A Forwarding Station Integrated the Low Energy Adaptive Clustering Hierarchy in Ad-hoc Wireless Sensor Networks

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Abstract: - An ad-hoc wireless sensor network is also called self-organized networking that wireless sensor nodes can automatically communicate for each other. Therefore, each sensor node is no need for the information such as location of each sensor. Similarly, it consumes much energy on the information exchanged of each sensor node in order to maintain the entire ad-hoc wireless sensor network alive. Therefore, there are totally three phases in this paper. First, the setup phase is that all sensor nodes are randomly deployed and the ad-hoc wireless sensor network is divided into many clusters in each round. Therefore, every cluster has only one cluster head. Second, each sensor node transmits its message to the cluster head where it belongs to and then the cluster head transmits the messages coming from sensor nodes and deliver it to forwarding station. Finally, the forwarding station forwards the integrated messages from all cluster heads back to the base station. However, it consumes less energy for all cluster heads to transmit directly back to the base station. Hence, the far away location of the base station usually consumes the cluster head much energy to transmit the message to the base station. With the proposed three-phase scheme, the ad-hoc wireless network lifetime can be extended very well. Also, the simulation results show the entire ad-hoc wireless network lifetime can be extended very well.

Key-Words: - Ad-hoc Wireless sensor networks, Network lifetime, Three-phase scheme, Forwarding station, Self-organized, Cluster.

1 Introduction

Since the technology improves quickly [1] especially nanometer technology; for this reason, those sensor nodes are becoming smaller and much cheaper. Recently, not only those sensor nodes become smaller and cheaper, but also they come with the characteristics of chips faster, low power and transmission distance longer. That is the contribution of the nanometre technology. By those characteristics of sensor nodes, the ad-hoc wireless sensor networks lifetime can be extended very well [2]. Moreover, the main purpose to those wireless sensor nodes [3] is gathering useful messages and transmitting those messages to the cluster head and the base station for analysis or other purposes.

In some certain situations, those wireless sensor nodes are deployed into an area where is probably hard to reach. Therefore, the battery of each wireless sensor node is hard to be recharged. However, the energy of those wireless sensor nodes have to be considered for longer surveillance.

Normally, wireless sensor nodes are randomly deployed in a certain area and those wireless sensor nodes can directly deliver the message to the base station and the energy [4] will be run out quickly because of the distance constrain. The multi-hop [4] [10] is much better because each sensor node delivers the information to its neighbour sensor nodes. However, both the direct transmission and multi-hop still dissipate much energy because of unevenly sensor nodes [11-12] deployed in a certain area. Therefore, the clustering scheme [5] [7] [18 – 20] was mentioned especially for unevenly sensor nodes in a certain area.

The low energy adaptive clustering hierarchy [6] (LEACH) has much better performance than others such as direct transmission, multi-hop and so on. There are merely two phases in LEACH scheme which is setup phase and transmission phase. During the setup phase, those wireless sensor nodes are randomly deployed and self-organized to form clusters with the pre-determined variable. During the transmission phase, every cluster has merely one cluster head. The goal of each cluster head delivers the message back to the base station. With the probability and random, papers [7-9] compare to the LEACH scheme. The problem came from LEACH is each round contains the different cluster numbers. The different cluster numbers [15] then has the different sensor node numbers for each cluster that caused uneven cluster numbers and sensor nodes in a cluster. This will consume unevenly energy in each round becoming worse performance.

Paper [8] proposed the centralized WSNs that the base station mainly controls for all processing and calculating problem so that the entire wireless sensor network performance is much better. That is because the power supply [13] [14] [16] of the base station is city power supply and most of calculations can be done here to save sensor nodes' energy. Paper [25] shows the optimal cluster number selection [17] in ad-hoc wireless sensor network. With the optimal cluster number selection, the entire ad-hoc wireless sensor network can evenly select the cluster head numbers and then efficiently delivers the message back to the base station.

Finally, since the base station can be located far away from the sensing area. Also, the distance is mainly concerned for the energy consumption. Therefore, three phases are proposed in this paper to save the energy and extend the entire ad-hoc wireless network lifetime.

2 Network Model

In the low energy adaptive clustering hierarchy (LEACH), it has only two phases [6] to form clusters and select cluster heads. Each cluster head delivers the message back to the base station. In this paper, there are three phases for the entire ad-hoc wireless sensor network that are setup phase, transmission phase and forwarding phase. First, the setup phase is that those sensor nodes are self-organized into clusters Second, transmission phase is that each sensor node transmits its message to the its own cluster head. Third, forwarding phase is each cluster transmits to the forwarding station (F.S.) to wait for the final integrated message to be delivered back to the base station. With the proposed scheme in this paper, a forwarding station integrated the low energy adaptive clustering hierarchy, the network lifetime then can be extended.

The transmission energy consumption, E_{TX}, for sensor nodes are expressed by

$$E_{TX} = l \cdot E_{elec} + l \cdot \varepsilon_{fs} d_{toCH}^2 . \qquad (3)$$

The received energy consumption, E_{RX}, for sensor nodes are expressed by

$$E_{RX} = l \cdot E_{elec} , \qquad (4)$$

where l stands for the message (bits) transmitted from each sensor node to its won cluster head. Here, assumption of free space d^2 is implemented. ε_{fs} stands for an amplified transmitting energy in the free space. In this paper, parameters are used as shown in table 1.

Table 1: Parameters are used for the simulation.

Notation	Description
n	Total amount of sensor nodes
E_o = 0.5J/bit	Initial energy for every node
E_{elec} = 50nJ/bit	Per bit energy consumption
E_{DA} = 5nJ/bit	Energy of data aggregation
ε_{fs} = 10pJ/bit/m^2	Amplified transmitting energy
d_{toCH}^2	The distance from a node to the cluster head in free space
d_{toCH}^4	The distance from a node to the cluster head in multi-path
d_0	The distance from a node to cluster head
ρ	Nodes density
Forwarding Station	Unlimited power

3 A Forwarding Station Integrated the Low Energy Adaptive Clustering Hierarchy

The architecture of LEACH [6] cannot evenly consume the energy of all sensor nodes, because the uneven clusters [21-24] selection in every round. When the cluster head receives the messages from sensor nodes, it takes much energy to deliver the message back to the base station. The energy consumption of each cluster head depends on the distance between the cluster head and the base station. That means if the distance of the base station is longer, the energy the cluster head dissipates more energy. Therefore, there are three phases implemented in this paper. The first phase is setup phase including sensor nodes randomly deployment, clusters formation and cluster heads selection. The second phase is transmission phase including TDMA, message aggregation, and message transferred between sensor node and base station. Finally, the forwarding phase is that cluster heads deliver the message to the forwarding station which will have the enough power forwarding the message back to the base station as shown in Fig. 1.

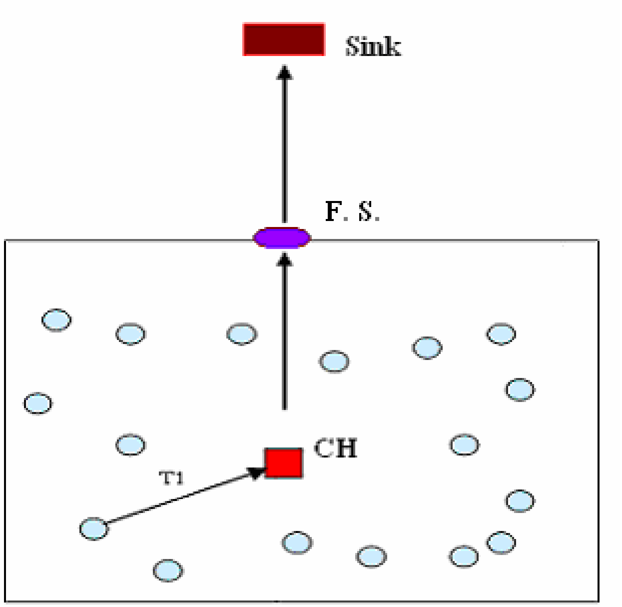

Fig. 1: three-phase to deliver the message back.

The following lists are three phases in the network.
1. Nodes firstly deployed into M x M m region.
2. Given the B.S. location.
3. Given the Forwarding station location.
4. B.S. is set at the outside of the sensing area;
5. Forwarding station is set at the centre of upper sensing area closer to the base station.
6. Nodes are organized by themselves into clusters with the given B.S. location and the Forwarding station address.
7. Every round will have the cluster numbers.
8. Message can be delivered back to the cluster head and forward to the forwarding station with TDMA and data aggregation.
9. Forwarding station will forward messages back to the base station.

4 Simulation Results
In order to have better simulation result, the simulation tool, Matlab, is used as simulator. In this paper, the base stations with no forwarding station are simulated to compare with the base stations with the forwarding station. The results of the base station with forwarding station or no following station are shown in table 2-3.

Table 2

Location of Base Station	First Node Die
50,125	950
50, 175	600
50, 225	250
50, 250	200
50, 300	195

Table 3

Forwarding Station, B.S.(50,300)	First Node Die
50,100	1000

4.1 Base Station at (50, 125)
100 sensor nodes are randomly deployed as shown in Fig. 2. Fig. 3 shows the formation of clusters and how many nodes are still alive there. “o” represents sensor node is still alive. “.” represents sensor node is no longer alive. “+” represents a cluster head. “*” represents a base station. Also, sensor node’s colour stands for which sensor node belongs to which cluster. As the base station is set at the point (50, 125), Fig. 4 shows how many nodes are still alive and how many nodes are no longer alive. Fig. 5 shows that the energy to packets is consumed in rounds. Fig. 6 shows the network lifetime.

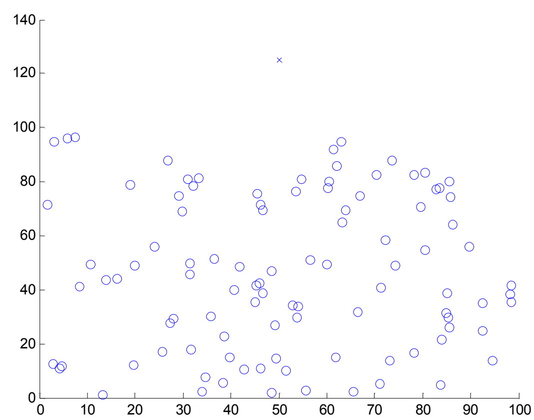

Fig. 2: 100 sensor nodes with B.S. (50,125).

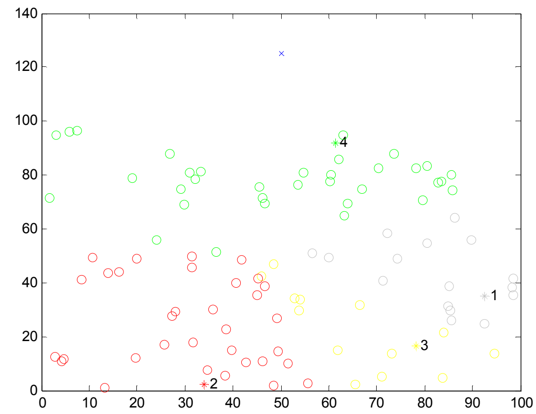

Fig. 3: clusters formation with B.S. (50,125).

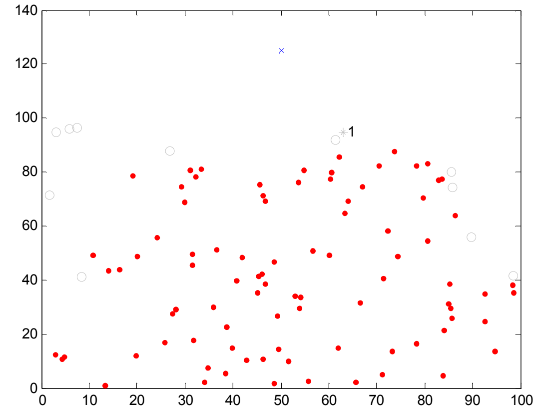

Fig. 4: sensor nodes running in 1200 rounds.

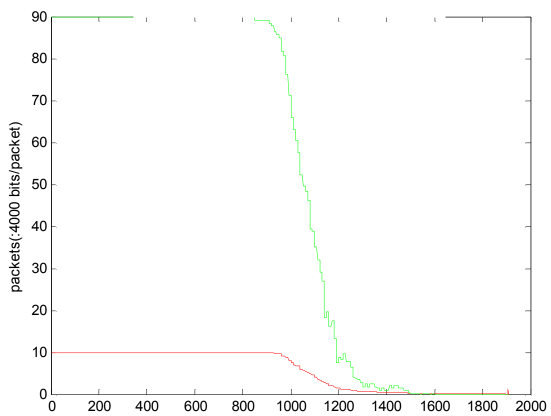

Fig. 5: packets and energy consumption.

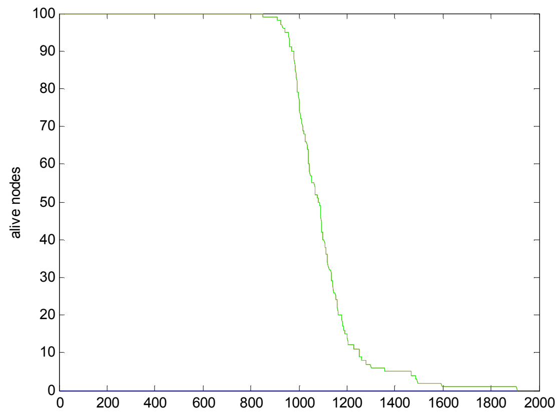

Fig. 6: network lifetime in rounds.

4.2 Base Station at (50, 175)

100 sensor nodes are randomly deployed as shown in Fig. 7. Fig. 8 shows the formation of clusters and how many nodes are still alive there. "o" represents sensor node is still alive. "." represents sensor node is no longer alive. "+" represents a cluster head. "*" represents a base station. Also, sensor node's colour stands for which sensor node belongs to which cluster. As the base station is set at the point (50, 175), Fig. 9 shows how many nodes are still alive and how many nodes are no longer alive. Fig. 10 shows that the energy to packets is consumed in rounds. Fig. 11 shows the network lifetime.

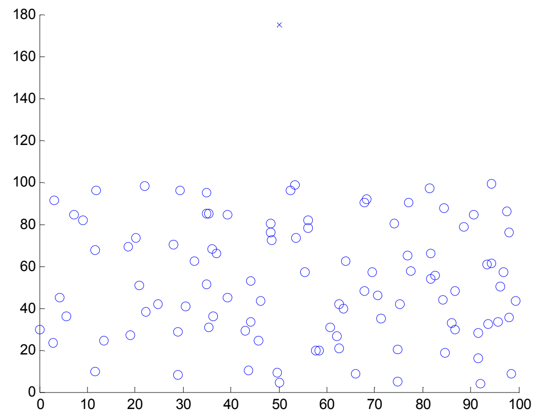

Fig. 7: 100 sensor nodes deployed with B.S (50,175).

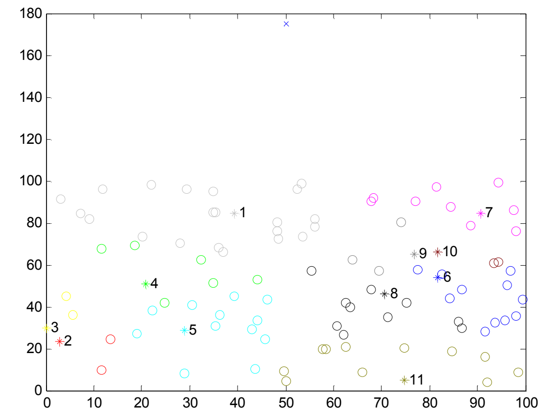

Fig. 8: clusters formation with B.S. (50,175).

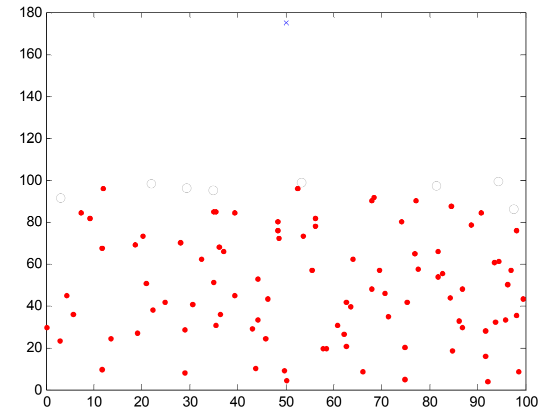

Fig. 9: sensor nodes running in 1200 rounds.

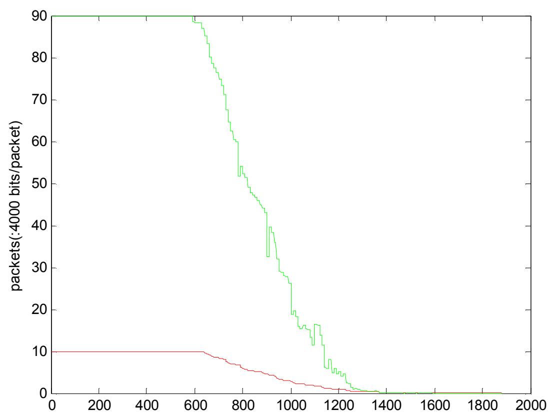

Fig. 10: packets and energy consumption.

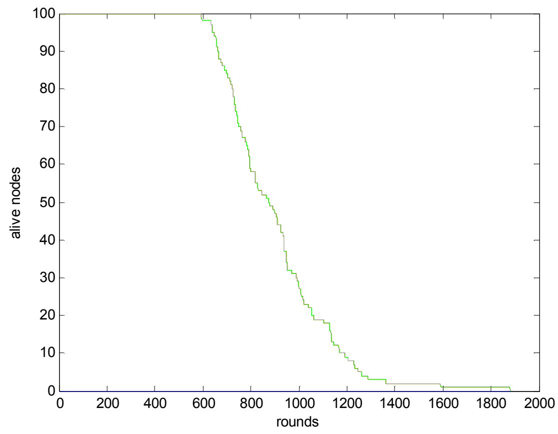

Fig. 11: network lifetime in rounds.

4.3 Base Station at (50, 225)

100 sensor nodes are randomly deployed as shown in Fig. 12. Fig. 13 shows the formation of clusters and how many nodes are still alive there. "o" represents sensor node is still alive. "." represents sensor node is no longer alive. "+" represents a cluster head. "*" represents a base station. Also, sensor node's colour stands for which sensor node belongs to which cluster. As the base station is set at the point (50, 225), Fig. 14 shows how many nodes are still alive and how many nodes are no longer alive. Fig. 15 shows that the energy to packets is consumed in rounds. Fig. 16 shows the network lifetime.

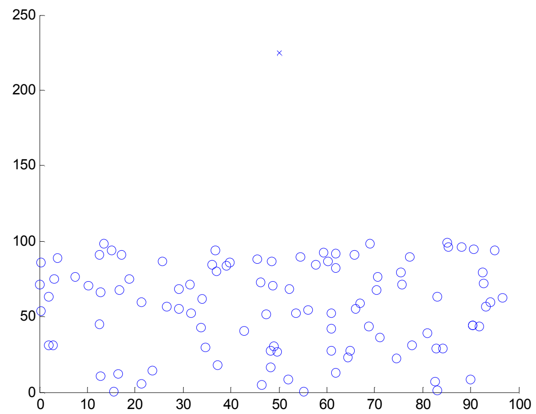

Fig.12: 100 sensor nodes with B.S (50,225).

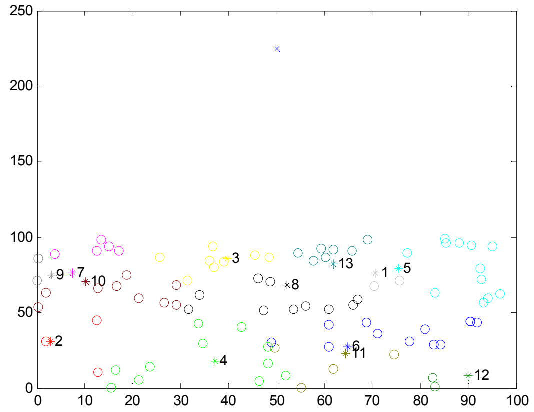

Fig. 13: clusters formation with B.S. (50,225).

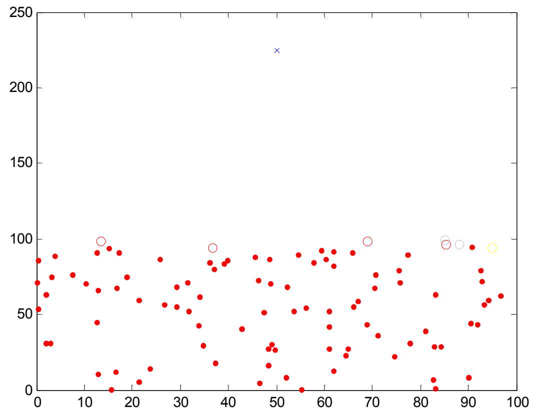

Fig. 14: sensor nodes running in 900 rounds.

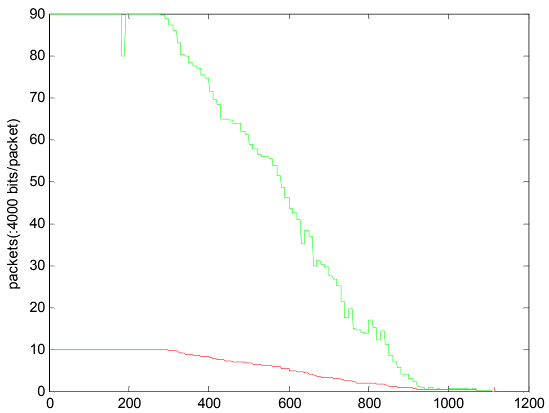

Fig. 15: packets and energy consumption.

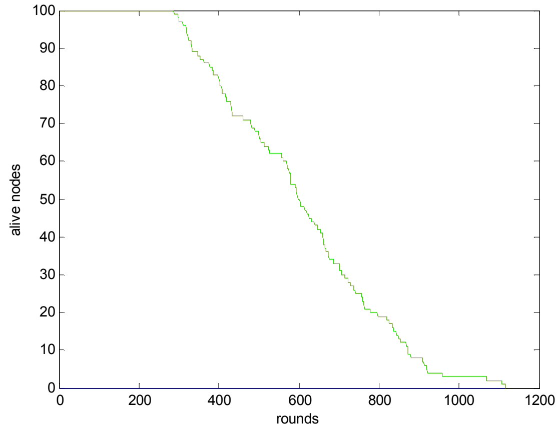

Fig. 16: network lifetime in rounds.

4.4 Base Station at (50, 250)

100 sensor nodes are randomly deployed as shown in Fig. 17. Fig. 18 shows the formation of clusters and how many nodes are still alive there. "o" represents sensor node is still alive. "." represents sensor node is no longer alive. "+" represents a cluster head. "*" represents a base station. Also, sensor node's colour stands for which sensor node belongs to which cluster. As the base station is set at the point (50, 250), Fig. 19 shows how many nodes are still alive and how many nodes are no longer alive. Fig. 20 shows that the energy to packets is consumed in rounds. Fig. 21 shows the network lifetime.

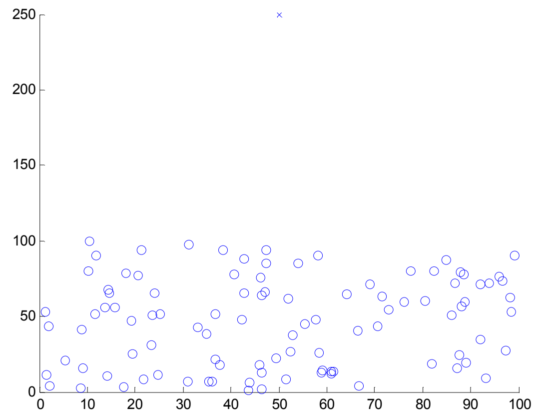

Fig.17: 100 sensor nodes with B.S (50,250).

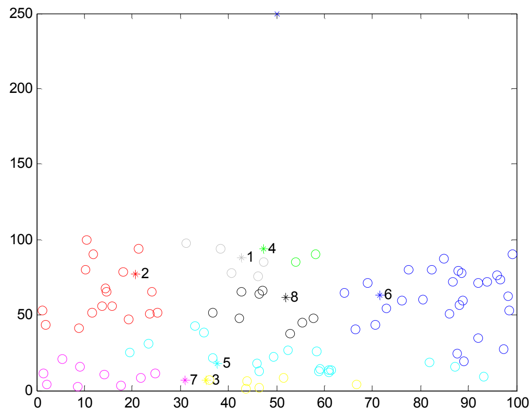

Fig. 18: clusters formation with B.S. (50,250).

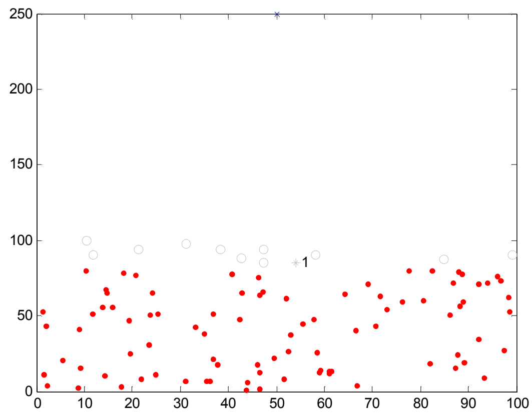

Fig. 19: sensor nodes situation in 600 rounds.

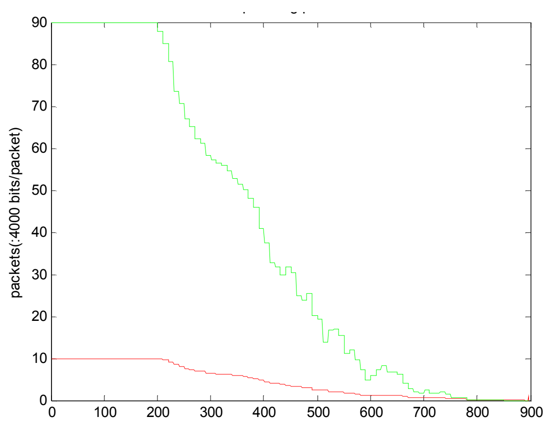

Fig. 20: packets and energy consumption.

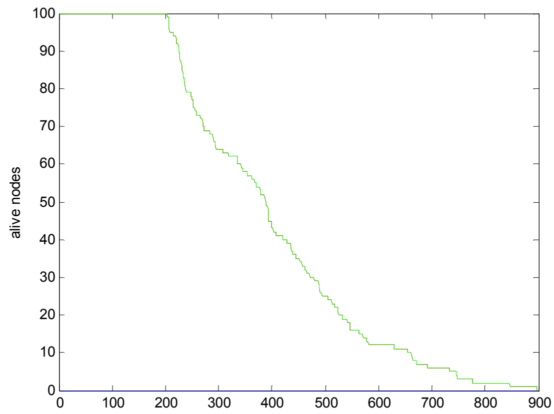

Fig. 21: network lifetime in rounds.

4.5 Base Station at (50, 300)

100 sensor nodes are randomly deployed as shown in Fig. 22. Fig. 23 shows the formation of clusters and how many nodes are still alive there. "o" represents sensor node is still alive. "." represents sensor node is no longer alive. "+" represents a cluster head. "*" represents a base station. Also, sensor node's colour stands for which sensor node belongs to which cluster. As the base station is set at the point (50, 250), Fig. 24 shows how many nodes are still alive and how many nodes are no longer alive. Fig. 25 shows that the energy to packets is consumed in rounds. Fig. 26 shows the network lifetime.

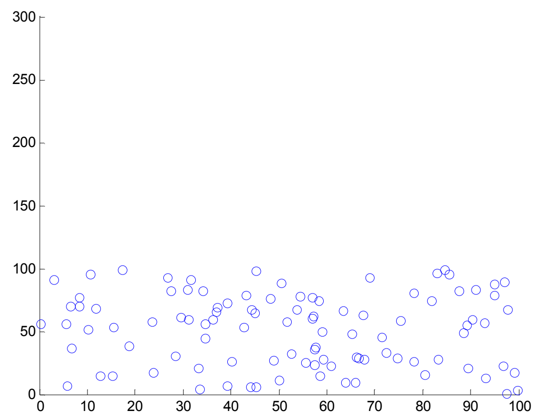

Fig.22: 100 sensor nodes with B.S (50,300).

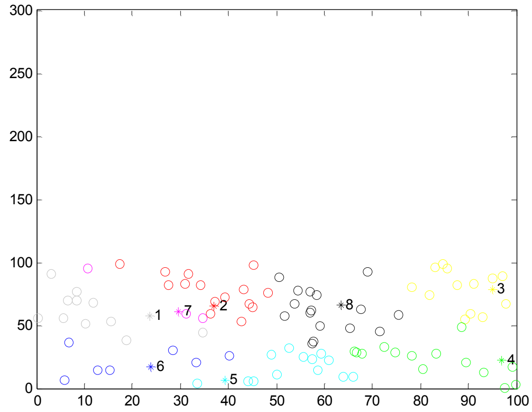

Fig. 23: clusters formation with B.S. (50,300).

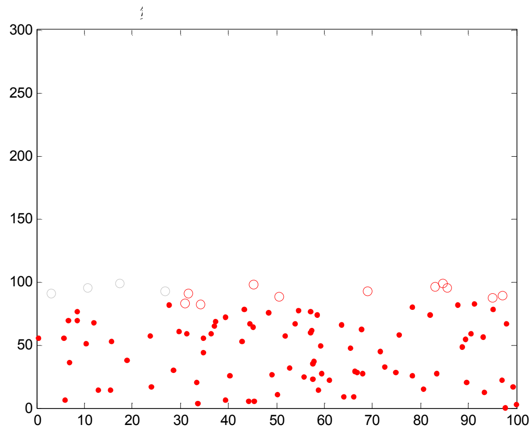

Fig. 24: sensor nodes situation in 300 rounds.

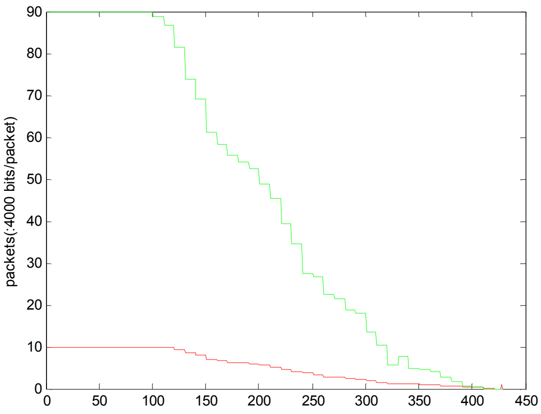

Fig. 25: packets and energy consumption.

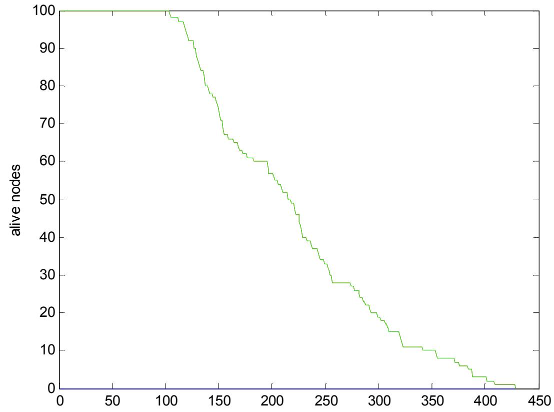

Fig. 26: network lifetime in rounds.

4.6 Forwarding Station at (50, 100)

100 sensor nodes are randomly deployed as shown in Fig. 27. Fig. 28 shows the formation of clusters and how many nodes are still alive there. "o" represents sensor node is still alive. "." represents sensor node is no longer alive. "+" represents a cluster head. "*" represents a base station. Also, sensor node's colour stands for which sensor node belongs to which cluster. As the base station is set at the point (50, 300) and the forwarding station (50,100), Fig. 29 shows how many nodes are still alive and how many nodes are no longer alive. Fig. 30 shows that the energy to packets is consumed in rounds. Fig. 31 shows the network lifetime.

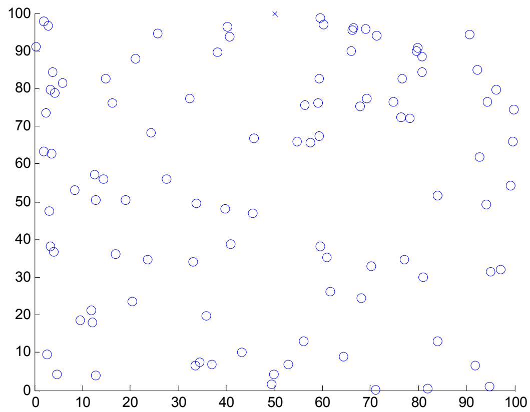

Fig.27: 100 sensor nodes with B.S (50,175) and F.S. (50,100).

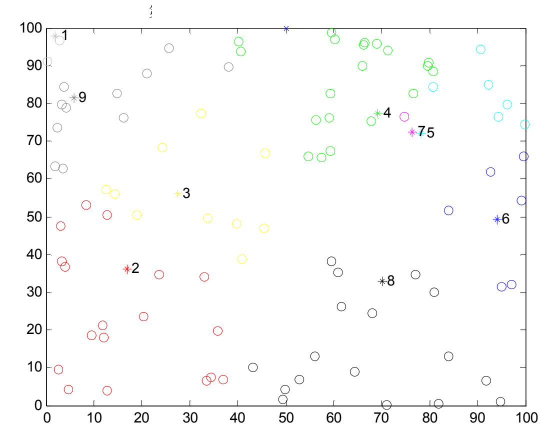

Fig. 28: clusters formation with B.S. (50,175) and F.S. (50,100).

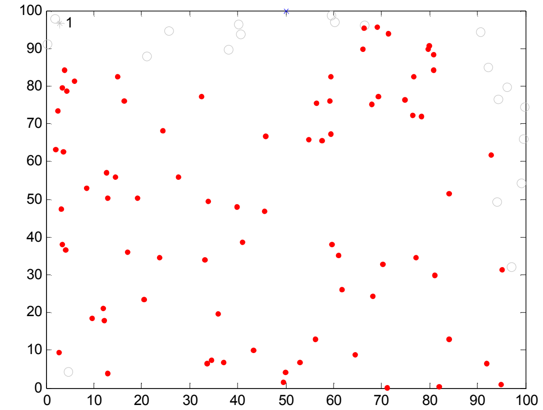

Fig. 29: sensor nodes situation in 1200 rounds.

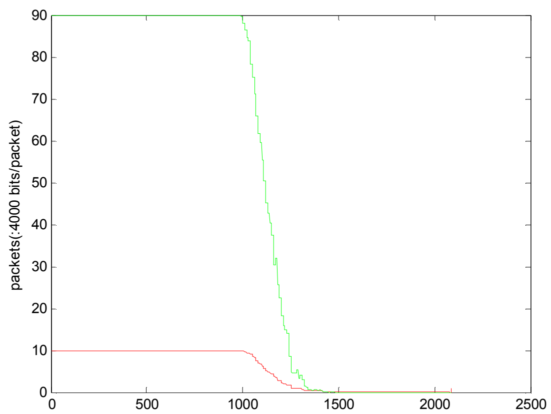

Fig. 30: packets and energy consumption.

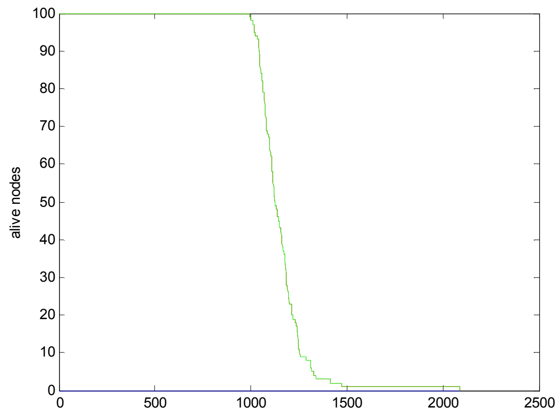

Fig. 31: network lifetime in rounds.

5 Conclusion

The clustering based wireless sensor network contains two phases to deliver the message back to the base station. Since the cluster head consumes much energy to deliver the message back to the base station. This paper proposes a forwarding station integrated the low energy adaptive clustering hierarchy that contains three phases – setup phase, transmission phase and forwarding phase. With the proposed scheme in this paper, the forwarding phase can also extend the location of the base station. Therefore, the network lifetime is extended. Simulation results show the entire network can be prolong very well.

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