VOL. 11, NO. 22, NOVEMBER 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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STUDY THE EFFECT OF NUMBER OF NODES IN LARGE SCALE WIRELESS SENSOR NETWORKS WITH DESIGN GUI SUPPORTTOOLS

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ABSTRACT

The Wireless Sensor Networks (WSN) has a limited power supply because each node was equipped with a battery. In most situations, they are deployed in a hostile environment where it is exceptionally hard to change or charge their batteries. Because of this, it becomes challenging in WSN to prolong the system lifetime and at the same time achieve a better throughput. The number of nodes in the network is regarded as the most significant factor in the WSN performance. Therefore, the current paper aimed to study the effect of the number of nodes on the performance of WSN. Quality of service (QoS) performance metrics in the study were network lifetime, energy dissipation and throughput in a different number of nodes. In addition, during the study, we proposed and implemented the graphical user interface (GUI) tools to generate the Network Simulator 2 (NS-2) script code for topology scenario file, and the graph tools (GT) to plot the NS-2 simulation results. The visual basic language was used to design the GUI for generating the NS-2 script code while MATLAB was used to design the GT. Simulation experiments were conducted using NS-2.34 with Massachusetts Institute of Technology (MIT) extension LEACH protocol for a different number of nodes. We conclude that the increasing number of nodes can cause decreasing the throughout and consuming high energy, hence, resulting in the reduction of network lifetime.

Keywords: WSN, QoS, performance metrics, number of nodes, GUI tools, MATLAB, NS-2.

INTRODUCTION

Wireless Sensor Networks is a collection of sensors devices having the ability to sense, compute and communicate wirelessly (Huang and Hua, 2011). Congestion is a well-know problem that decreases the WSN performance. One of the factors causing congestion is over node density the network. The authors in (Chitlange and Deshpande, 2015) examinedthe effect of node density on Congestion in WSN. Based on their results, the authors concluded that the threshold is about 45 nodes, as after 45 nodes Packet Delivery Ratio (PDR) and throughput goes on decreasing. They also described the relationship between the number of nodes and the control overhead; where they inferred that the increase in overhead control resulted in increasing the number of nodes in network. In this paper, we studied the effect of a large number of nodes in WSN performance metrics in terms of energy, lifetime and throughout.

WSN ENERGY MODEL

Diverse assumptions about radio attributes, including energy consumption in transmitting and receive modes will contribute to the behaviour of WSN nodes. Therefore, it is important to use the right energy model. In WSNs, there are four general energy models that are (Heinzelman, 2000), (Miller & Vaidya, 2005), (Zhu, 2003), (Medagliani, 2011). In this study, we used the radio energy model proposed by Heinzelman in (Heinzelman, 2000). The model assumed that the dissipating electronics energy,E_elec=50nJ/bit for transmitter and receiver operations and E_amp= 100pJ/bit/m^2 for the transmitter amplifier to achieve an acceptableE_b. The radio model energy consumption is shown in Figure-1.

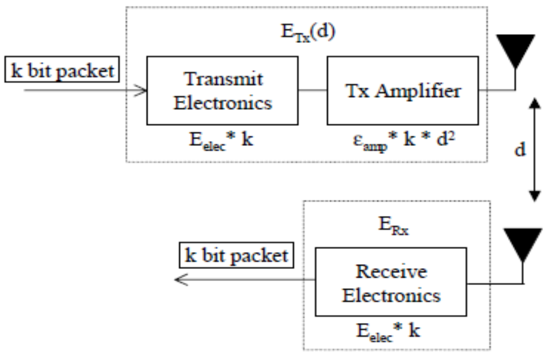

Figure-1. Radio model energy consumption.

Energy consumption during a message transmission is given as;

$$E_{Tx}(k,d) = E_{Tx-elec}(k) + E_{Tx-amp}(k,d) \quad (1)$$

$$E_{Tx}(k,d) = \begin{cases} k.E_{elec} + k.E_{friss-amp}.d^2 & : d < d_{Cros} \\ k.E_{elec} + k.E_{tow-ray-amp}.d^4 & : d \geq d_{Cros} \end{cases} \quad (2)$$

Where, the threshold $d_{Crossover}$,calculated as in Equation (3)

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$$d_{Crossover} = \frac{4\,\pi\sqrt{L\,h_r\,h_t}}{\lambda} \quad (3)$$

Next, energy consumption during a receiving,

$$E_{Rx}(k) = E_{Rx-elec}(k)$$
$$E_{Rx}(k) = k.E_{elec} \quad (4)$$

where k is the message data packet size, $E_{Tx}$is the energy model for the transmitter,$E_{Rx}$is the energy model of the receiver,$E_{elec}$is the radio electronics energy, $d$is the distance between the transmitter and the receiver. All simulation experiments reported in this paper used the model attributes (Heinzelman, 2000) as shown in Table-2.

Table-1. Simulation model attributes and parameters value.

Parameters	Value
Cross-over distance for Friss and two-ray ground attenuation models $d_{Crossover}$	87 m
Radio Data Rate	1 Mbps
Antenna	Omni-directional
Carrier Sensing Threshold (CSThresh)	1e-9 Watts
Receive Threshold (RXThresh)	6e-9Watts
Energy for Radio Circuitry	50nJoules
Minimum receiver power needed Prthresh for successful reception	6.3 nW
Beamforming Energy	5nJoules/bit
Antenna height above the ground h_t, h_r	1.5 m
Antenna gain factor G_t, G_r	1
Radio amplifier energy $E_{friss-amp}$	10 pJ/bit/m^2
Radio amplifier energy $E_{tow-ray-amp}$	0.001 3pJ/bit/m^4
Signal wavelength λ	0.325 m

SIMULATION CONFIGURATION

This study considered MIT NS-extension LEACH protocol proposed by Heinzelman (Heinzelman, 2000). MALTAB used to desing GUI plot tool. Microsft Visual basic with Microsoft Excel was also used to desing GUI tool support NS2.

FREQUENCY INFLUENCE ON WSN PERFORMANCE

In this part, we studied two different frequency influence on WSN performance. In most literature, the researchers in WSNs use energy radio model proposed by Heinzelman with 914 MHz radio frequency. This part also describes another frequency 191.42 MHz (Wang and Chandrakasan, 2002) already used by Halgamuge (Halgamuge, 2009). The number of nodes, packet size, sensor field, initial energy and the base station (BS) location are set to 100 nodes, 512 bytes, 1 joule, 200m × 200m and (11,275) respectively.

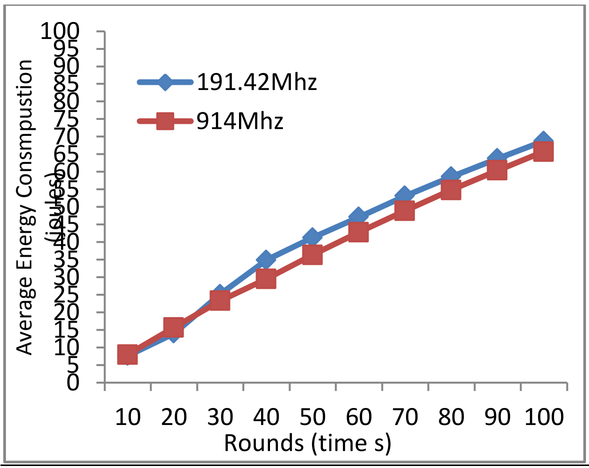

Figure-2. Energy consumption vs different frequencies.

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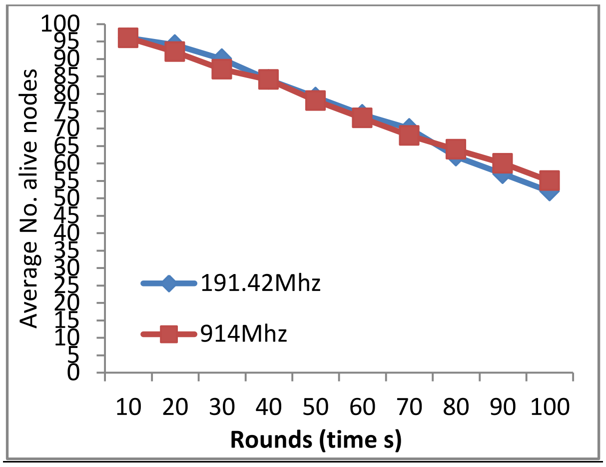

Figure-3. Network lifetime vs different frequencies.

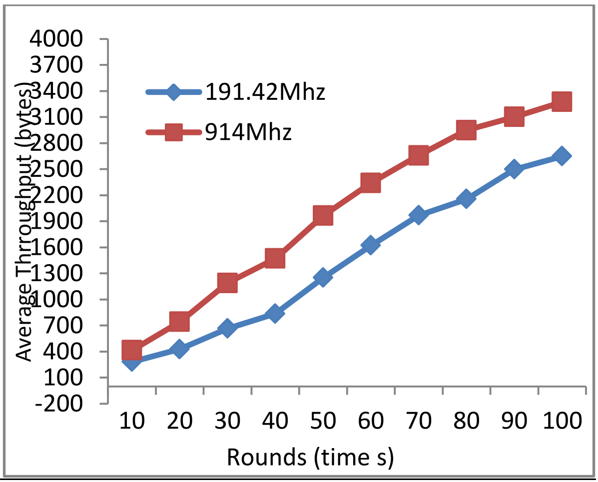

Figure-4. Throughput at the BS vs different frequencies.

Figure-2, Figure-3 and Figure-4showthe results of thesimulation study comparing between different frequencies, the 914 MHz shows the best performance in saving energy, network lifetime and throughput at the base station in comparison with 191.42MHz. From the equation that describes wavelength (λ) of the carrier signal$\lambda = \frac{c}{f}$ m where c is the speed of light and f the f frequency in MHz. It is evident that any increment will reduce the wavelength and result into improving the efficiency of system performance. In fact, the selection of the frequency depends on the application.

DESIGNA GUI TOOLS SUPPROT NS-2

GUI is a pictorial interface to a system. A perfect GUI can make programs simpler to use by giving them a steady appearance and with natural controls like pushbuttons, pushbuttons, list boxes, sliders, menus, and so forth. Thus, our desifned GUI tool was able to provide the script code for NS-2 topology scenario file and able to convert the results after the simulation in format text file to graph to easy analysis.

GENERATE A NETWORK NODE TOPOLOGY SCENARIO FILE

In this part, we proposed and implemented a GUI tool which is adnantaged for its easy use and flexiblity to make many scenarios in short time. Moreover, the user does not need to change the NS-2 just to help him/her to generate the script code that will run in NS2 compiler. Our proposed GUI Tool shows a simple model in the application in minute methods. Compared with the ordinary method in (Programdevelop.co-m 2015), the generated node scenario, a file named genscen in it / uAMPS / sims directory, the file is used to produce node scene files. And the user needs to write script commands to do it that means the user should learn how to program it very well and this is regarded as the most challenging task with electrical engineering students.

Figure-5 shows the flow chart to design GUI to generatethescript code for topology scenario file in NS2. 34 simulations

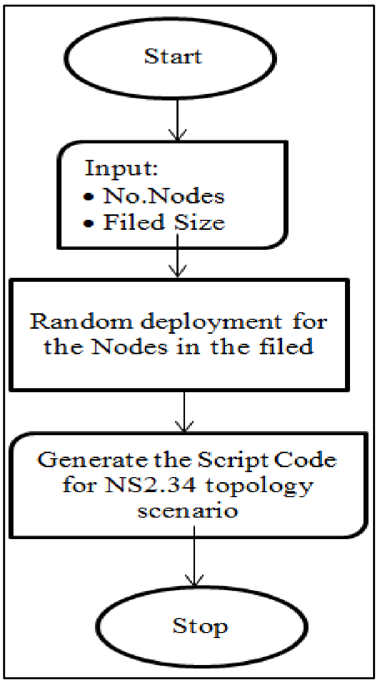

Figure-5. GUI flowchart.

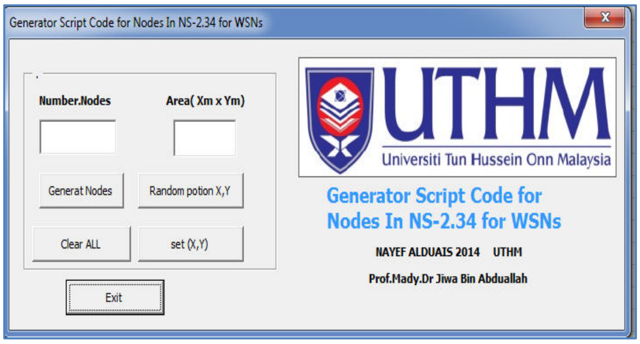

Figure-6. GUI to Generator script code for node deployment randomly in the simulation area M x M meters.

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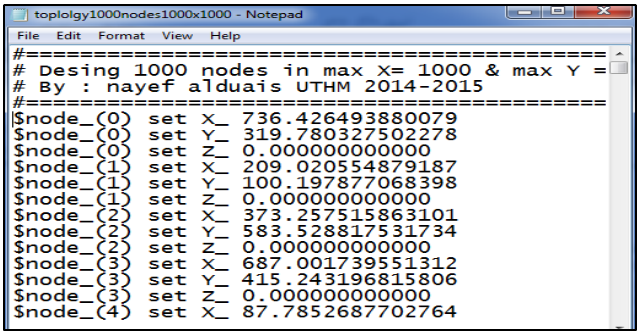
From Figure-6 it is appearant the GUI contents comprise two Textbox for inputthe number of nodes with square area size and four commands one to deployment random location (X,Y) for nodes and after that we can use the other commands to generate the NS2 script code for scenario topology file as shown in Figure-7.



```
toplolgy1000nodes1000x1000 - Notepad
File  Edit  Format  View  Help
#==============================================
# Desing 1000 nodes in max X= 1000 & max Y =
# By : nayef alduais UTHM 2014-2015
#==============================================
$node_(0) set X_ 736.426493880079
$node_(0) set Y_ 319.780327502278
$node_(0) set Z_ 0.000000000000
$node_(1) set X_ 209.020554879187
$node_(1) set Y_ 100.197877068398
$node_(1) set Z_ 0.000000000000
$node_(2) set X_ 373.257515863101
$node_(2) set Y_ 583.528817531734
$node_(2) set Z_ 0.000000000000
$node_(3) set X_ 687.001739551312
$node_(3) set Y_ 415.243196815806
$node_(3) set Z_ 0.000000000000
$node_(4) set X_ 87.7852687702764
```

Figure-7. NS2 script code created by GUI.

GRAPH TOOL FOR PLOT NS2 SIMULATION RESULTS

Wealso developed simple Graph Tool as shown in Figure-4 to plot the outcome results of simulation. This tool was able to read the outcome that has text form after simulation in NS2 simulation. One of its advantages is that this device can read many experimental results and plot the average ,just need to collect all your results experiments in one folder. It becomes easy to use, for example, suppose that we already have the result to plot it, just click on command called get file for file path and you can write the title an x andy label via the Textbox input as shown on Figure-8, after that click plot.

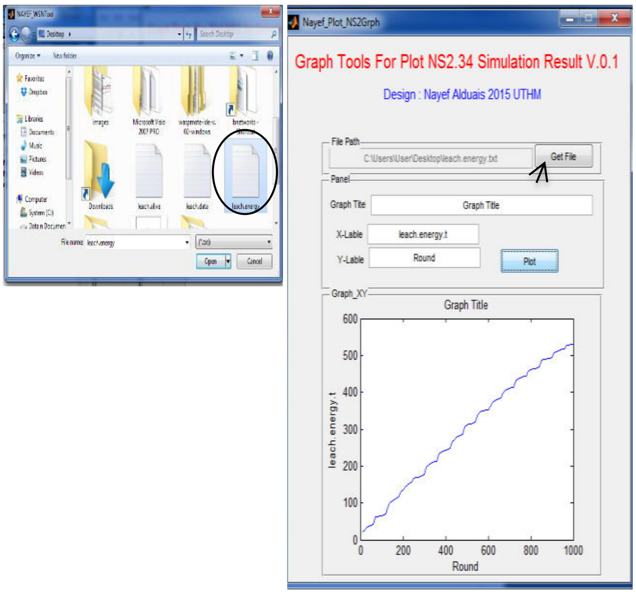


Figure-8. Graph tool for plot NS2 simulation outcome.

EFFECT OF NUMBER OF NODES VARIATION AN ENERGY; LIFETIME AND THROUPUT

There are several papers when the number of nodes is set to 100, giving so many assumptions for simplification Referring to Equation (5), in fact, as the number of nodes increases, there will be an increase in the total energy in the system. Equation (6) shows that the number of nodes N_sWill influence the value of the energy consumption within a cluster, $E_{cluster}$.

$$\text{Total init\_En} = (\text{init energy}) \times (\text{No. Nodes}) \quad (5)$$

$$E_{cluster} = E_{CH} + \frac{N_s}{C} \cdot E_{non-CH} \quad (6)$$

where $E_{cluster}$ is the energy consumption in a cluster during the frame, E_{CH} is the energy dissipated in the cluster-head node during a single frame, $C$is the optimum number of clusters,N_s is the number of nodes andE_{non-CH} is the energy dissipated in the non-cluster-head node during a single frame.

Table-2. Simulation parameters values.

Parameters	Values
Number of sensor nodes N_s	Variable
Node Placement	Uniform
Simulation area	200 m × 200m
Base station location	(11,275)
Data packet size	512 bytes
Packet heard size	25 bytes
Initial energy for each node	1 Joules
Simulation Time	1000 second
No. of Clusters	5

As we know, the selection of parameter simulation is a the very important point because that attribute will result into changing the advantages offered by these various protocols. In most literature, researchers in WSNs use the parameters that we used in this paper as shown in Table-2, especially for LEACH protocol. In this study, we set the number of nodes varied according to 50, 100, 150, 200, 250, 300, 400, and 500. The initial values of each node are set to 1 joule of energy, data packet size 512 bytes. Nodes are deployed randomly in the same field size of 200m x 200m where is the base station location far away from the sensor field at (11,275).

The simulation scenarios in this study have various steps: the first step was done with ten experiments for one scenario, where every experiment needs 100 seconds. In the second step, we took the average results for the performance metrics studied which were network's lifetime, energy dissipation, and throughput. Finally used the Equation (7), Equation (8), and Equation (9) to calculate the percentage of energy consumption, network's lifetime and throughput respectively separations for each varied number of nodes as shown in Table-3.

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$$En_{Cons} = \frac{Energy\ \ Consumption\ (joules)}{Total\ Energy(joules)} \times 100 \qquad (7)$$

$$No.alive\ Nodes\ \% = \frac{No.Alive\ Nodes}{Total\ No.Nodes} \times 100 \qquad (8)$$

$$\text{Throut}_{\text{per node}} = \frac{\text{throughout at the BS}}{\text{Total Nunmber of nodes}} \qquad (9)$$

Table-3. Average of Energy consumption, no.alive nodes and throughput at the BS with variable number of nodes.

No.Nodes	Total Energy(J) = 1 (J) × No.nodes	Average Energy Consumption(J)	Average No. Alive	Throughout (bytes)	Throughput per node (bytes)	Energy consumption %	No.Alive nodes %
50	50	47.144	5	3252	65	94%	10%
100	100	65.551	54	5595	55	66%	54%
150	150	84.310	103	5135	34	56%	69%
200	200	111.073	157	4674	23	56%	79%
250	250	168.676	174	3793	15	67%	70%
300	300	220.797	254	4057	13	74%	85%
400	400	319.083	349	3376	8	80%	87%
500	500	444.812	228	2748	5	89%	46%

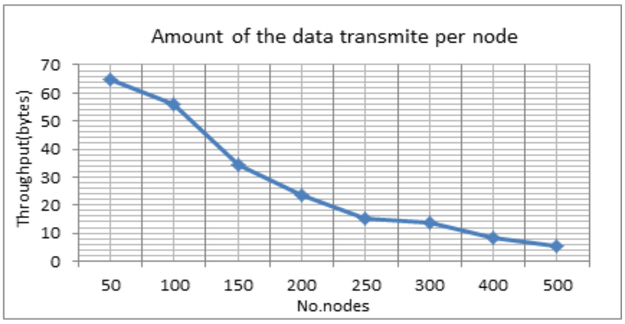
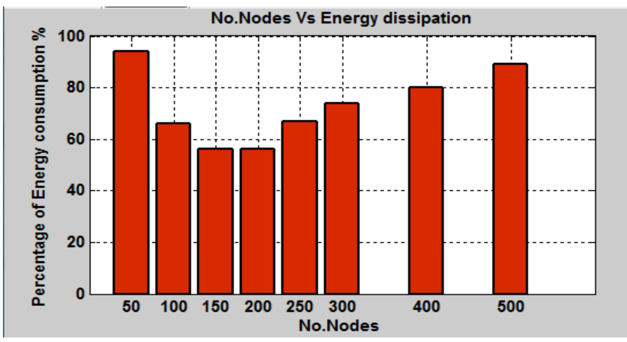
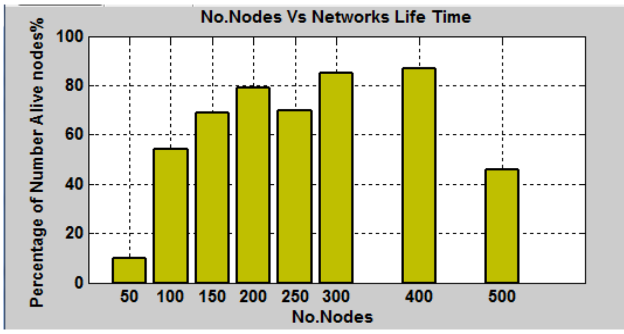


Figure-9. Throughput per node with variable No.nodes.



(a)



(b)

Figure-10(a). Percentage of Energyconsumption vs variable number nodes **(b).** Percentage of number alive nodes vs variable number nodes

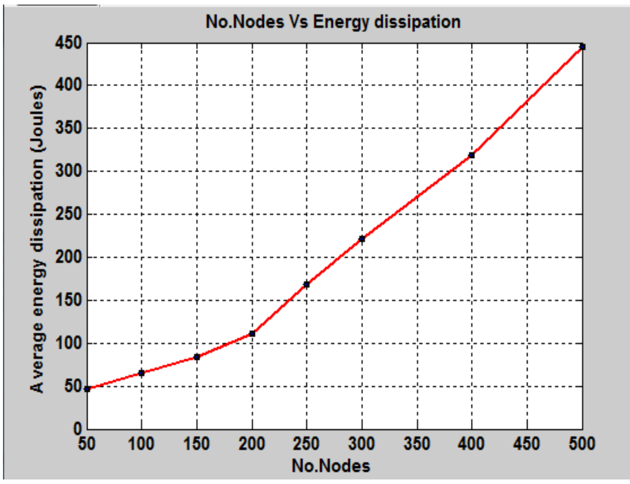


Figure-11. Average of energy consumptionwith variable number of nodes.

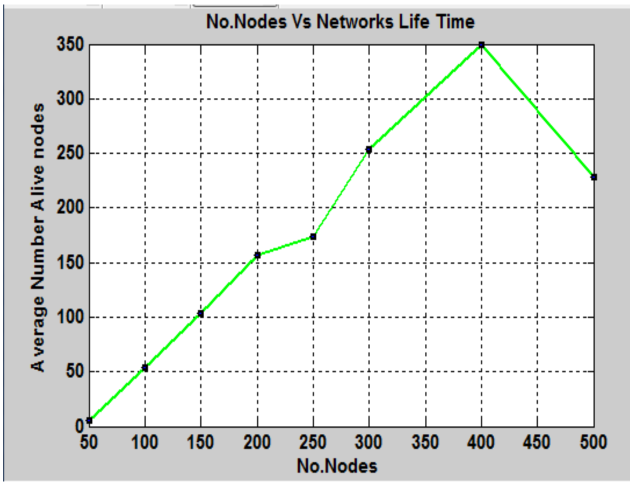


Figure-12. Average number of alive nodes with variable number of nodes.

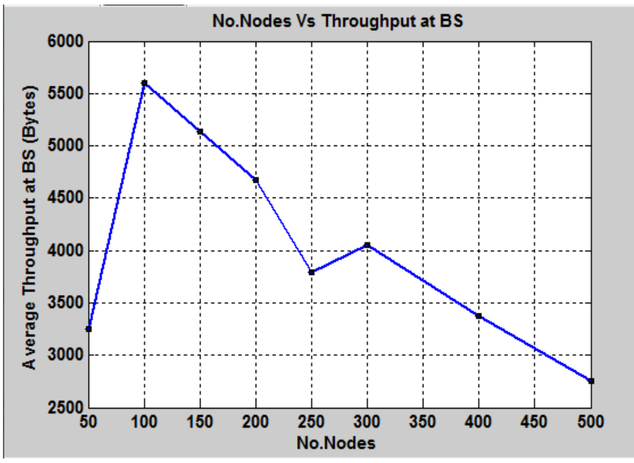


Figure-13. Average of throughput at the BS with variable number of nodes.

Based on the results shown in Figure-9, Figure-10(a),(b), Figure-11, Figure-12 and Figure-13, the total energy consumption increases linearly with the increment the number of nodes, offset decreases in the average of throughout (bytes) at the base station. The lowest energy consumption percentage of the total energy of the network is achieved when the number of nodes 100, 150 and 200 nodes. In most previous literature, researchers in WSNs used the 100 nodes. In addition, from the results of the current study, it is evident that the largest throughput of the base station presents when the number of nodes is set to 100. In fact, we can not verbalize for sure to choose the number of nodes to simulate WSN. We can say that that it relates to the type of protocol to set theparameters.

CONCLUSIONS

In this paper, we reported a study in the effect of the number of nodes in WSN. Performance metrics studied were the network's lifetime, energy dissipation and throughput. In addition, during this study, we proposed and implemented the GUI Tools to generate NS-2 script code for topology scenario file and graph tools for plot the results after simulated in NS-2 program. The visual basic language was used to design the GUI tool for generating NS-2 script code and MATLAB used to design Graph tool for plot NS-2 results. Simulation experiments were carried outby NS-2.34 with MIT extension LEACH protocol. The proposed GUI tool has successfully generated the scenario topology file for different number of nodes. It can be concluded that increasing the number of nodes causes a decrease of the throughout and consuming higher energy, which will reduce the network lifetime. In addition, the developed GUI tool is flexible to be used and better than the text code especially for those who do not have excellent skills in programming.

ACKNOWLEDGEMENT

The authors would like to thank the Ministry of Education Malaysia for the generous financial support under Research Acculturation Grant Scheme (R054).

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