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A NEW HIERARCHICAL ROUTING PROTOCOL MLHEED FOR LARGE SCALE WIRELESS SENSOR NETWORK

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ABSTRACT
The choice of routing protocols is an important element for large scale wireless sensor network. These protocols allow minimization of information processing at each sensor. Indeed, each packet sent or received use a limited energy resources. The best flow of information minimizes the energy consumption which is provided in this case by battery. It is a limited resource and can quickly run out. The frequent replacement of the latter in this context is excluded. To remedy this problem, we propose in this paper a new hierarchical protocol MLHEED (Multi-Level Hybrid, Energy-Efficient, Distributed approach). This protocol takes into account these critical points that characterize this type of network. Its objective is to maximize the lifetime of the network after deployment. For this, we adopted a multi-hop routing between elected nodes (cluster head). The protocol MLHEED is based on the HEED protocol for organizing wireless sensor network in the form of clusters, and selecting one representative for each cluster (cluster head). We adopted two approaches: the first approach is based on the execution of HEED protocol, after each level to another, which results in a multi-hop communication. The second approach is an improvement of the first, since the execution of HEED protocol at level passage becomes costly in terms of energy consumption. Thus, we adopted a method for the selection of cluster head. This method takes into account two factors which are the distance between the cluster heads and the base station, and the residual energy in the election (cluster head).

Both approaches were evaluated by simulation according to existing metrics and new metrics proposed and have proven their performance.

INTRODUCTION
In wireless sensor network, we find several techniques to minimize energy consumption, among these techniques is the routing. The routing problem is to establish an optimum route through the network under performance criterion. Routing protocols proposed for wireless sensor networks can be classified into two main categories [2,3]: flat routing and hierarchical routing.

Flat routing [1]
The objective of this type of routing is to minimize duplication of data that can be very disadvantageous especially in terms of energy consumption and network overload. Among these protocols, we find Direct Diffusion [4,3] that builds and maintains multiple paths for each destination. There are also "Minimum Cost-Forwarding" [3,5] that seeks the best path in terms of metrics used for sending data. Another algorithm: EnergyAware-Routing [6] constructed a set of best paths and chooses one of them in a probabilistic way.

Hierarchical routing
The second family includes the different technical protocols that use clustering and aggregation of data to minimize the number of packet transmitted to the base station. The formation of clusters and their choice of elected nodes are based on the energy reserve of sensors and the proximity of the elected nodes. Among these protocols, there is the LEACH protocol [7] that constructs clusters in a completely distributed and HEED protocol [8] which uses a principle similar to LEACH while ensuring a good distribution of clusters.

Description of the protocol MLHEED (Multi Level Hybrid, Eenergy-Efficient, Distributed approach)
In the theme of wireless sensor network, there are several approaches to hierarchical routing, efforts were concentrated on the definition of a hierarchical topology with two or more levels based on the clusters. In this context we proposed a new protocol based on clustering technique and the technique of multi-level hierarchy.

Our protocol is based on the HEED protocol to organize the wireless sensor network in the form of clusters and the selection of elected officials (one sensor node, which organizes the operation within the cluster) appears for each cluster.

Since, our MLHEED protocol is based on the HEED protocol, we will start by presenting it in the following subsections:

HEED (Hybrid, Eenergy-Efficient, Distributed approach)

The HEED protocol makes no restrictions on the distribution and density of nodes. It does not depend on network topology or size but it assumes that the sensors can change their transmission power. The HEED protocol selects the cluster head on the basis of two criteria: the remaining energy in the nodes and the degree of the nodes. It aims to achieve a uniform distribution of clusters in the network of wireless sensor and generate balanced clusters in size. A node is elected with a probability equal to $P_{ch} = C_{prob}\frac{E_r}{E_{total}}$,$E_r$: remaining energy of node. E_{total}total energy in the network and C_{prob} : the optimal number of clusters. However, the evaluation of E_{total} presents a challenge because of the absence of any central control. Another, problem in determining the optimal number of clusters. In addition, the HEED protocol does not specify a particular protocol to be used for communication between the cluster head and the receiver. Inside the cluster, the problem does not arise since the communication between the cluster members and cluster head is direct (one hop). On the other hand, with the HEED protocol, topology clustering does not perform minimum energy consumption in the intra-cluster communications and generated clusters are not balanced in size. Following these critical points in the HEED protocol, we propose MLHEED protocol that supports communication between elected node and those nodes in the cluster and elected them. Our MLHEED protocol ensured a multi-hop communication.

The MLHEED protocol

The first step of the HEED protocol is hold the wireless sensor network as a cluster. Each cluster is characterized by an cluster head which collects information of its cluster nodes before sending it to the base station. The problem arises when there are elected rather far from the base station, they will suffer in terms of energy causing them switched off quickly compared to cluster head close to the base station. To solve this problem we adopted a new approach called the MLHEED (Multi Level Hybrid, Eenergy-Efficient, Distributed), which is to impose on elected to get their information removed step by step through the elected neighbors until the station base.

The network is then organized as a levels, the number of levels depends on the size of the network. We understand well that this approach is well suited especially for large network. After the selection of the head using the technique of the HEED protocol (level 1), we apply again the HEED protocol on the head that we have originally chosen is the first level, then we repeat this process which depends on network size , when the network is larger there will be more levels in the decomposition of the network. In the next section we evaluate the performance of MLHEED protocol.

Performance evaluation of MLHEED protocol

We evaluated the performance of the protocol MLHEED by its implementation and simulation using MATLAB. We present some results in this section. We start first by specifying the metric we used for simulation.

Metric of simulation

In the Table below we set the value of the parameters of the simulation MLHEED protocol

Table 1: Parameters of the simulation

Parameters	value
Size of data packet	800bits
Size of broadcaste packet	200bits
T_{no}	5 TDMA
E_{elec}	50nj/bit
E_{fs}	10pj/bit/m^2
E_{amp}	0.0013pj/bit/m^4
E_{fusion}	5nj/bit/signal
C_{prob}	5%

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E : énergie	0.5 J
d_0	87m

The principle of MLHEED protocol

After running the HEED protocol, the network will be organized as clusters, each cluster is characterized by a set of nodes and their cluster head. The cluster head is responsible for collecting information of its nodes to send it to the base station. Each cluster is defined by a coverage radius R1. Then we run again another time HEED protocol with a radius R2> R1 elected on a level to get the politicians we elect will appoint super-head. We must ensure that the covered radius increases from one level to another to ensure good interaction between cluster head. So to apply the HEED to the next level of cluster head of the previous level, increase the radius of coverage because otherwise no elected cluster will be located in the coverage radius of each other and the elected cluster will be isolated . In the following subsections we simulate our protocol for different levels. By definition, each level is the result of executing HEED protocol on wireless sensor network.

MLHEED protocol at two levels

To organize the network of cluster head shape with a radius R1 of coverage for each cluster, we perform again the HEED protocol on cluster head are selected at level 1 with a coverage radius twice the radius of the cluster of level 1, we have at the end groups consisting of elected and super-head of cluster head is the level two. So, after the phase of the network organization, the data transfer phase can start: each node sends its data to its cluster head. The latter after receiving all the data members of its cluster, will merge them (aggregation) if they have a super-head, it will send him the merged data, otherwise it is a super-head of group, it will wait for the other cluster head (which he is himself a head) to transmit their data, then it will merge and send it to the base station. In the following figure we compare the protocol HEED Level 1 and Level 2 in terms of the life of network area (100 * 100) and an equal number of node 100 with a coverage radius equal to 25 m and the radius of coverage level two is double the radius of the coverage level 1.

The figure 1 shows the effectiveness of our protocol to organize the network as levels, which is explained by the lifetime of wireless sensor network of more than level 2 nodes alive over at level 1 as a consequence the flow of information from a super-head to the head then to the base station becomes more efficient in terms of energy consumption from direct communication with the head of the base station. In Figure 1 we see that the two curves coincide when the number of node equals 20, so no need to apply Level 2, the level 1 performance.

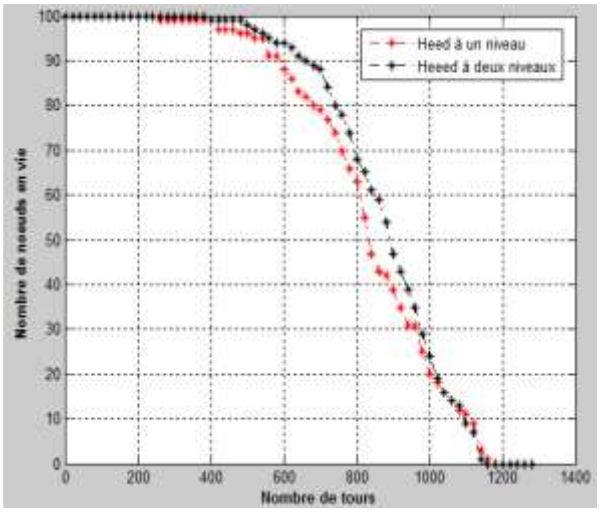

Figure 1: lifetime of wireless sensor network on two levels with 100 nodes over an area 100 * 100.

Now we repeat the simulation of 200 nodes randomly distributed over an area 200 * 200 with energy 1J for each sensor node. The simulation results are shown in the following figure:

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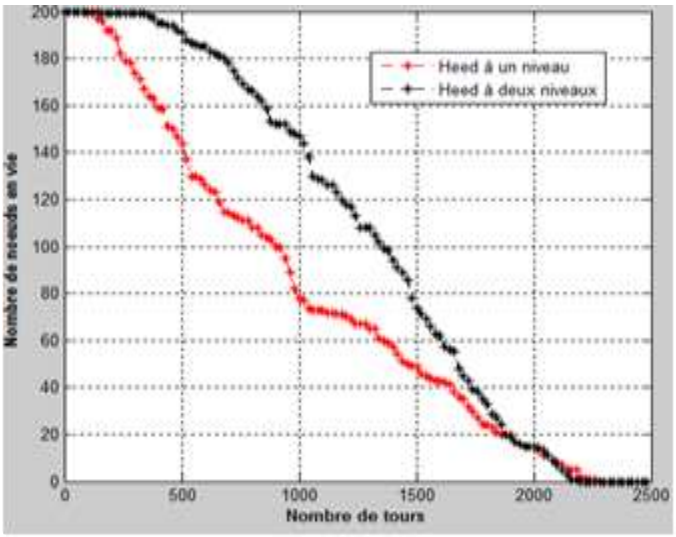

Figure 2: lifetime of wireless sensor network on two levels with 200 nodes over an area 200 * 200.

Now the difference between the curves is appeared, we note that the level two more efficient, increases when the size of the network becomes effective MLHEED from HEED (Level 1). So multi-hop communication becomes useless to maximize lifetime of wireless sensor network. In the following we increase the size and the area monitored by the wireless sensor network, simulation results are shown in the following figures

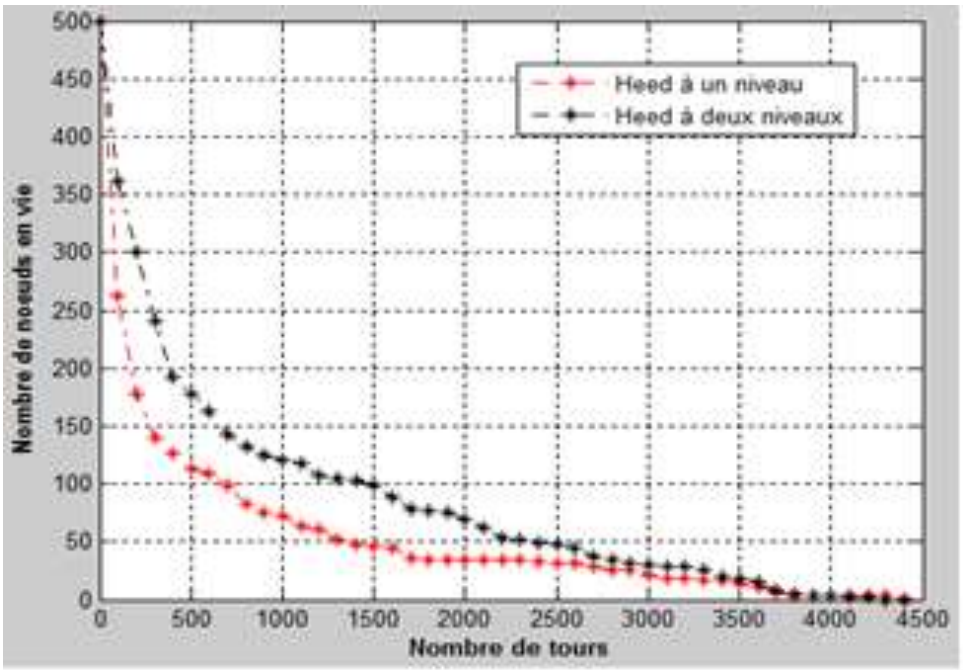

Figure 3.a: lifetime of wireless sensor network on two levels with 500 nodes over an area 500 * 500.

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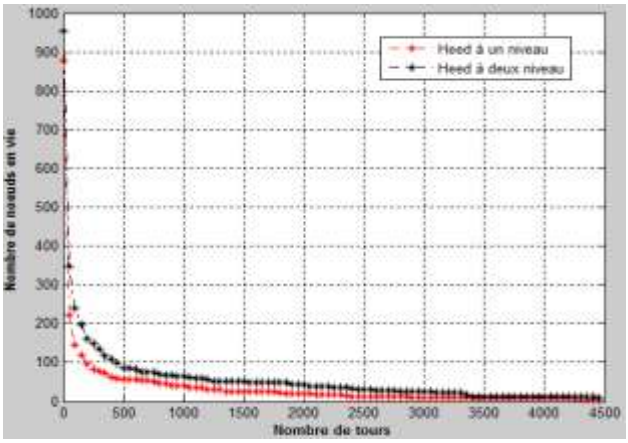

Figure 3.b: lifetime of wireless sensor network on two levels with 1000 nodes over an area 1000 * 1000.

We note that for both figures 3(a.b), the lifetime for the level two is better than the Level 1 (HEED) even in a large network, but the two curves in a rapid decrease due to the fact the head is too far from each other and the base station is far away so that the head consume more energy to move their data to the base station. The head that are close to the station below have more chance to remain in sight. This also justifies why the two curves meet at the end, as the last remaining nodes which are limited in number are the nearest base station. We try in the next subsection to increase the number of levels for the performance MLHEED network of wireless sensor.

MLHEED protocol at three levels

In this subsection we make the simulation protocol MLHEED at three levels for the impact of this protocol on wireless sensor network. We follow the same procedures we used in the sub-Section 3. We apply the HEED protocol on cluster head of the level 2 with a coverage radius greater than the radius of coverage of level 2.We will have at the end the clusters formed from super-head for level 3. After organizing network in the form of levels, the data transmission phase begins. Thus, each node sends data packets to the head and the heads collect the information of its nodes and then sent to the super-head, to the base station. We start the simulation of the life of 200 node distributed over an area 200 * 200 with an energy 1J for each node. The simulation result is shown in the following figure

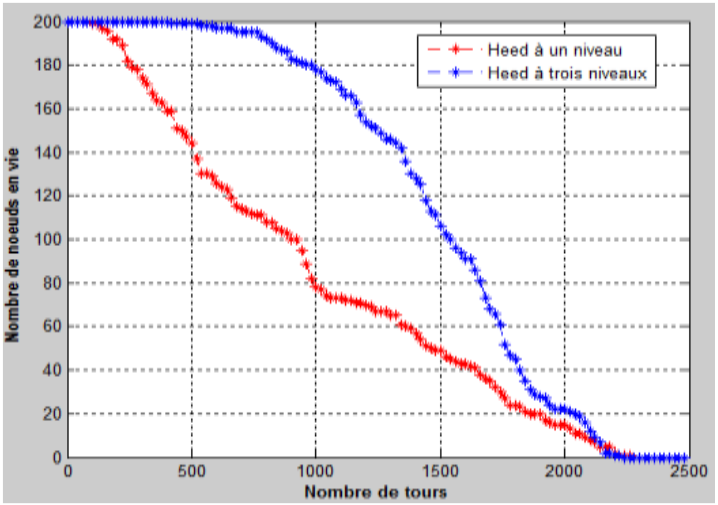

Figure 4.a : lifetime of wireless sensor network at three levels over an area 200 * 200 and 200 nodes

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Now, we simulate the protocol MLHEED has three levels of a wireless sensor network has great size, life span of 1000 node distributed over an area 1000 * 1000 with an energy 1J for each node. The simulation result is shown in the following figure:

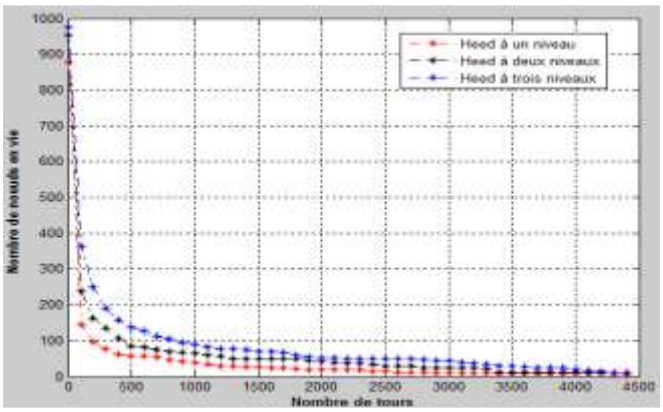


Figure 4.b : lifetime of wireless sensor network at three levels over an area 1000 * 1000 and 1000 nodes

When we increase the number of levels in the wireless sensor network, the network lifetime becomes better compared to the lifetime of level 1 which explains the effectiveness of protocol MLHEED. The Figure 6.b shows that Level 3 is better than the Level 2 and Level 1.We present the following figure a comparison between the different levels.

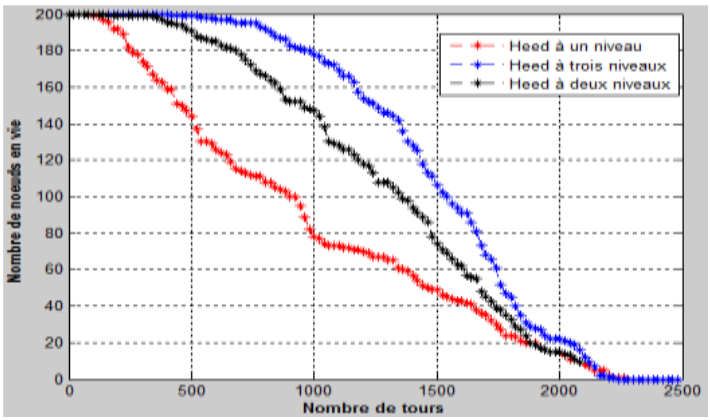


Figure 5 : comparison of the lifetime of wireless sensor network between the different levels

In this section, we showed the performance of protocol MLHEED from the HEED protocol. Thus the mechanism of multi-hop routing becomes a solution to minimize energy consumption compared to a single jump, or the execution of HEED protocol at each transition from one level to another wasted energy in sensor nodes. In this context, we proposed an approach for the improvement of our protocol, which is the objective of the next section.

Amelioration of MLHEED protocol

Description

In the previous section, we started by simulating protocol MLHEED, and we executed the algorithm HEED protocol for each transition from one level to another, consequently the performance of the algorithm of the HEED protocol for level 2 and Level 3 results in energy loss for the super-head. In this section we propose a solution not to run the algorithm HEED protocol again, so we apply once the protocol HEED for level 1. After the election of the head for each cluster (level 1), we run another algorithm on them to have the super-head.

- We define our algorithm: Each cluster head will calculate a factor $f = \frac{E_r}{d}$ or E_r is the residual energy of the cluster and head: d distance is the distance between the chosen cluster and the base station, then it will broadcast its factor of a door that is twice the radius of level 1. Each cluster head will receive the message containing the values of the factors that brought about its neighbors, the node will be the largest

factor in the value of the radius will be elected the super-head. In case a cluster head node is carried in two cluster head nodes are elected super-head he will choose to join the super-head closed.

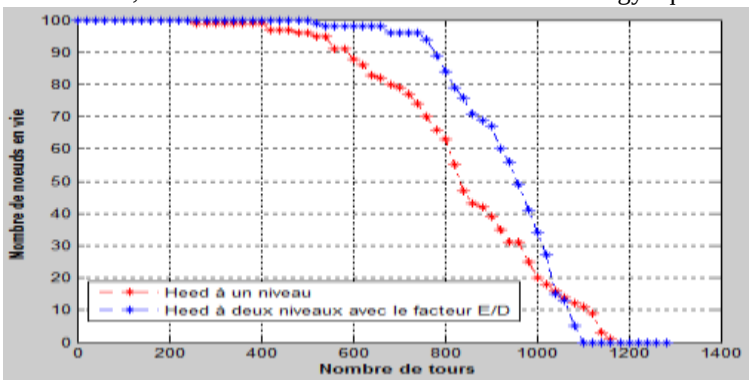
- After running the algorithm HEED protocol at level 1 and the election of super-head at level 2 based on the factor $f = \frac{E_r}{d}$, the phase of data transmission can begin: each node sends its data to its cluster head it after receiving all the data members of its cluster, it will merge them (aggregation) it has a super-cluster head is going to transmit the merged data if it is a super-cluster head it will wait for the other cluster head which he is elected he will transmit their data is then merged and transmitted to the base station. The advantage of this idea is to take into account the residual energy of cluster head and the distance between cluster head and the station.

Validation

In this section we validate our simulation approach for the improvement reported for MLHEED Protocol:

With 100 node disturbed over an area 100 * 100 m2

- We first simulate the life of Heed to a level and then we apply the factor E / d on the second level on a surface 100mx100m, the number of nodes 100 and the initial energy equals 0.5J and the coverage radius



for level 1 = 25m radius of coverage for Level 2, R2 = 50m with position of the base station Bx = 50m and By=150m.

Figure 6: lifetime for MLHEED (level 1) and second levels

In Figure 6, the lifetime for level 2 is better than MLHEED (level 1). This explains the efficiency factor for the election of super-head2.2) with 200 nodes distributed over an area 200 * 200.
Then we simulate the life of MLHEED (Level 1) and the factor E / d at two levels to the surface 200x200, the number of nodes = 200 nodes with initial energy = 1J. The radius of the cluster level 1 = 25m, the radius of the cluster level 2 = 50m, 100m and Bx =100m, By = 250m.le simulation result is shown in the following figure

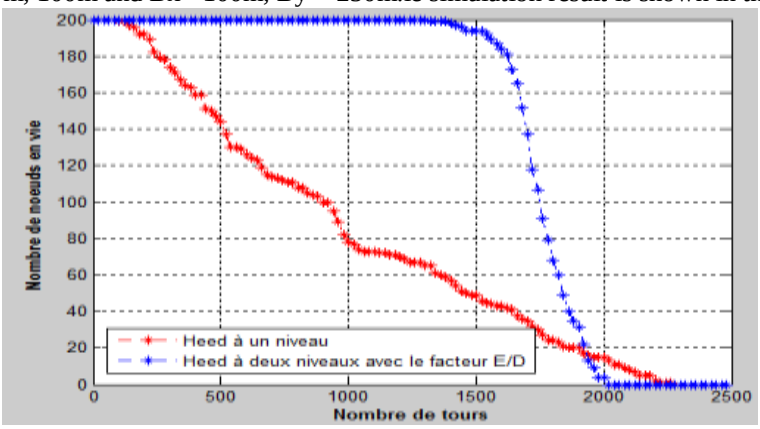


Figure 7: the lifetime of wireless sensor network

In this case, the factor becomes effective compared MLHEED protocol (level 1).

With 1000 node distributed over an area 1000 * 1000

We simulate of the lifetime of MLHEED at a level and with the factor E / d at two levels to the surface = 1000x1000 and the number of nodes = 1000 nodes with initial energy 3J.Le radius for the cluster level 1 = 25m and the radius of cluster level 2 = 50m. the position of the base station Bx = 500m and By=1050m

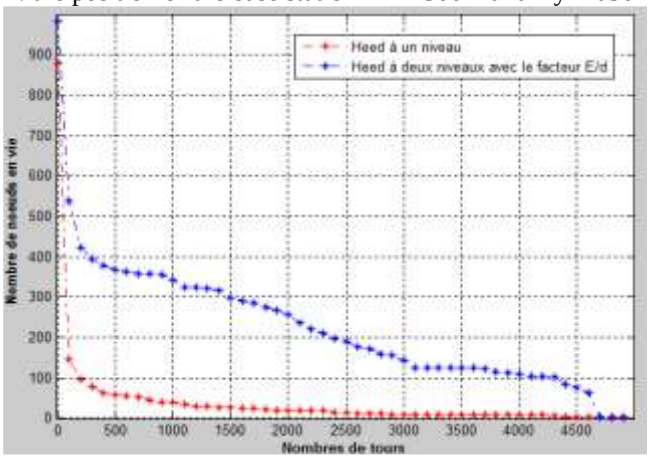


Figure 8: the lifetime of wireless sensor network using the protocol MLHEED (level 1) and the second level

Improvement of this approach, we reduced the number of advertisement messages exchanged during the establishment phase cluster by applying the HEED protocol. But we guarantee that the cluster head of level two, will be the largest value of energy, it will be closest to the base station, it will be two conditions met. The curves we see that there is more energy efficient because the number of nodes alive in the network falls below the other curves. However when the number of nodes in the network wanted significantly decreased the curve of life of a wireless sensor network using the HEED is improved at two levels below that of the HEED protocol to a single-level again, we note that the realization of a hierarchy of a small number of nodes is not profitable.

CONCLUSION

In this paper, we described the efficacy of hierarchical protocol for wireless sensor network of large size. Therefore we proposed a new MLHEED protocol based HEED protocol and taking into account two factors, the distance between clusters head and the base station and the residual energy in cluster head.

For this, we showed the effectiveness of our protocol compared to HEED protocol in terms of energy consumption, which is shown by simulation results. However, our protocol is based on a hierarchical topology with two or more levels and each level based on clusters and a head for each cluster.

These head nodes requiring numeracy and communication more important, their choice require the instrumentation of the network, for applying the selection criteria. Another critical point is the need for decentralized decision-making, especially in large networks. In this context, our objective is to propose a MAC protocol based on topology organized as clusters, with a cooperative MIMO communication between them.

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