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# Energy Management of Wireless Sensor Networks by Using Games Theory

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**Abstract**

Wireless Sensor Networks (WSNs) because of their limitation in energy consumption in their nodes, high rate of energy consumption and inability interchangeable battery, are always in danger of extinction. The highest energy consumption in these networks is done when communicating of the nodes with the base station (BS) and sending information, which its reason is the limitation of BS in receiving and saving the incoming message. Now, if we will be able to increase the lifespan of these networks. So, a lot of algorithms and models have been suggested to reduce the energy consumption of WSNs. In this study, we have tried to present a new model in order to nodes cooperation in communicating with the BS and also reducing the number of messages by using games theory and exclusively enter market game (EMG).

***Key words:*** Wireless Sensor Network; Game Theory; Enter Market Game; Base Station.

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## 1. Introduction

WSNs are considered as the most widely used network in many activities such as: military activities, medical, control of oil and gas fields, transportation activities and etc [1].

This network is always in danger of extinction because of having limitations in its nodes such as: low internal memory, a year battery life and inability interchangeable battery. So a lot of algorithms and models have been suggested to reduce the energy consumption of these networks. As we stated at the beginning, the main aim of the present study is to extend the lifetime of WSN by providing an optimal message transfer model, through games theory. The main idea of this model is to create an intelligent message transfer system, in order to control and limit the number of message from the nodes.

It should be noted that these limitations must be considered in proportion to the BS. The message transmission system should operate in time for the influx of large volumes of message, additional messaging protection and at the right time again they send to the BS. Figures (1) and (2) represent the architecture of transferring message and WSN protocol stack.

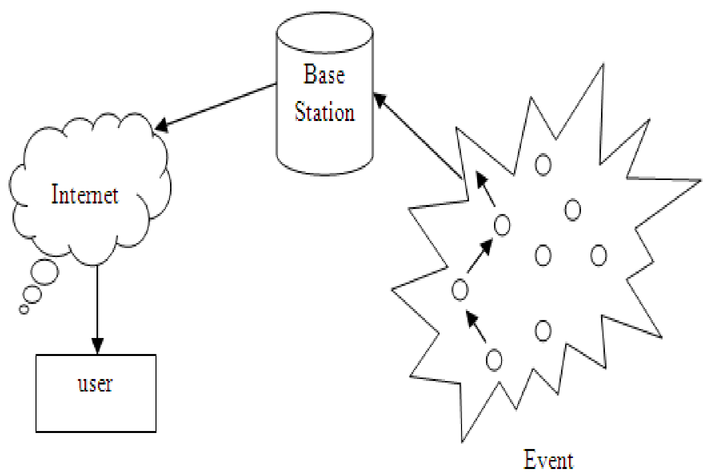


**Figure 1:** architecture of transferring message

### *1.1. Wireless Sensor Networks (WSNs)*

WSNs including emerging technologies which by using new approaches, made people's life easier. These networks have a large number of cheap sensor nodes, as each of these nodes are able to collect, process and store the information around themselves [2]. The nodes are able to communicate with other nodes in a sensor network unities. In order to cover a wide geophysical area, a large number of sensor nodes is required. In this case, the identification accuracy of this region increases [3,4]. Figure (3) represent the internal architecture of a sensor node.

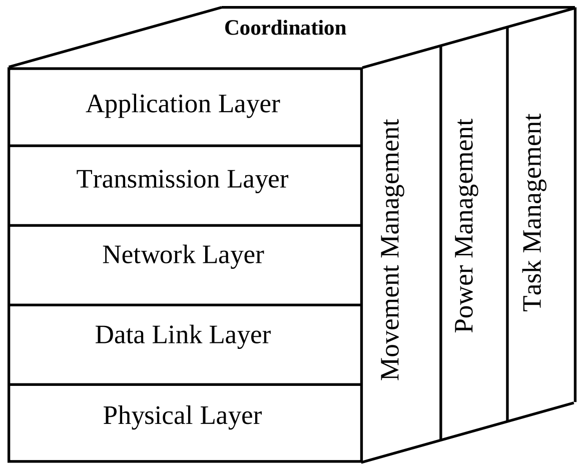


**Figure 2:** WSN protocol stack

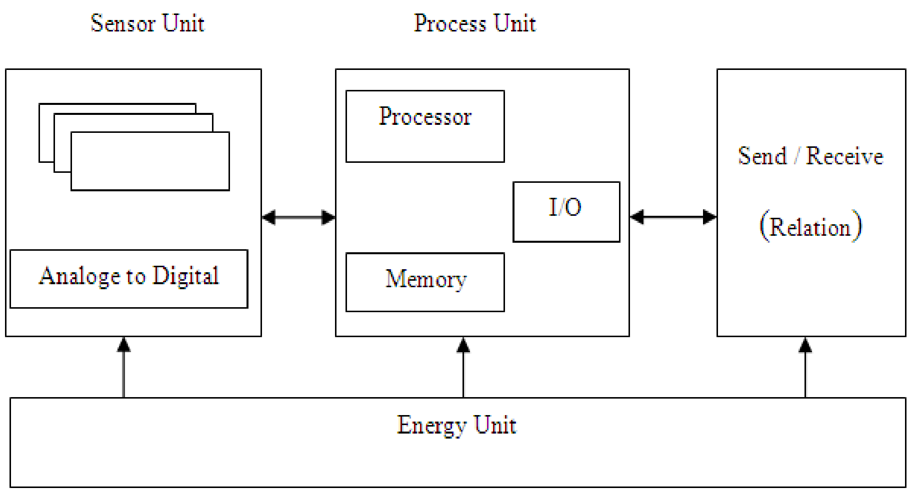


**Figure 3:** internal architecture of a sensor node

### *1.1.1. Placement of node in sensor network*

According to the part 1.2, in order to put the nodes in a network in the best way, at a first we must consider the location of the sensor nodes as a circular area, and then specify a desired point in the area. Then we must calculate the possibility of the desired point in the area of interest. To find this point we can use the following equation (1):

$$P_i = \sum_{i=0}^{n} \binom{n}{i} p^i (1-p)^{n-i} \qquad (1)$$

Where, each of *P*,*n*,*i* parameters indicates rate risk, the total number of nodes and the desired node. Equation (1), makes it possible that the desired point in the area of interest, be covered by at least one node (active node). In the following and after identifying a node by the equation (1), the rest of the nodes on the circular area should be put in passive mode. Figure (4) shows the placement of nodes in sensor network environment.

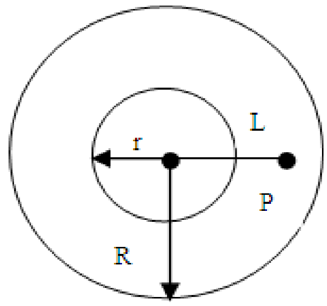


**Figure 4:** placement of nodes in sensor network

### *1.2. Games Theory*

Games theory can be defined via a broadcast mode and expressed as a mathematical equation in order to collect mathematical models, studying location and providing a model of cooperation. Accordingly, it can be used to select the locations and detecting lasting results to take good decision by identifying the best activity.

In order to define locations in the game through games theory, there are a series of elements that are below [5]:

- There are two small player (these players consist of person, company, wireless nodes)
- Each player can be a number of sustainability strategies, alternate activity or selection of a stream.
- The strategy chosen by each player is determined by the score.
- In connection with the outcome of the game, audit done by mathematically by each player. The audit which provide some of the results of each player that the sum of each player is different.

In general, game theory is considered as one of the main mechanisms for resolving issues of WSNs. Typically a game consist a set of strategies for each player and also includes a set of useful functions corresponding [3].

Games theory has a supporting role in the design and operation of WSNs. Figure (5) shows communication between WSNs and games theory.

Normally in a game, $n$ nodes is received for WSNs by name of $G = (N, S, U)$. Where :

*G*= special games.

*U*= useful function corresponding of the node *i* that is provided by:

$U_i = \{1,2,3, \dots, n\}$. $U_i$ is a useful some that each node receives at the end of its operation.

$N$=limited set of sensor nodes

$N = (n_1, n_2, \dots, n_n)$.

$S$= the strategy of $i$ sensor node that can be presented by the equation (2).

$$S = (s_1, \dots, s_n) \rightarrow s_i(i = 1,2, \dots, n) \quad (2)$$

The table (1) reflects the components associated with games theory and WSNs.

**Table 1:** components associated with games theory and WSNs

| Elements of WSNs | Game Component |
|---|---|
| Available nodes in WSNs | Players |
| Modulation of design, coding rate, the level of energy transfer | Set of strategy |
| Performance indicators (throughput, delay, signal noise ratio, ...) | Set of audits |

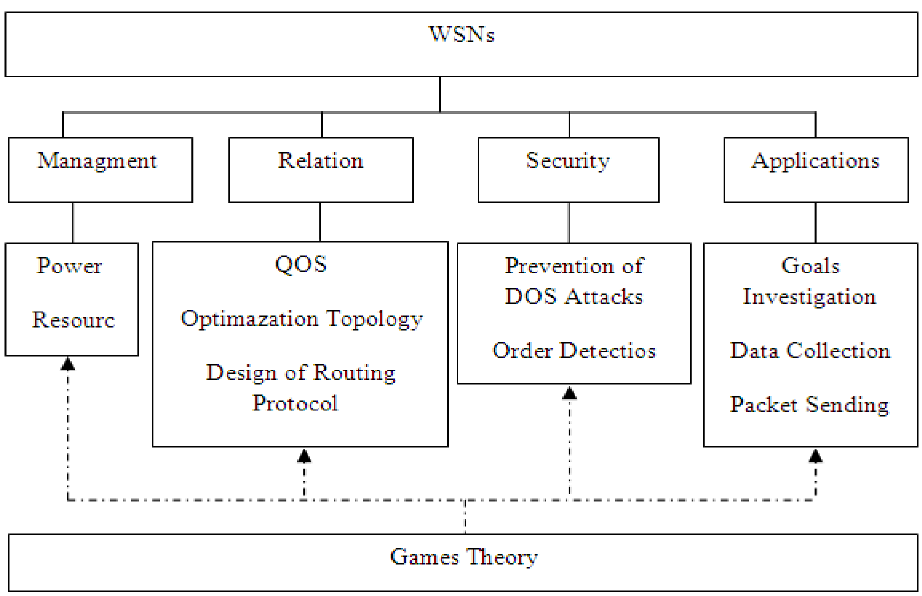


**Figure 5:** communication between WSNs and games theory

The strategy of a player will be completed through existing operations in all possible situations of the game. A player tries to have the greatest amount of selfishness, so that to achieve a superior than all other nodes. Here, $s_i$ is a special strategy which is selected by *i* node and $s_{-i}$ are special strategies which are selected by all other nodes in the game [6].

This strategy is called "Combining Strategy" and is written for $S = \{s_i, s_{-i}\}$. The following equation (3) represents a useful function for the excellence of one player to the other players.

$$U_i(s_i, s_{-i}) = \left(\frac{b}{F}\right)\left(\frac{r}{s_i}\right) f(\gamma_j) \qquad (3)$$

Where:

$U_i(s_i, s_{-i}) =$ the ability of *i* node to transmit data to *j* node.

$b =$ the number of data per packet sent.

$F$ = the overall size of the package.

$r$ = data transfer rate (bit/Sec).

$S_i$ = selected strategy.

$f(\gamma_j) =$ effective functions to increase the intake of the node. This function is calculated by:

$$f(\gamma_j) = (1 - 2P_e)^F \qquad (4)$$

Where:

$P_e =$ error rates associated with channel mode and the intervention of other nodes.

## 2. Related Work

### *2.1. Non-Cooperative Game Theory*

This game study on available strategies on the interactions of players, taken at the time of audit and its goal is gaining access to more resources through the selection of one by one individual strategies. A mong the applications of this game, can be noted such as: energy consumption control, congestion control, allocation of distributed resource, etc. It should be noted that non-cooperative game alone cannot provide the correct solutions to solve the problem of sensor network, and can only pave the way to this solution [5].

### *2.2. Cooperative Game Theory*

Cooperative game theory is considered as one of the most important game theories to reduce energy consumption and extend the lifetime of WSNs. Because a large number of available nodes on the network, work as partner and groupwork. So the game reduce energy consumption of WSNs through the method of grouping nodes (players) [7,8,9].

### *2.3. Gureen Game Theory*

Gureen game theory is actually a simple game that basis there is an unlimited number of players (node in sensor network) and a referee (BS). Based on the aforementioned game, players in the game have no information about the existence and function of referee and only the referee can consider the following players. So, the gureen game theory represents a focused game that has led to a centralized algorithm. Basis of the game is as follows which the referee to identify and determine the active node (awaken), runs a game of question and answer for players. Thus the referee asks questions of players successively to get Yes/No answers and finally acquires the sum of responses for each node [8,9].

## 3. Production Model

### *3.1. Overview*

Exchanging message between nodes in WSNs and BS (central processor) is one of the most important factors related to energy consumption in WSNs. In fact, the main criteria to compare the energy consumption and network required energy, is proper communication between nodes and BS [2,10,11]. As mentioned in the previous sections, the proposed model in this study in order to reduce energy consumption in WSNs, is derived from games theory and exclusively EMG. So in this section we describe the structure of the game and finally we offer an optimized version of message transmission for sensor nodes.

### *3.2. Enter Market Game Theory (EMG)*

According to the EMG, *N* player decide to enter the market simultaneously and linked together or exit the market. If they choose to enter the market, in this case, the state audit is carried out based on the number of players on the market. It should be noted that in this case the communication between players hardly done and to some extent communicate in this mode is forbidden. The variable represents the market capacity and its range is equal to: $1 \leq C \leq N$. In each round of the game, player $i$ which decides to enter the market, its value is equal to $s_i = 1$, and this despite the fact that if he decides to withdraw from the market, its value is equal to $s_i = 0$. Here, the probability of player entrance considered $P$ and its leaving probability considered *1-P*. In general, the probability of player entrance to the equation (5):

$$P = (C - 1)/\,(N - 1) \qquad (5)$$

According to the $P_i$ audit function, audit operations related to players decided hypothetically. Equation (6) represent entrance and exit function of the market (audit function).

$$P_i = \begin{cases} o & if\ s_i = o \quad \text{(exit)} \\ \frac{V}{K} & if\ s_i = 1 \ \ and \ \ K < C \quad \text{(enter)} \\ \left(\frac{V}{K}\right) - \left(\frac{K-C}{K}.F\right) & if\ s_i = 1 \ \ and \ \ K \geq C \end{cases} \qquad (6)$$

**Table 5:** pseudocode of entrance and exit function

```
IF  s_i = o  Then
      P_i = 0;
      P_i (State) = Leave The Market ;
else IF  (s_i = 1 and K < C )  Then
      P_i = V/K ;
      P_i (State)  = Enter the Market ;
else IF (s_i = 1 and K ≥ C )  Then
      Generate  (r) ;   // Generated the Random Number
      IF  r < {p_j}    Then (s_i = 1 and K < C )
            //{p_j} = the Set of Random Value's with p
            P_i = V/K ;
            P_i (State) = Enter the Market ;
       else IF   r > {p_j}    Then
            P_i = (V/K) − ((K−C)/K . F));
            s_i = 0;
            P_i (State) = Leave The Market ;
       End if
       End if
End if
End if
End if
```

According to the equation (6) and algorithm 1, $V$ and $F$ parameters are fixed values which respectively are advantages and disadvantages of this method. The $K$ value indicates the number of players on the market and variable $C$ represent market capacity. In general, the result of this function is outlined in three states:

- $s_i = 0$

In this case the player decides to leave the market, thus the function is equal to zero.

- $s_i = 1$ & $K < C$

In this case the player decides to enter the

market, however the number of players on the market is less than the overall market capacity. So to get the value of the audit function, should divided the benefits of the $V$ model by the number of $K$ incoming players. So, the audit of each external player is equal to ($N – K$) which the value obtained in this case will lead to zero.

- $s_i = 1$ & $K \geq C$

In this case, the player decide to come in market while the number of players in the market is less than the total capacity of the market. Thereforehe, when the value of $K$ is equal or more than the market capacity ($K \geq C$), a random value $r$ is generated for each player. Now if the random value be less than the market thresuld value ($r < \{p_j\}$ ), then the player will be audit according to $s_i = 1$ & $K < C$, and thus will be enter the market. But, if the random value be greater than the market thresuld value ($r > \{p_j\}$ ), then the player will be audit according to $s_i = 0$ , and thus will be withdrawn from the market.

**Point**: the thresuld is actually a set of $P$ probability value.

The algorithm of EMG can correctly describe a part of great class of homogeneous games according to the generated large number of Nash Equilibrium game. Anyway here instead of homogeneous games, players are motivated and eager to have homogeneous activities, and based on this successful homogeneity, different players doing various activities (many players enter the market and mani/more leave).

**4. Discussion**

In this section, as a case study, we compare the available parameters in WSNs according to EMG and a usual networks.

***4.1. EMG and its Modification Comparison with Respect to lifetime:***

Here, lifetime means the number of repetions before death of the first node. The best condition in EMG, is a condition where in more of the total existing nodes in the network being active. Table(2), shows obtained values of network lifetime at the time of using EMG and normal mood. According to the obtained values, it is known that sensor networks in usual mood have shorter lifetime.

**Table 2:** The obtained values of comparing network lifetime by EMG

| EMG | PGUR[12] | AGUR[12] | Without Game |
|---|---|---|---|
| 2400 | 1550 | 1402 | 978 |

Clearly, the lifetime of algorithm of the EMG is about 150% more than the network lifetime without the game. So it can be said with certainty that the performed network by EMG model has longer lifetime which indicating low energy consumption in the network.

### *4.2. EMG and its Modification Comparison with Respect to QoS Ratio:*

Table (3) shows the obtained values of the network QoS in different conditions. Clearly, the algorithm of EMG has 90% increased QoS than a usual network.

**Table 3:** The obtained values of comparing network QoS by EMG

| AGUR[12] | PGUR[12] | EMG | Without Game |
|---|---|---|---|
| 99% | 98% | 94.4 % | 4.7 % |

### *4.3. EMG and its Modification Comparison with Respect to Average Residual Energy:*

The most energy consumption in the nodes occurs when the nodes want to send their messages to the BS. Now if the number of sent messages is greater than the limit, additional messages will be rejected, but if the number of sent messages be less of equal to the limit, the BS will be able to broadcast new message to all available nodes. So because of message broadcasting, node's energy finished quickly. Table (4) shows the obtained values of the network's average of the remaining energy in different condition.

As the lifetime of model increases, the remaining energy decrease (EMG). But if the life of network be short, consequently, less energy consumption occure in the mentioned model and at least it has more remaining energy than other models (without game).

**Table 4:** The obtained values of comparing network average residual energy by EMG

| EMG | PGUR[12] | AGUR[12] | Without Game |
|---|---|---|---|
| 0.27 jules | 0.36 jules | 0.37 jules | 2 jules |

## 5. Conclusion

According to the conducted assessments in section 4, it can be concluded that that designing WSNs by games theory, improve performance and reduce energy consumption too much. Due to the EMG model and the results, it turns out that the EMG model in all the tests has better performance. So that in the field of improvement of the average of remaining energy, which is the main concern of this study, the mentioned model shows the least. In generated it can be said, as the life of a mode increases the remaining energy decrease (EMG), but if the lifetime of a network be short, less energy consumption happen and finally it will have more remaining energy than other models (without game).

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