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QBEECH: MULTI-HOP CLUSTERING ALGORITHM OF COGNITIVE SENSOR NODES GUIDED BY QUEEN NODES

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Abstract: **Quadrature-Based Energy Efficient Clustering Hierarchy(QBEECH) is a multi-hop clustering algorithm which consists of Cognitive Radio sensor nodes, Queen nodes and Base station. Normal CR nodes are guided by 4 Queen Nodes for hassle-free communication at a faster and secured manner. In this algorithm, the nodes communicate with each other using smart directional antenna for power consumption. To prove the superiority of the algorithm, it is compared with other state-of-the-art algorithms like LEACH, C-LEACH, ENERGY-LEACH and MULTI-LEACH. The proposed algorithm is tested in various situations by changing certain parameters. In all the conditions it shows better output than the other algorithms having the highest HNA(Half Node Alive), FND(First Node Dead) and network stability.**
Keywords: Cognitive Radio Wireless Sensor Network, Network lifetime, Cluster-Based Algorithm, QBEECH, LEACH

I. Introduction

The Cognitive sensor nodes are common in these days for sensing and sending the required information at a faster rate by means of various channels. Because of the huge amount of data to be sent but lack of channels make the process slower and call dropping probability more. Due to the recent development of sensing the data from remote areas and sending into the internet is fascinating which attracts many scientists and researchers to work on this topic. Since there are so many technologies and most of them need specific bandwidth to communicate their information from one place to another, makes most of the bandwidth congested but these are not fully utilized. Sometimes a band is used by many numbers of users but at the same time, the other bands remain idle having very low traffic. Cognitive radio [10] concept is very powerful and helps to reduce these problems and uses the bandwidth at its fullest and in a very effective manner. In this transmitters and receivers are given a few channels of different frequencies and they can adjust the channels of transmission and reception according to the traffic in the channel. If a channel has traffic more than the threshold limit then automatically the channel of transmission will be changed by the transmitter and accordingly, the receiver will also change the reception channel to receive the required data. This helps to reduce the packet dropping probability. In our architecture, few low-frequency channels are assigned to transfer the information for long length communication and high-frequency channels to communicate within the cluster. In LEACH protocol only one bandwidth has been used and hence the packet dropping probability is much more than our hierarchy where cognitive radio concept is being used. Thus the throughput and efficiency both are increased at the same time.

In LEACH protocol homogeneous network is used, whereas QBEECH [23] protocol has a hybrid network where there are sensor nodes which sense the required data and send to the cluster heads and these nodes have the same amount of initial energy. Cluster Heads send the information after compression to the Queen Nodes that are deployed randomly or uniformly.

- Queen Nodes dont have any power of sensing data

- Queen Nodes can receive the data from Cluster Heads, compress it and send it to BS

- These Nodes dont have any energy constraints and work as line-powered sensors.[2]

In Energy LEACH, the LEACH protocols defects have been reduced and better Network lifetime is gained. Centralized LEACH also improved the network lifetime and stability by uniformly distribute the Cluster Head all over the arena. But all these algorithms are not sufficient and by QBEECH algorithm the stability and network lifetime can be increased further.
The paper is organized in the following subdivisions. In section 2 related works are discussed, in section 3 Energy Utilization Model has been proposed, section 4 presents network model and QBEECH algorithm, Section 5 presents the simulation results and comparisons between various previously well-known algorithm and the advantages of our proposed algorithm than others in various aspects. Finally, section 6 is the conclusion of the paper.

II. Related Work

Each and every protocol has its own advantages and disadvantages. Researchers are working on minimizing the energy consumption in each round of transmission of energy and consequently increasing the network lifetime and stability [3] [9] [19] [20] [21] [22]. Various surveys are also made in this field [6] [7] [8]. Nodes cant be deployed so often, so, an efficient algorithm is very necessary to transmit data quickly, effectively and securely. For this effective transmission and low energy transmission clustering algorithm is very helpful. Moreover, clustering of nodes helps in decreasing the data by compression and reduces the packet dropping probability and also in faster communication. For this scientists are using Cognitive radio based Sensor Nodes and simulate in various simulators like NS2, OMNET++ etc. [11] They are trying to harvest energy from various natural resources to increase the Network Lifetime as well as stability. [12] [13] [14] [15] [24] [25] Ahmez Al-Baz and Ayman El-Sayed introduced their new algorithm to select cluster head in LEACH which enhance the performance of the network and decrease the path cost. It also improves the lifetime of the network as well. [26] Ammar S. Al-Zubaidi discussed the enhancement of the stability of the improved-LEACH protocols. [27] Hanen Idoudi et al described their cluster based cognitive radio sensor network and the effectiveness of their algorithm in the paper [28]. M. Indhumathi et al in their paper [29] applied IDS(Intrusion Detection Systems) in cognitive radio networks which helps in the improvement in performance of the system. Liang Zhao in his paper [30] proposed a modified LEACH which is proved to have better lifetime and stability than the algorithms that are being compared with. He also took different scenarios for proving his theory.

A. LEACH Protocol

LEACH Protocol is a pioneering work considering the Clustering techniques employed to resolve diverse energy optimization problems in WSN. It was introduced in [1]. There are various phases in this, namely, Advertisement phase, Set-up Phase, Schedule Creation and Data transmission.

1. Advertisement phase - In this phase, the nodes advertise and decides whether to be a part of a cluster according to the probability and the cluster head selection is also done in this phase.

2. Set-up Phase - In this phase nodes after making their choice of being a part of a cluster convey its presence to the respective cluster head.

3. Schedule Creation - TDMA scheduling is done where each member nodes are told the timings of their data transmission.

4. Data Transmission - In this phase the datas are transmitted to their respective CHs and then the CHs sens the datas to the Base Station.

B. Energy LEACH

This protocol is developed on the basis of LEACH protocol but in LEACH, communication pattern is single hop. So it is definitely not suitable for large networks because if a cluster head is not situated near the Base Station lots of energy will be consumed. So a new modified version of leach was developed called the Energy LEACH (E-LEACH) as in [5]. It is characterized as follows-

- When the cluster-heads are in the near vicinity of the base station, they directly communicate with the base station.

- When they are far away from the base station, they telecommunicate by the multiple-hop way. The sensor nodes in different areas use variable frequencies for communication.

C. C-LEACH

C-LEACH[4] or Centralized LEACH[1] is an improvised LEACH where one of the defects of LEACH protocol has been modified. In this algorithm on the basis of the position of the nodes, the Cluster Heads are being selected. So, the two cluster heads will maintain a certain distance between themselves which help in increasing the stability period and network lifetime to a further extent.

D. MULTI-LEACH

Multi-LEACH[5] is another improvised work on LEACH where the initial energy of all the nodes is same. Some of the nodes are kept for further levels. Nodes from the 1^{st} level give the information to their respective CHs, then the CHs give the data to the 2^{nd} level and goes on and finally to the Base Station(BS). Level of the network depends upon the size of the arena, bigger the area more the levels. Thus some of the nodes died faster than the previous networks but it has longer Network lifetime. This architecture also has some flaws which are being reduced in QBEECH.

III. Energy Utilization Modelling

The Energy Utilization Modelling is designed as per the First order Radio Energy Model as described in [1].In this model, the transmitter losses energy to run the radio electronics and the power amplifier, and the receiver expends energy to run the radio electronics. Power control can be executed by the radios and hence they use the minimum energy required to reach the intended destination.
Hence the energy expended by the transmitter to transmit bit data over a distance d is given by:

$$E_{TX}(L,d) = LE_{elec} + L\epsilon_{fs}d^2, (d < d_0)$$
$$= LE_{elec} + L\epsilon_{tr}d^4, (d >= d_0)$$

Accordingly the energy expended by the receiver is given as

$$E_{RX}(L) = E_{elec}L$$

where $d_0 = \frac{\sqrt{\epsilon_{fs}}}{\sqrt{\epsilon_{mp}}}$ E_{elec} is the consumed energy per bit, ϵ_{fs} is energy consumed by free space amplifier and ϵ_{tr} is energy consumed by multipath amplifier. Along with this, we also take into account the energy consumed for data aggregation and is denoted by ϵ_{DA}.

IV. Network Model And Algorithm Description

A. Network Model:

Unlike the LEACH[1] or LEAUCH[6] or other clustering algorithms, it does not cluster randomly and clustering nodes do not change for every round. In Quadrant Based Energy Efficient Clustering Hierarchy (QBEECH) [23] (flowchart of it is given in figure 4) before any transmission, the CR sensor nodes are clustered as per quadrant. In our model N CRSN nodes are deployed randomly in an area and they will transmit the data periodically to Queen Nodes and Queen Nodes will transmit the data to the base station after compressing the data as required. 4 queen nodes are deployed in the 4 Quadrants each quadrant having one. Let s_i denotes the i^{th} CR sensor node and the corresponding set of nodes are given by $S = \{s_1, s_2, s_3 \dots S_N\}$ and q_k denotes the K^{th} Queen node and the corresponding set of nodes are given my $Q = \{q_1, q_2, q_3, q_4\}$ and c_j represents the number of the channels that are available for the j^{th} CRSN node at particular round out of all the channels that are available from the set $C = \{c_1, c_2, \dots c_{MAX}\}$ where MAX is the maximum number of channels that are available. Here in our case we took two sets of channels C_1 is the set of higher frequency channels that help to transmit the data to a shorter distance and hence is used for transmitting the information for normal CRSN nodes to its Cluster Head(CH) and C_2 is the set of lower frequency channels that are used by the Queen Nodes to transmit the data to Base Station(BS). Now we assume:

1. The CRSN nodes are deployed randomly in square area and after deployment, neither the Base Station nor the CRSN nodes be moved.
2. All CRSN nodes are homogeneous in nature and the Queen nodes have higher energy and are deployed randomly in each quadrant.
3. All the CRSN nodes have the capability of fusing the information and have unique Identification Number (ID) which will be given by the base station.
4. Both CRSN nodes and Queen nodes have the capability of spectrum sensing and detect the available channels through which the data to be transmitted and received.
5. The CRSN nodes will use the higher frequency channels available to send the information to the cluster heads and the Queen nodes will use the lower frequency channels to communicate with the base station.

In LEACH algorithm, the overall communication used to happen via only one frequency band which cause in decreasing the throughput of the system and call dropping probability to be more. All the nodes want to communicate at the same time which makes the situation worst. So, in our algorithm, we use CR to give many channels and hence improved the drawbacks of the WSN.

B. Formation of Quadrant

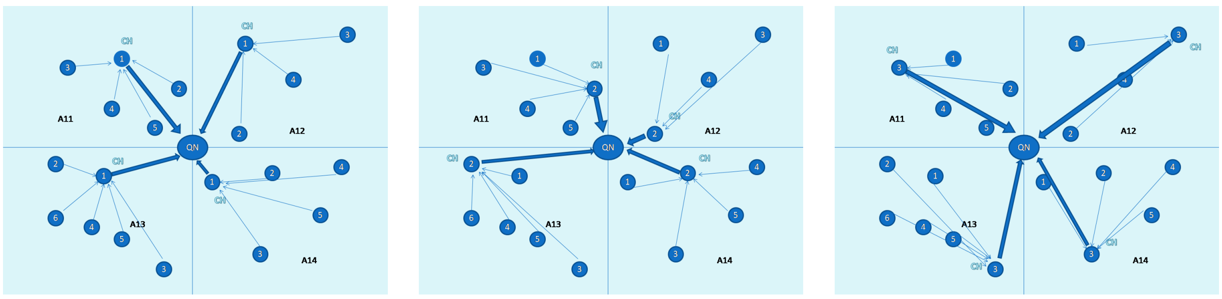
Given area is divided into 4 quadrants and each quadrant is further subdivided into 4 small quadrants. Therefore the total area is divided into 16 small quadrants. The nodes in each small quadrants will form a cluster and one of the nodes will become the Cluster Head. Let 1st quadrant is A which consists of 4 smaller quadrants. Set $A = \{A_{11}, A_{12}, A_{13}, A_{14}\}$. Likewise, there are other 3 quadrants namely B, C, D. This technique will help in sending the data to a smaller distance and hence the dissipation of energy became less compared to other architectures. In figure 1 first three steps of the data transmission from the member nodes to the cluster heads are shown for Quadrant A. Likewise for other quadrants it will be same. In step 1, node 1 of each small quadrants is chosen as CH and all the other nodes transmit their data to their respective CHs. The CHs compress the data and send to respective QN. Deciding node serial number is discussed in details in the subsections, formation of Node

Symbols	Meaning
n	total number of CRSN nodes
Q_i	Queen Nodes
BS	Base Station
CH	Cluster Head
R_{MAX}	Maximum number of rounds
$E_{threshold}$	Threshold energy below which a CRSN node cant be a Cluster head
FND	First Node Die
HNA	Half Node Alive
D_{pkt}	size of packet
d_i	distance between nodes and assigned CH

Table 1: Symbols used

Parameter	Value
The number of CR nodes (n)	200,500
The number of Queen Nodes (Q)	4
The location of BS	(100,100),(250,250)
Network size (L $*$ B)	200$*$200,500$*$500
Data aggregation energy (ϵ_{DA})	5nJ/bit/round
Data packet size (Dpkt)	4000 bytes
ϵ_{mp}	0.0013 pJ/bit/m^4
$\epsilon_{fs} = \epsilon_{tr}$	10 pJ/bit/m^2
E_{elec}	50nJ/bit
Initial Energy (E_0)	0.5 J

Table 2: Simulation Parameters



Step 1 Step 2 Step 3

Figure. 1: First 3 steps of Quadrant A data transmission

MAC table and formation of Cluster Nodes. In step 2, node 2 is chosen as CH for each small quadrants and in the same format it goes on until the energy get exhausted.
In figure 2 data transmission of the whole arena is given where all the Quadrants A, B, C and D are present and 4 Queen Nodes are kept at the middle of each quadrant and the Base Station(BS) is kept at the middle of the arena. Step 1 is shown in this figure where node 1 of each small quadrant are chosen as CHs, all the other member nodes transmit data to their respective CHs and the CHs send their data along with the other member nodes after compression to their respective QNs. QNs send their data to the base station.

C. Formation of Node MAC table

All the CRSN nodes are deployed in the area. After deployment, the sensor nodes will wake up and send the information of their location to the base station at first. According to the information sent the Base Station will make the IDs of the node as per First Come First Serve basis on the predefined quadrants i.e. the sensor nodes in each quadrant will send their presence in the network to the base station first will be given the first priority in the Node MAC table. As the nodes are deployed randomly, the number of nodes will not be same in every quadrant. The sensor nodes will be sent the list of neighboring sensor nodes that are present in their quadrant. The base station will send the list of nodes according to the priority list of entry when all the nodes made their presence in the network within a certain time limit. The Node MAC table will consist of other neighboring nodes details like distance, the direction from them so that they can adjust their transmitting energy in each and every round.

D. TRANSMISSION VIA SMART DIRECTIONAL ANTENNA

Since the CRSN nodes have the prior knowledge of their neighboring nodes' position and know the Cluster Head's position hence it can adjust the smart directional antenna [16](described in figure 3) to transmit the data to the Cluster Head. It will make the communication more secure and in a very energy efficient way.
A smart directional antenna [16] [17] [18] has the capability of performing continuous beam steering. It is able to change the transmitting and receiving gains in the desired directions. Adaptive antennas [16] has the capability of beam and null steering both which helps to suppress the undesired interferences. The number of simultaneous communication L_{max} can be represented as :

$$L_{max} = \frac{2^{\alpha} G_d^2 - 1}{2SINR_t R^2 R_c^{\alpha-2}(K_1 \overline{G} i_1 + K_2 \overline{G}' i_2)}$$

where,

$$i_1 = \int_0^{2\pi} F(\phi) d\phi$$

$$i_2 = \int_{\frac{\phi^{3dB}}{2}}^{2\pi - \frac{\phi^{3dB}}{2}} \{[\overline{G}' F(\phi)]^{\frac{1-\alpha}{\alpha}} - 1\} F(\phi) d\phi$$

$G(\phi)$ represents the normalized radiation pattern of a generic destination, ϕ is the azimuth angle, ϕ^{3dB} is the 3 dB antenna beamwidth of $G(\phi)$ and $SINR_t$ is the Signal to Interference Noise Ratio threshold [16].

$$K_1 = \frac{R_c^{1-\alpha} - R^{1-\alpha}}{2\pi(\alpha - 1)R}$$

$$K_2 = \frac{R_c^{1-\alpha}}{2\pi(\alpha - 1)R}$$

$$\overline{G} = \frac{1}{2\pi} \int_0^{2\pi} F(\phi) d\phi$$

$$\overline{G}' = \frac{1}{2\pi - \phi^{3dB}} \int_{\frac{\phi^{3dB}}{2}}^{2\pi - \frac{\phi^{3dB}}{2}} F(\phi) d\phi$$

and R_c is the region bounded by mitigable interferences, R is the region bounded by non-mitigable interferences and G_d is the transmission or receiving gain, in this case both are assumed to be equal.

E. Formation of Cluster Head

In QBEECH algorithm formation of the cluster is very simple. The first node of the Node MAC table that has been sent to all the CRSN nodes will be chosen as the cluster head for the 1^{st} round and in the 2^{nd} round, the node which is in the 2^{nd} rank of the Node MAC table will be made cluster head. So the criteria for becoming the cluster head are:

1. The CRSN node must have a threshold level of energy of becoming the cluster head. Let the threshold energy of becoming the Cluster Head is $E_{threshold}$. So, $E_i >= E_{threshold}$ where, E_i is the residual energy of the Ith sensor node.

2. The election of Cluster Head will be on the basis of Node MAC table and every node will be given equal chance of becoming the cluster head if it has sufficient energy of becoming the cluster head. For two consecutive rounds, the cluster head will not be same if there are other nodes present in the Node MAC table.

In leach and any other algorithms the Cluster Heads are elected and there the nodes lose some amount of energy. Moreover, the probability of becoming the cluster head is not evenly distributed. Same nodes can be cluster head repeatedly if it is chosen in the election again and again. The nodes have prior knowledge of becoming the Cluster Head and hence the system will also be fast. The nodes can adjust their transmission energy according

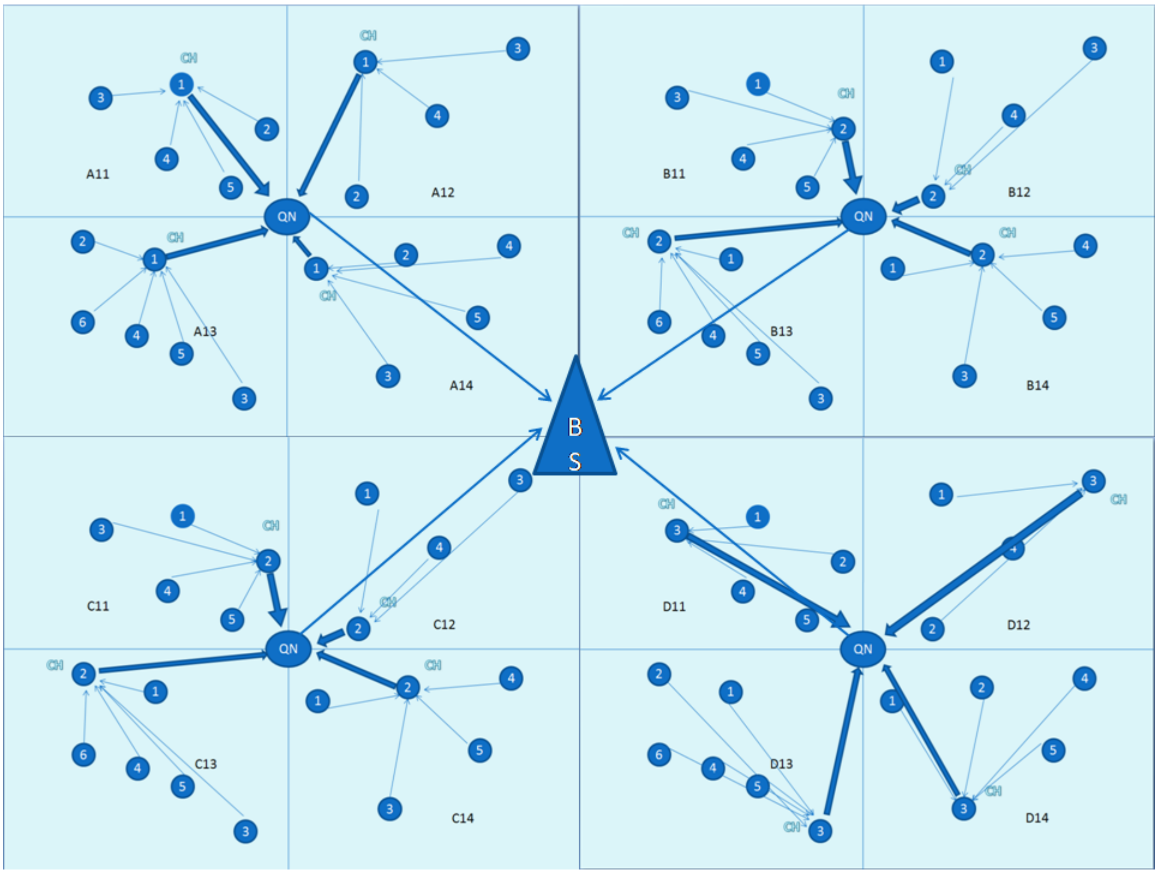
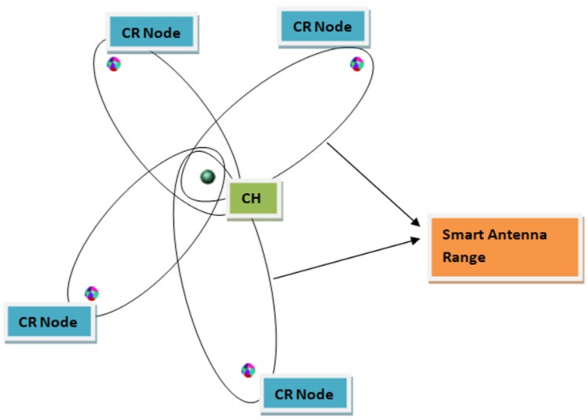


Figure. 2: 1^{st} step of data transmission in the whole arena



antenna.jpg antenna.jpg

Figure. 3: Smart Directional Antenna

to their Node MAC table which consists of the direction and the distance from those nodes to their neighboring nodes.
As soon as the CRSN nodes lost the capability of becoming the Cluster Head it will send the Quit message to all the other nodes and hence its name will be deleted from the Node MAC table of becoming the Cluster Head.

F. Transmision Through Queen Nodes

Four queen nodes are deployed, one in each quadrant. In the first case, those are deployed randomly, in the second case those are deployed in the middle of each quadrant so that it is equidistance from every part of the small quadrants adjacent to it. The normal CRSN nodes will transmit the data to their CHs and the CHs will transmit the compressed data to their assigned Queen Nodes (QNs) and the queen node will transmit the compressed data to the base station. The time when the CHs will transmit the data to QNs and QNs will transmit to the BS, CRSN nodes will remain in temporary sleep state. This will increase the lifetime of the network. For the second case, the network lifetime is even better.

V. Results and Analysis

A. Experiment 1

This is done with the dimension of the area as 200 X 200 with 200 nodes and initial energy level at 0.5 J. The base station is taken at the center of the arena. All the parameters are maintained same in all the algorithms.
In figure 5 comparison is done between LEACH, C-LEACH, MULTI LEACH, ENERGY LEACH and QBEECH. The rightmost curve is the QBEECH [23] which shows the highest stability and highest Network Lifetime among other algorithms. The horizontal axis represents the number of rounds and the vertical axis represents the number of alive nodes in each round.

Algorithm	FND	HNA	10% alive
LEACH	668	812	861
C-LEACH	718	838	879
ENERGY LEACH	709	813	846
MULTI LEACH	213	1001	1522
QBEECH	1659	1977	2089

Table 3: Comparison of First Node Dead, Half Node Dead and 10% alive nodes in the network in different algorithms

In table 3 comparison of FNA, HNA and 10% alive nodes of the network is given. For better realization FND, HNA and 10% alive nodes comparison are given as a tabular graph in figure 6.
The number of Cluster heads in each round is shown in figure 7 (d) where the number of cluster heads changes for all the other algorithms but is constant for a certain number of rounds in QBEECH. This is because 16 small quadrants have 16 total CHs. The number of cluster heads changes when they are dead. The throughput or the number of packets that are transferred to the cluster heads per round is shown in figure 7 (e).

Algorithm 1 QBEECH

1. Initialize all the parameters:
L=length of the area
B=breadth of the area
N=number of CRSN nodes
Q_i=Queen Nodes
R_0=radius of sensing information
E_0=initial energy of each CRSN nodes
E_{TX}=transmitter energy
E_{RX}=Receiver energy
E_{fs}=Amplification energy when $d < d_0$
E_{mp}= Amplification energy when $d \geq d_0$
E_{DA}=Data Aggregation energy
R_{MAX}=maximum number of rounds
2. d_0=$\sqrt{(\epsilon_{fs}/\epsilon_{mp})}$;
3. Divide the whole area into four Equal sized Quadrants
4. Divide one big Quadrant into four small equal sized Quadrants
5. Make Node MAC table
6. For 1^{st} round choose the first node of the Node MAC table as the Cluster Head
7. 2^{nd} round onward Cluster Head will change and the node will get the chance of being cluster head if and only if it has $E_{threshold}$.
for $(i = 1; i <= R_{MAX}; i++)$ **do**
  a. d_i=distance between node to its assigned cluster head
  b. Calculate Energy Dissipated as per Energy equations
  c. High Frequency channels (from set C_1) are available for the CRSN nodes
  d. Data transmitted from CRSN nodes to CHs
  e. CRSN nodes go to temporary sleep state
  f. Again High frequency channels (from set C_1) are made available for the CHs
  g. CHs transmit to Queen nodes
  h. CHs will go to temporary sleep state
  i. Low frequency channels (from set C_2) are given to Queen Nodes
  j. Queen Nodes transmit to Base Station
  k. CRSN and CHs will awake
  l. CH election for next round according to Node MAC table and $E_{threshold}$.
  m. Calculate whether any node died or not
  n. For each round calculate the no of dead nodes, throughput etc.
end for
8. Terminate the programme

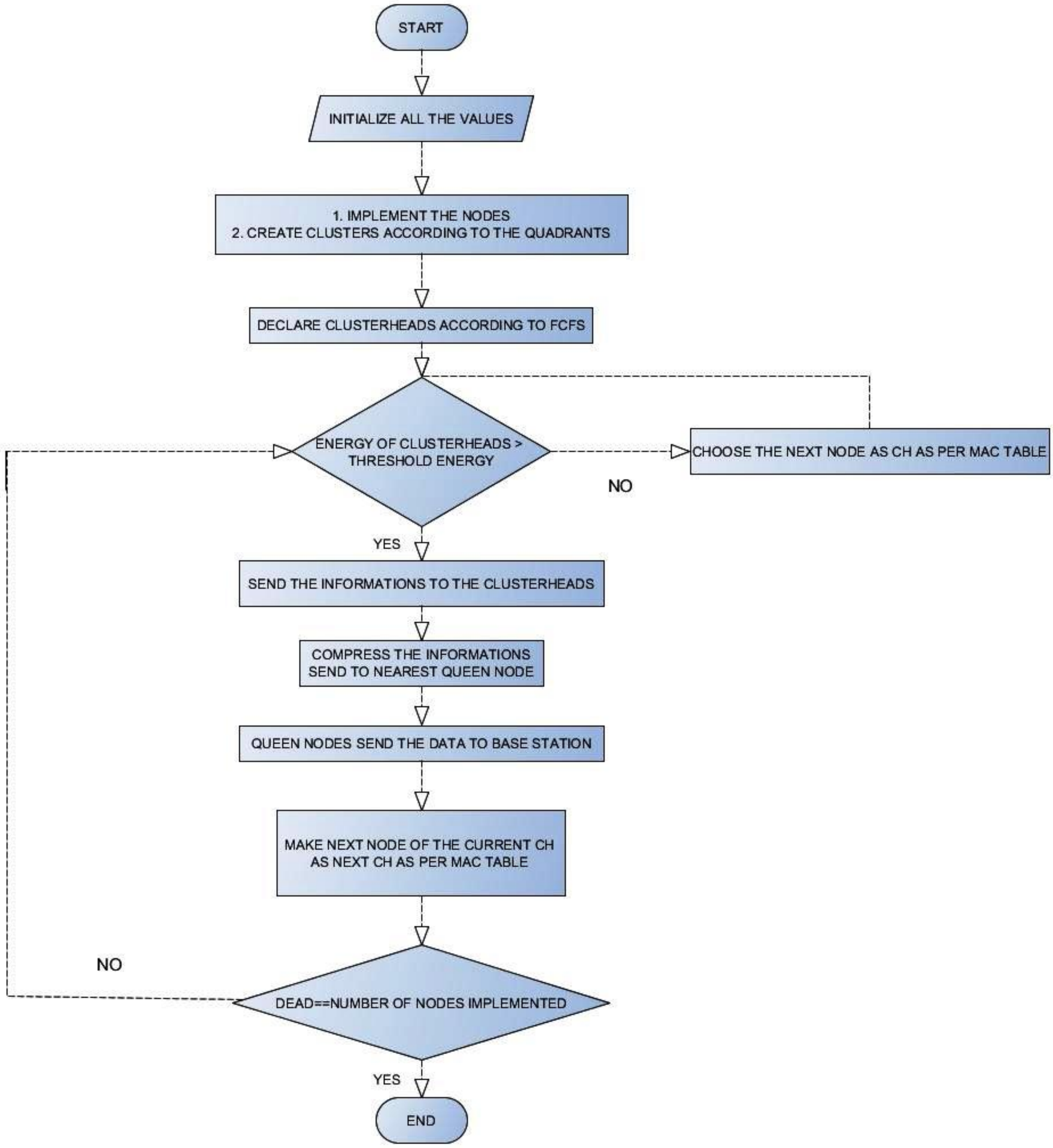


Figure. 4: Flowchart of QBEECH

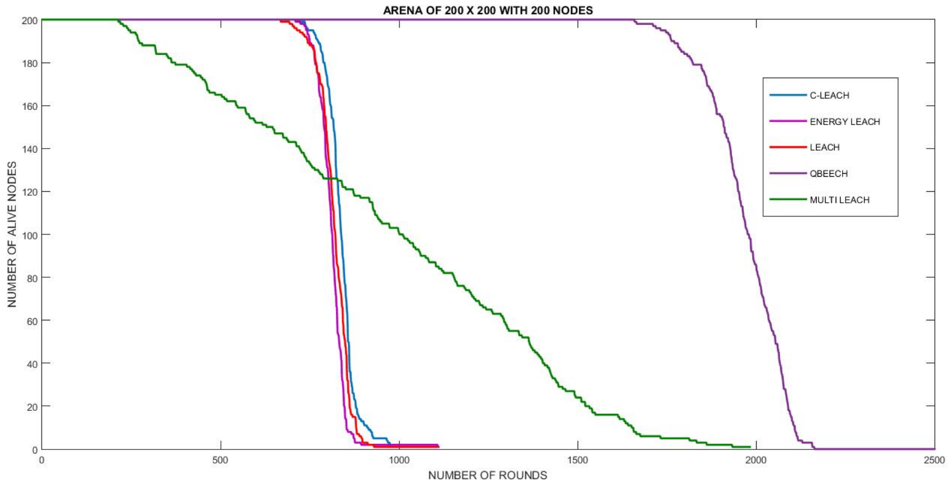
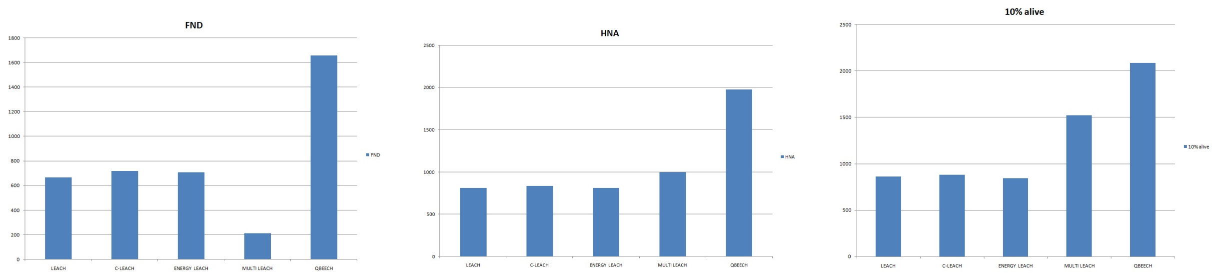
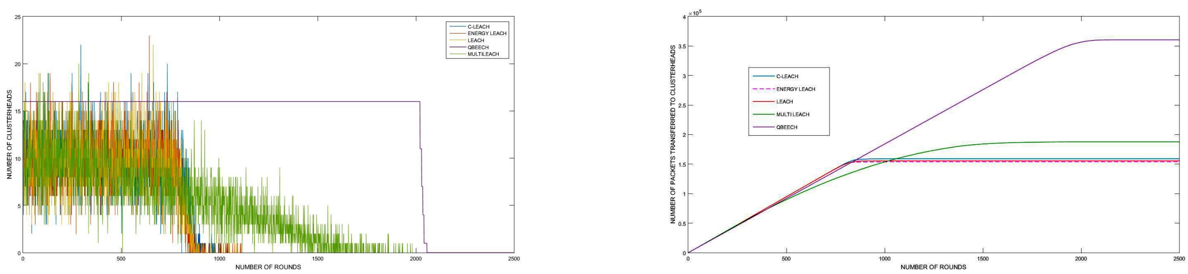


Figure. 5: Comparison of number of alive nodes in each round



a(FND) b(HNA) c(10% alive)

Figure. 6: Comparison of FND, HNA and 10% alive of the sensor nodes for different algorithms



d(No. of CHs) e(Throughput)

Figure. 7: Comparison of the number of CHs(d) in every round and Throughput(e)

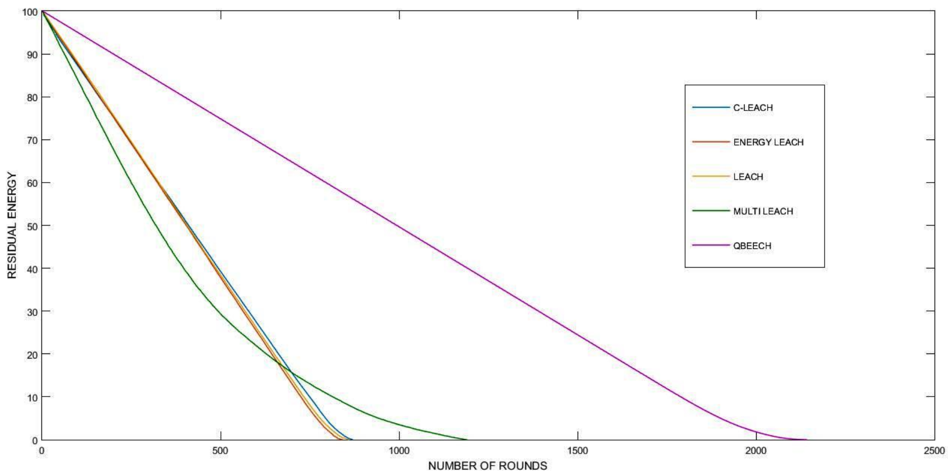


Figure. 8: Residual Energy Comparison

Table 4: Comparison of First Node Dead, Half Node Dead and 10% alive nodes in the network in different algorithms

Algorithm	FND	HNA	10% alive
LEACH	63	179	214
C-LEACH	69	180	216
ENERGY LEACH	66	183	217
MULTI LEACH	48	199	253
QBEECH	422	1149	1596

In figure 8 the residual energy is compared. Since each node has initial energy of 0.5J and there are 200 nodes in the network, the residual energy started from 100J and get decreased with the increase in the number of rounds. The slope which is present on the right side of the graph is the QBEECH and has the best output among the other algorithms.

B. Experiment 2

In this, we compared all the algorithms in an arena of 500 X 500 with 500 nodes and the initial energy of all the nodes are at 0.5 J. In this circumstance also QBEECH algorithm has the highest stability as well as highest Network Lifetime.

In figure 9 comparison is done between LEACH, C-LEACH, MULTI LEACH, ENERGY LEACH and QBEECH. The rightmost curve is the QBEECH which shows the highest stability and highest Network Lifetime among other algorithms. The horizontal axis represents the number of rounds and the vertical axis represents the number of alive nodes in each round.

In table 4 comparison of FNA, HNA and 10% alive nodes of the network is given. For better realization FND, HNA and 10% alive nodes comparison is given as a tabular graph in figure 10.

The number of Cluster heads in each round is shown in figure 11 (d) where the number of cluster heads changes for all the other algorithms but is constant for a certain number of rounds in QBEECH. This is because 16 small quadrants have 16 total CHs. The number of cluster heads changes when they are dead.

In figure 12 (e) the number of packets transferred to the Queen Nodes(QNs) and the Base Station(BS) in QBEECH are compared with the number of packets transferred to the BS by the CHs in LEACH protocol. In figure 12 (f) the number of packets transferred to the CHs by the member nodes in each round is shown for all the algorithms i.e., LEACH, C-LEACH, MULTI-LEACH, E-LEACH and QBEECH. The curve which goes to the topmost in the graph is the QBEECH and gives the best result among all other algorithms.

C. Experiment 3

In this case, the Base Station is taken outside the arena and the number of alive nodes is calculated accordingly. It is assumed that the base station is at a distance of 250 meters further from the center point and is perpendicular to the borderline. The area is taken as 200 X 200 meters with 200 CRSN nodes and the BS is at coordinate (100,250) with an initial energy of 0.5 J. According to the architecture designed for QBEECH, the energy consumed by CRSN nodes for transmission and reception in each round is independent of the position of BS. This is not same for other algorithms, the energy consumption will vary in every round and is dependent on the position of the BS.

In figure 13, comparison is done between LEACH, C-LEACH, MULTI LEACH, ENERGY LEACH and QBEECH. The rightmost curve is the QBEECH which shows the highest stability and highest Network Lifetime among other algorithms. The horizontal axis represents the number of rounds and the vertical axis represents the number of alive nodes in each round.

It is clearly noticed that there is no change in the number of alive nodes compared to the previous case where BS was at the center of the arena. Although the energy consumed by the queen nodes

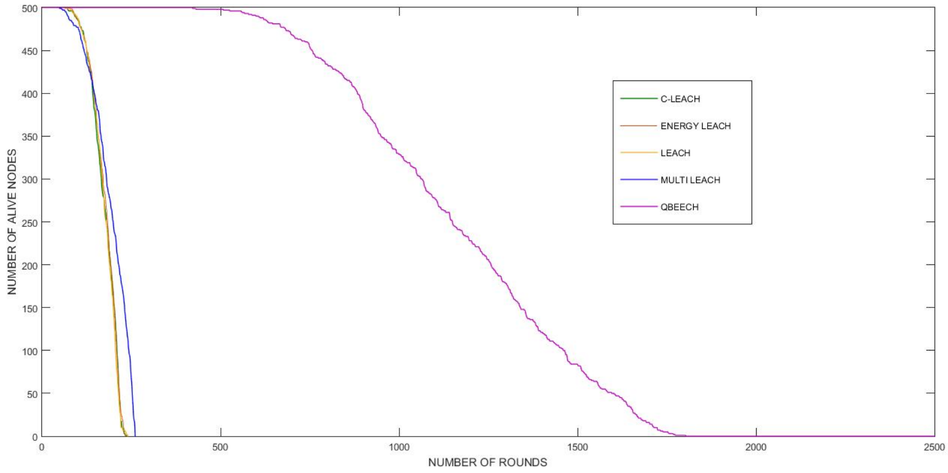
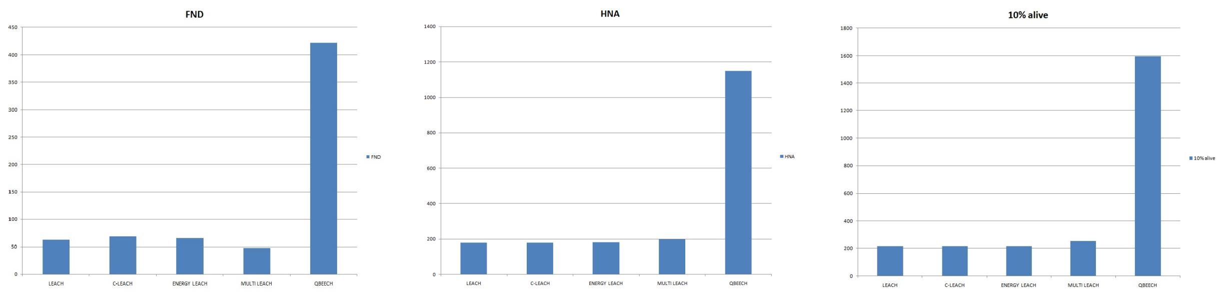


Figure. 9: Comparison of number of alive nodes for 500 nodes in area (500 X 500)



a(FND) b(HNA) c(10% alive)

Figure. 10: Comparison of FND, HNA and 10% alive of the sensor nodes for different algorithms

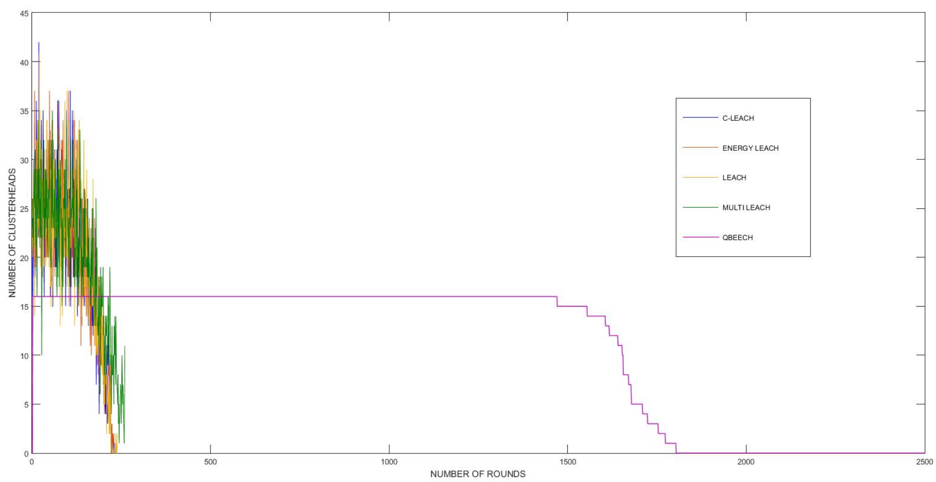
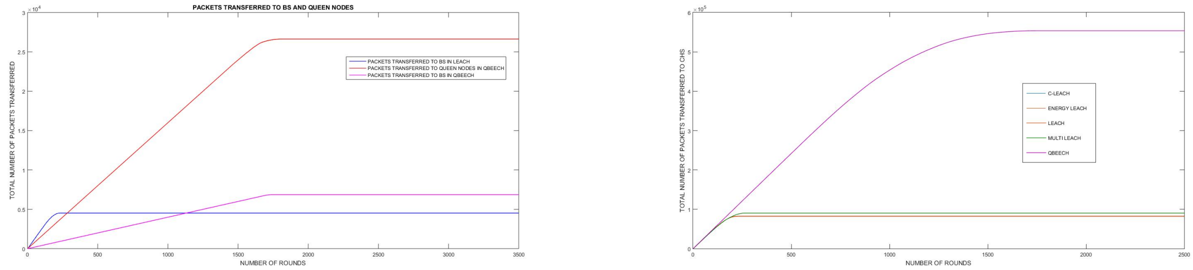


Figure. 11: (d)Comparison of the number of CHs



e(Throughput to BS) f(Throughput to CHs)

Figure. 12: Comparison of the number of packets transferred to Base Station(e) and the number of packets transferred to Cluster Heads(f)

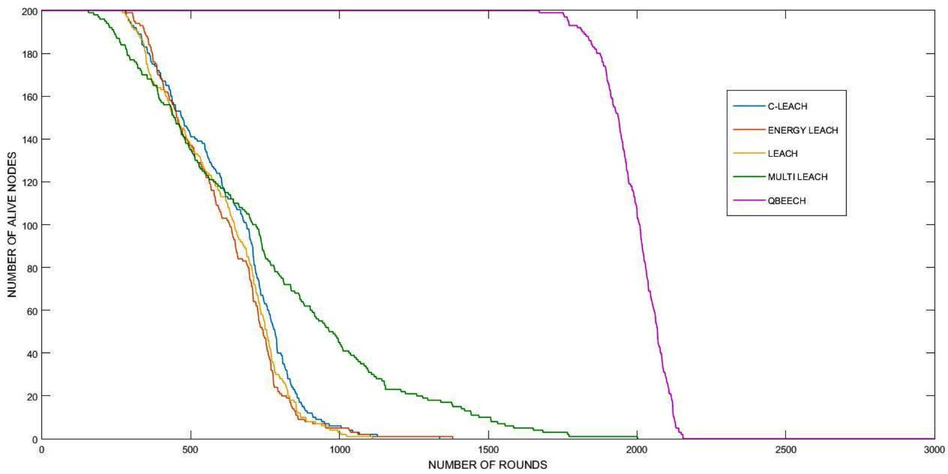


Figure. 13: Comparison of number of alive nodes

to transfer the data to BS will be more in this case. According to our assumption, Queen Nodes consists of as much amount of energy required until the whole network is dead.

D. Experiment 4

In this case, two results are compared when Queen Nodes are deployed randomly each in a big quadrant to the Queen Nodes which are deployed at the center of each big quadrant. Curve varies because the rate of death of CRSN nodes gets changed with the planned distribution of Queen Nodes.

Figure 14 has a disadvantage, the Queen nodes are distributed in a random manner which leads to the situation where sometime Queen Node may be very nearer to BS and sometime it may be very far away.

When distributed randomly QNs consume energy in a nonuniform manner i.e. if the nodes are close to base station then they will lose less amount of energy while they are far apart from the base station they will lose much more energy. Again we assume that the Queen Nodes will never be dead before all the nodes die. Thus in the figure 15 QNs are uniformly distributed. We compare the results of alive nodes versus Number of rounds when Queen Nodes are distributed randomly and when they are distributed in a uniform manner.

In figure 16, Comparison between uniformly and randomly distributed Queen nodes are plotted where blue line represent uniformly distributed QNs and red line represent non uniformly distributed QNs. In both the cases, stability and network lifetime are almost equal but the curve is different.

VI. Conclusion and Future Work

QBEECH is a powerful and easy algorithm that is proposed in this paper reduces the defects present in other clustering algorithms like LEACH, ENERGY LEACH, MULTI LEACH etc. This algorithm can be improved further and the stability of the network can be increased along with the Network Lifetime. To increase the network lifetime flying nodes can be implemented or energy harvesting process can be adopted. Wireless Sensor Network is still deeply concerned by the researchers and much development can be done in this field. In recent future, all these researches will be implemented by more than a few millions of people all over the world.

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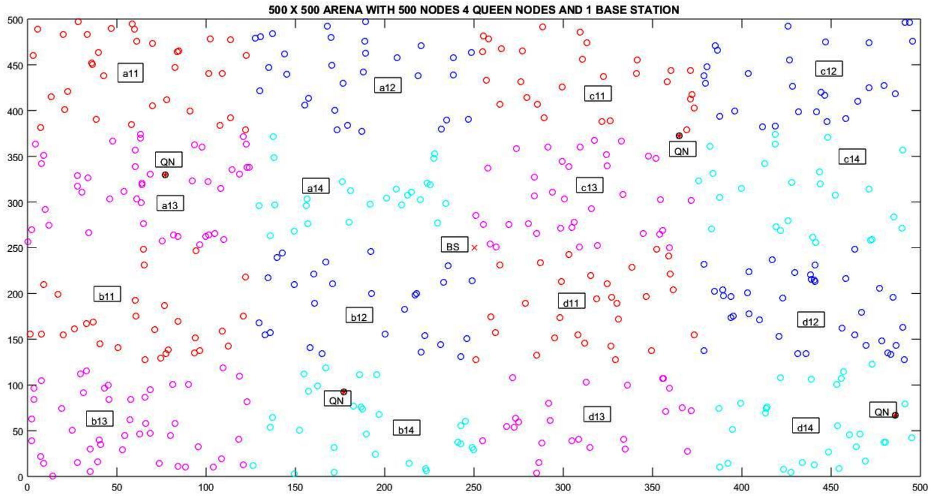

Figure. 14: Random Distribution of Queen Nodes

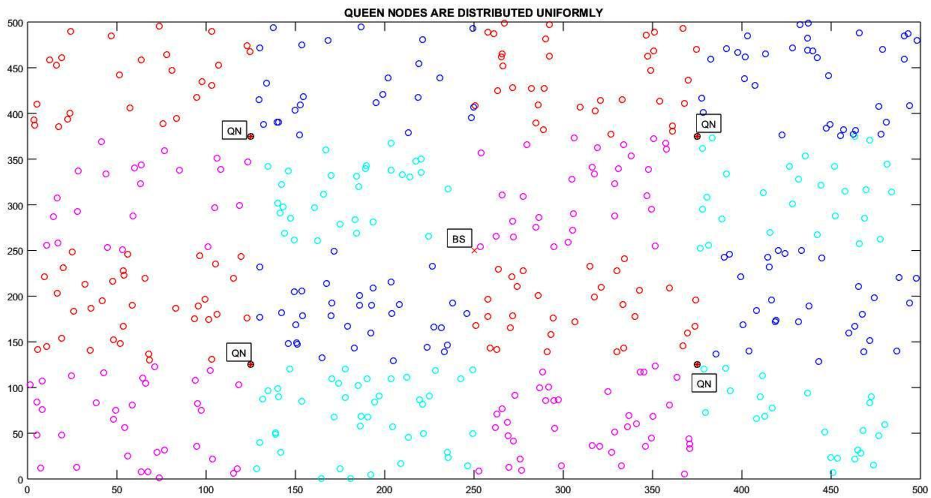

Figure. 15: Uniform Distribution of Queen Nodes

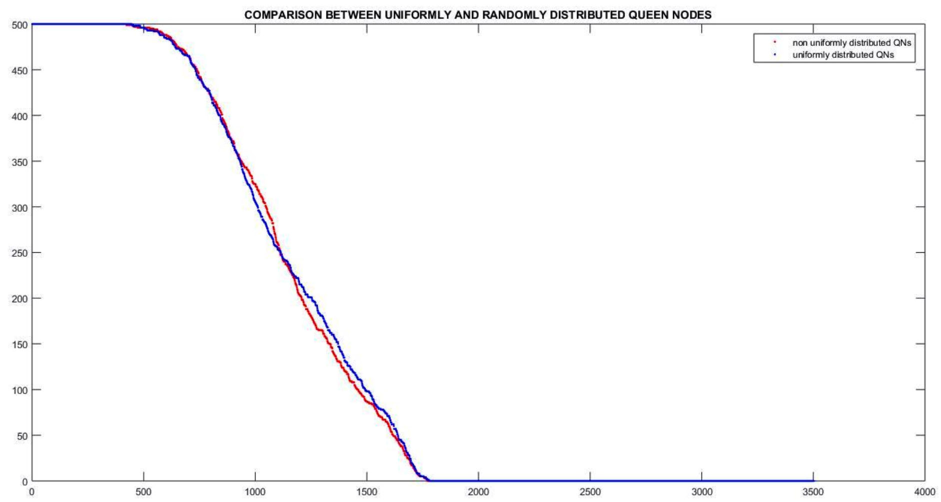

Figure. 16: Comparison between uniform and random distribution of Queen Nodes

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