A Comparative Performance Analysis of Centralized and Distributed Hierarchical Routing Protocols in WSN

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Abstract - *Wireless sensor networks (WSNs) are becoming a centre of research, with issues such as energy consumption, energy efficiency, scalability, routing algorithms, cluster head selection in sensors nodes based on a hypothesis, resilience, efficiency, and more. Despite having open problems in wireless sensor networks, there are significantly a large number of applications available globally. Because the nodes in WSNs are powered by batteries, one of the most important considerations when building any application in WSNs is how to keep the WSN alive and running for a longer period of time. This is one of the biggest drawbacks of WSNs, as they are non-rechargeable. So, this problem can be resolved or overlooked if one focus on the way the network is being formed. In order to build a network, routing protocols are employed. There are various advantages of using WSNs despite some drawbacks as they can be deployed in remote areas for environmental monitoring, surveillance, patient monitoring, agriculture etc. With so many lives lost due to natural disasters, environmental monitoring has become critical. According to a report by UN, between 1970 and 2019, climate, water, and weather hazards were responsible for half of all disasters, accounting for 45 percent of all deaths and 74 percent of all reported economic losses hence its monitoring is a must. Hierarchical clustering protocols such as LEACH, LEACH C, MOD LEACH, HEED, EAMMH, EEMRP etc. are among most energy efficient routing techniques available. In this research article, the performance of Leach, Leach C, MOD Leach, HEED, EAMMH, EAMRP hierarchical routing protocols are analyzed, with respect to various parameters such as throughput, alive nodes, energy consumption, dead nodes and the scalability of the routing protocols and also AQI is being monitor reducing WSN.*

Key Words*: *Wireless sensor networks (WSNs), LEACH, LEACH C, MOD LEACH, HEED, EAMMH, EEMR.

1. INTRODUCTION

1.1. WIRELESS SENSOR NETWORK

As the demand of laptops, tablets, mobile phones, GPS devices, and many more exceptional electronics devices which keeps increasing with more advancement taking place at a gradual scale which we refer as the post-in desktop computer era, computing devices now are a lot cheaper, more portable, easily accessible, and more inescapable in our daily to daily lifestyle. It is now so easy to design, from commercially available off the shelf components, a pocket size embedded system which has potential equivalent to a 90's in3desktop computers. Such ingrained computing devices can be backed with scaled down Windows operating systems, ubuntu operating systems and many more The Fig. 1.1 Wireless Sensor Network Akyildizet al[9] shows the architecture of WSN. The Wireless Sensor Network (WSNs) is a unique network connected wirelessly that consists of a large area for circulation, self-direction, miniature, low power driven devices typically known as sensor nodes. These wireless networks unquestionably enclose a large part of spatially allocated, mini, battery driven, implanted computing devices and these devices are connected to cordially accumulate, compute and to convey the information to the desired destination and it has managed the ability of embedded computing and processing. Motes or sensor nodes are miniature embedded computers, that are meant to work together for the formation of large or small networks.

WSNs deploy to a few hundreds and up to hundreds of thousand theses low powered multi-functional motes which operates in an environmental area which is left unattended and performs sensing, computational and its communication abilities. The essential parts of a sensor node without any doubt are a unit for sensing, ADC (analog to digital converter), C.P.U.

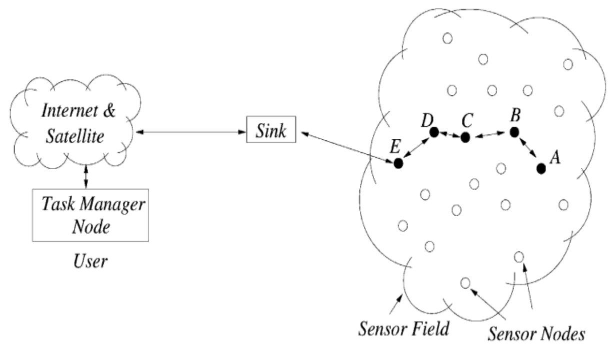

Figure 1.1Wireless Sensor Network.

Sensor nodes are MEMS (micro electro mechanical systems) that implement fairly calculated reaction towards any alteration in environment like the rising or lowering of the temperature, heat, pressure etc. Sensor nodes recognize or compute physically available data in the surroundings which is being scrutinized. The continuous analog signal sensed through these nodes which is then converted into a digital signal by an analog-to-digital converter (ADC) and after that it is passed through the controllers for more scanning. Sensor nodes (SN) are made up of miniature size, and it absorb very low power, are driven in huge volumetric densities, and are said to be self-governing and highly flexible towards any environment. Wireless sensor networks (WSNs) are specially interesting in hazardous or isolated environments where there is little to no monitoring available, or when a mountain of sensor nodes needs to be stationed. We can use the sensor nodes for observing the temperature or pollution level within a building, but it's quite possible that we are well acquainted of the exact position of the sensor node. However, the wireless sensor network is most preferred for keeping track of the temperature, pollution levels etc. in a remote forest or a remote environment, where sensor nodes can be placed from an aircraft and as for the exact location of the sensor it might be unknown but if the location is required these nodes can be deployed with a GPS . However, the main factor or main principle of the WSNs is the selection of the algorithm which can make use of all the available information through these sensor nodes to calculate each of their location.

1.2. VARIOUS ROUTING PROTOCOLS IN WSN

Philip Sallis, Routing is an important part of a wireless Ensor network and hence it should be done very carefully. Routing protocols are used for delivering the information gathered from the surrounding to the base stations from the sensor nodes and forming a secure connection. The routing protocols will describe on how these sensor nodes will form connection with each other for communication and also what will be the criteria for the distribution of the collected sensed information throughout the wireless network. There are numerous ways as to categories the protocols used for routing in the wireless sensor network as shown in Fig. 1.2.

- Node centric routing protocols.
- Data centric routing protocols.
- Source initiated routing protocols.
- Destination initiated routing protocols.

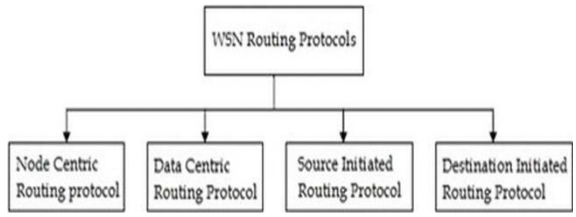

Figure **Error! No text of specified style in document.**.2 Basic classification of the routing protocols

1.3. CATEGORIES OF ROUTING PROTOCOLS

Jaspal et al, When transmitting the information in a sensor network, manly two techniques are used, the former being the flooding and the later is referred to as gossiping. There is no need for the maintenance of the topology and no routing algorithm is required.

In the flooding protocol, when sensor nodes receive the data packets, these data packet is then broadcasted to all the other neighboring nodes. The broadcasting is continuous until one of following two conditions are meet:

The former is that the packet has either reached its destination successfully and later being, the packet has reached its maximum number of hops. The flooding technique is quite simple can be easily implemented. The disadvantage of flooding technique is the resource blindness, overlapping and failure. Advance version of the flooding technique is the gossiping protocol. In the gossiping protocol, when sensor node gets the data packet, it transmits it its randomly selected neighbor. On its next turn, the sensor nodes again sends the data by picking another arbitrarily sensor nodes. This process is repeated. As in the flooding technique the broadcasting is used which is not used in gossiping protocol. Although the delay is increased using this way, but the implosion issue can be avoided.

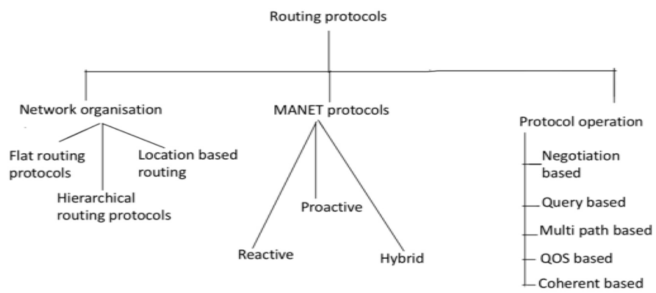

Figure **Error! No text of specified style in document.**.3 Categories Of Routing Protocols

1.4. NECESSITY OF ROUTING PROTOCOLS

Hannah, Jay[7] Between 1970 and 2019, climate, water, and weather hazards were responsible for half of all disasters, accounting for 45 percent of all deaths and 74 percent of all reported economic losses. Human activity has led the climate to rise at a rate not witnessed in at least 2,000 years, according to the study, which was conducted by 234 scientists from 66 countries. In 2019, CO2 levels in the atmosphere were higher than they had been in at least 2 million years, while methane and nitrous oxide levels were higher than they had been in the previous 800,000 years. Global surface temperatures have risen faster since 1970 than they have in any other 50-year period in at least the last 2,000 years. According to the analysis, temperatures over the last decade (2011–2020) have surpassed those of the most recent multi-century warm period, which happened around 6,500 years ago. Meanwhile, the global mean sea level has risen faster since 1900 than it has in any of the previous 3,000 years. According to the study, human-caused greenhouse gas emissions contributed to a 1.1°C increase in global temperature between 1850 and 1900, and world temperatures are expected to approach or exceed 1.5°C in the next 20 years. Delmotteet al.

2. LITERATURE REVIEW

Heinzelman et al, Clusters are organized in the LEACH routing protocol in such a fashion that the division of energy between nodes in the wireless network is identical. Cluster formation occurs in the LEACH protocol, which means that distinct groupings of sensor nodes are created into clusters. Inside each cluster, one node is designated as the cluster head, and it will operate as the routing node for all of the other sensor nodes within that cluster. The cluster head (CH) is already selected before the communication process in a routing protocol begins, and if communication fails, it is due to a problem that originated in the cluster head. The main problem with a cluster head failure is that its battery must be drained before the other nodes in the cluster, as the appointed cluster head is doing his job of routing for the entire cluster. The LEACH protocol uses a randomization process to select the cluster head (CH) from a group of sensor nodes, and this selection is made from several sensor nodes on a temporary basis, making the LEACH protocol even more long-lasting because the load on a single node's battery is not overloaded for an extended period of time. Sensor nodes choose a cluster head among themselves based on protocol-defined probability criteria that are broadcast to other nodes.

Tripathi et al[11], LEACH C is a centralized version of LEACH routing protocol. The main idea behind the working of LEACH C routing protocol is that their network location is made known to the sensor nodes also the cluster heads are elected in the most optimal fashion. We can say that the centralized leach protocol is location aware routing protocol.

Mahmoodet al[3], MOD Leach stands for modified version of Leach Routing Protocol. In this algorithm a new method for cluster head replacement is used. Here, the threshold is pre-established and is being put for cluster head replacement. For if the present cluster heads still contains sufficient power which is higher than the predetermined threshold value then it will remain a cluster head in the wireless sensor network for the upcoming round. The cluster head will only change if the value of threshold exceed the power of the cluster head working. With this energy is being conserved as in every rounds cluster heads are not getting replaced. However, it is an improvement over leach algorithm but it still have its drawbacks such as it is a single hop protocol and is not suitable or not be used for large wireless sensor networks.

Huanget al[8], EEMRP stands for an energy efficient multi hop routing protocol which is built on grid clustering in order to solve the energy consumption of sensor nodes(SN). This protocol works in a way that the sensor network is constructed in unequal grid having different cluster levels. For the minimisation of the energy consumption the routing algorithm boosted the process of selection of the communication management nodes (CM) and cluster heads by joining sensor nodes level of energy, their location and their levels of the wireless sensor network. Where a sensor node having higher residual energy is placed near the sink node in every grid having high chances of becoming a cluster head or the communicating management node. The shortest route is chosen for delivering aggregated data to the sink node. Results shows that it extends the lifetime of the sensor network. One of the major drawback of EEMRP is that when the number of rounds increases this multi hop routing algorithm because of the distance only can result in communicating nodes with high residual energy being neglected as approaching hops which can lead to uneven level of energy and unstable energy consumption amid the communicating nodes in the sensor network making reduction in the lifetime of the network specially in terms of first node dead(FND).

2.1. EAMMH Routing Protocol

Mundadaet al[10], The EAMMH routing protocol is a hybrid of energy-conscious and multi-hop intra-cluster routingalgo. The EAMMH works in such a way that in the number of rounds every round starts with a set up phase. In the setup phase when the sensor nodes are being deployed neighbour discovery starts. There are number of methods by which this can be done namely, k of n approach, beacon messaging. The sequence of the setup phase is as follows:

- CH (Cluster Head) election.
- Cluster Formation.

The second phase is the data transmission phase is which once the clusters are formed , time slots are allocated to the sensor nodes for sending the data. After that when the sensor nodes finally receives the data from one of it neighbors the aggregation of data with its own take place. A heuristic approach is used given by the heuristic function,

$h = K (Eaverage / h_{min} * T)$……………………………... (1)

where

K is a const,

Eaverage is average energy of the current route,

h_{min} is minimum hop count in current route,

T = traffic in the current path.

The route containing the highest h value is considered. If this routes,

E_{min}> threshold, it is selected. Else the route with he next high h value is selected,

where,

E_{min} = Eaverage/const………………………………………(2)

If not even a single sensor node in the routing table has E_{min} greater than the threshold energy, it selects the sensor node with highest minimum energy.

3. MAINSCRIPT

```
clear
clc
IniEng=0.5;%0.5; % Initial Energy of Every Node
NetSize=100; % Network Size
NoOfNode=200; % Number of Node
NoOfRound=2000; % Number of Round
cluster_head_percentage=0.1;
%Eelec=Etx=Erx
ETX=50*0.000000001;
ERX=50*0.000000001;
%Transmit Amplifier types
Efs=10*0.000000000001;
Emp=0.0013*0.000000000001;
%Data Aggregation Energy
EDA=5*0.000000001;
sink.x=0.5*NetSize;
sink.y=1.35*NetSize;
rng('default')
for i=1:1:NoOfNode
random_node(:,i)=rand(2,1);
end
disp('Running EAMMH protocol.. please wait...')
[STATISTICS]=EAMMH_1(IniEng,NetSize,NoOfNode,NoOfRound,cluster_head_
percentage,ETX,ERX,Efs,Emp,EDA,random_node,sink);

disp('Running LEACH protocol.. please wait...')
[STATISTICS1]=leach_2(IniEng,NetSize,NoOfNode,NoOfRound,cluster_head_per
centage,ETX,ERX,Efs,Emp,EDA,random_node,sink);%% Leach

disp('Running LEACH-C protocol.. please wait...')
[STATISTICS2]=Leach_Centralized_3(IniEng,NetSize,NoOfNode,NoOfRound,clu
ster_head_percentage,ETX,ERX,Efs,Emp,EDA,random_node,sink);
disp('Running MOD-LEACH protocol.. please wait...')
[STATISTICS3]=modleach_4(IniEng,NetSize,NoOfNode,NoOfRound,cluster_head
_percentage,ETX,ERX,Efs,Emp,EDA,random_node,sink);

disp('Running EEMRP protocol.. please wait...')
[STATISTICS4]=eemrp_5(IniEng,NetSize,NoOfNode,NoOfRound,cluster_head_pe
rcentage,ETX,ERX,Efs,Emp,EDA,random_node,sink);

disp('Running HEED protocol.. please wait...')
[STATISTICS5]=heed_6(IniEng,NetSize,NoOfNode,NoOfRound,cluster_head_per
centage,ETX,ERX,Efs,Emp,EDA,random_node,sink);

r=0:NoOfRound;
```

Figure 3.1. MATLAB Code the main script.(A)

```
figure(1)
hold on
plot(1:NoOfRound+1,[STATISTICS.AVG])
plot(1:NoOfRound+1,[STATISTICS1.AvgEnergy])
plot(1:NoOfRound+1,[STATISTICS2.AvgEnergy])
plot(1:NoOfRound+1,[STATISTICS3.AvgEnergy])
plot(1:NoOfRound,[STATISTICS4.En])
plot(1:NoOfRound,[STATISTICS5.En])

xlabel('No of rounds')
ylabel('Average Energy dissipation')
title('Energy consumption comparison')
legend('EAMMH','LEACH', 'LEACH-C','MOD-LEACH','EEMRP', 'HEED')

figure(2)
hold on
plot(1:NoOfRound+1,[STATISTICS.DEAD]);
plot(1:NoOfRound+1,[STATISTICS1.DEAD])
plot(1:NoOfRound+1,[STATISTICS2.DEAD])
plot(1:NoOfRound+1,[STATISTICS3.DEAD])
plot(1:NoOfRound,[STATISTICS4.dead])
plot(1:NoOfRound,[STATISTICS5.dead])
xlabel('No of rounds')
ylabel('No of dead nodes')
title('Network lifetime comparison in terms of dead nodes')
legend('EAMMH','LEACH','LEACH-C','MOD-LEACH','EEMRP',
'HEED','Location','southeast')

figure(3)
hold on
plot(1:NoOfRound+1,[STATISTICS.packets])
plot(1:NoOfRound+1,[STATISTICS1.PACKETS_TO_CH]+[STATISTICS1.
ETS_TO_BS])
plot(1:NoOfRound+1,[STATISTICS2.PACKETS_TO_CH]+[STATISTICS2.
ETS_TO_BS])
plot(1:NoOfRound+1,[STATISTICS3.PACKETS_TO_CH]+[STATISTICS3.
ETS_TO_BS])
plot(1:NoOfRound,[STATISTICS4.pckt])
plot(1:NoOfRound,[STATISTICS5.pckt])
xlabel('No of rounds')
ylabel('Total no of packets')
title('Throughput comparison')
legend('EAMMH','LEACH','LEACH-C','MOD-LEACH','EEMRP',
'HEED','Location','northwest')
```

Figure 3.2. MATLAB Code the main script.(B)

```
figure(4)
hold on
plot(1:NoOfRound+1,NoOfNode-[STATISTICS.DEAD]);
plot(1:NoOfRound+1,NoOfNode-[STATISTICS1.DEAD]);
plot(1:NoOfRound+1,NoOfNode-[STATISTICS2.DEAD]);
plot(1:NoOfRound+1,NoOfNode-[STATISTICS3.DEAD]);
plot(1:NoOfRound,NoOfNode-[STATISTICS4.dead]);
plot(1:NoOfRound,NoOfNode-[STATISTICS5.dead]);
xlabel('No of rounds')
ylabel('No of alive nodes')
title('Network lifetime comparison in terms of alive nodes')
legend('EAMMH','LEACH', 'LEACH-C','MOD-LEACH','EEMRP', 'HEED')
figure(6)
hold on
last=2001;
eemrp_d=[STATISTICS4.dead];
eemrp_d(end:last,:)=eemrp_d(end,:);
eammh_d=[STATISTICS.DEAD]';
eammh_d(end:last,:)=eammh_d(end,:);
leach_d=[STATISTICS1.DEAD]';
leach_d(end:last,:)=leach_d(end,:);
leachc_d=[STATISTICS2.DEAD]';
leachc_d(end:last,:)=leachc_d(end,:);
modleach_d=[STATISTICS3.DEAD]';
modleach_d(end:last,:)=modleach_d(end,:);
hee_d=[STATISTICS5.dead]';
hee_d(end:last,:)=hee_d(end,:);
barr=[ modleach_d leach_d hee_d eemrp_d eammh_d    leachc_d  ];
bb=bar(0:200:last,barr(1:200:last,:));
bb(1,1).FaceColor='c';
bb(1,2).FaceColor='b';
bb(1,3).FaceColor='y';
bb(1,4).FaceColor='m';
bb(1,5).FaceColor='g';
bb(1,6).FaceColor='k';
xlim([150 2200])
legend('Mod-LEACH','LEACH','HEED','EEMRP','EAMMH','LEACH-
C','Location','northwest')
xlabel('Round Intevals')
xlabel('Round Intervals')
ylabel('No of dead nodes')
title('Dead nodes wrt Rounds')
```

Figure 3.3. MATLAB Code the main script.(C)

4. RESULT ANALYSIS

Here, we have compared the different routing protocols with respect to energy consumption, throughput, sensor nodes lifetime and at last we have presented a bar graph showing the number of dead nodes as the number of rounds increases.

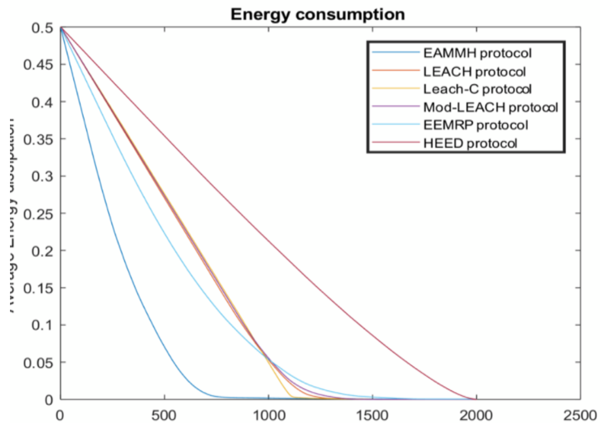

Figure 4.1. Energy Consumption.

From this graph, we can conclude as the number of rounds increases energy is dissipated more in HEED protocol than the rest of the routing protocol. In terms of energy dissipation, EAMMH protocol performs well. EEMRP also performs well but when the rounds increases it dissipates energy quickly when compared with Leach, Leach C, MOD Leach routing protocols.

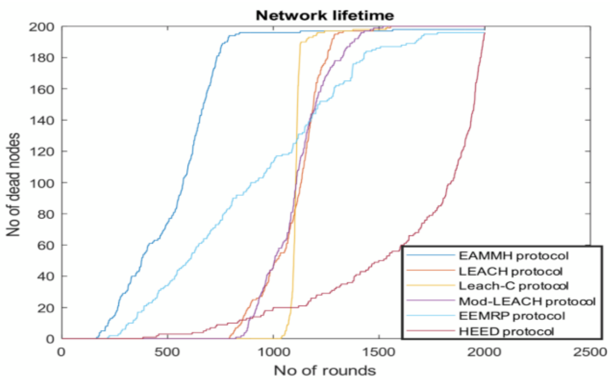

Figure 4.2. Network lifetime.

From this graph it can be concluded that before 500 rounds Leach, C Leach and MOD Leach i.e Leach versions none of the sensor node has died. While when the no of rounds increase only HEED protocol is performing well as highest sensor nodes remain alive from HEED protocol when compared with the rest of the protocols. EEMRP protocol after 1000 rounds performs well with respect to Leach versions.

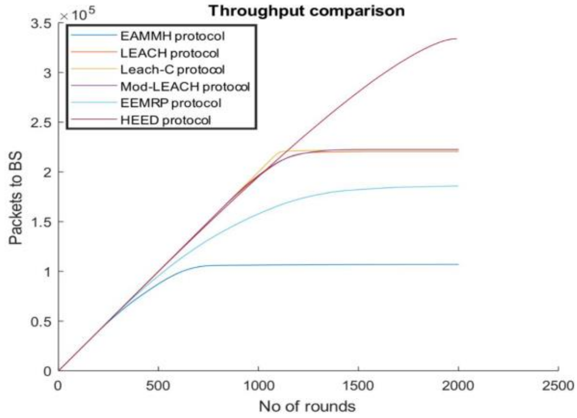

Figure 4.3. Throughput comparison.

Below 500 rounds all protocols delivers the packets with same speed. At 1000 rounds nodes of some protocols become to die. HEED has the highest packets delivered to base station while Leach versions does not have much differences.

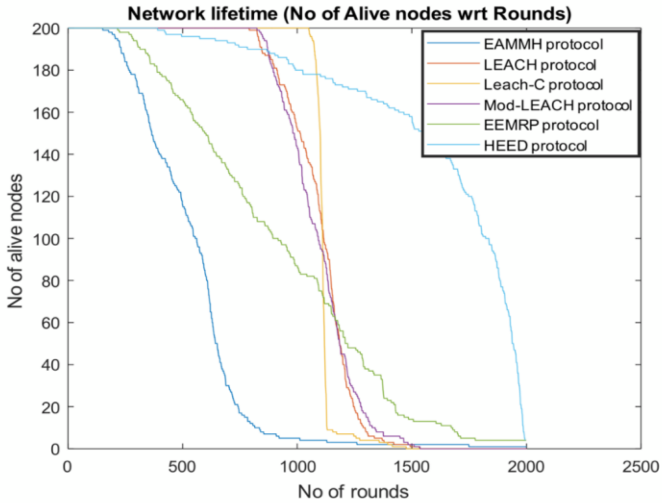

Figure 4.4. Alive nodes.

As, the number of rounds increases beyond 500 except EAMMH rest of the protocols have 100% alive nodes. At 1000 rounds we see a significant decreases in alive nodes of EAMMH protocol as compare to the rest of the protocols. HEED has the highest alive sensor nodes in comparison to other routing protocols.

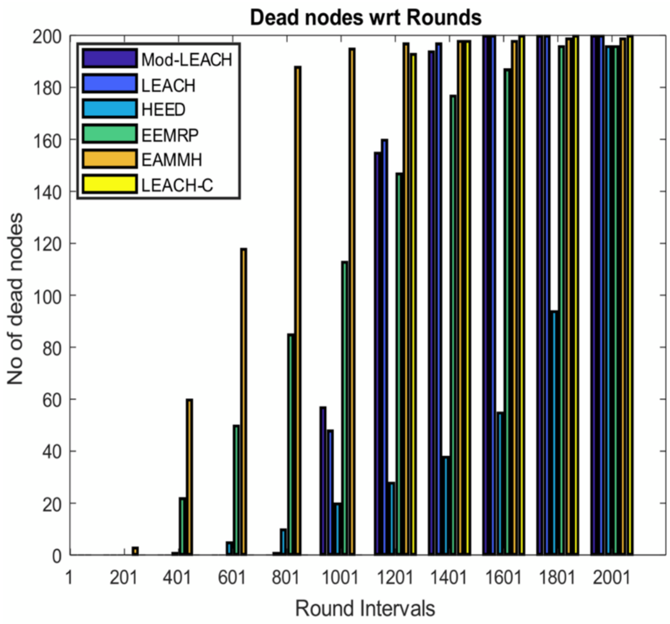

Figure 4.5. Bar graph of dead nodes.

In can be concluded that in areas where there is a requirement of small sensor networks Leach versions can be effected in providing sensor data while for the large networks it energy dissipation is a issue then EAMMH protocol can be effective.

We have performed an experiment using WSN in our neighbourhood, in an industrial area and traffic area for monitoring the air quality throughout the day. Results are shown below:

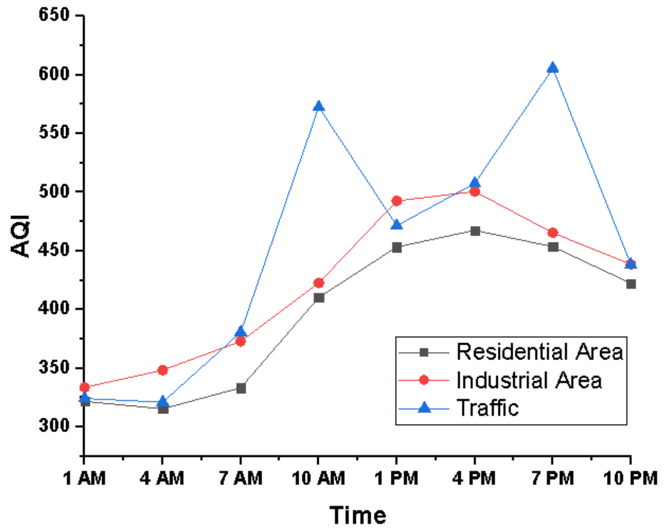

Figure 4.6. AQI.

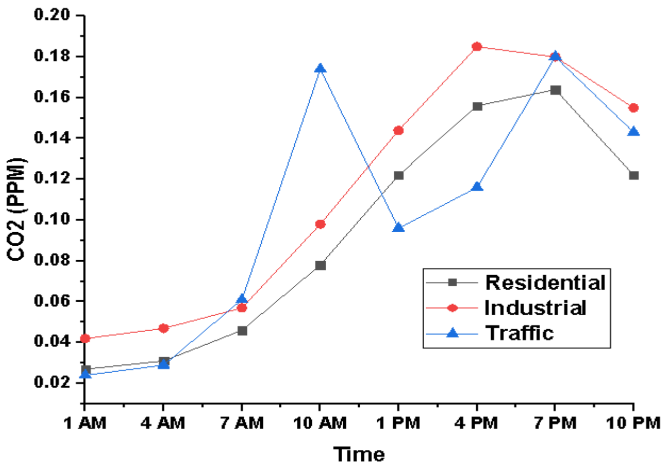

Figure 4.7. CO2

This is the setup of our experiment.

Figure 4.8. Experimental Setup.

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