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Improvement of Leach Routing Algorithm Based on the Use of Game Theory and Centralized Adjustment Mechanism

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Abstract

Wireless Sensor Networks usage is spreading throughout many aspects of life, such as health, military, security, environment monitoring and others, providing more important services with less efforts and costs. The rational energy consumption in WSNs is one of the main fields of scientific researches that have been done on the different layers of the protocols' stack, LEACH is an energy-efficient routing protocol based on the clustering technique that expands the lifetime span of a WSN remarkably. However the randomly chosen cluster head may be located near to another one, thing that causes a useless waste of energy that is proportional to the number of cluster heads located close to each others.

A proposed distributed algorithm is designed by applying game theory concepts to design a non-cooperative game and a Nash Equilibrium solution's concept to avoid this issue, by computing a value of the probability to be cluster head, that takes into account the localization of other neighbor cluster heads, in addition to a centralized mechanism in the base station that help determining which nodes are to be considered as neighbors.

Keywords: LEACH, Energy, Game Theory, Non-cooperative game, Mixed strategy Nash Equilibrium, centralized adjustment .

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INTRODUCTION

Wireless sensors networks (WSN) are an infrastructure-less networks where nodes are small devices called sensors. A sensor have two major tasks to fulfill, the first is sensing physical parameters such as temperature, light, sound... the second is conveying the gathered data to the base station so that it could be processed.

Unlike the traditional kinds of networks, WSN nodes have a limited source of energy which should be used rationally. Many researchers focused on the routing issue as a fruitful field of research where some of the proposed routing protocols seems to be energy- efficient and prolongs the lifetime span of the network. The clustered routing protocols has gained increasing attention from researchers because of its potential ability of extending WSN lifetime. Heizelman [1] designed and implemented the first distributed and clustered routing protocol with low energy consumption, other works came later as an improvement based on LEACH [2] [3] [4] [5] [6] [7] [11] [12] [13] [14] [15]. This paper presents a new improved LEACH algorithm based on game theory.

The remainder of this paper is organized as follows: Section 2 present an overview on LEACH that also include a description of the problem we aim to solve and its formulation, it also present an overview on some of the related works in attempt to improve LEACH. Section 3 is a brief introduction to the basics of game theory, whereas Section 4 describe the model of game used to overcome the issue. Section 5 is a comparison and analysis of simulation results of the algorithms.

RELATED WORK

In this section we will first present the original LEACH protocol, and then present one of his disadvantages that is due to the random decision of being cluster head. we will also enumerate some of the works that have been done in attempt to improve LEACH, whether through the use of distributed or centralized algorithms in order to adjust the value of LEACH threshold.

Leach Protocol

LEACH is a routing protocol based on clustering technique, throughout several iterations called rounds, LEACH use an algorithm to form small groups called clusters such that nodes inside the same cluster adhere to the same head of the cluster called cluster head. In each round nodes participate in a set-up and a steady-state phase [1].

Set-up Phase

Each node calculate a threshold $T(n)$ and then generate a random s between 0 and 1, if $s > T(n)$ then the node decide to be cluster head and broadcast a message informing neighbor nodes about its decision, else ($s < T(n)$) the node will choose the closest node claiming to be cluster head, the node then send message to the chosen one. The threshold $T(n)$ is calculated as follows :

$$T(n) = \begin{cases} \dfrac{p}{1 - p \times \left(r \bmod \left(\frac{1}{p}\right)\right)} & n \in G \\ 0 & others \end{cases}$$

G is the set of nodes that are not selected as cluster head in the last *1/p* rounds and r is the round number.

Steady-state Phase

based on the messages received in the set-up phase a cluster head knows the member nodes of its cluster and arrange a TDMA schedule and send it to other members, each node then use the specified time slot and send its sensed data to cluster head, once it receives all members' data, the cluster head process the aggregation of data and eliminate eventual redundancies, and send it in one single hop to the base station as shown in Figure 1.

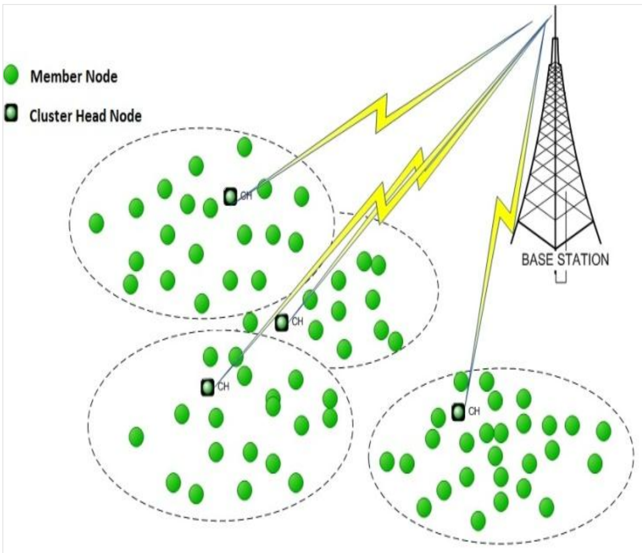

Figure 1. LEACH Communication Architecture.

Leach disadvantages

When nodes are deployed, the energy consumption is not the same for all nodes, especially when nodes are randomly scattered in fields, the cluster heads that are located near to the base station would consume less energy than the ones located far from it. the farthest cluster head have to increase their transmission power to reach the base station, which mean more energy consumed. Therefore, the energy consumption will not be fairly balanced among node, which may lead to the partition of the network caused by some nodes' early death. Original LEACH is a scholastic algorithm, nodes decide to become cluster head without taking into account other cluster heads' localization, which may cause a high concentration of cluster heads in a small area. In [11] the authors explain by using data communication model that the total energy consumption is proportional to the number of cluster heads located in small area with a negligible distance that separates them, authors also proposed progressive approach of selecting cluster heads, and formulated a modified threshold that take into consideration the number of neighbor nodes that decide not to become cluster heads due to their localization close to another one.

The work presented in this paper is a try to overcome the issue of having high concentration of cluster heads in a small zone by combining the use of a game model presented in the next section, and a progressive approach of cluster heads' selection.

LEACH-C

LEACH-C [12] is a modified LEACH using centralized clustering algorithm, which is similar to the steady-state phase protocol as LEACH. LEACH-C is different from LEACH at the two steps in the setup phase. In the setup phase of LEACH-C, each node inform the BS about its current position and its residual energy level. The BS will compute the number of optimal cluster heads and divide the network into clusters for the current round. the BS than broadcasts an advertisement message to all sensor nodes in the network containing the configuration that identify cluster heads and their members.

A Location Based Clustering Algorithm for Wireless Sensor Networks

Authors in [11] present an improvement on LEACH protocol based on the location of cluster heads, they first established that the more cluster heads are concentrated in small area the more energy is consumed, to overcome this issue they used a progressive technique of selection considering that the network area is divided as shown in Figure 2. :

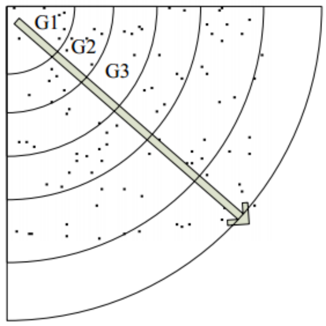

Figure 2. Progressive approach to selecting cluster heads

This progressive technique is used in order to let nodes in given zone G_i knows about the existence of a neighbour cluster head in a previous zone G_{i-1}, and avoid being cluster head if there is a very close one, when a node decide to avoid being cluster head, it will inform the other nodes in G_{i+1} , in this way nodes of G_{i+1} that received desisting messages from *k* nodes will adjust the formula of the threshold *T(n)* as follows :

$$T(n) = \begin{cases} \dfrac{p}{1 - p \times \left(r \bmod \left(\frac{1}{p}\right)\right) - pk} & n \in G \\ 0 & others \end{cases}$$

LEACH-GA: Genetic Algorithm-Based Energy-Efficient Adaptive Clustering Protocol for Wireless Sensor Networks

LEACH-GA [7] is modified version of LEACH protocol, it proposes a genetic algorithm-based adaptive clustering protocol with an optimal probability prediction to extends the lifetime span of a WSN.

LEACH-GA has set-up and steady-state phases for each round, in addition to a preparation phase before the beginning of the first round. In the preparation phase, all nodes initially perform cluster head selection process and then send their messages with statuses of being a candidate cluster head or not, node IDs, and geographical positions to the base station. As the base station received the messages from all n nodes, it then searches for an optimal probability $p_{opt} = k_{opt}/n$ of nodes being cluster heads via a genetic algorithm by minimizing the total energy consumption required for completing one round in the sensor field.

the analytical formulas considered in LEACH-GA of the optimal probability p_{opt} and the optimal number of clusters k_{opt} are :

$$k_{opt} = \begin{Bmatrix} \sqrt{\frac{n}{\pi}}\frac{M}{\sqrt{E[d_{toBS}^2]}} & \text{if } d_{toBS} < d_0 \\ \sqrt{\frac{n}{\pi}}\sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}}\frac{M}{\sqrt{E[d_{toBS}^4]}} & \text{if } d_{toBS} \geq d_0 \end{Bmatrix}$$

and

$$p_{opt} = \frac{k_{opt}}{n} = \begin{Bmatrix} \sqrt{\frac{1}{n\pi}}\frac{M}{\sqrt{E[d_{toBS}^2]}} & \text{if } d_{toBS} < d_0 \\ \sqrt{\frac{1}{n\pi}}\sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}}\frac{M}{\sqrt{E[d_{toBS}^4]}} & \text{if } d_{toBS} \geq d_0 \end{Bmatrix}$$

where :

n is the total number of nodes.

$d_0 = \sqrt{\varepsilon_{fs}/\varepsilon_{mp}}$ denotes the threshold distance

ε_{fs} is the transmitter amplifier if the distance $d_{toBS} \leq d_0$

ε_{mp} is the transmitter amplifier if the distance $d_{toBS} \geq d_0$

M is such as the network area size is M×M

$E[d_{toBS}^2]$ and $E[d_{toBS}^4]$ are the expected values of d_{toBS}^2 and d_{toBS}^4

d_{toBS} is the distance that separate a node from the base station

The genetic algorithm use an objective function and search the solution space through an evolutionary optimization process incorporating probabilistic transitions and non-deterministic rules, and applying selection, crossover and mutation operators. Once the optimal probability p_{opt} is calculated the base station broadcasts an advertisement message containing the optimal value of probability to all nodes in order to form clusters in the following set-up phase. The preparation phase is performed only once before the set-up phase of the first round. The processes of following set-up and steady-state phases in every round are the same as LEACH.

WALEACH: Weight Based Energy Efficient Advanced Leach algorithm

WALEACH [14] is modified version of another LEACH based algorithm called ALEACH [13], both algorithms work in distributed fashion by considering an adjusted value of threshold *T(n)*.

ALEACH consider compute *T(n)* as follows : $T(n) = G_p + CS_p$, where $G_p = \frac{k}{N-k*(r \bmod \frac{N}{k})}$ is the general probability, and $CS_p = \frac{E_{current}}{E_{max}} \times \frac{k}{N}$ denote the current state probability, where $\frac{N}{k}$ refers to the desired percentage of cluster heads during each round and $E_{current}$ and E_{max} is remaining energy and maximum energy of a node respectively.

As for WALEACH, the algorithm attempt to increase lifetime span of a WSN by assigning weights to G_p and CS_p as follows : $G_p = \frac{N-(w*k)}{N} \times \frac{k}{N-k*(r \bmod \frac{N}{k})}$ and

$CS_p = \frac{w*k}{N} \times \frac{E_{current}}{E_{max}}$, w is used to assign the weight to the probabilities.

Authors of WALEACH also presented another coverage based algorithm called CVLEACH [5] that improve LEACH by creating non-overlapping clusters using overhearing properties of the sensor nodes.

GAME THEORY BASICS

Game theory is a set of analytical tools that allows formulating mathematically situation of strategic interaction between a group of agents, called players, seeking their own gain. A player's choice of his best strategy that maximizes his gain could dramatically decrease other player's gain. In some cases players tend to cooperate and form strategic coalitions increasing their individual gain, such a model is called cooperative game, we discuss in this paper the non-cooperative game model where no coalition is allowed, a player decide his strategies depending on others players' actions.

Formally the strategic form of a non cooperative game Γ is $\Gamma(N, A, u)$ where *N={1,2,..,n}* is a set of n players, A is the set of strategies possible with $a = [a_1, a_2, \dots a_n]^T \epsilon A = \times_n^1 A_n$ is a strategy profile where a_i is the pure strategy of the i[th] player and $a_{-i} \epsilon A_{-i} = \times_{k \neq i}^N A_k$ is the strategies of other *n-1* players. u is an n-tuple of payoff functions $u = (u_1, u_2, \dots, u_n) \in \mathbb{R}^n$ such that $u_i : A \to \mathbb{R}$ is the payoff function of the i[th] player [8].

A non-cooperative game takes place as a sequence of rounds, in each round a player i try to maximize his payoff by choosing his best strategy as response to others players' choices. Nash Equilibrium is one of the solution concepts used in order to find the best strategy profile that satisfy all players, then a Nash equilibrium is a strategy profile a^* such that if all players have previously agreed about it, no one would have unilateral interest in deviating from it, formally : $a^* \epsilon A$ is a Nash equilibrium if : $\forall i \in N, \forall a_i \in A_i$: $u_i(a^*) \geq u_i(a_i, a^*_{-i})$.

GAME MODEL AND PROPOSED ALGORITHM

Game Model

The game model we propose is a non-cooperative game, this model is increasingly used in different applications for WSNs such as routing, security or QoS [9], a similar model is used in [10] in order to reduce OLSR control overhead.

Our model is defined as follows :

$\Gamma(\mathrm{N}, (\mathrm{S_i})_{i\in N}, (\mathrm{U_i})_{i\in N})$ where N is the set of players or nodes, $\mathrm{S_i}$ is the strategy set for the node i and $\mathrm{S_i}$ = {BCH, NBCH} where BCH is Be Cluster Head, and NBCH is Not Be Cluster Head , $\mathrm{U_i}$ is the utility function for the i^{th} node. The value of the utility function that a node will get depends on its own strategy and the other players strategies, the utility function for a node i can be expressed as follows:

$$\mathrm{U_i} = \begin{cases} \mathrm{G_m}\ ;\ \text{if}\ \mathrm{S_i} = \text{"NBCH" and } \exists\, \mathrm{j} \in \mathrm{N} \mid \mathrm{S_j} = \text{"BCH"} \\ \mathrm{G_m} - \mathrm{C}\ ;\ \text{if}\ \mathrm{S_i} = \text{"BCH"} \\ 0\ ;\ \text{if}\ \mathrm{S_i} = \text{"NBCH"}\ \forall\, \mathrm{i} \in \mathrm{N} \end{cases}$$

$\mathrm{G_m}$ is the gain that a node get when it avoids to be cluster head while some neighbor nodes chooses to be so, C is the cost that a node pay when it chooses to be a cluster head, the cost C can be expressed as a function $f(n,d)=C$ where n is the number of the cluster members and d is the distance between a node and the base station, it is clear that the cluster head's energy spent in reception and aggregation of the data depends on the number of its cluster members, also the energy that the cluster head use in sending the data to the base station depends on the distance that separates them, the centralized mechanism that adjust the number zones as will be introduced later in this paper will inform nodes about changes on total estimated number of nodes that are still alive, each node then will change number of players N and the cost C. The payoff matrix for any node can be expressed as shown in Table 1:

Table 1. Payoff Matrix for a player i.

		N-1 other players	
		At least one BCH	All NBCH
Player i	BCH	($\mathrm{G_m}$-C , $\mathrm{G_m}$ -C)	($\mathrm{G_m}$-C , $\mathrm{G_m}$)
	NBCH	($\mathrm{G_m}$, $\mathrm{G_m}$ -C)	(0,0)

If we consider the fact that a player chooses a strategy is an event, then each event occur with a probability, theses probabilities will helps us to construct the mixed strategy Nash Equilibrium.

In LEACH protocol p denote the probability that a node chooses to be cluster head, then *p(BCH) = p*, and the probability of not choosing to be cluster head is *p(NBCH)=1-p*, as a result the probability that all other nodes do not choose to be cluster head is $p(All\ NBCH) = (1\text{-}p)^{N\text{-}1}$. Finally the probability that at least one player chooses to be cluster head is $p(At\ least\ one\ BCH)=1\text{-}(1\text{-}\ p)^{N\text{-}1}$. if we consider the payoffs in Table.1 and the probabilities listed above, we can construct the mixed strategy Nash Equilibrium as follows:

$$(1 - (1 - \mathrm{p})^{\mathrm{N}-1})(\mathrm{G_m} - \mathrm{C}) + (1 - \mathrm{p})^{\mathrm{N}-1}(\mathrm{G_m} - \mathrm{C}) = (1 - (1 - \mathrm{p})^{\mathrm{N}-1})\mathrm{G_m}$$

From the equation above, the probability of choosing to be cluster head p can be expressed as :

$$p = 1 - (C/G_m)^{1/(N-1)}$$

this result means that the equilibrium is valid when the probability of choosing to be cluster head is $1-(C/G_m)^{\frac{1}{N-1}}$, p depends on N,C and G_m .

The gain of choosing to be cluster head increases when neighbor nodes that are cluster heads are located far, we propose a gain G_m constructed as follows :

$$G_m = a \times D_i$$

where a is a positive constant and D_i is defined as :

$$D_i = \begin{cases} \varepsilon\ if\ \exists\, j \in N \mid Dist(i,j) \leq D_{min} \\ \quad and\ \ S_j = \text{"Be CH"} \\ \dfrac{Dist(i,j)}{D_{min}}\ if\ \exists\, j \in N \mid Dist(i,j) > D_{min} \\ \quad and\ \ S_j = \text{"Be CH"} \end{cases}$$

where $\varepsilon \in \mathbb{R}^{*+}$ is a small positive number that minimizes the value of the gain, and D_{min} is the minimal distance that should separates two cluster heads. D_i increases when the distance that separates a node from a cluster head is larger, and it tends to take a negligible value when the cluster head is a close neighbor.

Proposed Algorithm

In order to compute the value of p_{NE} nodes need to know about their neighbors strategies. Authors in [11] proposed a progressive approach of selection, where the network is divided into regions, and used a technique of temporal distribution of selection; nodes of region i decide first, then nodes in region $i+1$ decide right after, in this way nodes of region $i+1$ are able to take into account existence of cluster heads from previous region and give up the attempt of being cluster head every time there is a very close neighbor one, in our algorithm, we propose the same progressive approach established with another technique.

The approach assume that the area where sensors are deployed is square, the network is divided into cells, and each zone is a cell or a group of cells as shown in Figure.3

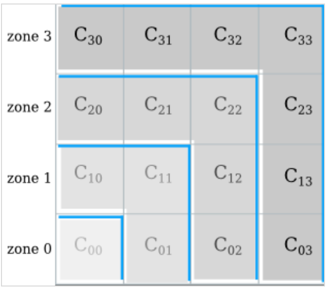

Figure 3. Network area subdivision into zones.

Every node *i* is capable of calculating its own zone by finding the indexes *j1* and *j2* of its own cell $C_{j1\,j2}$, the indexes can be determined by computing the following integer parts : $j1 = \lfloor y_i / s \rfloor$ and $j2 = \lfloor x_i / s \rfloor$, where x_i and y_i are the coordinates of the node *i*, and *s* is the width of one cell, it is equal to width of the area divided by the desired number of zones, the selection process then will be delayed progressively from zone *k* to zone *k+1*, in this way nodes of zone *k* will play the game and choose their strategies while taking into consideration the strategies chosen by nodes in zone *k-1*, with the exception of nodes that belongs to zone 0 where the selection process starts first. If the index of zone is included in the messages, nodes of a given zone could be alarmed if no cluster head where selected nearby in the previous zone, in this case nodes consider that the closest cluster head is located far away enough with a distance that maximizes the gain, this behavior encourage the selection of cluster heads near the zones that do not contain enough clusters.

We consider that the game is played during each round of LEACH protocol. In the set-up phase of each round, a node *i* will calculate the threshold *T(i)* modified s follows :

$$T(i) = \begin{cases} \dfrac{p_{NE}}{1 - p_{init}\left(r mod \dfrac{1}{p_{init}}\right)} & if\, i \in G \\ 0 else & \end{cases}$$

where p_{init} is the initial percentage of cluster heads, p_{NE} is the probability calculated using the mixed strategy Nash Equilibrium, and G is the set of nodes that are not selected as cluster head in the last $1/p_{init}$ rounds.

If we consider that the number of zones decided in the beginning of the algorithm take the same value all along the running time, and that nodes will consume energy and die progressively during this time, the density of nodes in zones will decrease, and the delayed selection process within the same zone will take place between just a few players than it was in the starting of the algorithm, in this case we will have more zones than it should be compared to the number of nodes that are still alive, the thing that leads to the construction of smaller clusters than it is desired theoretically, and the more nodes dies the smaller clusters gets.

To overcome this issue, we propose, in addition to the distributed strategy of the suggested algorithm, a centralized mechanism in the base station that will adjust the number of zones during running time whenever it is convenient. In order to achieve this mechanism in an optimal way, the base station will not decide about nodes' belonging to a specific zone for each node, it will instead broadcast a number of the desired zones that will help a node to compute the number *s* used to determine its own indexes as mentioned above.

The communication between nodes and the base station consume a relatively important energy, therefore the broadcast needed to adjust the number of zones should not happen frequently nor rarely, in this work we consider that the number of zones decreases by one whenever the network loses the quarter of its nodes, for instance if a network contain 100 nodes and 4 zones, it will have 3 zones when 75 nodes are alive, 2 zones for 50 nodes, and finally just 1 zone for 25 nodes since the average cluster in Leach theoretically contain 20 nodes, implicitly networks with height density should be divided into more zones, Figure 4. explain how the number of zones changes based on the number of nodes that are still alive :

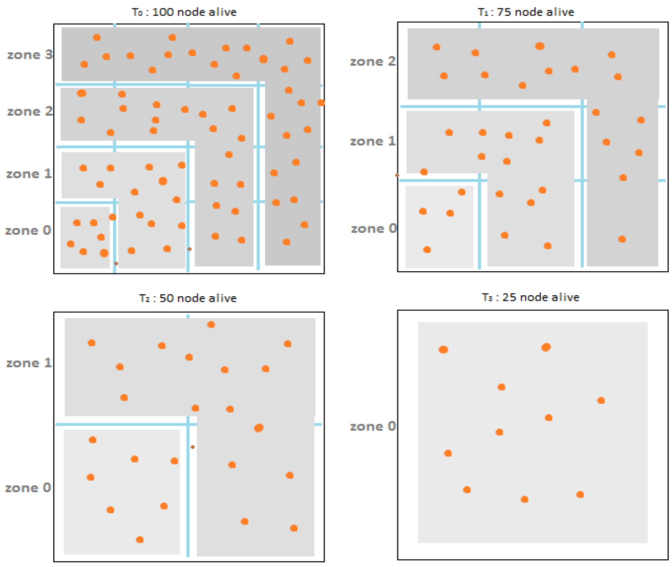

Figure 4. Network area subdivision into zones.

The broadcasted message from the base station that adjust the number of zones will also adjust the value of Nash Equilibrium probability formula $p = 1 - (C/G_m)^{1/(N-1)}$ since it extend the zone area, which mean adding more nodes to the set of players

PERFORMANCE ANALYSIS

WSNs are deployed in different environments, each environment have its specifics characteristics, the design of routing protocols depends tightly on these characteristics that are considered as pre-conditions needed for the correct carrying out of the protocol.

Since our algorithm is a modification of original LEACH, we assume that the network satisfies the following assumptions :

- The base station have always enough energy, it is located in the network area so that it could be reachable for all nodes with a less amount of energy than the case of far located base station, in this way the standard deviation between the estimated average cost of being cluster head and the real costs of it is lower.

- Nodes are homogenous and have an identify ID, nodes have also the same initial energy.
- The data gathered by member nodes is aggregated and fused by the cluster head before being conveyed to the base station.
- Sensor nodes are static and scattered in a square area.

In this section, we will present the simulations parameters and results for two simulations under different conditions.

SIMULATIONS PARAMETERS

In order to compare the performances of the original LEACH protocol and our proposed algorithms, we simulated the algorithms using NS2 simulator, we used the MIT uAMPS LEACH NS Extensions to evaluate LEACH performance, we evaluated our work by modifying the top level of the extensions, the proposed algorithm is implemented by modifying the Tcl class APPLICATION/LEACH that contains the required function for sending and receiving data, and for the cluster head decision and selection process.

We modified the start() function such as nodes calculate their zones in this function, and delay the execution of the DecideClusterHead() based on the zone index value, we also modified sending and receiving function to support zone information so that a node could identify the zone of the message sender, we added the necessary functions needed to compute the value of the Nash Equilibrium probability.

We also modified functions in the ns-bsapp.tcl file that implement the base station behavior that allows to broadcast messages containing the cluster heads selected in a centralized way, we changed the frequency of this broadcast and its purpose in a way that it will not send the selected cluster heads, it will instead send the number of the desired zones into which network should be divided, keeping the selection process distributed as in LEACH.

The algorithms are compared based on the results of two scenarios, the comparison is made based on the energy consumption and the lifetime span of network, we present in Table.2 the values of the simulation parameters for scenario 1 and 2 :

Table 2. Simulation parameters.

Parameter	Scenario 1	Scenario 2
Simulation area	100×100	500×500
Network size	100 nodes	400 nodes
Initial energy	2J	2J
Simulation Time	1000s	1000s
Base station at	78,60	384,299
Clusters' Number	5	25
Number of zones	4	4

SIMULATIONS RESULTS

Scenario 1

The results of this scenario are presented in Figure.5 and Figure.6; LEACH nodes have a longer lifetime and die slower compared to our algorithms, the energy consumption of LEACH algorithm is nearly uniform which explain the stability of the alive nodes number through simulation time. However, the improved version of our algorithm show a lower rate of energy consumption compared to the origin proposed one:

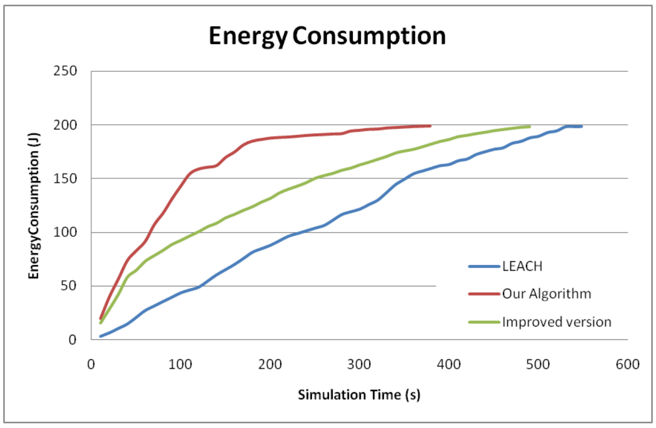

Figure 5. Energy consumption in scenario 1.

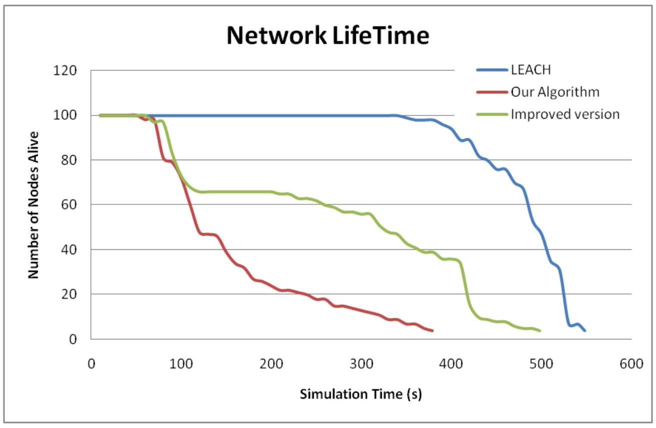

Figure 6. Lifetime span in scenario 1.

The lower performance of our approach is explained here by the low density of nodes per zone in this scenario, if we assume that a node is playing a given round with 20 players and the separation distance between cluster heads is 15, the cost C is estimated here based only on the number of the cluster members 0.4 =20*cu , cu is the cost of being cluster head for one member and is estimated by 0.02J based on previous LEACH simulation results. the probability value could be represented as follows :

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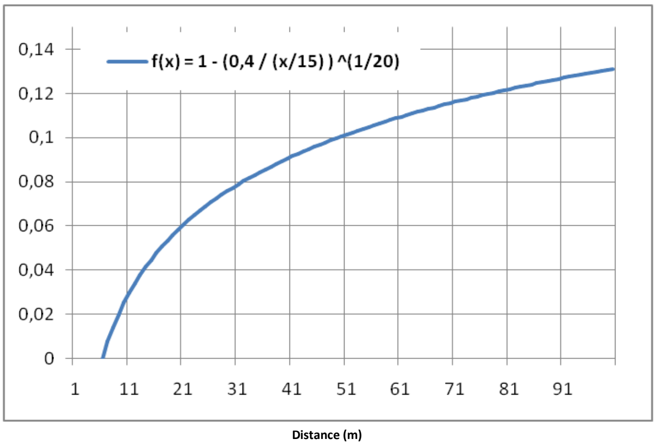

Figure 7. Nash Equilibrium probability variation (20 player).

We could observe that the value of the probability tends to take higher values than 0.05 the desired percentage in LEACH, which causes selection of cluster heads more than needed, as a result the energy is wasted in our algorithm more than LEACH.

As for the improved version, we could see that it tend to behave in a similar fashion as the origin algorithm at the beginning of simulation time, and that it changed the rate of died nodes after time 80 when approximately the network lost about 30 nodes and base the station reduced the number of zone.

Figure.8 represent the values of p_{NE} with different set of players, when the number of nodes decrease, the actual probability increases compared the theoretical one, by reducing the number of zones nodes will have more players in their sets and minimize the gap between the theoretical and the actual value of p_{NE}.

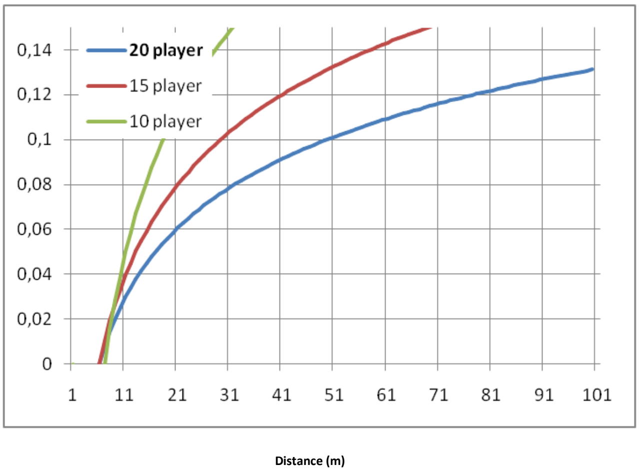

Figure 8. Values of p_{NE} with different set of players (20,15,10)

Scenario 2

The results are shown in Figure.9 and Figure.10; in this case our approach show slightly larger lifetime span, this time the density of nodes per zone is elevated, and our algorithm show a stable behavior generally and consume energy in a nearly uniform slow rate starting from 200s of the simulation time which help keeping more alive nodes than LEACH does through the simulation time of this scenario :

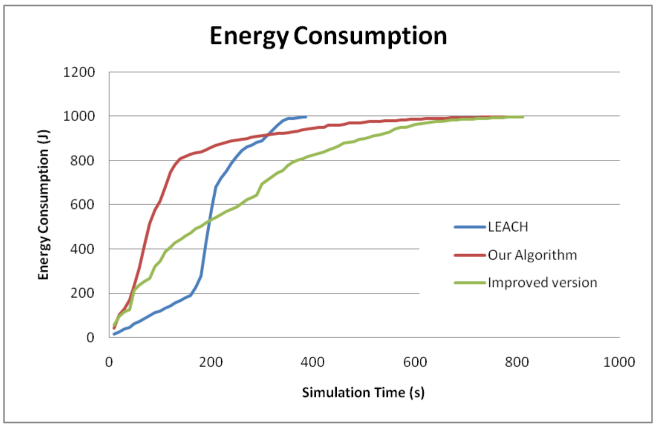

Figure 9. Energy consumption in scenario 2.

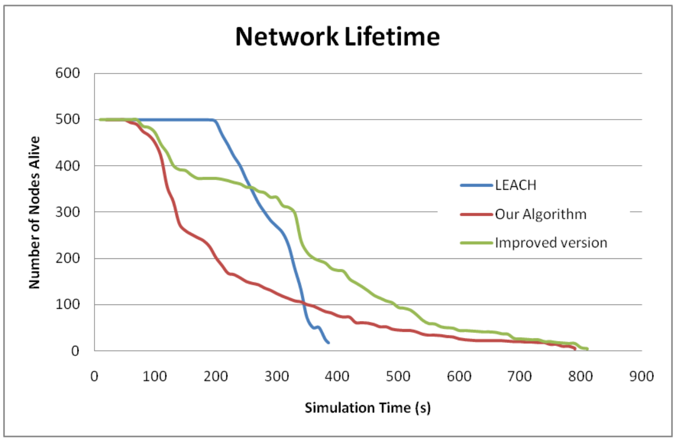

Figure 10. Lifetime span in scenario 2.

as in scenario 1, we could observe that the improved version behave in the same manner, by changing the rate of energy consumption and the number of died nodes whenever the network lost the number of nodes that indicates a diminution of zones.

With the assumption that a node is playing with 50 node, the probability value could be represented this time as Figure. 11, we could observe also the gap between values of p_{NE} when the number of nodes decrease in Figure. 12 :

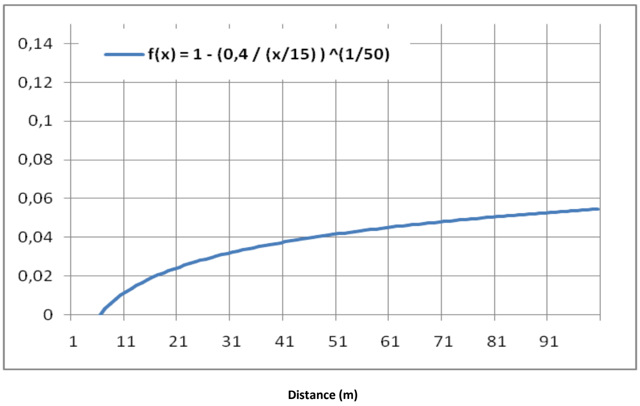

Figure 11. Nash Equilibrium probability variation (50 player).

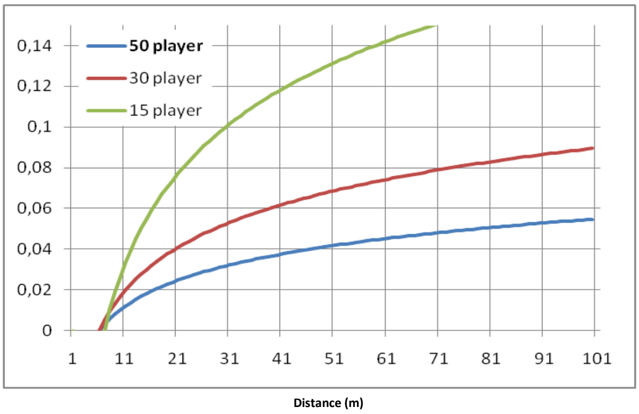

Figure 12. Values of p_{NE} with different set of players (50.30.15)

We could see that with the higher density of nodes in scenario 2 the value of the probability function tends to take a reasonable value that vary tightly around the theoretical desired percentage, especially when the separation distance is between 40 and 100 m.

CONCLUSION

In this article, we propose an improvement of LEACH protocol using a non-cooperative game model and mixed strategy Nash Equilibrium solution concept, in this model of game we consider that playing nodes are given higher gain by avoiding to be cluster head when a close neighbor node is a cluster head, simulation results confirm that in larger networks the proposed algorithm is showing better performance than LEACH, however results confirm also that the proposed algorithm need to be ameliorated in order to operate better under different environment conditions.

The aim of our future work is to obtain a more precise value the equilibrium probability, by computing a more precise value of the cost that takes into account also the distance between the cluster head and the base station, we also aim to find a more sophisticated manner of area subdivision technique in order to give a node more information about neighbor decisions.

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