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Investigation of Energy Efficiency in Wireless Sensor Network using Hexagon Equation

***Abstract**. Wireless Sensor Networks (WSN) are one of important tools for controlling and collecting data in the internet of things (IoT). For wireless sensor network design, power consumption and network lifetime functions are important for maintenance. Therefore, low-cost innovations that could reduce energy consumption and extend the network lifetime are essential in development of next-generation WSN. In this research, a hexagonal equation model for WSN was utilized to reduce energy consumption. The design was generated in an area of 35m $\times$ 35m and the number of sensor nodes was 30, 40, 50, 60, 70, 80, 90, and 100 loads, respectively. The results of energy efficiency were compared to Developed Distributed Energy-Efficient Clustering (DDEEC) and Distributed Energy-Efficient Clustering algorithm (DEEC). The results showed that the DDEEC method performed better than the DEEC method in terms of the power dissipation on the nodes 30-100 loads.*

Streszczenie.** Bezprzewodowe sieci czujników (WSN) są jednym z ważnych narzędzi do kontrolowania i gromadzenia danych w Internecie rzeczy (IoT). W przypadku projektowania sieci czujników bezprzewodowych zużycie energii i funkcje związane z okresem eksploatacji sieci są ważne dla konserwacji. Dlatego tanie innowacje, które mogłyby zmniejszyć zużycie energii i wydłużyć żywotność sieci, są niezbędne w rozwoju sieci WSN nowej generacji. W tym badaniu wykorzystano model równania heksagonalnego dla WSN w celu zmniejszenia zużycia energii. Projekt został wygenerowany na obszarze 35m $\times$ 35m, a liczba węzłów sensorów wynosiła odpowiednio 30, 40, 50, 60, 70, 80, 90 i 100 obciążeń. Wyniki efektywności energetycznej porównano z algorytmem Developed Distributed Energy-Efficient Clustering (DDEEC) i Distributed Energy-Efficient Clustering (DEEC). Wyniki pokazały, że metoda DDEEC wypadła lepiej niż metoda DEEC pod względem rozpraszania mocy na węzłach 30-100 obciążeń.* (Badanie efektywności energetycznej w bezprzewodowej sieci czujników za pomocą równania sześciokątnego)***

Keywords: Wireless Sensor Networks (WSN), internet of things (IoT), hexagonal equation, DEEC, DDEEC.
Słowa kluczowe: Bezprzewodowe sieci czujników (WSN), internet rzeczy (IoT), równanie heksagonalne, DEEC, DDEEC

Introduction

A wireless sensor network is a combination of multiple interoperable sensors with connected nodes for transmitting and receiving data. The sensor node provides many advantages such as low cost, easily accessible to network devices, lightweight, operable and controllable by microcontrollers receiving power supply of transceivers and converters to generate electricity. However, these nodes still have limited power capacity because they rely on a limited power source such as a battery [1, 2]. In most cases, the surrounding environm ent of the sensor is a critical factor in charging or
replacing the battery. Therefore, reducing the power that can prolong the life of the sensor is critical in operation and maintenance to reduce costs and improve efficiency [3]. For this reason, proposed algorithms for designing sensor nodes such as sequential, distributed or centralized techniques are proposed. Clustering is a method used for clustering sensor nodes with the cluster head (CH) responsible for receiving data from members of the node and sending it to a sink or base station (BS) [4-6]. The distance (CH) will affect the power consumption for sensor networks; therefore, the protocol of hexagons routing (HEX) is introduced. The concept of uniform randomness is used to design in wireless sensor networks. In this method, an area of $35m \times 35m$ m is defined in a 2D image in which each sensor has the same probability of placement at any points in a given hexagon. The design of the wireless sensor layout with a hexagonal area with various numbers of sensor nodes ranging from 30 to100. They were also considered to determine the energy reduction efficiency by the Developed Distributed Energy- Efficient Clustering (DDEEC) and Distributed Energy-Efficient Clustering algorithm (DEEC) to compare reducing network power consumption and increasing network lifespan.

Materials and Methods

A. Network model

From Figure 1, a hexagonal design [7] with sensors (represented by white circles) is evenly distributed in a 2D figure with the center of hexagonal clusters, called clusters (represented by black circles). The goal of the design is energy saving. Communication capabilities of conventional sensors are limited by the minimum power required to transmit radio signals. The cluster head's ability to communicate with other cluster heads to transmit and receive data in a diameter of the hexagon is displayed, where D is the transmission range of the cluster head which determines the size of the hexagon cluster. Therefore, the maximum radius is represented by $R = D / 2$ which will allow the cluster head to transmit data to the neighboring cluster head at a distance of $\sqrt{3R} = \frac{\sqrt{3D}}{2}$.

Kumar et al. [8] presented a clustering method for hexagonal cell structure and Voronoi with WSN to analyze the optimal CH count computational analysis. The Multi hop communication grouping method can reduce power consumption and thus increase the network's lifespan.

Dajin Wang [9] proposes a method of using hexagonal equations which are suitable for grouping sensor networks so that they can be achieved smoothly by dividing the area into clusters and the largest areas. To analyze the benefits of hexagonal cluster subdivisions, they reduce the overall power consumption in the cluster. The result of the analysis shows that the subdivision can significantly increase the overall energy efficiency of the cluster. It also greatly saves energy on the load transmission range and usage density.

Mirjana Maksimović [10] studied eighteen models on sensor net work by using hexagonal equations for fire alarm. The results demonstrated that nine of eighteen could detect the signals accurately and timely, and could reduce energy consumption, and thus rendering in prolonging the life of battery.

Tharanga Prematgilake [11] reported Fruchterman-Reingold algorithm for WSN by allocating the edges of the hexagonal topology to the sensor nodes.

Several methods such as EESAA, LEACH, PEGASIS were previously investigated for WSN energy efficiency.

Here, we determined the energy efficiency in WSN by the comparison methods of DEEC and DDEEC by determining the energy efficiency of sensor network, which was positioned in an area of $35m \times 35m$

B. The developed distributed energy- efficient clustering protocol

DDEEC [12] is a form of DEEC [13] where all nodes use the default power level, and the remaining power level is determined by the cluster header. In calculating the reference power of nodes that should be used each cycle, the number of nodes (N), area ($M \times M$) in a hierarchical network of clusters and cluster heads, and data from cluster load measurements are collected and aggregated and transmitted directly to the base station. Additionally, the network topology is fixed and unchanged. This requires the base station to be centrally located. This last figure represents two different levels of networks with two types of nodes: advanced node mN with the initial energy $Eo(1+a)$ and $a\ (1-m)N$ with the initial energy of Eo. The total initial power of the differential network is expressed in Equation .1

(1) $$Et_{otal} = N(1-m)Eo + NmEo(1+a) = NEo(1+am)$$

C. DDEEC details

DDEEC is the same method as DEEC. It is a condition for estimating the mean power of the network and cluster head in which the selection algorithm depends on the mean power around r , as expressed in Equation 2.

(2) $$\overline{E}(t) = \frac{1}{N} E_{total}(t - \frac{r}{R})$$

where R is the total cycle life in the network, which can be calculated using Equation 3.

(3) $$R = \frac{E_{total}}{E_{Round}}$$

where E_{Round} is the total amount of energy distributed in the network between cycles. It can be calculated using Equation 4.

(4) $$E_{Round} = L(2NE_{elec} + NE_{DA} + kEmpd^{4}_{toBS} + NEfsd^{2}_{toCH})$$

where

k is the number of clusters; E_{DA} is the data integration cost used in the cluster.; BS is the mean distance between the cluster and the base station, taken from the design of the hexagonal. ; CH is the average distance between the cluster members and cluster header 6.

(5) $$d_{toCH} = \frac{M}{\sqrt{2k\pi}}, d_{toBS} = 0.765\frac{M}{2}$$

(6) $$k_{opt} = \frac{M}{d^{2}_{toBS}} \frac{\sqrt{N}}{\sqrt{2\pi}} \frac{\sqrt{Efs}}{\sqrt{Emp}}$$

In calculating the difference between DDEEC and DEEC, the cluster head probabilities are defined for normal nodes and advanced nodes. Then, with each iteration, the remaining energy is reduced as expressed in Equation 7

(7) $$EdisAN = L(E_{TX} + Emp(DoptBS^{4}) + E_{RX} + E_{DA})n / Kopt$$

where $EdisAN$ represents the mean power dissipated by each node cycle. Then the number of possible iterations for Nb_{CH} with an initial energy of $(1+a)Eo$ is shown in Equation 8

(8) $$Nb_{CH} = (1+a)Eo / E_{disAN}$$

Similarly, the power dissipated by a node can be determined with a normalized value E_{disAN} in each cycle. The possible number of iterations for the normalized value can be determined from Equation .9

(9) $$Nb_{NN} = Eo / E_{disNN}$$

Figure 2illustrates both the free space channel model of $(d^{2}\ powerloss)$ and multi- path fading $(d^{4}\ powerloss)$ as shown in Equation .10

(10) $$ETX(L,d) = \begin{cases} LE_{elec} + Lefsd^{2} & if \quad d < d_{o} \\ LE_{elec} + Lefsd^{4} & if \quad d > d \end{cases}$$

Method

Table 1. Hexagonal design parameters

Parameters	Values
Node	30,40,50,60,70,80,90 and 100
2D Area Size	$35m \times 35m$
node transmission range (m)	5.5
The number of cells in the vertical direction	14
The number of cells in the horizontal direction	10
Hexagon orientation	0 or 1

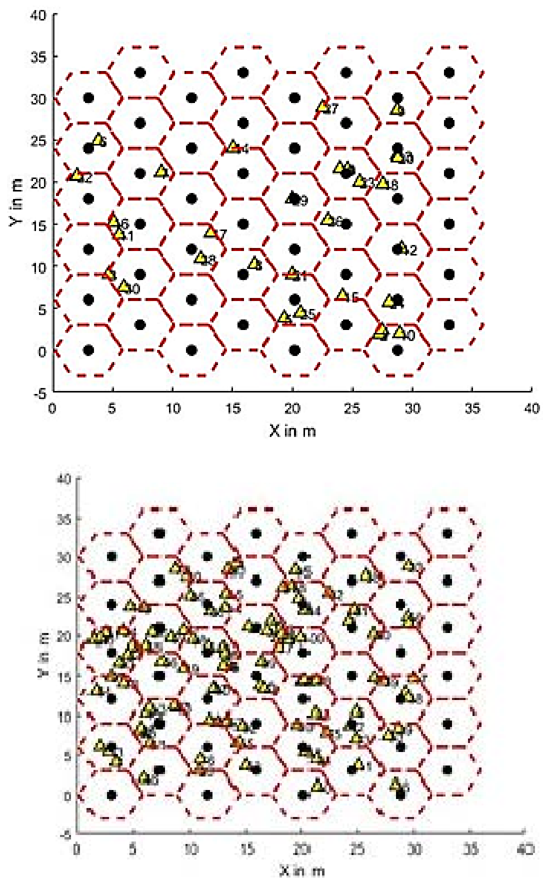


Fig. 1. A random hexagonal placement of a sensor node in an area of 35m × 35m

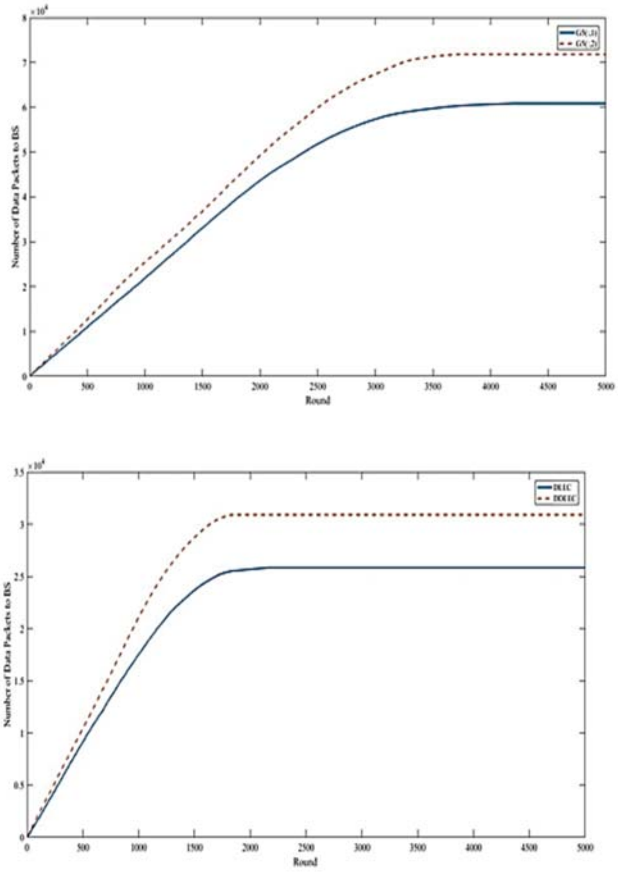


Fig. 2 .A comparison between the number of living nodes for DEEC and DDEEC.

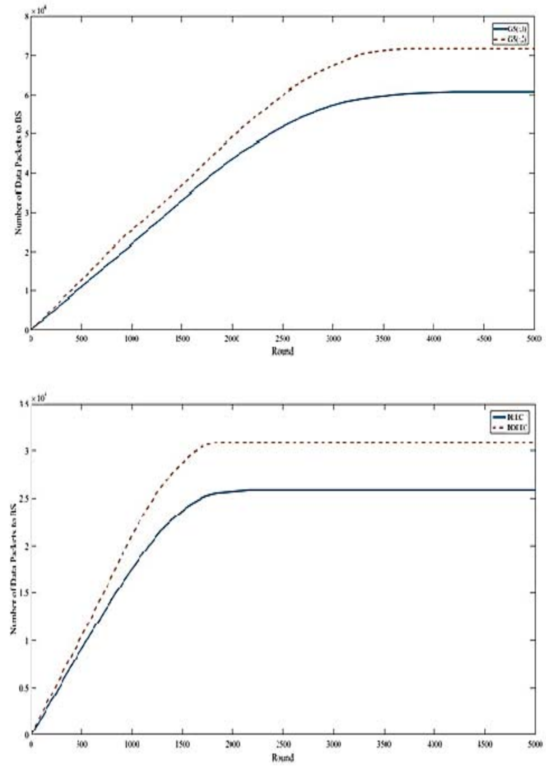


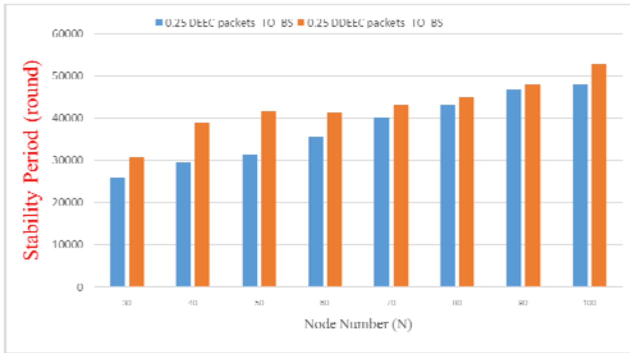
Fig. 3 comparison between the number of packets sent to the BS for DEEC and DDEEC.

Table 2. Parameter values for network setup

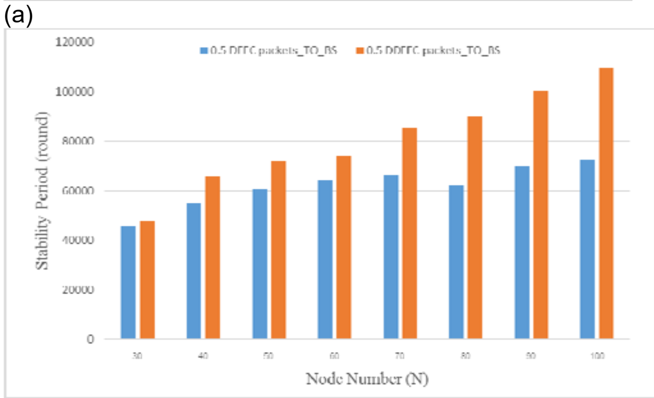
Parameters	Values
Network Size	$35m \times 35m$
Sensor Nodes	30,40,50,60,70,80,90 and 100
E_{elec}	5 nJ/bit
Eo	0.25J,0.50J and 1 J
E_{DA}	5 nJ/bit/message
Distance threshold (d_o)	80 m
Message Size	5000 bits
$Popt$ [14]	0.1

Results

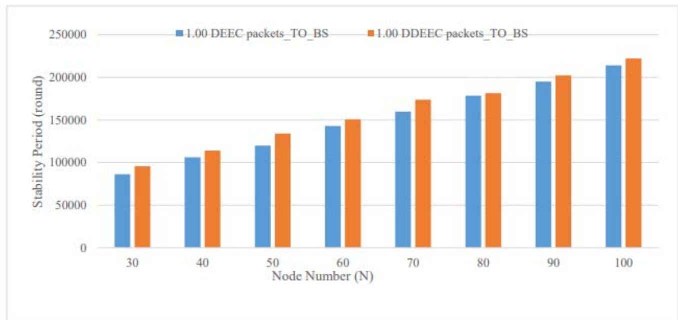
In a 2D hexagonal design experiment, the number of BS sensor nodes with different parameters shown in Table 1, and their efficiency was determined by DEEC and DDEEC with the parameters in Table 2. These can be summarized as shown in Figure 4.



(a)



(b)



(c)

Fig. 4. Performance comparison in a sensor network (a) Eo = 0.25 J value, (b) Eo = 0.50 J value, and (c) Eo =1 J value.

From Figure 4, it can be explained that the comparison of energy determinations in the number of cluster heads from 30 – 100 is for efficiency given the Eo converter with a difference of 0.25 – 1 J. The DDEEC method is more effective than the DEEC method by comparing both the number and the Eo. Therefore, DDEEC method is more distributed than DEEC method in hexagonal-based sensor node design pattern in 2D form

Conclusion

In designing the experiment results for the hexagonal pattern sensor nodes placement in 2D plain to determine the power dissipation efficiency by DEEC and DDEEC methods, the number of nodes and the Eo value affect the energy consumption rate. The suitable energy distribution is the DDEEC method, which is more dispersed than the DEEC method. This allows the wireless sensors to have a long service life and can greatly reduce the sensor network maintenance costs in the agricultural sector

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