International Journal of Computer Science, Communication & Information Technology (CSCIT)
Vol.6 pp.9-18

Remarkable Performance of Multilevel Deployment in Wireless Sensor Networks

Abderrahmane El Aalaoui[#1], Abderrahmane Hajraoui[#2]
[#]*Department of Physics,Communication and detection systems laboratory*
Faculty of Sciences, University of AbdelmalekEssaadiTetouan, Morocco
[1]elaalaoui.abderrahmane@gmail.com
[2]hajraouiabder@gmail.com

***Abstract*— In this paper, we present a multilevel network model using two criteria. The first one makes it possible to determine the number of levels according to the dimension of the space and the second one makes it possible to determine the rate of the nodes in each level. Using this wonderful model, we evaluate the performance of LEACH as a cluster communication protocol. In this case, the name of the protocol is LEACH 3D-*n*Level. We also compare the energy efficiency of a three dimensional network in different large spaces. We organize the deployment of the networks in these spaces so that the energy consumed is minimal. With these new operations, the LEACH 3D-TwoLevel, the LEACH 3D-ThreeLevel, the LEACH 3D-FourLevel and the LEACH 3D-FiveLevel offer a network lifetime increase of 11%, 52%, 75% and 378%. They also offer a network throughput increase of 56%, 62%, 253% and 360%.**

***Keywords*—Wireless Sensors Network, WSN, LEACH protocol, Multilevel deployment, Three dimensional network, Energy efficiency.**

I. INTRODUCTION

Recently, wireless sensor networks have known a great prevalence. It is due to their large applications in large spaces such as underwater, space communications, atmospheric, forest or building. In the reality, the nodes deployment of WSN is done in a random manner and on a three dimensional space (see figure 1), against a two dimensional plane model (see figure 2) [1]. A three dimensional WSNs is a set wireless sensor nodes distributed in a three dimensional space. Each sensor node has a function to sense an event measure, such as temperature, pressure or vibration and send their measurements toward a processing center called sink [1, 2]. Due to the limitation in their battery capacity which their replacement is impossible, the optimization of this unique resource has become a major issue. Nodes clustering are an effective technique for improving the energy efficiency and prolonging the lifetime of a WSN [3]. It has been widely studied in two dimensional WSNs. LEACH [3,4] is one of the first protocols, which use this technique and has been applied into the underwater environment [5,6,7,8].

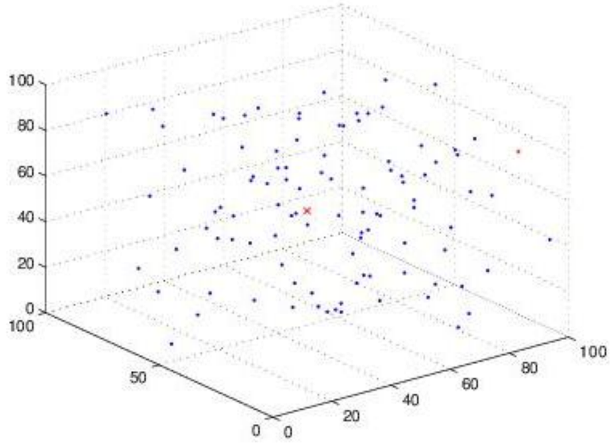


Fig. 1: 3D deployment

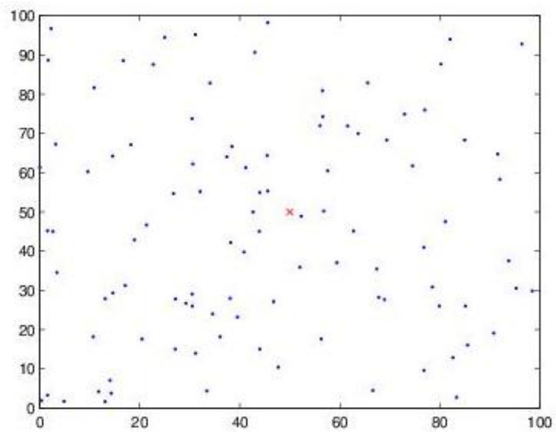


Fig. 2: 2D deployment

The works in [9] show that a real network consumes more energy than a network in two dimensional plan. However, in large spaces, the energy consumption increases even if the network communicates with a technique like LEACH, only a good management of the nodes deployment can solve this problematic. We propose in our work a controlled deployment of sensors, in order to control the intensive energy leakage in extended spaces.

ISSN 2356-5608

II. RELATED WORK

In the reference [10], they propose a three dimensional coverage model and an optimum deployment scheme for wireless sensor networks. In [11] and [12], the proposed approach is aimed at optimizing the number of sensors and determining their localization to support distributed sensor networks. In [13], the authors study the issue of optimal deployment to achieve four connectivity and full coverage for wireless sensor networks.

In the reference [14], the authors present an effective method to estimate the number of nodes to be deployed in a given area for a predetermined lifetime. This is on the condition to ensure total energy utilization and 100% connectivity. In [15], the authors improve an energy efficient position based on three dimensional (3D) routing algorithm using distance information. This affects transmission power consumption between nodes as a metric. F. Saleem et al in [16] propose a scheme which reduces coverage and energy consumption by dividing the network into small segments with static number of Cluster Heads.

III. OVERVIEW

Generally, in a WSN, the transmission energy of a segment of size L, is expressed as follows:

$$\begin{cases} E_{TX} = LE_{elec} + L\varepsilon_{fs} d^2 & if \quad d \le d_0 \\ E_{TX} = LE_{elec} + L\varepsilon_{mp} d^4 & if \quad d > d_0 \end{cases} \qquad (1)$$

With: $d_0 = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}}$

When the distance between the node and the base station increases, the transmission energy also increases. In Figure 3, we illustrate the difference between the energy consumption, in the two spaces: 2D and 3D.

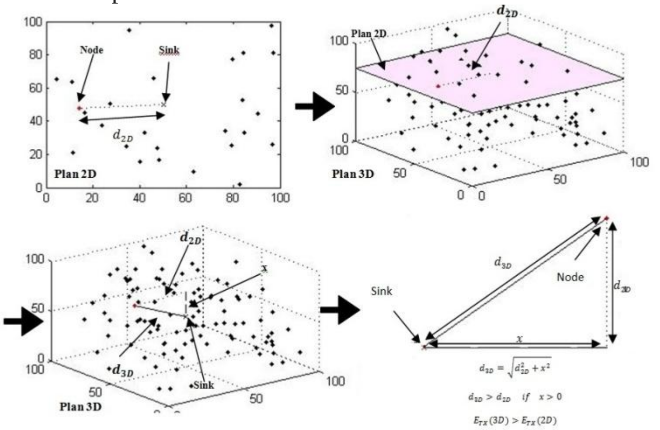


Fig. 3: The difference between the energies dissipated in 3D and 2D

The distortion of the space results a change of the vertical location of the nodes. Therefore, an extended distance from the base station appears. This distance can be more extended in a large space.

We consider a base station located in the center of a space designated by a cube. The farthest point (node) of the center (BS) , is the cube corner. And the distance between center and the corner is expressed by formula (2):

$$d = \frac{\sqrt{3}}{2} x \qquad (2)$$

Where *x* is the cube dimension.

The graph (see Figure 4) shows the position of the farthest node from the base station, respecting to the volume space.

The change of d in equations (1) by that in (2), gives the following equations (3):

$$\begin{cases} E_{TX} = LE_{elec} + L\varepsilon_{fs} \frac{3}{4} x^2 & if \quad d < d_0 \\ E_{TX} = LE_{elec} + L\varepsilon_{mp} \frac{9}{16} x^4 & if \quad d \ge d_0 \end{cases} \qquad (3)$$

With: $d_0 = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}}$

In our research, we are interested only by the extended spaces $(d > d_0)$. Equations (3) therefore can be written as follows:

$$E_{TX} = LE_{elec} + L\varepsilon_{mp} \frac{9}{16} x^4 \qquad (4)$$

We can conclude that, more the studied spaces are extended enough; more the energy consumption increases during transmission of the bits. The graph (see figure 5) shows this relationship. For energy consumption, the space remains useful, if it does not exceed the dimension limit: 100m. Beyond that, it is infected by intense energy leaks.

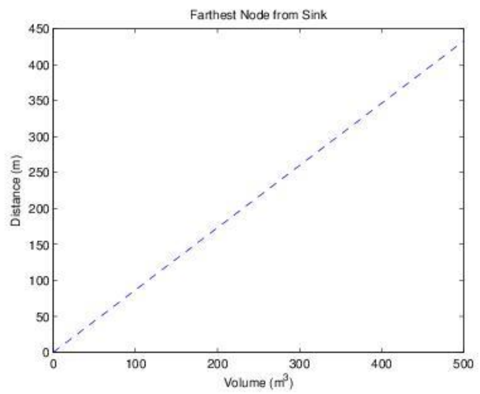


Fig.4: The influence of the space dimension on the distance of the farthest node from the base station

ISSN 2356-5608

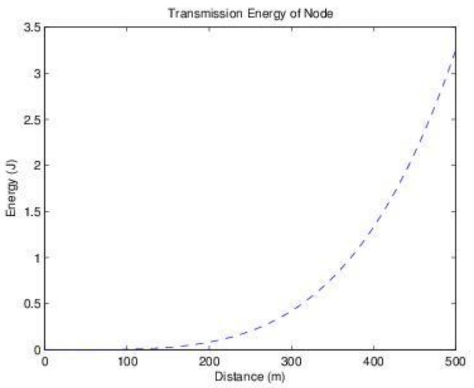


Fig.5: The influence of the space dimension the energy consumption

IV. Multilevel Deployment Model of Three Dimensional WSN

Our study, allows analyzing in the extended spaces, the effect of the node deployment on energy consumption. Therefore, a controlled deployment will be chosen to develop our conception. Such dynamism minimizes the rate of nodes located in wide distances from the base station, and maximizes this rate in short distances.

Authors in [9], studied the WSN in a volume space of $100m^3$ with centered base station. According to equation (2), the distance d of the farthest node cannot be greater than 86.6m: $d = \frac{\sqrt{3}}{2}$x 100=86.6 m

And since

$$d_0 = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \approx 87.7\ m$$

Then, the equation (1) of the energy according to the simulation in [9] is written as follows:

$$E_{TX} = LE_{elec} + L\varepsilon_{fs}d^2 \qquad (5)$$

Our proposition is to segment the deployment of the nodes in levels. When the dimension of the space exceeds the limit 100m. According to the critical distance d_0, the number of levels is calculated in the following way:

$$n = real(\frac{D}{d_0}) \qquad (6)$$

D: the space dimension

Each level contains a nodes rate different to next level, as well as the dense levels are closer to the base station and vice versa.

A. *Energy Model*

This study assumes a simple model for the radio hardware. The transmitter dissipates there, energy for running the radio electronics, for amplifying and for transmitting the signals. The receiver runs to the radio electronics for signals reception [7]. Therefore, they are considered multipath fading model (d^4 power loss) for large distance transmissions and the free space model (d^2 power loss) for proximal transmissions. Thus to transmit a bits message over a distance d, the radio expends:

$$E_{TX}(l,d) = E_{TX-elec}(l) + E_{TX-amp}(l,d) \qquad (7)$$

$$E_{TX-elec}(l) = lE_{elec} \qquad (8)$$

$$E_{TX-amp}(l,d) = \begin{cases} l\varepsilon_{fs}d^2 \ when\ d < d_0 \\ l\varepsilon_{mp}d^4 \ when\ d \geq d_0 \end{cases} \qquad (9)$$

Where d is the distance threshold for swapping amplification models. It can be calculated as:

$$d_0 = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \qquad (10)$$

To receive an *l* bits message, the receiver expends:

$$E_{RX}(l) = lE_{elec} \qquad (11)$$

To aggregate n data signals of length *l* bits, the energy consumption was calculated as follows:

$$E_{DA-expend}(l) = lnE_{DA} \qquad (12)$$

B. *Network Model*

1. N sensors are uniformly distributed in n levels within a space 3D. It is a rectangular field A=D x D x D. The base station is positioned in the center of the space region.

2. According to the equation (13), each level contains a rate R of N. This is indicated in the following table.1:

TABLE I
Nodes Rate

Level *n*	**Two Level**	**Three Level**	**Four Level**	**Five Level**
Level 1	90%	70%	40%	35%
Level 2	10%	20%	30%	25%
Level 3	N/A	10%	20%	20%
Level 4	N/A	N/A	10%	15%
Level 5	N/A	N/A	N/A	5%

ISSN 2356-5608

International Journal of Computer Science, Communication & Information Technology (CSCIT)
Vol.6 pp.9-18

$$N = \sum_{i=1}^{n} R_i \times N \qquad (13)$$

3. All nodes are deployed randomly.
4. Each sensor can sense the environment in a sphere field of radius r.
5. All sensors are homogeneous, i.e., they have the same capacities.
6. All the sensor nodes have a particular identifier (ID) allocated to them. Each cluster head coordinates the MAC and routing of packets within their clusters.

C. *Optimal number of cluster*

We assume there are N_1, N_2...N_n nodes distributed uniformly in volumes $(2d_0)^3$, $(3d_0)^3$...D^3 respectively. If there are c_1, c_2…c_n clusters, there are on average $\frac{N_1}{c_1}$, $\frac{N_2}{c_2}$ ... $\frac{N_n}{c_n}$ respectively, nodes per cluster. Each cluster-head dissipates energy receiving signals from the nodes and transmits the aggregate signal to the base station. Therefore, the energy dissipated in the cluster-head node during a single frame is:

$$\begin{cases} E_{CH1} = l\frac{N_1}{c_1}E_{elec} + l\frac{N_1}{c_1}E_{DA} + l\varepsilon_{fs}d_{toBS\,1}^2 \\ E_{CH2} = l\frac{N_2}{c_2}E_{elec} + l\frac{N_2}{c_2}E_{DA} + l\varepsilon_{mp}d_{toBS\,2}^4 \\ \vdots \\ E_{CHn} = l\frac{N_n}{c_n}E_{elec} + l\frac{N_n}{c_n}E_{DA} + l\varepsilon_{mp}d_{toBSn}^4 \end{cases} \qquad (14)$$

Where l is the number of bits in data message. d_{toBS} is the distance from the cluster head node to the BS, and we have assumed perfect data aggregation E_{DA}.

The expression for the energy spends by a non-cluster head is given by:

$$E_{nonCH} = lE_{elec} + l\varepsilon_{fs}d_{toCH}^2 \qquad (15)$$

Where d_{toCH} is the distance from the node to the cluster head.

Let $E[d_{toBS\,1}^2]$, $E[d_{toBS\,2}^4]$, … $E[d_{toBSn}^4]$ be the Expected distances of clusters head c_1, c_2…c_n respectively, from the base station. Assuming that the nodes are uniformly distributed in each level, so it is calculated as follows:

$$\begin{cases} E[d_{toBS1}^2] = \int_0^{x_{max\,1}}\int_0^{y_{max}}\int_0^{z_{max}}(x^2+y^2+z^2)\,f_1(x,y,z)dxdydz \\ E[d_{toBS2}^4] = \int_{x_{max\,1}}^{x_{max\,2}}\int_0^{y_{max}}\int_0^{z_{max}}(x^4+y^4+z^4)f_2(x,y,z)dxdydz \\ \vdots \\ E[d_{toBSn}^4] = \int_{x_{\max(n-1)}}^{x_{maxn}}\int_0^{y_{max}}\int_0^{z_{max}}(x^4+y^4+z^4)f_n(x,y,z)dxdydz \end{cases} \qquad (16)$$

Where $f_1(x,y,z)$, $f_2(x,y,z)$… $f_n(x,y,z)$ are the probability density functions of three dimensions random variable $X(x,y,z)$ which is a uniform for each level and given by:

$$\begin{cases} f_1 = \frac{1}{V_1} = \frac{1}{(2d_0)^3} \\ f_2 = \frac{1}{V_2} = \frac{1}{(3d_0)^3} \\ \vdots \\ f_n = \frac{1}{V_n} = \frac{1}{D^3} \end{cases} \qquad (17)$$

If we assume that base station is the center of the network, we can pass in the spherical coordinates:

$$\begin{cases} E[d_{toBS\,1}^2] = \int_0^{r_{max\,1}}\int_0^{\pi}\int_0^{2\pi} r^2 f_1(r,\theta,\varphi)r^2\sin\theta\, drd\theta d\varphi \\ E[d_{toBS\,2}^4] = \int_{r_{max\,1}}^{r_{max\,2}}\int_0^{\pi}\int_0^{2\pi} r^4 f_2(r,\theta,\varphi)r^2\sin\theta\, drd\theta d\varphi \\ \vdots \\ E[d_{toBSn}^4] = \int_{r_{\max(n-1)}}^{r_{maxn}}\int_0^{\pi}\int_0^{2\pi} r^4 f_n(r,\theta,\varphi)r^2\sin\theta\, drd\theta d\varphi \end{cases} \qquad (18)$$

The area of network is aspheric with radius $r_{max\,1} = 2d_0\sqrt[3]{3/4\pi}$, $r_{max\,2} = 3d_0\sqrt[3]{3/4\pi}$ … $r_{\max(n-1)} = nd_0\sqrt[3]{3/4\pi}$, $r_{max\,n} = D\sqrt[3]{3/4\pi}$.

If the density of sensor nodes is uniform throughout the area then becomes independent of r, θ and φ then:

$$\begin{cases} E[d_{toBS1}^2] = f_1(r,\theta,\varphi)\int_0^{2d_0\sqrt[3]{3/4\pi}}\int_0^{\pi}\int_0^{2\pi} r^4\sin\theta\, drd\theta d\varphi \\ E[d_{toBS2}^4] = f_2(r,\theta,\varphi)\int_{2d_0\sqrt[3]{3/4\pi}}^{3d_0\sqrt[3]{3/4\pi}}\int_0^{\pi}\int_0^{2\pi} r^6\sin\theta\, drd\theta d\varphi \\ \vdots \\ E[d_{toBSn}^4] = f_n(r,\theta,\varphi)\int_{nd_0\sqrt[3]{3/4\pi},}^{D\sqrt[3]{3/4\pi}}\int_0^{\pi}\int_0^{2\pi} r^6\sin\theta\, drd\theta d\varphi \end{cases} \qquad (19)$$

$$\begin{cases} E[d_{toBS\,1}^2] = \frac{6}{5}\left(\frac{3}{4\pi}\right)^{\frac{2}{3}} {d_0}^2 = 0.4664\, {d_0}^2 \\ E[d_{toBS\,2}^4] = \frac{3}{14}\left(\frac{3}{4\pi}\right)^{\frac{4}{3}} \frac{3^7-2^7}{3^3} {d_0}^4 = 2.4333\, {d_0}^4 \\ \vdots \\ E[d_{toBSn}^4] = \frac{3}{14}\left(\frac{3}{4\pi}\right)^{\frac{4}{3}} \frac{D^7-(nd_0)^7}{D^3} = 0.0319\, \frac{D^7-(nd_0)^7}{D^3} \end{cases} \qquad (20)$$

The expected squared distance from the nodes to the cluster head (assumed to be at the center of mass of the cluster) is given by:

ISSN 2356-5608

$$\begin{cases} E[d_{toCH1}^2] = \int_0^{r_{max1}} \int_0^{\pi} \int_0^{2\pi} r^2 f_1(r,\theta,\varphi) r^2 \sin\theta \, dr d\theta d\varphi \\ E[d_{toCH2}^2] = \int_{r_{max1}}^{r_{max2}} \int_0^{\pi} \int_0^{2\pi} r^2 f_2(r,\theta,\varphi) r^2 \sin\theta \, dr d\theta d\varphi \\ \vdots \\ E[d_{toCHn}^2] = \int_{r_{\max(n-1)}}^{r_{maxn}} \int_0^{\pi} \int_0^{2\pi} r^2 f_n(r,\theta,\varphi) r^2 \sin\theta \, dr d\theta d\varphi \end{cases} \quad (21)$$

If we assume this area is defined by two spheres with radius $r_{max\,1} = 2d_0 \sqrt[3]{3/4\pi c_1}$, $r_{max\,2} = 3d_0 \sqrt[3]{3/4\pi c_2}$ … $r_{\max(n-1)} = nd_0 \sqrt[3]{3/4\pi c_{n-1}}$, $r_{max\,n} = D\sqrt[3]{3/4\pi c_n}$. And their probability density functions $f_1(r,\theta,\varphi)$,$f_2(r,\theta,\varphi)$… $f_n(r,\theta,\varphi)$ are constants for r, θ and φ; (21) will be simplified to:

$$\begin{cases} E[d_{toCH\,1}^2] = f_1(r,\theta,\varphi) \int_0^{2d_0\sqrt[3]{\frac{3}{4\pi c_1}}} \int_0^{\pi} \int_0^{2\pi} r^4 \sin\theta \, dr d\theta d\varphi \\ E[d_{toCH\,2}^2] = f_2(r,\theta,\varphi) \int_{2d_0\sqrt[3]{\frac{3}{4\pi c_2}}}^{3d_0\sqrt[3]{\frac{3}{4\pi c_2}}} \int_0^{\pi} \int_0^{2\pi} r^4 \sin\theta \, dr d\theta d\varphi \\ \vdots \\ E[d_{toCHn}^2] = f_n(r,\theta,\varphi) \int_{nd_0\sqrt[3]{\frac{3}{4\pi c_n}}}^{D\sqrt[3]{\frac{3}{4\pi c_n}}} \int_0^{\pi} \int_0^{2\pi} r^4 \sin\theta \, dr d\theta d\varphi \end{cases} \quad (22)$$

The density of nodes is a uniform throughout the cluster area of the two levels. So:

$$\begin{cases} f_1 = \frac{1}{V_1} = \frac{c_1}{(2d_0)^3} \\ f_2 = \frac{1}{V_2} = \frac{c_2}{(3d_0)^3} \\ \vdots \\ f_n = \frac{1}{V_n} = \frac{c_n}{D^3} \end{cases} \quad (23)$$

$$\begin{cases} E[d_{toCH\,1}^2] = \frac{6}{5}\left(\frac{3}{4\pi c_1}\right)^{\frac{2}{3}} {d_0}^2 \\ E[d_{toCH\,2}^2] = \frac{3}{10}\left(\frac{3}{4\pi c_2}\right)^{\frac{2}{3}} \frac{3^5-2^5}{3^3} {d_0}^2 \\ \vdots \\ E[d_{toCHn}^2] = \frac{3}{10}\left(\frac{3}{4\pi c_n}\right)^{\frac{2}{3}} \frac{D^5-(nd_0)^5}{D^3} \end{cases} \quad (24)$$

Therefore, the total energy dissipated in the network per round, is expressed by:

$$\begin{cases} E_{Total\,1} = c_1 E_{cluster\,1} \\ E_{Total\,2} = c_2 E_{cluster\,2} \\ \vdots \\ E_{Totaln} = c_n E_{clustern} \end{cases} \quad (25)$$

Where $E_{cluster\,1}$, $E_{cluster\,2}$ … $E_{cluster\,n}$ are the energy dissipated in clusters of each level which is given by:

$$\begin{cases} E_{cluster\,1} = E_{CH1} + (\frac{N_1}{c_1} - 1) E_{nonCH\,1} \approx E_{CH1} + \frac{N_1}{c_1} E_{nonCH\,1} \\ E_{cluster\,2} = E_{CH2} + \left(\frac{N_2}{c_2} - 1\right) E_{nonCH\,2} \approx E_{CH2} + \frac{N_2}{c_2} E_{nonCH\,2} \\ \vdots \\ E_{clustern} = E_{CHn} + (\frac{N_n}{c_n} - 1) E_{nonCHn} \approx E_{CHn} + \frac{N_n}{c_n} E_{nonCHn} \end{cases} \quad (26)$$

This can be calculated by:

$$\begin{cases} E_{cluster\,1} = l\left(\frac{N_1}{c_1} E_{elec} + \frac{N_1}{c_1} E_{DA} + \epsilon_{fs} d_{toBS\,1}^2\right) \\ \quad + l\left(\frac{N_1}{c_1} E_{elec} + \epsilon_{fs} d_{toCH\,1}^2\right) \\ E_{cluster\,2} = l\left(\frac{N_2}{c_2} E_{elec} + \frac{N_2}{c_2} E_{DA} + \epsilon_{mp} d_{toBS\,2}^4\right) \\ \quad + l\left(\frac{N_2}{c_2} E_{elec} + \epsilon_{fs} d_{toCH\,2}^2\right) \\ \vdots \\ E_{clustern} = l\left(\frac{N_n}{c_n} E_{elec} + \frac{N_n}{c_n} E_{DA} + \epsilon_{mp} d_{toBSn}^4\right) \\ \quad + l\left(\frac{N_n}{c_n} E_{elec} + \epsilon_{fs} d_{toCHn}^2\right) \end{cases} \quad (27)$$

Therefore, the total energy dissipated in each level is simplified by:

$$\begin{cases} E_{Total\,1} = l\begin{pmatrix} 2N_1 E_{elec} + N_1 E_{DA} + c_1 \epsilon_{fs} d_{toBS\,1}^2 \\ + N_1 \varepsilon_{fs} \frac{6}{5}\left(\frac{3}{4\pi c_1}\right)^{\frac{2}{3}} {d_0}^2 \end{pmatrix} \\ E_{Total\,2} = l\begin{pmatrix} 2N_2 E_{elec} + N_2 E_{DA} + c_2 \epsilon_{mp} d_{toBS\,2}^4 \\ + N_2 \varepsilon_{fs} \frac{3}{10}\left(\frac{3}{4\pi c_2}\right)^{\frac{2}{3}} \frac{3^5-2^5}{3^3} {d_0}^2 \end{pmatrix} \\ \vdots \\ E_{Totaln} = l\begin{pmatrix} 2N_n E_{elec} + N_n E_{DA} + c_n \epsilon_{mp} d_{toBSn}^4 \\ + N_n \varepsilon_{fs} \frac{3}{10}\left(\frac{3}{4\pi c_n}\right)^{\frac{2}{3}} \frac{D^5-(nd_0)^5}{D^3} \end{pmatrix} \end{cases} \quad (28)$$

ISSN 2356-5608

The total energy consumption of our study is:

$$E_{Total-nLevel} = \sum_{i=1}^{n} E_{Total\,i} \quad (29)$$

The total energy consumption in case of two levels is:

$$E_{TotalTwoLevel} = l\left(2NE_{elec} + NE_{DA} + c_1\epsilon_{fs}d_{toBS\,1}^2 + c_2\epsilon_{mp}\,d_{toBS\,2}^4 + \varepsilon_{fs}\frac{3}{10}\left(4N_1 d_0{}^2\left(\frac{3}{4\pi c_1}\right)^{\frac{2}{3}} + N_2\frac{D^5-(2d_0)^5}{D^3}\left(\frac{3}{4\pi c_2}\right)^{\frac{2}{3}}\right)\right) \quad (30)$$

Authors in [9] define the energy consumption of three dimensional WSN as:

$$E_{Total} = l\left(2NE_{elec} + NE_{DA} + c\epsilon_{mp}d_{toBS}^4 + N\varepsilon_{fs}\frac{3}{10}\left(\frac{3}{4\pi c}\right)^{\frac{2}{3}}D^2\right) \quad (31)$$

$E_{TotalTwoLevel} < E_{Total}$ Implies that:

$$c_1\epsilon_{fs}d_{toBS\,1}^2 + c_2\epsilon_{mp}\,d_{toBS\,2}^4 < c\epsilon_{mp}\,d_{toBS}^4 \quad (32)$$

We have from equation (20):

$$c_1\epsilon_{fs} \times 0.4664\, d_0{}^2 + c_2\epsilon_{mp} \times 0.0319\frac{D^7-(2d_0)^7}{D^3} < c\epsilon_{mp} \times 0.0319\, D^4 \quad (33)$$

(33)$\div$ (ϵ_{mp})

Gives:

$$c_1 \times 0.4664\, d_0{}^4 + c_2 \times 0.0319\frac{D^7-(2d_0)^7}{D^3} < c \times 0.0319\, D^4 \quad (34)$$

Noting that:
$d_0 \approx 87.7\ m$ and $D = 200\ m$
Thus:

$$c_1 \times 27.59\ 10^6 + c_2 \times 961.56\ 10^6 < c \times 51.04\ 10^6 \quad (35)$$

And

$$c_1 \times 0.54 + c_2 \times 18.84 < c \quad (36)$$

Therefore:

$$c > c_1 > c_2 \quad (37)$$

And:

$$p > p_1 > p_2 \quad (38)$$

Where p_1 and p_2 are the probabilities for becoming a cluster head.

The number of cluster head of the second level must be absolutely lower than the number of cluster head of the first level. It is obvious, since the space of the second level contains number of sensors lower than the first one.

Similarly, we conclude the other conditions of the other studies: three levels, four levels, five levels and *n* levels as follows:

Case of three levels

$$p > p_1 > p_2 > p_3$$

Case of four levels

$$p > p_1 > p_2 > p_3 > p_4$$

Case of five levels

$$p > p_1 > p_2 > p_3 > p_4 > p_5$$

.

.

.

Case of *n* levels

$$p > p_1 > p_2 \ldots > p_n$$

V. Simulation Results

A. *Parameter settings*

TABLE II
SIMULATION PARAMETERS

Parameter	Value
Initial Node Energy	0.5 J
N	100
E_{elec}	50 nJ/bit
E_{DA}	5 pJ/bit
ϵ_{fs}	10 pJ/bit/m^2
ϵ_{mp}	0.0013 pJ/bit/m^2
l	4000 bits
P	0.05
Rounds	4000

TABLE III
PROBABILITIES

Dimension(m)	P_1=P	P_2	P_3	P_4	P_5
200	0.05	0.01	N/A	N/A	N/A
300	0.05	0.01	0.005	N/A	N/A
400	0.05	0.01	0.005	0.001	N/A
500	0.05	0.01	0.005	0.001	0.0005

In this section, we study the performance of LEACH 3D protocol under different scenarios using MATLAB. We consider a model illustrate in the figure 1 with N=100 nodes randomly and uniformly distributed in a different space dimensions and divided in a levels. To compare the performance of LEACH 3D with LEACH 3D-*n*Level protocol, we use the parameters shown in table 2 and for each level, we apply the probabilities shown in table 3.

ISSN 2356-5608

B. *Simulation metrics*

We define two performance metrics to evaluate both protocols as: First Node Dies (FND) or stability period and Last Node Dies (LND) or instability period. Moreover, the performance metrics used in the simulation study can be as follow:

- Lifetime
- Throughput
- Increase

C. *Simulation results*

1) Network lifetime: The number of nodes dead for each round of data transmission is observed for the LEACH 3D and 3D-*n*Level protocols to evaluate the lifetime of the network. Figures 6, 7, 8 and 9 show the performance of LEACH 3D compared to LEACH 3D-*n*Level. It is observed that the LEACH 3D is less perform than LEACH 3D-*n*Level. It is due to energy dissipation of individual node throughout of the network. This depends essentially on the distance between nodes and sink.

2) Throughput: Figures 14, 15, 16 and 17 illustrate that the Number of packets sent to base station is greater in our proposition than the LEACH 3D. This difference is been wide if we pass to the number of levels increases. Referred to figures 10, 11, 12 and 13, they show clearly that provide LEACH 3D-*n*Level a good throughput compared to LEACH 3D protocol. This increase is justified by the high lifetime which give the controlled three dimensional deployment of the nodes in the network

TABLE IV
ROUND of FIRST DEAD NODE

Dimension (m)	Protocol	Round
200	LEACH 3D	322
	LEACH 3D-TwoLevel	358
300	LEACH 3D	83
	LEACH 3D-ThreeLevel	126
400	LEACH 3D	28
	LEACH 3D-FourLevel	49
500	LEACH 3D	9
	LEACH 3D-FiveLevel	43

TABLE V
NUMBER of LAST REMAINING NODES at ROUND 4000

Dimension (m)	Protocol	Number
200	LEACH 3D	0
	LEACH 3D-TwoLevel	2
300	LEACH 3D	1
	LEACH 3D-ThreeLevel	3
400	LEACH 3D	0
	LEACH 3D-FourLevel	2
500	LEACH 3D	1
	LEACH 3D-FiveLevel	4

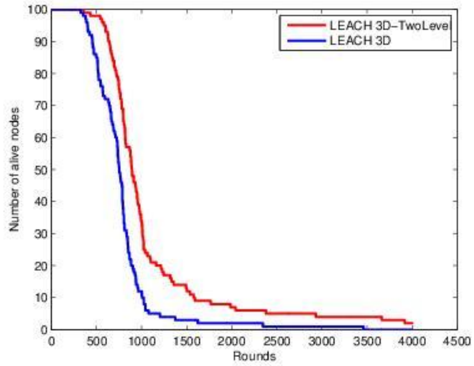


Fig. 6: Number of alive nodes per round comparison of LEACH 3D and LEACH 3D-TwoLevel

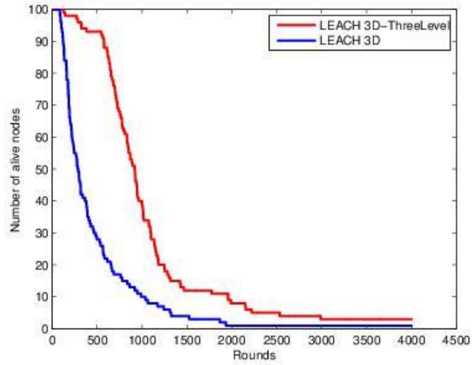


Fig. 7: Number of alive nodes per round comparison of LEACH 3D and LEACH 3D-ThreeLevel

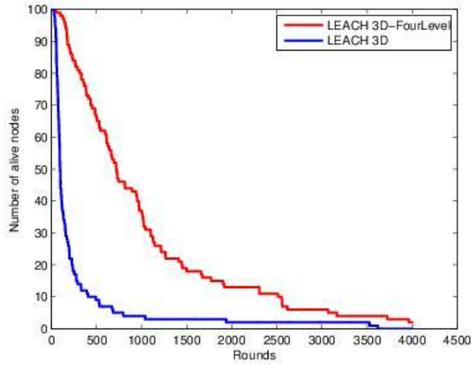


Fig. 8: Number of alive nodes per round comparison of LEACH 3D and LEACH 3D-FourLevel

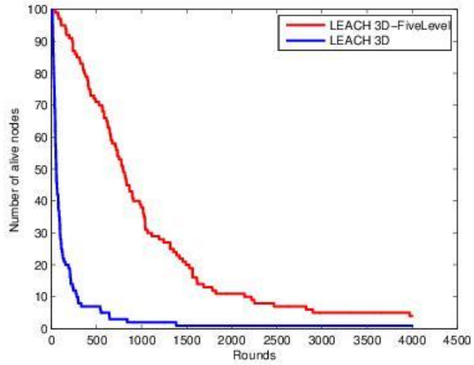


Fig. 9: Number of alive nodes per round comparison of LEACH 3D and LEACH 3D-FiveLevel

ISSN 2356-5608

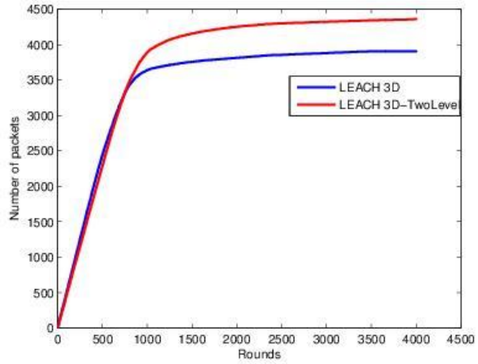


Fig. 10: Performance of the protocols LEACH 3D and LEACH 3D-TwoLevel

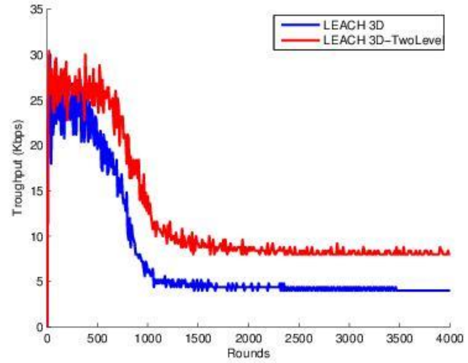


Fig. 14: Throughput comparison of LEACH 3D and LEACH 3D-TwoLevel

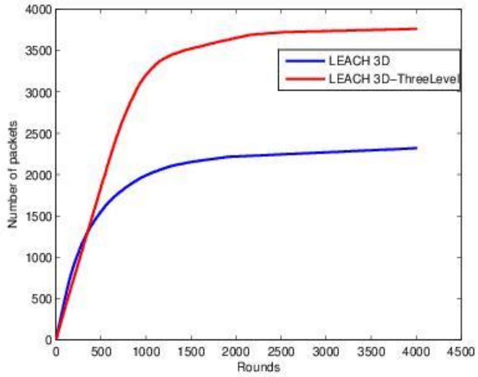


Fig. 11: Performance of the protocols LEACH 3D and LEACH 3D-ThreeLevel

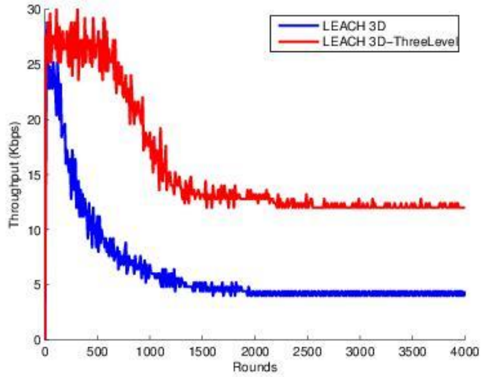


Fig. 15: Throughput comparison of LEACH 3D and LEACH 3D-ThreeLevel

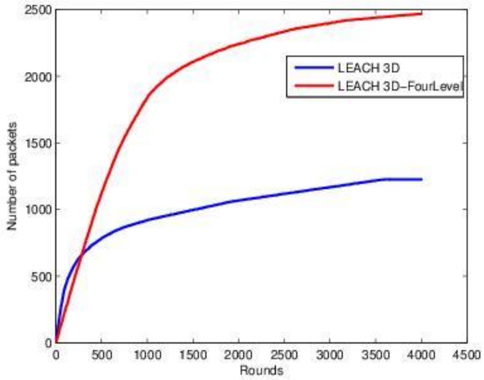


Fig. 12: Performance of the protocols LEACH 3D and LEACH 3D-FourLevel

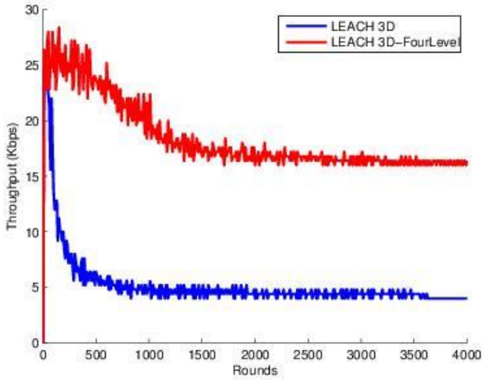
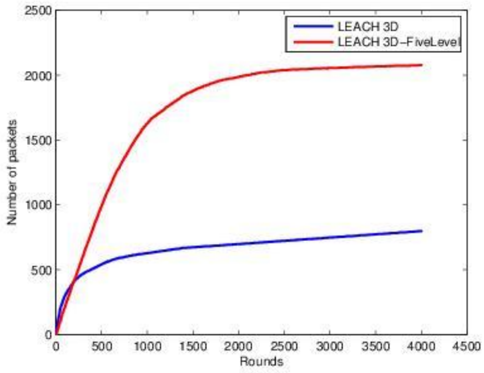
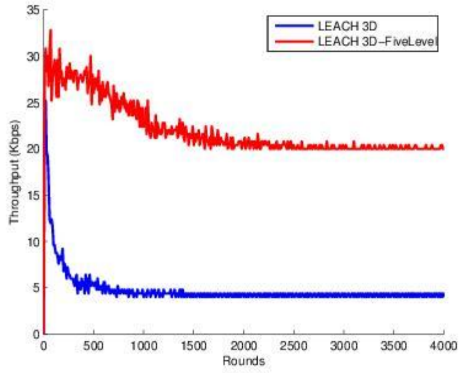


Fig. 16: Throughput comparison of LEACH 3D and LEACH 3D-FourLevel



d)
Fig. 13: Performance of the protocols LEACH 3D and LEACH 3D-FiveLevel



d)
Fig. 17: Throughput comparison of LEACH 3D and LEACH 3D-FiveLevel

ISSN 2356-5608

3) *Increase:* Generally, we can illustrate the increase of the LEACH 3D-*n*Level in the table 6. It's noted that the throughput increases more than 56 % in LEACH 3D-TwoLevel, more than 62 % in LEACH 3D-ThreeLevel, more than 253 % in LEACH 3D-FourLevel and more than 360 % in LEACH 3D-FiveLevel. Whereas, LEACH 3D-*n*Level outperforms the FND by more than 11 % in LEACH 3D-TwoLevel, by more than 52 % in LEACH 3D-ThreeLevel, by more than 75 % in LEACH 3D-FourLevel and by more than 378 % in LEACH 3D-FiveLevel. In the other hand and compared to LEACH 3D, LEACH 3D-*n*Level send more than 12 % packets in LEACH 3D-TwoLevel, 149 % packets in LEACH 3D-ThreeLevel, 101 % packets in LEACH 3D-FourLevel and 160 % packets in LEACH 3D-FiveLevel.

TABLE VI
INCREASE of LEACH 3D-*N*LEVEL COMPARED to LEACH 3D

Parameter	Two Levels	Three Levels	Four Levels	Five Levels
FND*	11 %	52 %	75 %	378 %
NP**	12 %	149 %	101 %	160 %
Throughput	56 %	62 %	253 %	360 %

*: First dead node
**: Number of packets

4) *Result analysis:* From our simulations, we observed that LEACH 3D-*n*Level consumes less energy, increases network lifetime, improves the throughput and delivers more packets to the base station compared to LEACH 3D. These results can be interpreted by the difference of distance between nodes in both situations which is caused by the random nodes deployment (LEACH 3D) and by controlled nodes deployment in levels (LEACH 3D-*n*Level).

VI. CONCLUSION

According to the study done in this paper, the analytic of 3D WSN in wide space is more complicated than in limited space. That is why, many researchers project the 3D WSN in short projections. We have demonstrated this by simulation. This approximation is not reasonable, especially if the dimension of network is greater than 100m. We have proposed a controlled deployment according to solve this problematic. In fact, we have organized the deployment of the networks in wide spaces. The energy consumed is become minimal. With these new operations, the LEACH 3D-TwoLevel, the LEACH 3D-ThreeLevel, the LEACH 3D-FourLevel and the LEACH 3D-FiveLevel offer a network lifetime increase of 11%, 52%, 75% and 378%. They also offer a network throughput increase of 56%, 62%, 253% and 360%.

REFERENCES

[1] H.M. Ammari, S.K. Das, "Critical Density forcoverage and connectivity in three dimensional wireless sensor networks using percolation theory". *IEEE Trans. Parallel Distrib*, vol. 20, Issue.6, pp. 872 – 885. June 2009.

[2] Kay Romer and FriedemannMattern. "The Design Space of Wireless Sensor Networks". *IEEE Wireless Communications*, Vol. 11, Iss. 6,pp 54-61.Dec. 2004.

[3] Wendi R. Heinzelman, AnanthaChandrakasan, and HariBalakrishnan, "Energy efficient communication protocol for wireless micro sensor networks", *33rd Annual Hawaii International Conference on System Sciences*, pp 1-10, 2000.

[4] W. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "An application specific protocol architecture for wireless micro sensor networks", *IEEE Transactions on Wireless Communications*, vol. 1, Iss. 4, pp. 660-670, October 2002.

[5] Xia Li, Yongqian Wang, and Jingjin Zhou, "An energy-efficient clustering algorithm for underwater acoustic sensor networks", *International Conference on Control Engineering and Communication Technology (ICCECT)*, pp. 711 - 714, Dec. 2012.

[6] X.Li, S.-L.Fang, and Y.C. Zhang, "The study on clustering algorithm of the underwater acoustic sensor networks,"*14th International Conference on Mechatronics and Machine Vision in Practice (M2VIP)*,pp4-6,Dec. 2007.

[7] Guangsong Yang, Mingbo Xiao, En Cheng, and Jing Zhang, " A cluster-head selection scheme for underwater acoustic sensor networks", *International Conference on Communications and Mobile Computing (CMC)*, vol. 3, pp. 188 - 191, Apr. 2010.

[8] Liu, G., and Wei, C., "A new multi-path routing protocol based on cluster for underwater acoustic sensor networks", *International Conference on Multimedia Technology (ICMT)*, pp. 91-94,2011.

[9] M.Baghouri, A.Hajraoui, S.Chakkor. "Three Dimensional Low Energy Adaptive Clustering Hierarchy for Wireless Sensor Network". *19th International Conference on Communications (part of CSCC'15)*,Zakynthos Island, Greece, pp 214-218,July 2015.

[10] Fu Xiao, Yang Yang, Ruchuan Wang and Lijuan Sun. "A Novel Deployment Scheme Based on Three-Dimensional Coverage Model for Wireless Sensor Networks". *The Scientific World Journal*, Volume 2014, Article ID 846784, 7 pages, 2014.

[11] S. S. Dhillon and K. Chakrabarty, "Sensor placement for grid coverage under imprecise detections,". *International Conference on Information Fusion*, pp. 1581–1587, Annapolis, Md, USA, July 2002.

[12] S. S. Dhillon and K. Chakrabarty, "Sensor placement for effective coverage and surveillance in distributed sensor networks". *IEEE Wireless Communications and Networking Conference*, pp. 1609–1614, New Orleans, La, USA, March 2003.

[13] X. L. Bai, Z. Q. Yun, D. Xuan, T. H. Lai, and W. Jia, "Deploying four-connectivity and full-coverage wireless sensor networks,".*7th IEEE Communications Society Conference on Computer Communications (INFOCOM '08)*, pp. 296–300, Phoenix, Ariz, USA, April 2008.

[14] AnandSeetharam, Abhishek Bhattacharyya, Mrinal.K.Naskar andAmitava Mukherjee, "Estimation of node density for an energy efficient deployment scheme in wireless sensor network". *3rd International Conference on Communication Systems Software and Middleware and Workshops (COMSWARE '08)*, pp. 6-10, Bangalore, India, Jan. 2008.

[15] Jeongdae Kim and Daeyoung Kim, "Energy Efficient Position-Based Three Dimensional Routing for Wireless Sensor Networks",*Journal of Systemics*, Vol. 6, No. 2, pp. 1-5, 2008.

[16] F. Saleem, Y. Moeen, M. Behzad, M. A. Hasnat, Z. A. Khan, U. Qasim and N. Javaid "IDDR Improved Density Controlled Divide and Rule Scheme for Energy Efficient Routing in Wireless Sensor Networks". *9th International Conference on Future Networks and Communications (FNC)*, Vol. 34, pp. 212-219, 2014.

ISSN 2356-5608

ACKNOWLEDGMENT

The authors would like to thank, for their technical support, Ph.Ds. Saad Chakkor, El Ahmadi Cheikh, Mostafa Baghouri and Abdelkader Bourzek from Abdelmalek Essaadi University Morocco. A great appreciation is also extended to colleagues: Pr Eric Busvelle from Dijon University France and also Pr Jean Louis Lilien from Liege University Belgium, for their continued help. The authors would also like to add a special thanks to Pr A. El Khamlichi from Abdelmalek Essaadi University Morocco, for his good assistance.

BIOGRAPHY

[1]AbderrahmaneEl Aalaoui was born in Tantan Morocco. He's a member in the Physics department, Team Communication and Detection Systems, Faculty of Sciences, University of Abdelmalek Essaâdi, Tetouan Morocco, and his research area is wireless intelligent sensors and theirs applications, routing and real time protocols for energy optimization in wireless sensors networks. He obtained a Master's degree in Electrical and Computer Engineering from Faculty of Sciences and Technology of Marrakech Morocco.

[2]Abderrahmane Hajraoui is a professor of the Higher Education at University of Abdelmalek Essaâdi. He's a director thesis in the Physics department, Communication and Detection Systems laboratory, Faculty of sciences, Abdelmalek Essaâdi University, Tetouan, Morocco. His research areas are Signal and Image Processing, Automatics, Automation systems, Simulation systems, Antennas and radiation, Microwave devices and intelligent wireless sensors networks.

ISSN 2356-5608