transmitted to the BS by discarding unnecessary and I correlated information from the data. Reinforcement Q -learning technique helps the nodes in the network to learn by communicating with environment. These nodes will learn to take best suited decisions in order to maximize their energy levels. Therefore, by adopting these machine learning algorithms, many challenges in the WSNS can be easily resolved. In future work we can improve the performance of the proposed routing scheme from following aspects :

A. Complexity

The routing protocol should be optimised in a way that it reduces the complexity of the routing scheme yet maintains the efficiency of the protocol.

B. Deployment

The nodes in the network should be deployed keeping the metrics such as energy and connectivity into consideration so that the energy consumption in the network is optimal .

C. Fault tolerance

Fault tolerance is a very important parameter that should be emphasised because a single node failure can damage the whole network. Therefore fault tolerance should be taken into consideration to avoid any damage caused by link failure or CH failure. A sensor node has a small memory and a very limited capability of Calculation . This makes the proposed routing protocol vulnerable to any kind of attacks by hackers
. Therefore, to avoid CH level attacks proper encryption and authentication algorithms should be applied . Therefore, all these issues should be addressed in future work to make the routing scheme more effective and efficient to use .

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