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Energy Efficient Data Aggregation in Wireless Sensor Networks

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ABSTRACT
Designing energy efficient data aggregation technique in clustering environment for Wireless Sensor Networks (WSNs) is a challenging task when nodes in the network are resource constrained. Data aggregation is necessary in WSNs as different sensors in the same region transmit duplicate information in the network. So to reduce the flow of this duplicate information transmitted in the network, the concept of data aggregation is necessary. The propose system also introduces an efficient mechanism of cluster head selection so that area covered by cluster head is minimum overlap area that cover the entire network. The performance of proposed scheme is evaluated using custom simulator. Simulation results prove that the proposed scheme performs better than other comparable schemes in the literature without increasing the communication overheads.
Keywords – Base Station (BS), Clustering, Data Aggregation, Node, WSNs, Zone.

I. INTRODUCTION TO WSNS

A wireless sensor network (WSNs) consists of large number of wireless sensors that are able for measuring various environmental effects (temperature, light, sound and humidity), military area, industrial process control and patient monitoring. These sensors are very small in size but are huge in numbers. All the sensors are relies on battery for their power. In most situations, they are deployed in a harsh or hostile environment, where it is very difficult or even impossible to change or recharge the batteries. They consist of built-in processor which is used to process the sensed data.

This processor will also perform logical operations which are helpful in decision making. A sensor node might vary in size from that of a shoebox down to the size of a grain of dust. The cost of sensor nodes is similarly variable, ranging from a few to hundreds of dollars, depending on the complexity of the individual sensor nodes. Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and communications bandwidth. The sensors have built in antenna that will help them in communication to other sensors in their limited communication range. Sensor nodes are usually densely deployed in the field of interest. Sensor nodes are highly limited in energy, computation, and storage capacities. Sensor nodes are usually randomly deployed in the required area. Once deployed, sensor nodes have to autonomously configure themselves into a communication network. Sensor networks are application specific. A network is usually designed and deployed for a specific application. The design of a network changes according to the application that required it. Sensor nodes are usually deployed in harsh or hostile environments and operate without attendance so they are prone to physical damages or failures. Network topology changes frequently due to node failure, damage, addition, energy depletion, or channel fading. Due to the large number of sensor nodes, it is usually not possible to build a global addressing scheme for every sensor because it would introduce a high overhead for the identification maintenance. In most sensor network applications, the data sensed by sensor nodes flow from multiple source sensor nodes to a particular sink, exhibiting a many-to-one traffic pattern. In most of the sensor network applications, sensor nodes are densely deployed in a region of interest and collaborate to accomplish a common sensing task.

1.1 CLUSTERING

Clustering mechanisms have been applied to sensor networks with hierarchical structures to enhance the network performance and reducing the necessary energy consumption (Fig. 1). The primary idea is to group nodes around a cluster head that is responsible for state maintenance and inter-cluster connectivity. In multi-hop wireless networks, node clustering is a technique that aggregates nodes into groups (clusters) to reduce the routing overhead and to provide a convenient framework for efficient resource (e.g., bandwidth) allocation, energy management, fault - tolerant routing, and high end - to - end throughput. In clusters without any cluster head, a proactive strategy is used for intra-cluster routing while a reactive strategy is used for inter-cluster routing. However, as the network size grows, there will be heavy traffic overhead within the network. Therefore, normally one node is selected as the cluster head of a cluster, and it acts as the local coordinator of transmissions within its cluster. A hierarchical routing or network management protocol can be more efficiently implemented with cluster heads. However, a cluster head performs additional functions as a central administration point, and a cluster - head failure would degrade the performance of the entire network; it may become the bottleneck of the cluster. So it is desirable to change the cluster head according to the need.

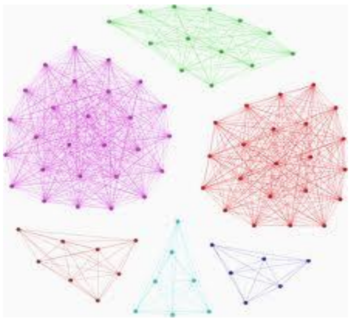

Fig 1: Clustering in WSNs

1.2 DATA AGGREGATION

Data aggregation is an effective technique for removing data redundancy and improving energy efficiency in WSNs. The basic idea is to combine the data received from different sources so that the redundancy in the data is minimized and the energy consumption for transmitting the data is reduced in the aggregation process. Sensory information is communicated to the Base Station through wireless hop by hop transmissions. To conserve energy this information is aggregated at intermediate sensor nodes by applying a suitable aggregation function on the received data. Aggregation reduces the amount of network traffic which helps to reduce energy consumption on sensor nodes. Data aggregation arises from the observation that most of this redundancy could be avoided if data were partially processed locally to the sensors, for example, by averaging it over time or space before forwarding it (Fig. 2). This is what data aggregation does, by applying fusion/consolidation functions to the data along its way to the sink or BS (base station).

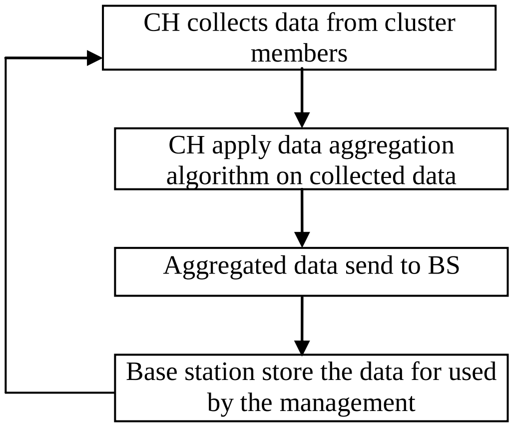

Fig 2: General architecture of Data Aggregation

II. LITERATURE REVIEW

In [1], author proposed an optimal routing and data aggregation scheme for wireless sensor networks. Proposed work focus on maximizing the network lifetime by using 'maximum lifetime routing algorithm' and 'smoothing function'. To increase the network lifetime, an optimal routing and data aggregation scheme for wireless sensor networks is proposed. The scheme jointly optimizes the data aggregation and routing. Simulation results prove that the proposed algorithms reduce the data traffic and at the same time also improve the network lifetime.

An aggregation framework on wireless sensor networks is proposed [2]. The framework works as a middleware for aggregating data measured by a number of nodes within a network. The main goal of the author is that the data aggregation algorithm is to gather and aggregate data in an energy efficient manner so that network lifetime is enhanced.

Method given in [3] investigates the extended battery life for individual wireless motes while maintaining sampling adequacy and reliability in transmitting accurate data. By operating under less than optimal power levels, this effectively increases motes battery life for reliable data collection from wireless sensor networks.

Author in [4] makes the synopsis diffusion approach secure against attacks in which intermediate nodes contribute false sub-aggregate values. The work present a novel verification algorithm by which the base station can determine if the computed aggregate (predicate Count or Sum) includes any false contribution.

Author in [5] classifies the different aggregation techniques that are designed to achieve some important objectives e.g. reducing data size, minimizing transmission energy, enhancing accuracy etc. The work proposed gives a survey of aggregation techniques that can be used in distributed manner to improve lifetime and energy conservation of wireless sensor networks.

Scheme in [6] discuss the various data aggregation algorithms in wireless sensor network. Data aggregation technique increases the lifetime of sensor network by decreasing the number of packets to be sent to sink or base station. Author first explores the data aggregation algorithms on the basis of network topology, then they explore various tradeoffs in data aggregation algorithms and finally they highlight security issues in data aggregation.

Author in [7] analyzed the issues related to security in WSNs and remedies related to those issues. In the proposed work author also highlight the research area in the field of wireless sensor networks.

Security threats and various key distribution techniques are defined in [8]. These techniques can be used to secure the sensor network.

Research in [9] revealed a deterministic key management scheme, called DKS-LEACH, to secure leach protocol against malicious attacks. They design and performed a theoretical evaluation of their security model which secures the setup and study phases of leach protocol. Using a TOSSIM simulator they performed an evaluation of the power consumption of DKS-LEACH. This prevents the election of untrustworthy cluster head as well as different kind of attacks from malicious sensor nodes.

Author in [10] presented pairing based encoding scheme. The pairing scheme used to achieve security by applying proposed encoding techniques. IN this instead of using heavy cryptography algorithm use of multiple encoding scheme is done along with light weight encoding scheme. And from the simulation results it has been seen that this scheme is very efficient than other heavy cryptography algorithms.

A survey on robust and secure aggregation protocols that are resilient to false data injection attacks is presented in [11]. In this various vulnerabilities of data aggregation for different system also discussed.

III. PROPOSED SYSTEM MODEL

This section provides an overview of the proposed system model. Proposed scheme uses the concept of static clustering. The clusters are fixed and are decided before the network deployment. So network area is divided into fix size clusters. Number of cluster in horizontal and vertical direction is decided. Every cluster is again divided into fix size equal four zones. Equal sensors are deployed randomly in each zone as shown in Fig. 3.

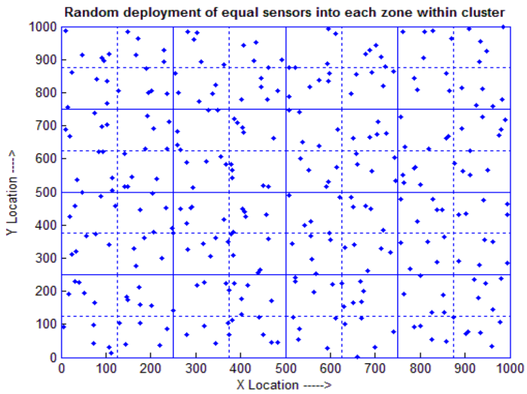

Fig 3: Random network deployment

3.1 Division of Network into Clusters

In this algorithm firstly divide the area into equal no of rows and columns i.e. n. The area that form after dividing the network is treated as a cluster. Total no. of sensors in each cluster is i, so the no. of sensors in each cluster is $p=i/n^2$. Now deploy p random sensors into in each cluster as describe in Fig 4.

Algorithm 1: Network clustering

Step 1: Divide the area into no. of rows and columns.
No. of rows= No. of columns = n.

Step 2: Total no. of sensors = i.

Step 3: Total no. of clusters in the area = (no. of rows) * (no. of columns) = $n*n = n^2$.

Step 4: calculate no. of sensors in each cluster= i/n^2.

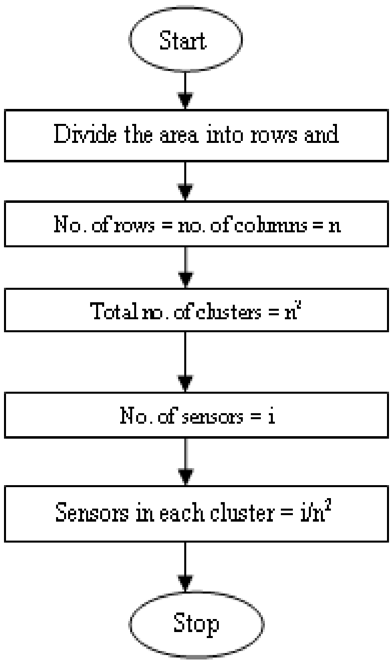

Fig 4: Division of area in to fix size clusters

Cluster heads are selected randomly; it is possible that two or more cluster heads selected in the network area are very close to each other as scenario shown in Fig 5. The drawback of this scheme is that cluster head will be in the network area that forms overlap zone. This way half of the area is uncovered and remaining half of the network area is overlap area. So a scheme will require that will efficiently cover the entire network area, without forming an overlap zone. The proposed scheme is a progressive approach to selecting cluster head in such a way that will overcome the problem of overlap zone, make decision independently without calculating the location of cluster head from the adjacent clusters. A local clustering algorithm will be required that will decide cluster head on the basis of location information of the own cluster.

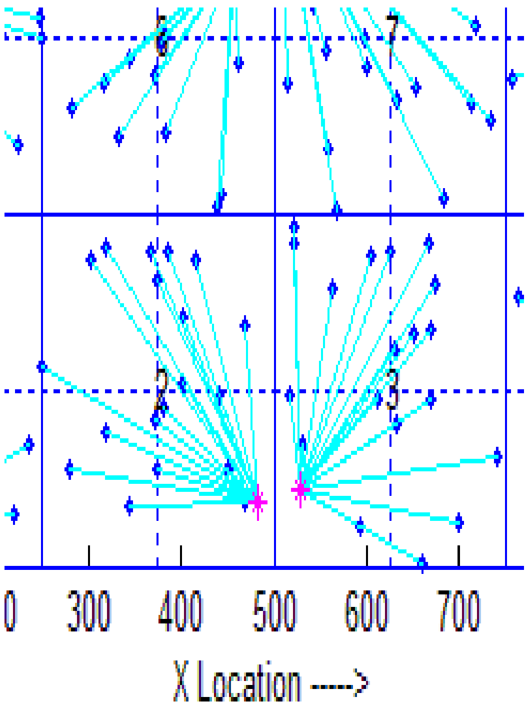

Fig 5: Random approach to selecting CH

In Fig 5, CH (*) from cluster 2 and cluster 3, nodes (.) are their cluster members, respectively. Location of these CH's is very near to each other. The energy that a CH consumes is the sum of energy consumed in receiving and sending data. But in this case the total energy consumption of two CH is greater than the case that there is only one CH. So if CH from adjacent clusters is not controlled, or CH selected randomly from the entire area, a big extra energy loss occurs. So in the proposed system a node in any cluster could decide that it is suitable to be a new CH based on the location of CH from the adjacent clusters. But the scheme will be efficient if selection of a CH from one cluster is completely independent from the selection of a CH from other cluster. In proposed scheme we divide the network into different zones. CH is selected from same zone in all the clusters. This may result efficient selection of CH so that two CH from adjacent clusters are on average distance away from each other. This way all CH's will cover the entire network with equal distance to each other. As shown in Fig 6.

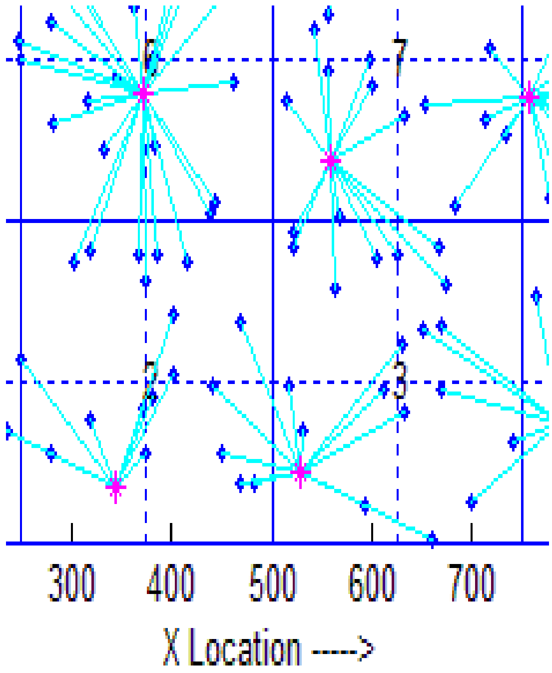

Fig 6: Progressive approach to selecting CH

3.2 Division of Clusters into Fix Zones

After division of network into fix size clusters, every cluster is further divided into four zones named bottom left zone (BLZ), bottom right zone (BRZ), upper left zone (ULZ) and upper right zone (URZ).

Cluster Head (CH) is selected from similar zones in every cluster i.e. if CH is selected from BLZ then CH from all the clusters is selected from BLZ. For each cluster 1 to n^2, rotate the selection of CH from zone wise, i.e. if in first round select the cluster head from BLZ, in second round select the CH from BRZ, in third round select the CH from ULZ and in fourth round select the CH from URZ from all clusters in fifth round again select this sequence (BLZ, BRZ, ULZ, URZ) for the subsequent rounds. Move to next round to select a new CH from next zone. With this technique, cluster heads are selected in such a way that these cluster heads cover the entire network on equal distance (Fig. 7).

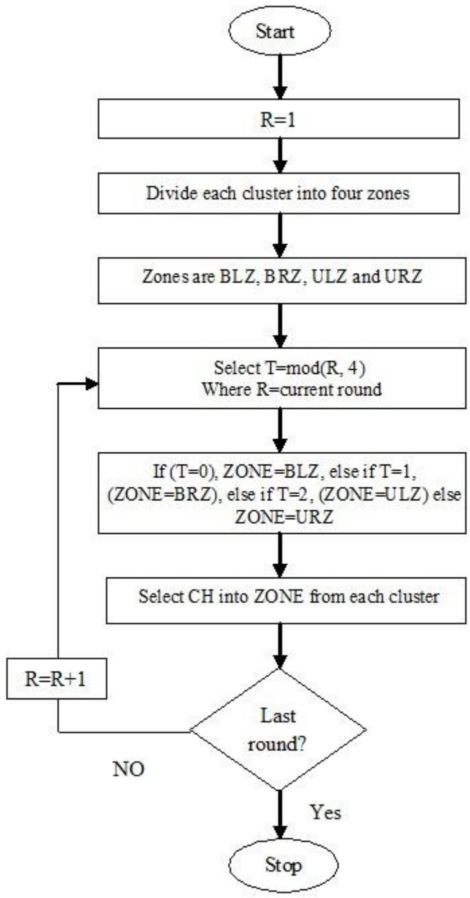

Fig 7: Selection of cluster head from one zone

3.3 Data Aggregation

Data aggregation is an effective technique for removing data redundancy and improving energy efficiency in WSNs. The basic idea is to combine the data received from different sources so that the redundancy in the data is minimized and the energy consumption for transmitting the data is reduced in the aggregation process.

Table.1: Mapping Table

RANGE	VALUE
0-10	1
10-20	7
20-30	6
30-40	2
40-50	9

In proposed data aggregation scheme, for the data to be aggregated, define a range value for each type of event that is to be sensed by any sensor. These values are stored in a table along with the event value and are stored in the memory of every sensor (Fig. 8). This table is known as mapping table. When sensor senses the data, this data is searched in the mapping table for the corresponding range value. Replace the event data value sensed by the sensor with the corresponding range value from the Table 1.

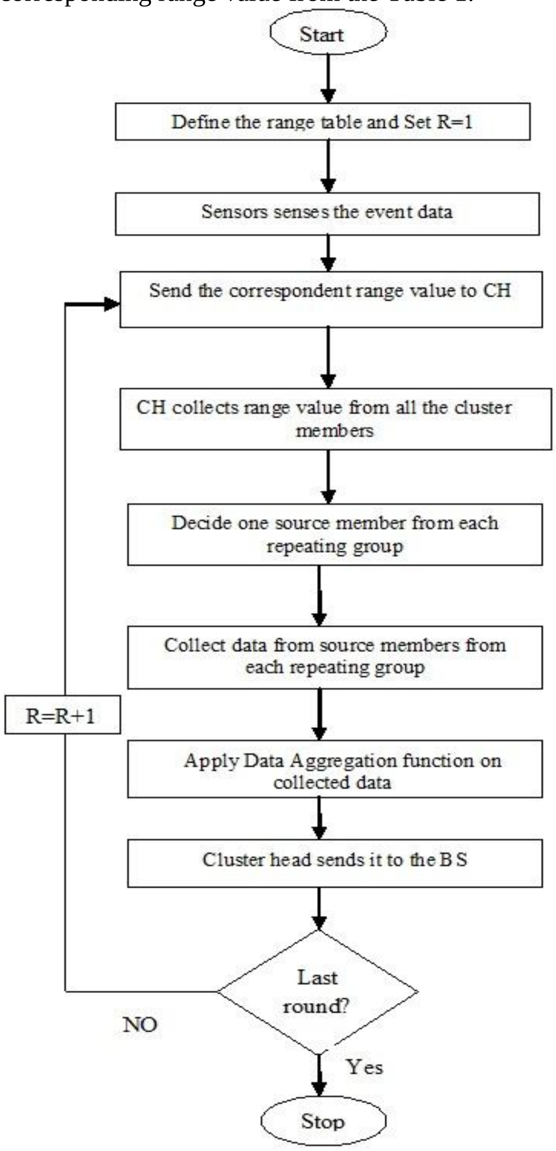

Fig 8: Data aggregation

There are ten sensors that sense the following values 39, 7, 19, 49, 24, 5, 42, 34, 12, 4. Sensor reading will be replaced by correspondence value from the Mapping Table, i.e. if the reading sensed by the sensor is 49 then it will be replaced by 9 and 9 will be send to the cluster head. Original reading of sensor is hidden and is not transferred to the cluster head over the unsecure wireless medium. So these ten sensors will send 2, 1, 7, 9, 6, 1, 9, 2, 7 and 1. So on the basis these values cluster head will decide the repeating group.

Do it for all the sensors. Now all the sensors send this range value to their cluster heads. Cluster head prepare repeating group for all those sensors that fall within the same range. Only one sensor is selected from each repeating group that is the candidate who will send data to the cluster head. Now cluster head calculates data aggregation of these collected values. Cluster head send this aggregated data to the base station (BS).

New cluster head is selected again from each cluster. Normal sensor will detect events. Process of cluster head selection is continued, i.e. cluster head are selected from zone BLX, BRX, ULX, URX. This sequence of cluster head selection is continue till the lifetime of the network

IV. SIMULATION RESULTS & DISCUSSION

In the simulation, we set that there are 320 sensors randomly distributed in a 1000m ×1000m sensor network with 16 clusters.

The Network area is divided into 'N' no. of clusters.
N= 16.
Let 'L' be the length and 'W' be the width of the cluster.
L=250m
W=250m
The area of the cluster is 'A'=L*W.
A=250*250=62500m^2
'NOCM' are the number of cluster members.
NOCM=20.
'NOZM' is the number of zone members.
NOZM=5.
Width of every zone (ZW) is half the width of cluster, i.e.
ZW=W/2.
ZW=250/2=125m
Similarly length of every zone (ZL) is half the length of cluster, i.e.
ZL=L/2.
ZL=250/2=125m

4.1 Random Approach

In random approach to selecting cluster heads, network area is divided into fix size clusters. There are total sixteen (16) clusters in the network. So total sixteen (16) cluster heads are selected, i.e. one cluster head from each cluster. Cluster head is selected randomly from each cluster area. Average range of every cluster head is fixed so that it can cover the entire cluster area, i.e.
Covering Range = SQRT ((CW*CW) + (CH*CH)).
Fig. 9 shows random approach of selecting cluster heads. In this approach maximum area where the cluster heads are selected is overlap area.

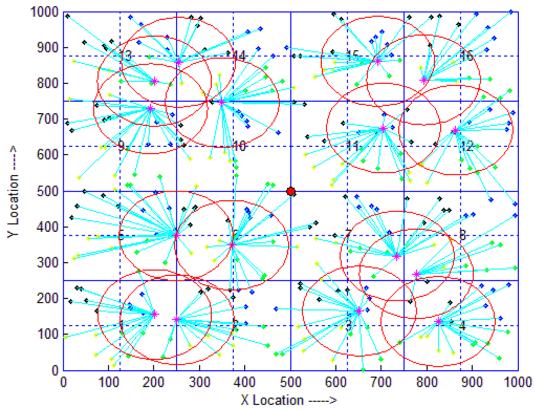

Fig 9: Random approach to selecting CH

4.2 Progressive Approach

Same network is used for progressive approach that is used in random approach, i.e. same network size, same cluster size, same number of sensor in each cluster and also same sensor location for each sensor. In progressive approach of cluster head selection, cluster head is selected from different zone in each round but from same zone in every cluster in same round. Fig. 10 shows progressive approach of cluster head selection. In this approach overlap area covered by the cluster heads is minimized. Simulation result proves that in progressive approach of cluster head selection, entire network area is covered by all the cluster heads but in random approach of cluster head selection, half of the network area is uncovered and half area which is covered is overlap area.

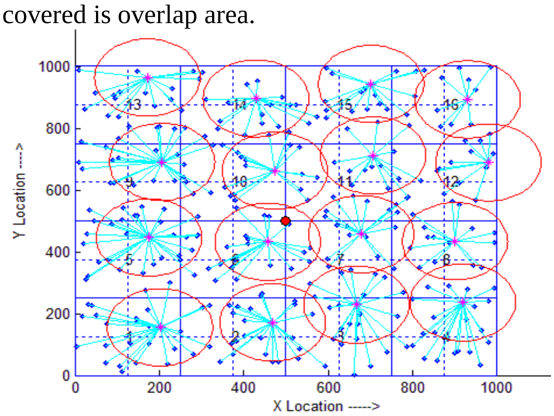

Fig 10: Progressive approach to selecting CH

4.3 Sensor Coverage

Sensor coverage has been recognized as an important factor in clustering and data aggregation. To extend sensor coverage, one potential approach is to select a cluster head in such a way that each of which can cover unique set of sensors so that overlap area is minimized. The number of sensors that are deployed in a network is very large so a complete coverage is sometime not available. Simulation result has been calculated to check the coverage of sensors by cluster head in percentage under different scenarios. In one scenario cluster heads are selected randomly from the entire network (Random Network Nearest). In other scenario, the cluster head is selected randomly from each cluster (Random Cluster Nearest). In third scenario (proposed approach), cluster head is selected randomly from the same zone within all clusters (Random Zone Nearest). If some sensor is under the coverage range of some cluster head, it is said to be covered. Covering range of cluster head is increased from ten meter to two hundred meter. Results in Fig. 11 show that proposed scheme is better in terms of coverage than the other two schemes.

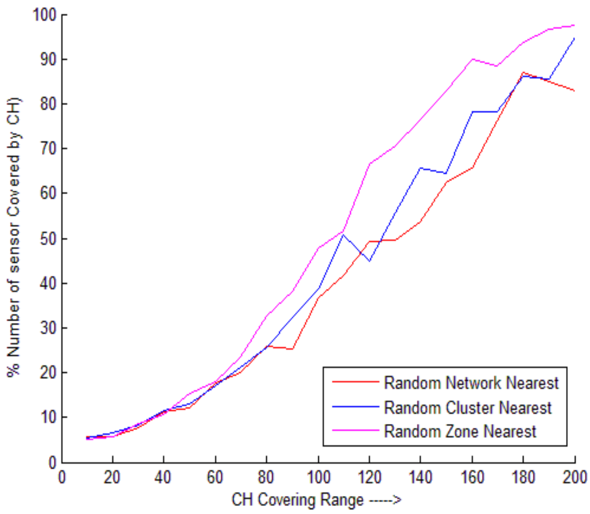

Fig 11: Sensor Coverage with Different CH Range

V. CONCLUSION AND FUTURE SCOPE

In this paper, we proposed cluster head selection and data aggregation technique. Experiment results show that the proposed method is able to average the energy consumption of sensor nodes, lengthen the lifetime of each sensor node, prolong network lifetime, and optimize data volume transmission of the whole system.

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