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Energy Efficiency of Dynamically Distributed Clustering Routing for Naturally Scattering Wireless Sensor Networks

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Abstract. *This paper investigates the optimization on the energy efficiency of dynamically clustering for naturally scattering deployed cluster-based wireless sensor networks (WSNs). The nodes deployment would be approximated Gaussian distributed in large area for naturally scattering senior nodes. Thus, in this paper we based on the numerical results in previous works and further proposed a dynamically clustering scheme to improve the lifetime for large area WSNs. Simulation results show that the proposed dynamically distributed clustering scheme outperforms conventional LEACH scheme with lower scattering circumstances.*
Keywords: Wireless sensor networks, Energy efficiency, Dynamical clustering, Naturally scattering.

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1. **Introduction.** Recently, the wireless sensor network (WSN) is popular because it is applicable in various fields like agriculture, health, military etc. In WSN, many tiny sensor nodes are used for sensing the environmental conditions over a particular specified region. The small sensors comprise the capabilities of wireless communication and data processing [1] with technologies of microelectro-mechanical systems and telecommunication battery. These small sensors could be used as the surveillance and the control capability under a certain environment. As mentioned in [2] routing is a technique for sending data from source to destination by using the neighbor nodes as routers so that data can be reached to base station (BS). In the radio model used by all routing protocols for transmission and reception of data, the transmitter has energy dissipation for running both the radio

electronics and the power amplifier whereas receiver has energy dissipation only for running the radio electronics [3]. In [4], the direct transmission protocol is described. In this protocol, sensor nodes directly transmit the sensed data to BS. The nodes which are farther away from the base station die out quickly as they require high transmission power. It has been concluded that it is not an energy efficient protocol when compared with clustering protocol. Then, to enable communication between sensors not within each others communication range, the common multi-hop routing protocol is applied in the ad hoc WSNs [3]. However, due the highly complexity in routing protocols and the most likely heavy load on the relaying nodes, this scheme is not suitable for the highly densely WSNs [5]. Specially, the location of WSN could be a region where people could not easily reach and there is a difficulty to recharge the device energy. Therefore, the energy efficiency of the sensor networks is an important research topic and the lifetime of WSNs could be considered as the most significant performance in the WSNs [4]. The structure of low-energy adaptive clustering hierarchy (LEACH) is one of the initiate algorithm to balance the energy issues for cluster based WSNs [6]. The cluster-based one is that those closer sensors belong to their own clusters. One of sensors, called cluster head (CH), in each cluster is responsible for delivering data back to the base station. In this scheme, the CH performs data compressing and sending back to the base station. Thus, the lifetime of CH may be shorter than that of other sensors due to the large energy dissipation in performing the long distance data transmission to the sink. The optimal number of clusters in a square area for sensor network with a uniform distributed nodes has been analysis in previous works [7]. Therefore, for WSNs with a large number of energy-constrained sensors, it is very important to design an algorithm to organize sensors in clusters to minimize the energy used to communicate information from all nodes to the base station [8]-[9]. However, when the sensor networks are outspread a wide area and are naturally scattering deployed [10]-[11]. The distribution of nodes would be approximated Gaussian distribution. Then the optimal number of clusters would depend on the different area. Therefore, in this paper we further investigate the energy efficiency for the naturally scattering deployed clustering sensor networks.

2. **Network Models.** In practical, the geometry of the WSN is non-regular. However, the square is a basic area to be consisted of non-regular area. Thus, for simplification, in this paper we adopt a square area with the length M=300m. When the cluster area is of random distributed, the energy efficiency of sensor nodes on data transmitting is terrible [3]. Therefore, the FCA in previous work [12] is proposed to divide the sensor area into clusters and to deploy CHs uniformly over the network area. However, when the sensor networks are outspread a wide area and are naturally scattering deployed, the distribution of nodes would be Gaussian distributed. Based on the configuration of square area in a sub-area, the sensors are supposed to be spread out uniformly to the whole area. The data from each cluster would be collected by the CH and these data would be sent back to the BS. In cluster based WSNs, how to select the CH and further to clustering the sensing area are the main parts of the procedures. In a data collection procedure, it is called a round. After the setup state, the LEACH finished two steps of CH election and clustering the area. In CH election procedure for the rth round, the nodes with a random number, U[0,1], lower than the threshold by will be elected as one of the CHs, where p is the expected probability for the CH election, $p = q/Q$ and G is the set of having yet not been elected CH in recent (r mod $1/p$) rounds, and $n = 1, 2, , Q$, where Q is the total number of nodes in WSN.

$$\begin{cases} T_n\left(r\right) = \frac{p}{1 - p\times\left(r \mod \frac{1}{p}\right)} \; n \in G \\ T_n\left(r\right) = 0 \; n \notin G \end{cases} \tag{1}$$

After the CHs are elected, the clustering is performed by broadcasting the advertisement message in which the CH ID in included. Then, the nodes communicate with the nearest CH by CSMA/CA protocol and send the sensing data to the CH. Thus, the clustering procedure is finished. After the clustering procedure, the network is in steady state in which all nodes are in sleep state excepting the communicating nodes. Then, after the data aggregation in CHs, the CHs send aggregated data to the BS. Then a round is performed. In wireless communication, the channel models are modeled by

$$P_r = c\frac{P_t}{d^{\alpha}} \tag{2}$$

, where P_r and P_t are the received power at receiver and the transmitted power at transmitter respectively, c is the propagation coefficient, and α is the path loss exponent, $2 \leq \alpha \leq 6$. For a free space area, the path loss exponent is set by $\alpha = 2$. The location of the nodes is assumed to be known to base station by GPS.

3. **Energy Efficiency of Adaptive Clustering.** To evaluate the lifetime of the network, one round is defined as a cycle in which the base station receives data from the sensor node. In one round, it contains the time from the data collected at sensor to the corresponding CH and the time from the CH to the BS. We assume that in each round there is one frame consisted l-bit transmitted by each sensor node. In [7], total consumption energy in one frame in one round for WSNs can be obtained by

$$E_{\text{total}} = qE_{\text{cluster}} = l\left(2E_{elec}Q + E_{DA}Q + q\varepsilon_{mp}d^4_{to\text{BS}} + \varepsilon_{fs}\frac{1}{2\pi}\frac{M^2}{q}Q\right) \tag{3}$$

, where E_{elec} and E_{DA} are the electrical dissipation energy of receiving or transmitting and data aggregation for one bit, respectively. Then in a sub-area the optimal number of clusters by setting the derivative of E_{total} with respect to q to zero is obtained by [7]

$$q_{\text{opt}} = \frac{\sqrt{Q}}{\sqrt{2\pi}}\sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}}\frac{M}{d^2_{to\text{BS}}} \tag{4}$$

,

In this paper, to match the assumption of that the sensor nodes are randomly distributed in the clustering area, the sensor networks are divided to nine sub-areas. That is we assumed that the standard deviation of Gaussian distribution for nodes deploying is known. Then we can estimate the number of nodes in each sub-area. The optimal number of clusters for each sub-area can be obtained by (4). By (4), the optimal number of cluster for different areas and different number of nodes can be depicted in Fig. 1.

4. **Simulation Results.** In order to verify and compare the optimal energy efficiency for the energy model described in Section 3, computer simulation is performed in MATLAB programming. In our simulation, the total number of sensors nodes is Q=500, 1008. Then, the normal sensor nodes are $500q$ and $1008q$. The length of sensing square area is set $M = 300$ meters. To be generalized, we assume that the data aggregation is perfect, i.e. each CH sends out one packet of 2000 bits in each round. The simulation parameters are depicted in Table 1.

We simulate the mass node-deployment for the standard deviation of δ and zero mean for the Gaussion distributed in the sensing area with $Q = 1008$. When we apply LEACH to perform the clustering for the mass WSNs, we obtain the energy efficiency for different

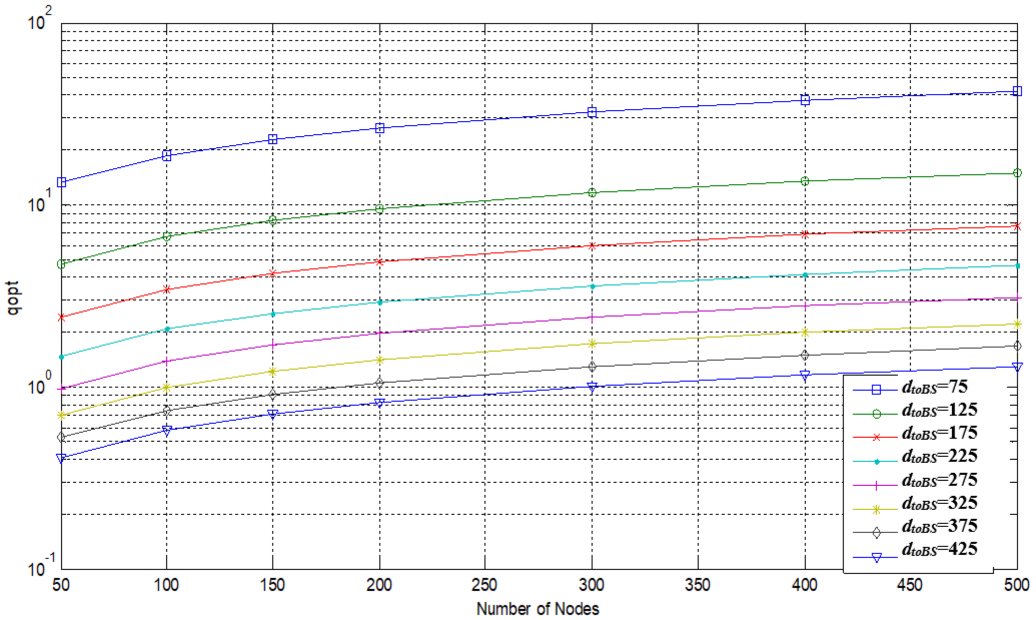


FIGURE 1. The optimal number of cluster for different areas and different number of nodes

TABLE 1. Simulation parameters

Simulation parameters	
Electrical energy	E_{elec} = 50 nJ/bit
Energy for data aggregation	E_{DA} = 5 nJ/bit/signal
Initial energy in each node	1.2J
Bits per packets	2000 bits
Sensing square area	(-150,-150)-(150,150)
Number of nodes	Q=500, 1008 nodes
BS position	(0,175)
Networking sub-area	100m×100m
Bn	ID of sub-area
Path loss exponents	free space $\alpha = 2$ multipath fading $\alpha = 4$
Amplifier energy	$\varepsilon_{fs} = 10$ pJ/bit/m^2 $\varepsilon_{mp} = 0.0013$ pJ/bit/m^4

number of clusters as shown in Fig. 2. From Fig. 2, it is observed that the lower standard deviation the better of energy efficiency. That is said that the higher density of the nodes the less energy consumption. In order to investigate the optimization of dynamically

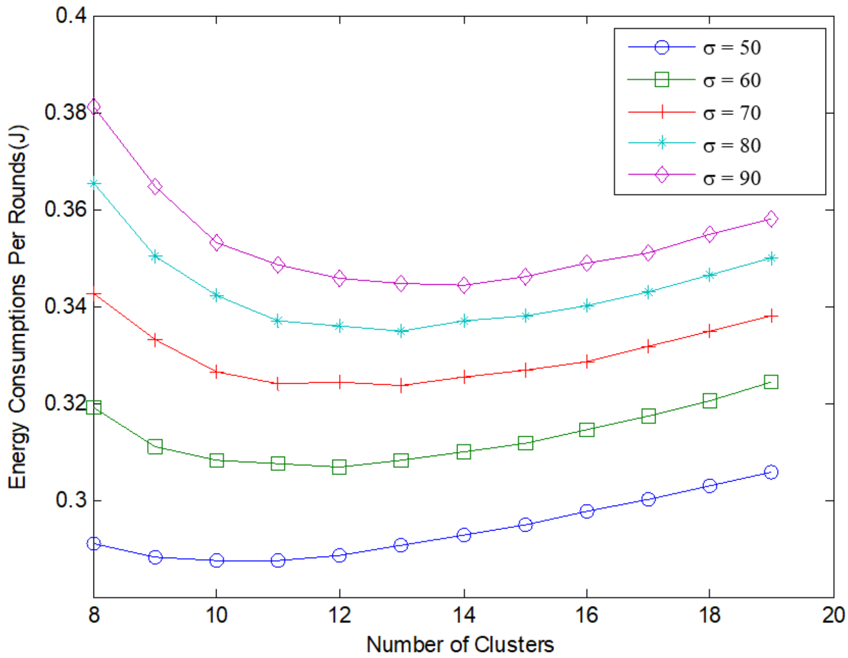
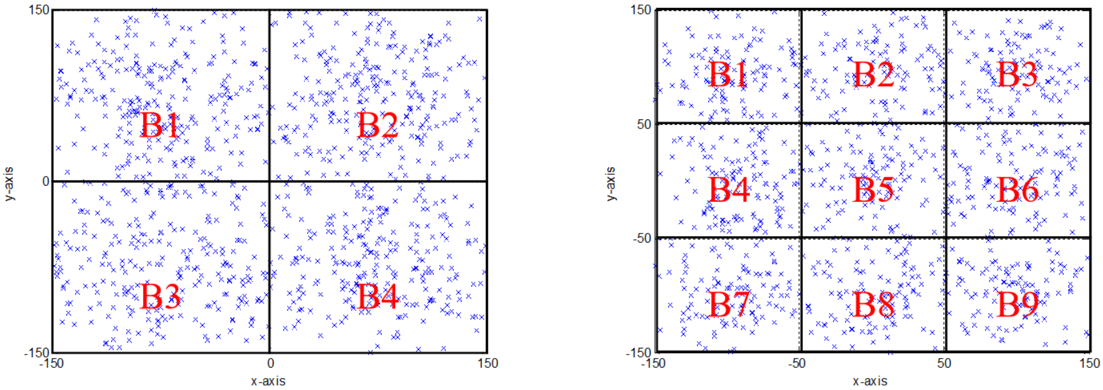


FIGURE 2. The energy efficiency for different number of clusters and various standard deviation of the Gaussian-scattering with $Q = 1008$

clustering, we equally divide the area in to n sub-areas, called dynamically distributed clustering (DDC) method. In this paper, we use simply deviding with 4 sub-areas and 9 sub-blocks, which are call DDC_4 and DDC9, respectively. The subareas are equally devided as shown in Fig. 3. Thus, we obtain an example for the number of nodes on the nine sub-areas B1-B9 as shown in Table 2. Then the optimal number of clusters q_{opt} can be obtained by (4) as shown in Table 2 for BS=$(0, 175)$. From Fig. 2, we obtain the optimal number of clusters for LEACH as shown in Table 2. Moreover, the optimal q_{opt} for each sub-block are calculated by (4) for DDC_4 and DDC_9, respectively, as shown in Table 2. In Fig. 3, the 1008 nodes are equally divided to 4 parts or 9 parts to 252 and 112 nodes respectively. In Fig. 3(a), the 252 nodes are Gaussian distributed in each sub-area with natural scattering, call DDC_4. Similarly, in Fig. 3(b), the 112 nodes are Gaussian distributed in each sub-area with natural scattering, call DDC_9. Then the optimal number of clusters can be obtained by (4) for each sub-area as shown in Table 2 and Table 3.

The energy efficiency of the DDCs are performed with Gaussian distributed by $\sigma = 25, 30, 35, 40, 45$ and $\sigma = 17, 20, 23, 26, 29$ for DDC_4 and DDC_9, respectively. The comparison of energy efficiency between DDC_4, DDC_9 and LEACH is shown in Fig. 4. From Fig. 4(a), it is seen that when $\sigma = 25$ the DDC4 outperforms LEACH with lower energy consumption in one round. However, when the distribution is more scattering with $\sigma = 35, 40, 45$, the LEACH still performed more energy efficiency than the DDC4. From Fig. 4(b), the similar results show that when $\sigma = 17, 20$ the DDC_9 outperforms LEACH with lower energy consumption in one round. However, when the distribution is more scattering with $\sigma = 23, 26, 29$, the LEACH still performed more energy efficiency than the DDC_9. From Table 3, we obtain the optimal number of clusters, q_{opt} for each sub-area calculated by (4) for DDC_4 and DDC_9, respectively. When the standard deviation of



(a) (b)

FIGURE 3. The sensing area is divided to subareas: (a) 4 subareas; (b) 9 subareas; with individual scattering with $\sigma = 45$ and 29 respectively.

TABLE 2. The number of nodes and q_{opt} for (a) $DDC_4$with individually scattering

	Q	q_{opt}	Q	q_{opt}	Q	q_{opt}	Q	q_{opt}	Q	q_{opt}	d_{toBS}
σ	25		30		35		40		45		
B	1008	**12**	1008	**12**	1008	**12**	1008	**12**	1008	**12**	
B1	252	4	255	4	252	4	252	4	252	4	141
B2	252	4	249	4	252	4	252	4	252	4	141
B3	252	2	252	2	252	2	252	2	252	2	269
B4	252	2	252	2	252	2	252	2	252	2	269

TABLE 3. The number of nodes and q_{opt} for DDC_9 with individually scattering

	Q	q_{opt}	Q	q_{opt}	Q	q_{opt}	Q	q_{opt}	Q	q_{opt}	d_{toBS}
σ	17		20		23		26		29		
B	1008	**18**	1008	**18**	1008	**18**	1008	**18**	1008	**18**	
B1	111	3	110	3	112	3	111	3	111	3	125
B2	112	5	112	5	111	5	112	5	110	5	75
B3	113	3	112	3	111	3	113	3	112	3	125
B4	112	1	110	1	113	1	110	1	112	1	202
B5	112	2	116	2	113	2	115	2	116	2	175
B6	112	1	112	1	112	1	111	1	112	1	202

the Gaussian distribution is smaller, the distribution becomes more non-uniformly distributed. Therefore, from Fig. 4, it is observed that when the standard deviation, σ is smaller with 17, the dynamically clustering scheme outperforms LEACH scheme.

5. **Conclusions.** In this paper, we investigate the clustering optimization for naturally scattering WSNs. We propose DDC schemes to divide a large area to small sub-areas for efficiently clustering WSNs. Then, the energy efficiency are compared for proposed

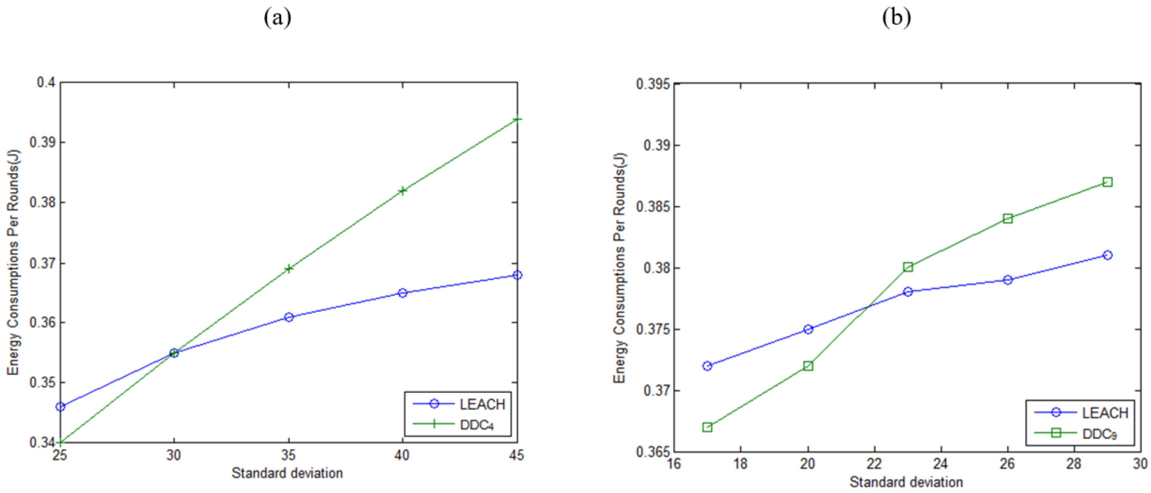


FIGURE 4. The sensing area is divided to subareas: (a) 4 subareas; (b) 9 subareas; with individual scattering with $\sigma = 45$ and 29 respectively.

DDC schemes and LEACH. Simulation results show that the proposed DDC schemes outperform LEACH with small scattering sinarios for total energy consumption in one round.

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REFERENCES

[1] D. Culler, D. Estrin, and M. Srivastava, Guest editors' introduction: overview of sensor networks, *IEEE Computer,* vol. 37, no. 8, pp. 41- 49, 2004.
[2] J.-S. Pan, L. Kong, T.-W. Sung, S.-C. Chu, and J. F. Roddick, Hierarchical routing strategy for wireless sensor network, *Journal of Information Hiding and Multimedia Signal Processing,* vol. 9, no. 1, pp. 256-264, 2018.
[3] S. P. Dongare, and R. S. Mangrulkar, An improved cluster head selection approach for energy efficiency in wireless sensor networks: a review, *in 2015 International Conference on Pervasive Computing (ICPC)* , pp. 1-6, 2015.
[4] M. Ahlawat, and A. Mittal, Different communication protocols for wireless sensor networks: a review, *International Journal of Advanced Research in Computer and Communication Engineering*, vol. 4, no. 3, pp. 213-216, 2015.
[5] S. Aram, I. Khosa, and E. Pasero, Conserving energy through neural prediction of sensed data, *Journal of Wireless Mobile Networks, Ubiquitous Computing, and Dependable Applications*, vol. 6, no. 1, pp. 7497, 2015.
[6] W. Heinzelman, A. Chandrakasan, and H. Balakrishnan, Energy-efficient communication protocols for wireless microsensor networks (LEACH), *in The 33rd Hawaii International Conference on Systems Science*, vol. 8, pp. 3005-3014, 2000.
[7] Y.-F. Huang, T.-J. Chan, T.-R. Chen, and M.-C. Chen, Energy efficiency optimization for hierarchical cluster-based wireless sensor network, *Far East Journal of Experimental and Theoretical Artificial Intelligence,* vol. 2, no.2, pp. 97-107, 2008.
[8] D. Meana-Llorin, C. G. Garca, V. Garca-Daz, B. C. P. G-Bustelo, and N. Garcia-Fernandez, SenseQ: replying questions of social networks users by using a wireless sensor network based on sensor relationships, *Data Science and Pattern Recognition,* vol. 1, no. 1, pp. 1-12, 2017.
[9] J.-P Li, and B.-C. Mu, Dynamic node localization algorithm based on cooperated prediction for wireless sensor networks, *Journal of Information Hiding and Multimedia Signal Processing*, vol. 8, no. 5, pp. 1173-1182, 2017.

[10] S. Souiki, M. Hadjila, and M. Feham, Energy efficient routing for Mobile underwater wireless sensor networks, *in 2015 12th International Symposium on Programming and Systems (ISPS2015)* , pp. 1-6, 2015.

[11] H. Shalma, and R. Rajesh, Dynamic cluster based energy controlled routing in Wireless Sensor Networks, *in 2014 International Conference on Information Communication and Embedded Systems (ICICES14)* , pp. 1-4, 2014.

[12] Y.-F. Huang, W.-H. Luo, J. Sum, L.-H. Chang, C.-W. Chang, and R.-C. Chen, Lifetime performance of an energy efficient clustering algorithm for cluster-based wireless sensor networks, *LNCS, 4743 (2007), Springer, Heidelberg*, pp. 455464.