ABSTRACT
Wireless sensor network is considered as the most applicable standards for the monitoring system. The optimization that relates to wireless sensor network planning, design, deployment, and operation has to consider many parameters so that there is no conflict among the sensor especially in a heterogenous network with various platforms. In such a network, energy consumption determines the system stability. Clustering mechanism in a wireless sensor network can also simplify network management process. Distributed energy efficient clustering (DEEC) is used as a clustering protocol. This protocol work based on residual energy. This protocol is robust enough, but in a certain condition, it has a pit of weakness. Game theory is being proposed as an optimization algorithm of the clustering process. It is used to adjust the probability of node to become a cluster head based on residual energy to prolong cluster lifetime. Threshold value can be more accurate by using selfish behavior game theory algorithm. The weighted factor is a factor that makes the resolution of probability values more real.

CCS Concepts
• Networks−Protocol testing and verification •Networks
−Network simulations

Keywords
Heterogenous wireless sensor network, game theory, DEEC

1. INTRODUCTION
Today, the sensor device is used to help the sensing process automatically and remotely for various areas of life. A monitoring or sensing system often uses a variety of sensor platforms for data collection agent that is supported by wireless networks. The sensor nodes can be arranged in a homogeneous or heterogeneous network. Homogeneous networks are equipped with uniform initial energy while heterogeneous networks are accorded with different energy level. In real life, homogeneous sensor network hardly exists. It because every sensor platform consumes energy at a different level. The heterogeneous wireless sensor network is the type of wireless sensor network that consists of sensor nodes with a different ability, such as different computing, power, and sensing range. This paper addresses the heterogeneous wireless sensor networks for increased reliability of the network. Clustering is a precious technique to improve the network lifetime, reduce the energy consumption and increase the scalability of the sensor network. The placement of sensors that are remote and difficult to reach, with limited power supply make the monitoring system must be supported by a robust network. Therefore, in design and management, we have to consider many factors to obtain a good quality of service. Various methods and algorithms are used to engineer the network to be able to support the sensor system. If the number of sensors that are used quite a lot and the area that you want to monitor is wide enough, then used clustering technology to simplify the various processes. In the cluster, there is a hierarchy of sensor functions. A heterogenous wireless sensor uses a specific clustering protocol for the network. Distributed Efficient Clustering (DEEC) [3,11] sensor network clustering protocol will be proposed in this paper, and game theory will be used to modify this clustering protocol. System performance will be evaluated by simulation. It shows some superiorities of the proposed method, in which the node sensor hierarchy act as the data retrieval agent of the system, then the cluster head acts as the coordinator of some node sensors, and the node sink acts as a collector of all information. The selection of the sensor hierarchies must use certain rules by paying attention to many things, including the distance between nodes, the amount of energy required, and the lifespan of the sensor. The cluster head election process concerns about the availability of energy because it takes a lot of energy allocation for data communication and also data aggregation. Another configuration of energy use for all nodes is to activate electronic components and amplification devices. Indirectly there is a high energy level requirement in the cluster head and sink nodes related to their function as a coordinator. Cluster head and sink node selection process using the selection protocol and algorithm to anticipate the emergence of network problems. This heterogeneous nature result in a uniform energy allocation also related to the function of the sensor. These various number of sensors require specific regulatory mechanism with a certain algorithm. Limited energy availability for the sensor can cause the sensor dead. Sensor lifetime will disrupt the stability of the monitor system because there will be many changes to the network. Therefore, efforts are made to improve the life of these sensors with various arrangements so that will be obtained a good performance monitor system in the form of the amount of data to large and real time. Clustering technology is expected to be able to maintain system stability. Clustering process begins with cluster head selection; Firstly it will be measured power from all nodes, then followed by the next stage of selection of sink node. For the optimization of clustering technology, game theory will be used. Game theory will facilitate the physical process with a
mathematical approach where the integrated party will be assumed as a player of a game competing with each other to win the game with certain rules and certain values. Clustering has been regarded as an efficient technique for data collection in wireless sensor networks. Cluster heads (CHs) responsible for data aggregation and forwarding agent for sink node. In real condition sensor node is likely to be selfish and refuse to declare itself as a cluster head. Several clustering algorithms were proposed to keep energy, extend network lifespan, and improve data transfer. Distributed energy efficiency clustering (DEEC) protocol is used for cluster formation strategy. This protocol work based on initial and residual energy, but there is a weakness in this protocol. Therefore, clustering algorithm based on game theory is proposed here. In the cluster head selection phase, each node competes as a potential cluster. The game theory algorithm defines the chance of nodes as probability based on energy availability. Simulation results will show that the lifespan of wireless sensor networks.

2. WIRELESS SENSOR NETWORK & GAME THEORY

2.1 Heterogenous Wireless Sensor Network
The wireless sensor network consists of many source sensors (sensor nodes) that act as agents to collect data from each event and the phenomena occurring in the surrounding environment and then communicate to the device wirelessly. Heterogeneous wireless sensor networks are distributed networks with hierarchical layers. In its use, the sensor working system is combined with other network devices to form a wireless sensor network system. In general, wireless networks are built with cluster topology and flat type. In this topology, the sensor nodes are arranged in a hierarchical arrangement. There are three categories of nodes, namely sensor node, cluster head, and sink node. Cluster head serves as a regulator of several sensor nodes in the application. The process of cluster head selection and configuration is based on energy residual. In the node sensor, there is an energy ratio that determines the lifetime. This network is very vulnerable to energy consumption, so it is necessary to think about the arrangement of its performance. On a heterogeneous wireless sensor network stability occurs when all live nodes, it means that optimum probability is maximum. If any node is dead, then the condition becomes unstable. This is because of the number of cluster head candidates nodes on each epoch decrease.

2.2 Game Theory
Game theory is an algorithm that is a mathematical expression but has a physical meaning. This algorithm can provide solutions by using strategies and rules as well as people playing which each side must meet the rules. The general concept of the game theory is two parties that play, each player has a strategy, and the winner is the one who has the best and appropriate strategy [15]. Game theory was used because under real conditions; not all node sensors are willing to be responsible for being a cluster head. This condition will try to overcome with the game theory approach cluster head selection with Game theory. Game theory was used as network stability optimization method for inter and intra-cluster. In an ideal situation, there is an equilibrium algorithm where all are expected to perform equally well, but there is an optimization in which one parameter is more prominent than the other. In the game theory equilibrium algorithm, all nodes behave using rules to achieve the balance pay off. In wireless networks, this can be seen in the initial energy allocation mechanism for the development of wireless sensor network clusters. Before doing the optimization on the sensor network, firstly we discussed the development of clusters that are part of the sensor network. The sink node sends a signal to calculate the vector eligibility for each cluster, and cluster head will respond. Based on a vector of eligibility, the head cluster selects an easily connected node. Game theory here is not a deterministic solution, but a possibility. The next process is comparing the residual energy and was continued with cluster head selection based on distance with the specific set rule.

In this selection the sensor node has two options, it can or cannot act as a cluster head. Since the nodes display a selfish behavior, they do not tend to act as a cluster head and assign head clustering to other nodes. In the case that none of the nodes acts as a cluster head, they can not send their data to the main station, and they cannot gain any utility. The best manner of each node occurs when the node itself is not chosen for being cluster head, but at least one of the other residual nodes is introduced as cluster heading.

2.3 Clustering
Grouping of sensors that performing similar tasks are known as cluster. Clustering is kind of network management optimized strategy to prolong the battery life of the individual sensors and the network lifetime. Several advantages of clustering in a wireless sensor network can be explained. Clustering can reduce the size of the routing table by localizing the route set up and also conserves bandwidth by limiting the scope of inter-cluster interactions. In a hierarchical cluster, it contains cluster head, sensor nodes, and sink Node. After the cluster head is selected, it collects the data from all of its member nodes and aggregates them to eliminate the redundancy. Thus it limits the amount of data transmission to sink node, hence remaining energy level is increased and network lifetime is maximized. The optimal number of cluster head that would lead to minimize the average energy spends in the network for each round.

2.4 Energy Model
This model becomes the beginning of the clustering process

![Figure 1. Radio energy dissipated model](image)

The physical situation of sensor node communication. The energy usage and configuration in the device was shown clearly. The transmission parameter that related to energy consumption is illustrated. The energy configuration in the transmitter part consists of electronic usage (Eelec), amplification of energy consumption for fading defense (Emp). Meanwhile, in the receiver part, there is also electronic energy usage. Figure 2 shows the energy model that describes the detail of energy consumption in a wireless sensor network. The energy model can be delivered as generally math equation. The math equation can explain the relation of each parameter in the energy model. Simplifying energy consumption calculation, the energy consumption was divided into two classifications. Initially, we calculate the energy consumption of cluster head (ECH). Cluster head energy consumption consists of energy consumption for data receiving from the sensor node, data aggregation energy (Eaggregate), and energy consumption for data sending to sink node (ETX to sink). This process is shown in Equation 1.
The ordinary node that is usually known as sensor node often assumed as cluster head node (non-CH). The total energy of each cluster per round was determined by cluster head energy and cluster head energy (E-non CH). This relation can be derived from Equation 2

\[ E_T = E_{CH} + n/k \cdot E_{non-CH} \]  

In which n is the number of node and k is the number of cluster. The amount of energy consumption is also determined by distance besides of the length of data. The distance limitation will influence the transmission performance due to the increase of fading. The kind of fading depends on the distance, figure 3 describes this situation. Assume the area A=MxM square meters, for simplicity n number of nodes, are uniformly distributed over the area, and assume sink node is located in the center of the field. Assume the communicating distance between two nodes is d. The energy disquestions relate to transmission process with different distance condition. The transmitter energy consumption (E_{TX}) is related to the distance as shown in Equation 3 and 4

\[ E_{TX}(l,d) = l \cdot E_{elec} + l \cdot E_{fs} \cdot d^2, \text{if } d \leq do \]  

\[ E_{TX}(l,d) = l \cdot E_{elec} + l \cdot E_{mp} \cdot d^4, \text{if } d > do \]  

E_{elec} is internal device energy for transmission. E_{fs} is free space fading energy and E_{mp} is multipath fading energy. By equating the two expressions at d=do, we will get do as in Equation 5

\[ do = \sqrt{\frac{E_{fs}}{E_{mp}}} \]  

2.5 Distributed Energy-Efficient Clustering (DEEC)
DEEC is a multiclustering protocol in which the cluster-heads election based on the probability that related to the ratio of the residual energy of each node and the average energy. DEEC is an energy-aware adaptive clustering protocol used in heterogeneous wireless sensor networks which is every sensor node independently elects itself as a cluster-head based on its initial energy and residual energy. This protocol uses initial and residual energy to determine the next cluster head. In a two-level heterogeneous network, there are two categories of nodes. The first category is a normal node which is accompanied by the initial energy that equal to E_0. The second category is an advanced node; this node type is accompanied with initial energy more than normal node. There are two variables a and m which determine the percentage of advanced nodes types. The limitation of this protocol is when the residual energy of advance node reduced until the level of energy is almost similar with the normal nodes energy level. Hence the advanced node will die rapidly than other. In DEEC protocol there is no threshold value in energy ratio.DEEC is a multilevel heterogenous network clustering protocol. The protocol mechanism initiates with equips the certain node initial energy of E_0(1+ a.m), which is a times more energy than the lower level energy E_0 and also multiply it by m. The total initial energy of the multi-level heterogeneous networks is given in Equation 6

\[ \sum_{n=1}^{N} E_0(1 + a \cdot m) \cdot N \cdot E_0(1 + a \cdot m) \]  

There are critical considerations for cluster head election are in DEEC to achieve good performance. Cluster-heads election depends on probability which based on the ratio between residual energy of each node and the average energy of the network hence the period of nodes that being cluster-heads are different. The probability to be cluster head is based on residual energy. The residual energy is the energy remaining after initial energy was used. The residual energy is the overleft energy from the initial energy after usage. There is a mechanism in DEEC to compare the amount of energy at each epoch to determine the probability. An epoch is a period that consists of many rounds that the cluster head was selected. When nodes have the same amount of energy at each epoch, choosing the average probability (p_i) to be the reference (P_{opt}). This situation can ensure the lifespan of node. The average energy consumption each round E(r) calculation is shown in Equation 7.

\[ \bar{E}(r) = \frac{1}{N} \sum_{i=1}^{N} E_i(r) \]  

The average probability calculation is shown in Equation 8.

\[ p_i = p_{opt} \left[ 1 - \frac{E_i(r) - E_{avg}(r)}{E(r)} \right] \]  

3. GAME THEORY ALGORITHM & CLUSTERING PROTOCOL
3.1 DEEC and Game theory
The DEEC protocol that based on game theory is proposed in this work to optimize wireless sensor network. The idea to optimize DEEC sparked when an advance node in a particular energy level degrades to be a normal node. By considering the distance and the usage of energy as critical things to calculate the probability. The cluster head candidate probability was determined by energy residual and initial energy ratio. P_{opt} is the reference of average probability (p_i) that in game theory is suitable with cluster number, and p_i is the product of P_{opt} with residual energy ratio. The total ratio energy that was equipped with the system and the energy usage of each round indicates the total round of the network life. The selection of cluster heads is critical in building an important wireless sensor network. At the time of cluster head elections are expected energy is not exhausted because it will be the stage of sending data to the sink node. The residual energy of a large node makes a sensor node selected as the cluster head. Being a cluster head requires much energy to regulate the sensor nodes. On the other hand, nodes with much energy left will have a long lifespan. There are also nodes with high residual energy levels but are reluctant to be cluster heads. Thus they manipulated the value of residual energy that they have. The selfish nodes may lie about residual energy values to avoid being selected. To solve this problem, then by assuming the cluster head declaration as a game and adopting game theory model[10][14][3].This model begins by describing the sensor node as the set of players (N), while the achievement is assumed as a utility (U). Players can declare themselves as cluster heads or not. If declared itself to be a clusterhead symbolized by D (declare), if not symbolized by ND (not declare). Energy consumption (cost = c) which will be used by a group of sensor nodes when declaring itself into cluster head (c_D) can be calculated by the Equation 9.

\[ c_D = n_{CH} \cdot E_{RX} + E_{agg} + E_{TX} \text{(CH to sink)} \]
The Equation 9 shows the relation between the amount of energy used by node and the statement of node. The equation indicates the node cost when it declared itself as cluster head or not. How much the amount of energy can show by the number of nCH cluster heads is multiplied with energy to receive data from the sensor node plus the energy of data aggregation and added with energy to send the aggregated data to the sink node. While if it does not want to be a cluster head, then the large cost incurred (cRD) is just the energy of a sensor node for sending data to cluster head (CH). The cost of energy of rejected declare node is expressed in Equation 10

\[ c_{RD} = E_{TX} \text{ (sensor node to CH)} \] (10)

At a particular distance between the node sensor to the remote node sink, it will make the energy used greater when a node declares itself to the cluster head. It because the transmission energy is proportional to the distance traveled. To anticipate this situation then the energy will be allocated as pay off of v, whose the magnitude will decrease according to cost statement of a sensor node. The remain energy was known as utility of declare node (UD). It can be expressed in Equation 11

\[ U_D = v - c_{RD} \] (11)

If a sensor wants to be a cluster head then utility (u) magnitude becomes v minus C, whereas if it does not want to be a utility cluster head becomes v minus cRD. The utility of rejected to declare node (URD) is shown by Equation 12

\[ U_{RD} = v - c_{RD} \] (12)

Conditions that may also occur is sensor nodes do not give a statement, which means the pay off and utility is zero. If the chance of a sensor node declaring itself to be a cluster head is expressed as a probability (p) otherwise if not declared is 1-p. The utility that associated with probability can be expressed in the Equation (13)

\[ U_{RD} = (v - c_{RD}). (1 - (1-p)^{N-1}) \] (13)

In an equilibrium condition :

\[ U_D = U_{RD} \] (14)

\[ P = 1 - \left[ \frac{c_{RD} - c_{RD}}{v - c_{RD}} \right]^{1/(N-1)} \] (15)

Weight factor in equation 15 enhances the DEEC protocol in order to make this protocol more accurate in cluster head probability determination. We find the current probability P’ by using the Equation 16

\[ P’ = 1 - \left[ \frac{c_{RD} - c_{RD}}{v - c_{RD}} \right]^{1/(N-1)} \cdot P_{init} \] (15)

Related to energy availability, the initial energy distributed is Eo and the energy multiplication factor is G, and the range of G values is 0 <G ≤ 1, the distribution of energy distributed to a number of N nodes at level one is multiplied by G. The probability of cluster head selection at each level is greatly influenced by this G factor. To obtain a probability value for each level that is close to the real condition, it is actually used a probability value that has been modified by the game theory algorithm. Here are some formulas to get probabilities at each level.

In an area 100mx 100m in spread node sensor of 100, the 0.6 part is allocated to a candidate cluster head called advanced node with initial energy supplied greater magnitude than Eo. In the hope that the node will survive so that in turn will become the cluster head. The simulation is done using Matlab.

### 3.2 Simulation & Experiment

To proof the network performance, we will simulate the clustering mechanism related to energy usage pattern. The clustering parameter was set to perform the certain expectation.

<table>
<thead>
<tr>
<th>Table 1 Parameter Setting</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>100x 100</td>
</tr>
<tr>
<td>Number of nodes</td>
<td>100</td>
</tr>
<tr>
<td>Eo (initiate energy)</td>
<td>0.5 J</td>
</tr>
<tr>
<td>Eda (aggregation energy)</td>
<td>5 pJ/bit/signal</td>
</tr>
<tr>
<td>Etx(Transmission Energy)</td>
<td>50 pJ/bit</td>
</tr>
<tr>
<td>Erx (Reception Energy)</td>
<td>50 pJ/bit</td>
</tr>
<tr>
<td>m (advanced node fraction)</td>
<td>0.6</td>
</tr>
<tr>
<td>a (energy fraction)</td>
<td>0.03</td>
</tr>
<tr>
<td>Efs (free space energy)</td>
<td>0.01 pJ/bit/m2</td>
</tr>
<tr>
<td>Emp (multi path energy)</td>
<td>0.01 pJ/bit/m4</td>
</tr>
<tr>
<td>N (Round number)</td>
<td>5000</td>
</tr>
</tbody>
</table>

In the first experiment related to the dead node, and the figure four show the result. The second experiment will evaluate the throughput of the network, and the result was shown in Figure 3.
Figure 3. Dead Node vs Round Number

Figure 3 illustrates the number of dead nodes in the lap of the cluster head round selection. The graph shows the transition to the number of dead nodes. There is a difference in the number of dead nodes between situations when DEEC protocol is used with game theory, and without using game theory. The number of nodes that die when the network did not use optimization with game theory more than when it used game theory algorithm.

Figure 4 Throughput vs Round Number (to Sink Node)

On data sending from the cluster head to the sink node, Figure 4 also illustrates relatively more optimal value when the network used game theory for optimization. In this delivery process, the protocol is preceded by data aggregation process to save bandwidth and energy. It also appears on the graph that more throughput is obtained on networks that implement clustering systems with optimization using game theory.

5. CONCLUSION

We found that DEEC without game theory still have a pit of weakness when advance node distance is relatively far away from cluster head because logically it consumes energy more than the closer ones. We have shown the experiment result with Matlab. Meanwhile, the DEEC protocol that has already optimized by game theory algorithm in work indicates better performance. The simulation starts to perform the unstable result when the fraction of node is unbalanced because there are redundant energy usage nodes. For the future work the research topic will concern about the distance especially the sink node location arrangement.

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7. REFERENCE

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