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## ABSTRACT

This paper proposes a novel energy efficient data relaying scheme to improve energy efficiency for cluster-based wireless sensor networks (WSNs). In order to reduce the energy dissipation of transmitting sensing data at each sensor, the fixed clustering algorithm uniformly divides the sensing area into clusters where the cluster head is deployed to the centered of the cluster area. Moreover, to perform energy efficient data relaying fixed clustering (EERFC), the cluster head is deployed as close to the sink as possible. Simulation results show that proposed EERFC definitely reduces the energy consumption of the sensors and it can further efficiently relay the cluster data.

## INTRODUCTION

The microchip and telecommunication technology have been developed to comprise the sensing capabilities with wireless communication and data processing (Culler, 2004). Microchip sensor devices can be applied to the certain environment for surveillance. In contrast, in some environments that sensors batteries are hardly to be recharged would be considered as an important research topic. Here, energy efficiency and lifetime of WSN are considered as most significant performance (Akyildiz, 2002). Therefore, minimizing and balancing the energy dissipation for all sensor nods is investigated in this paper.

Direct sending data would consume more energy than other methods in WSN (Akyildiz, 2002). Because every sensor node collects data and sends directly data back to the base station, “sink”, the far away sensors will run out of energy quickly. Thus, the direct transmission is not suitable for large area (Akyildiz, 2002). In order to have better performance, multi-hop routing protocol is applied to the ad hoc wireless sensors communication networks (Duarte-Melo, 2002) (Younis, 2004) (Zhu, 2003). However, sensor nodes closer to the BS consume more energy than other nodes to relay data(Younis, 2004). Thus, the multi-hop transmission is not suitable for densely WSN.

Moreover, the cluster-based scheme performs that those closer sensors belong to their own clusters. One of sensors, called “cluster head,” in each cluster is responsible for delivering data back to the base station. This scheme performs energy efficiency with that the cluster head can compress data and send back to the base station. Generally, the lifetime of clustering in WSN can be extended compared to the direct and multi hop transmission. Yet, the energy of cluster head is consumed more than other sensor nodes (Zhu, 2003) (Raghunathan, 2002) (Schurgers, 2001). However, with distributing more energy the cluster head can extend the network lifetime for heterogeneous WSNs. Therefore, this paper proposes a centralized algorithm to clustering sensors and to deploy energy efficient relaying nodes with fixed clustering scheme.

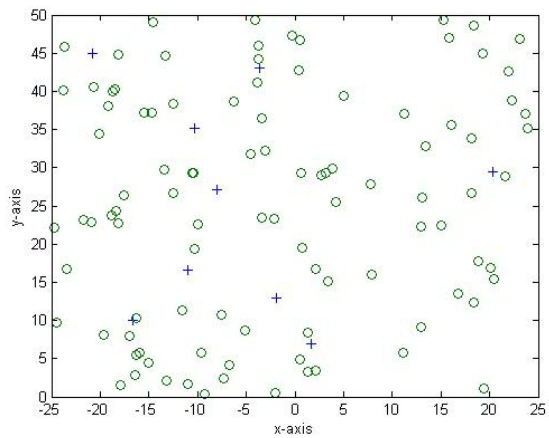
## NETWORK MODELS

With randomly distributed in the clustering area, the energy will be quickly run out in WSN (Duarte-Melo, 2002). Figure 1 shows the cluster head are uniformly distributed with length *D*. In the area of WSN, the channel models are modeled by

$$P_r = c\frac{P_t}{d^{\alpha}}, \tag{1}$$

where $P_r$ represents the received power, $P_t$ represents the transmitted power, $c$ is the propagation coefficient, and $\alpha$ is the path loss exponent, $2 \le \alpha < 6$.

**Figure 1: The random deployment with number of clusters *q*=9.**




In one round the cluster heads collect the sensing data of their cluster and send data back to the basestation (BS). Thus, each round of total energy is given by

$$E_T = \sum_{i=1}^{q}\left(\eta_i \cdot E_{ch,i} \cdot \frac{Q}{q}\right) + \sum_{j=1}^{Q-q} E_{n,j}\ , \tag{2}$$

where $\eta_i$ is a data compressing factor for the *i*th cluster, $0 < \eta_i < 1$. $E_{ch,i}$ and $E_{n,j}$ are one packet energy for *i*th cluster head and *j*th sensor.

## ENERGY EFFICIENT RELAYING WITH FIXED CLUSTERING

Minimizing the energy dissipation of the sensor nodes, an fixed clustering algorithm (FCA) is applied for clustering area in previous work (Huang, 2007). The FCA is used to divide the sensor area into clusters firstly and then to deploy cluster heads uniformly to the network area. The fixed cluster sensor network can be deployed by FCA shown in Figure 2. In Figure 2, $x(i)$ and $y(i)$ are the axis of corresponding position of the cluster head for the *i*th cluster .

Assuming sensor nodes are uniformly distributed, the power dissipation of a cluster head to relay the information of the cluster in one round can be obtained by

$$E_{ch,i} = \eta_i \cdot e_l \cdot W_i \cdot \frac{Q}{q}\,, \tag{3}$$

where $e_l$ is the energy needed in sending one packet per square meter whereas the path loss of a distance between *i*th cluster head and base station is given by

$$W_i \;=\; d_i^{\alpha}/c \;=\; d_i^2 \;=\; x^2(i)+[y(i)+B]^2, \tag{4}$$

where $\alpha = 2$ and $c = 1$. So, the energy needed for a sensor node sending one packet in a clustering area is obtained by

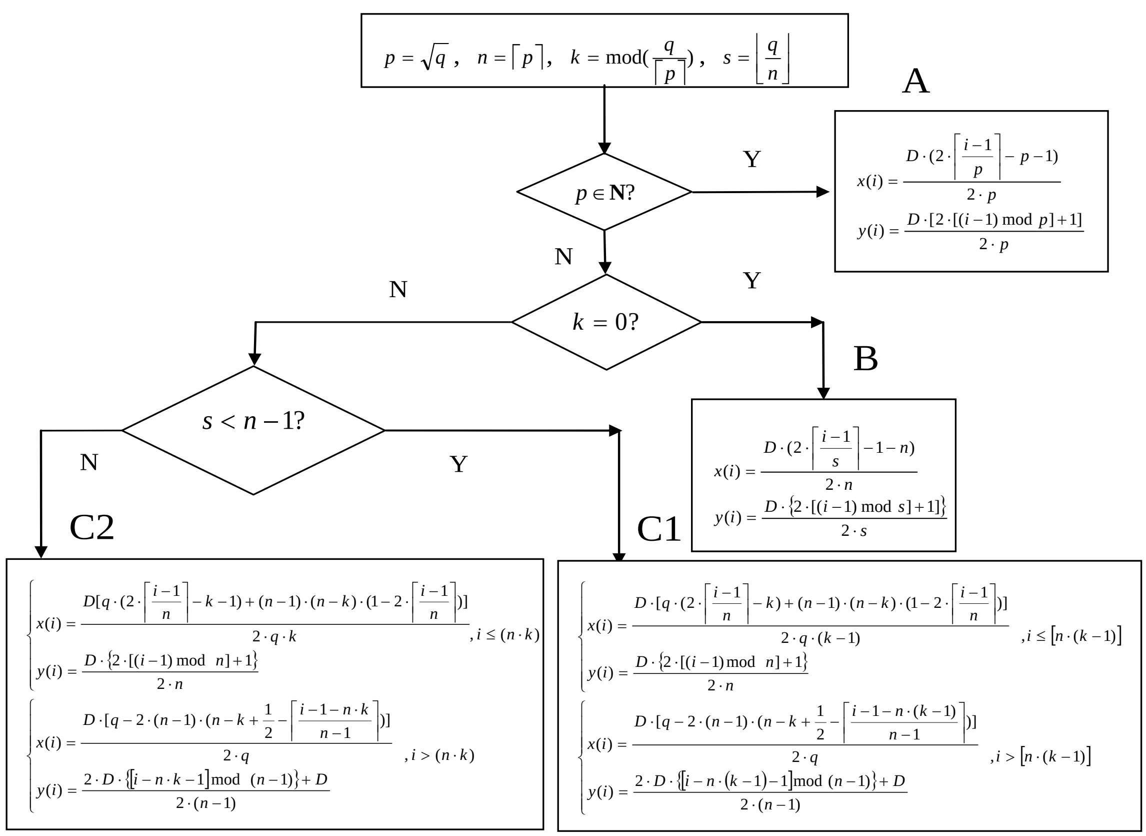
$$E_{n,j} = e_l \cdot Z_j\,, \tag{5}$$

where $Z_j = d_j^2$ is the random variable. The expected power that a sensor node to send one packet in a rectangular clustering is obtained by

$$E[Z] = E\left[(x-\frac{L_1}{2})^2 + (y-\frac{L_2}{2})^2\right] = \frac{1}{12}\left(L_1^{\,2} + L_2^{\,2}\right), \tag{6}$$

where $L_1$ and $L_2$ are the width and length of the rectangular area of the cluster. Cluster head is located at ($L_1$/2, $L_2$/2).

**Figure 2: FCA flowchart for a square area.**



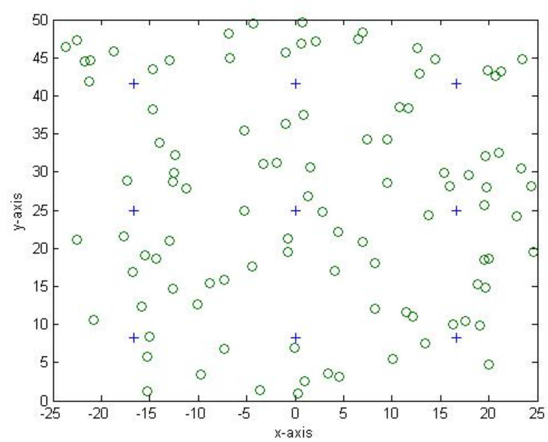
In RC, the cluster head is randomly selected as shown in Figure 1. The energy needed for each cluster to transmit one packet is obtained by

$$E[Z] = E[x^2 + (y+B)^2] = \frac{5D^2}{12} + B \cdot D + B^2 , \qquad (7)$$

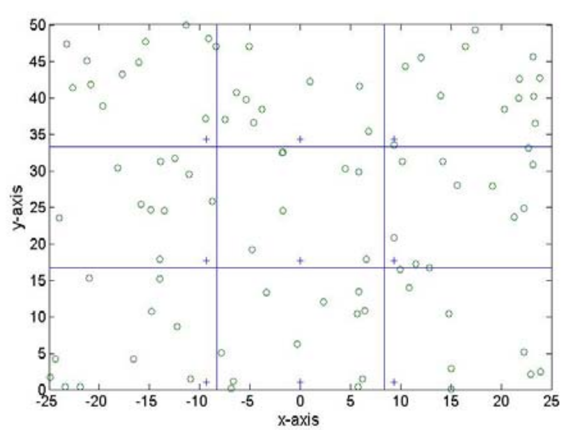
where $D$ is the length of the square and $B$ is the distance between sensing field and base station.

In FCA, cluster head is deployed at the centered of the cluster to balance the distance between cluster head and the farthest senor nodes. Therefore, the energy dissipation of the farthest senor nodes is minimized. However, the data relaying of the cluster head consumes more energy by U-turn relaying. The energy efficient relaying with fixed clustering (EERFC), cluster heads are deployed to the closest site to the base station, is proposed and discussed in this paper. When the base station is deployed at (0, -*B*) = (0, -10), an example of 9 clusters for the cluster head deployment in FCA and EERFC is shown in Figure 3.

**Figure 3: The deployment of cluster head: (a) fixed clustering (b) energy efficient relay and fixed clustering, with number of clusters *q*=9.**




(a)




(b)

## SIMULATION RESULTS

Assuming that the energy needed for sending one packet from each sensor is $e_l = 5\times10^{-7}$ Joule (J)/m$^2$. Total number of sensor nodes is one hundred, $Q$=100. Normal sensor nodes are 100-$q$. Sensing square area is $D$=50 meters. The worst case in data fusion with data compressing factors for all clusters $\eta_i$=1 is performed.

Figure 4 shows the comparison of energy dissipation between the EERFC and FCA and the energy consumption of one round vs. the number of clusters. It depicts total energy of normal sensor nodes is decreased as the number of clusters increases. That means, when clustering area is smaller, distance from sensor node to cluster head is shorter. Contrarily, when number of clusters increase, energy consumed in cluster heads also increases. Therefore, the energy dissipation of the cluster head of EERFC is much lower than FCA.

**Figure 4: Energy consumed by cluster head and sensor nodes in one round between EERFC and FCA.**

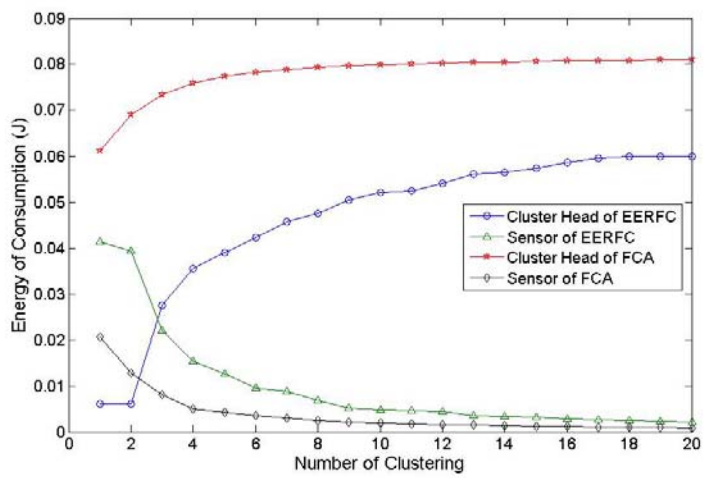
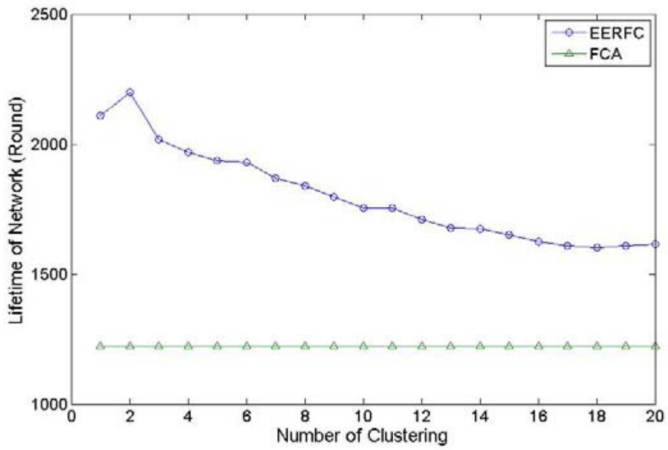



Figure 5 shows the comparison of lifetime in WSN for FCA and EERFC with the perfect energy distribution and the total energy $E_T$ = 100J for all nodes. By using efficient data relaying in EEFRC, Figure 5 depicts the lifetime performance of proposed EERFC can be improved more 30% than FCA scheme with the number of cluster 1 <$q$<20. Generally, the distributed energy for every sensor node should be almost the same for homogeneous WSNs. When number of clusters is small, ($q$<10), cluster head should be distributed more energy in order to relay more data. Similarly, the initial energy for all cluster heads should be almost the same. Therefore, this paper discusses to distribute two different kinds of energy to the nodes. In a heterogeneous WSN, cluster heads with higher energy batteries and sensor nodes with lower energy batteries are distributed, respectively.

**Figure 5: Lifetime comparison between EERFC and FCA with optimal energy distributed sensors.**




To investigate the lifetime of proposed EERFC with heterogeneous sensors, different total energy $E_{NS}$ and $E_{CH}$ is distributed to sensor nodes and cluster heads. In order to be more cost-effective, total energy of cluster heads and normal sensors is $E_T = E_{CH}+E_{NS} = 100$J. Hence, the initial energy of a cluster head and a sensor node is obtained as

$$E_{ch} = \frac{ER \cdot E_T}{(ER+1) \cdot q} \tag{8}$$

and

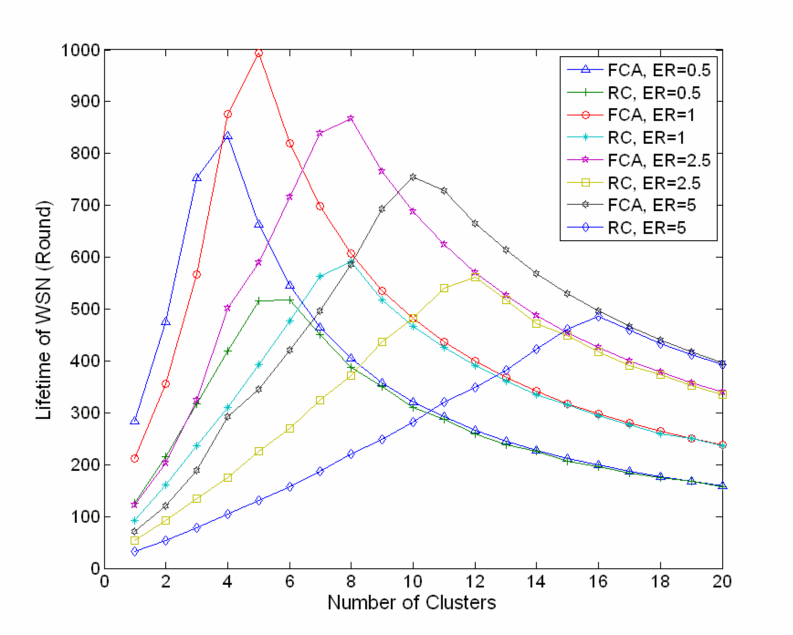
$$E_n = \frac{E_T}{(ER+1) \cdot (Q-q)} \tag{9}$$

where *ER* is the energy ratio of cluster heads to sensor nodes defined by

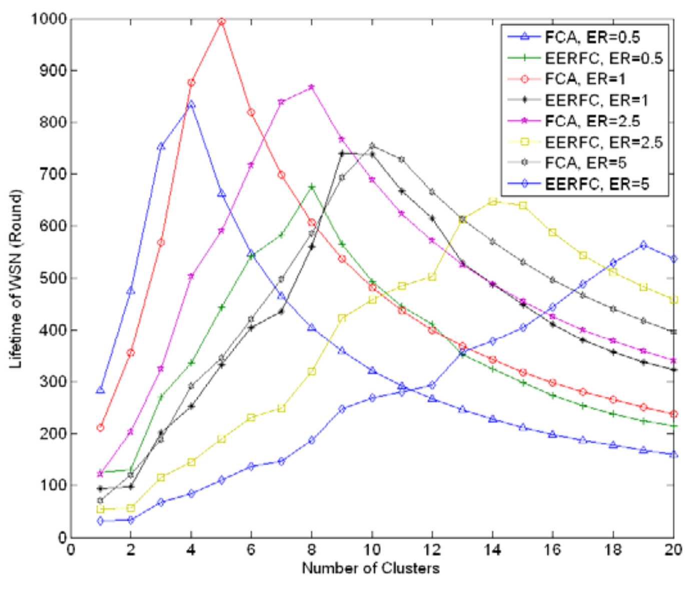
$$ER = E_{CH} \;/\; E_{N.} \tag{10}$$

Figure 6 shows the comparison between network lifetime and number of clusters for RC, FCA and EERFC. With the rising curve in Figure 6, it depicts that the energy dissipation of sensor nodes is decreased with the increasing number of clusters. In contrast, with the curve going down in Figure 6, it also shows that the consuming energy of cluster head increases with the increasing number of clusters. To compare the energy efficiency of WSNs, the energy efficiency (*EE*) can be proportional to the network lifetime.

**Figure 6: Lifetime comparison for heterogeneous WSNs: (a) FCA and RC (b) EERFC and FCA.**




(a)




(b)

According to the *ER*, the lifetime of WSN by deploying number of clusters can be maximized. Table 1 shows the maximal lifetime (*LT*) at the optimal number of clusters $q_{op}$ for RC, FCA and EERFC. Therefore, because of the random clustering endue the farther distance between cluster head and sensors, RC performs more worst than others.

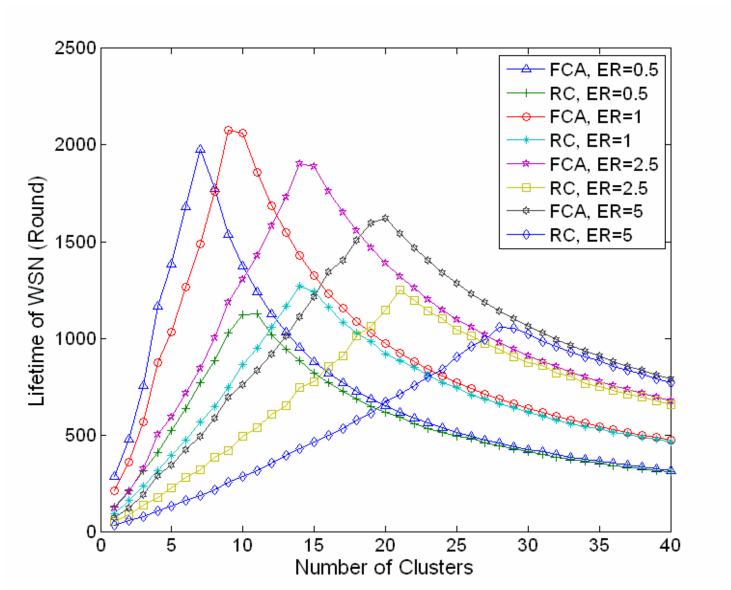
In addition, the EERFC performs a little bit worse than FCA by extending distance between cluster head and sensors.

**Table 1: Comparison of energy efficiency and optimal number of clusters for FCA, EERFC and RC with heterogeneous sensors and base station at (0,-10).**

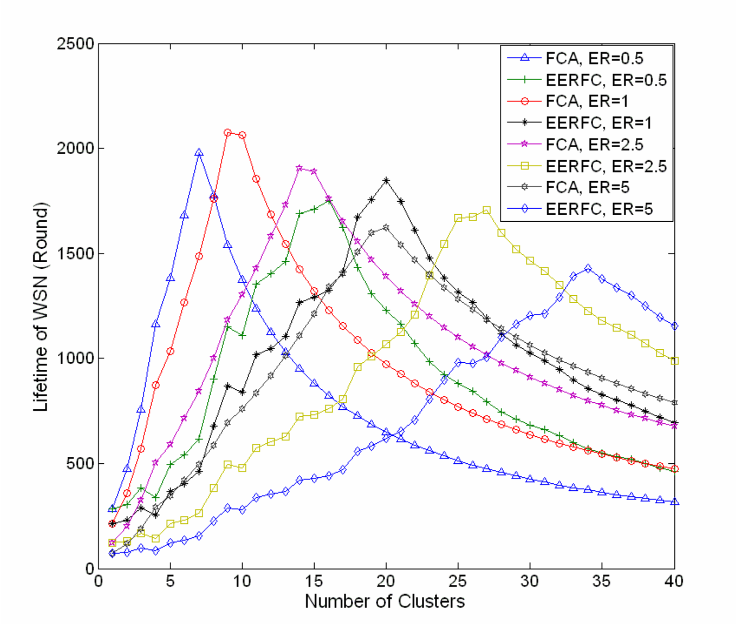
| | *ER* | 0.5 | 1 | 2.5 | 5 |
|---|---|---|---|---|---|
| FCA | *LT* | 834 | 994 | 867 | 754 |
| | $q_{opt}$ | 4 | 5 | 8 | 10 |
| EERFC | *LT* | 675 | 740 | 648 | 563 |
| | $q_{opt}$ | 8 | 9 | 14 | 19 |
| RC | *LT* | 516 | 591 | 562 | 486 |
| | $q_{opt}$ | 5 | 8 | 12 | 16 |

In order to minimize the energy dissipation of data relaying, a base station is relocated at the centered of sensing field (0, 25). The performance of lifetime of WSN vs. the number of clusters for FCA, EERFC and RC is showed in Figure 7. Therefore, table 2 lists and compares the maximal lifetime (*LT*) at the optimal number of clusters $q_{op}$ for RC, FCA and EERFC.

**Figure 7: Lifetime comparison for heterogeneous WSNs: (a) FCA and RC (b) EERFC and FCA, with base station at (0,25).**




(a)




(b)

**Table 2: Comparison of energy efficiency and optimal number of clusters for FCA, EERFC and RC with heterogeneous sensors and base station at (0,25).**

| | *ER* | 0.5 | 1 | 2.5 | 5 |
|---|---|---|---|---|---|
| FCA | *LT* | 1979 | 2077 | 1903 | 1622 |
| | $q_{opt}$ | 7 | 9 | 14 | 20 |
| EERFC | *LT* | 1750 | 1846 | 1704 | 1428 |
| | $q_{opt}$ | 16 | 20 | 27 | 34 |
| RC | *LT* | 1125 | 1271 | 1248 | 1056 |
| | $q_{opt}$ | 11 | 14 | 21 | 28 |

## CONCLUSIONS

In this paper, a centralized algorithm to organize sensors into clusters with energy efficient relaying with fixed clustering (EERFC) scheme is proposed to prolong the lifetime of cluster-based WSN. It uniformly divides area of cluster area for the WSN and save the energy dissipation of senor nodes in the cluster. Simulation results show that the EERFC can efficiently relay the data and minimize the energy dissipation in WSN. However, in heterogeneous WSN, a centralized algorithm to organize sensors into with energy efficient relaying with fixed clustering (EERFC) scheme can also balance the energy dissipation of the sensor nodes.

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