# Comparison of Energy Consumption of Wireless Sensor Network at Various Topology Deployment: Array, Grid, and Random

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Abstract—This paper is review wireless sensor network and it's energy consumption at different deployment methods. Wireless Sensor Networks (WSN) are emerging with many applications, because of the advances in large scale wireless communications. These networks are deployed to serve single objective application, with high optimization requirements such as power saving. The WSN design problem is of high complexity, and requires robust methodologies, including simulation support. We use NS2 as simulation program for this model. In this paper, the authors compare the energy consumption on three different deployment methods of WSN. These deployment methods refer to topology deployment. In this simulation, we deploy WSN on grid, array, and random topology. We use different numbers of WSN nodes for showing the scalability. We use AODV as routing protocol and CBR as the traffic. After that, we compare the energy consumption that consume by that networks. Based on simulation result, the array topology is the best topology for deployment. This topology is the lowest on energy consumption, 0.560%.

Index Terms—Wireless Sensor Network, Energy Consumption, Topology, Array, Grid, Random

## 1. Introduction

Recent advances in technology have enabled practical deployment of very large scale distributed systems. For instance, Wireless Sensor Networks (WSN)consisting of large number of tiny devices are being used in many applications such as transport management, energy saving, wild-life habitat monitoring, disaster recovery in urban areas and health care [2].

Wireless sensor networks (WSNs) have attracted a wide range of disciplines where close interactions with the physical world are essential. The distributed sensing capabilities and the ease of deployment provided by a wireless communicationparadigm make WSNs an important component of our daily lives. By providing distributed, real-time information from the physical world, WSNs extend the reach of current cyber infrastructures to the physical world [1].

WSNs consist of tiny sensor nodes, which act as both data generators and network relays. Each node consists of sensor(s), a microprocessor, and a transceiver. Through the wide range of sensors available for tight integration, capturing data from a physical phenomenon becomes standard. Through on-board microprocessors, sensor nodes can be programmed to accomplish complex tasks rather than transmit only what their observe. The transceiver provides wireless connectivity to communicate the observed phenomena of interest. Sensor nodes are generally stationary and are powered by limited capacity batteries. Therefore, although the locations of the nodes do not change, the network topology dynamically changes due to the power management activities of the sensor nodes. To save energy, nodes aggressively switch their transceivers off and essentially become disconnected from the network. In this dynamic environment, it is a major challenge to provide connectivity of the network while minimizing the energy consumption. The energy-efficient operation of WSNs, however, provides significantly long lifetimes that surpass any system that relies on batteries [1].

In our paper we analyze the deployment topology that minimal energy consumption. We use three different deployment that are array, grid, and random. Another aspect, we used MAC 802.15.4 and AODV routing protocol. Several research on energy consumption of WSN use MAC 802.11 as MAC and grid topology. Our contribution is analyzing the consumption energy of WSN on three different deployment topology using MAC 802.15.4.

## 2. Related Work

The IEEE 802.15.4 / ZigBee suite of standards is commonly recognized as the technology of choice for applications involving sensor networks, due to their ability to ensure reliable, low-power and cost-effective communication [12, 13].

In most current applications, sensor networks have low data rates. According to the IEEE 802.15.4 standard, the

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transmission capacity of each channel is 20*kb/s* (868*MHz* Channel), 40*kb/s* (915*MHz*) or 250*kb/s* (2.4*GHz*). The data rate required for sensing may be much lower, which permits a sensor node to act as a data-source and a relay at the same time [13].

During cooperation, a sensor node may fall into one of the following states [1,13]:

1) *Sensing*: a sensing node monitors the source using an integrated sensor, digitizes the information, processes it, and stores the data in its onboard buffer. These data will be eventually sent back to the basestation.
2) *Relaying*: a relaying node receives data from other nodes and forwards it towards their destination.
3) *Sleeping*: for a sleeping node, most of the device is either shut down or works in low-power mode. A sleeping node does not participate in either sensing or relaying. However, it "wakes up" from time to time and listens to the communication channel in order to answer requests from other nodes. Upon receiving a request, a state transition to "sensing" or "relaying" may occur.
4) *Dead*: a dead node is no longer available to the sensor network. It has either used up its energy or has suffered vital damage. Once a node is dead, it cannot re-enter any other state.

When we talk about the topology deployment, there some research about deployment topology.Ewa Niewiadomska-Szynkiewicz, et.al [4] in 2009 and Jing CHEN, et.al [9] in 2008 do some research on WSN energy efficient topologies. They used 802.11 and grid topologies for the research. Seong-Soon Joo, et.al [14] , in 2008 do some research onWSN using random topology for proposed WSN deployment algorithm , but they don't talk about energy consumption for each WSN nodes.

Antonis Antoniou, in [3], research the WSN using 802.11 and grid topology. He also using energy model from NS2 for wireless. The energy model that used by NS2 can be seen at equation 1.

$$E^{total} = \sum_{i=1}^{n} \left( p^{xmit} xt^{xmit}{}_i + p^{recv} xt^{recv} + p^{idle} xt^{idle} \right) \quad ..(1)$$

where:
$p^{xmit}$ : power when transmit the data
$t^{xmit}$ : amount of time during transmit the data
$p^{recv}$ : power when receive the data
$t^{recv}$ : amount of time during receive the data

$p^{idle}$ : power when idle or sleeping mode
$t^{idle}$ : amount of time during idle or sleeping mode

In [1], make a model for simlpified energy model, can be seen at figure 1 and the equaition 2.

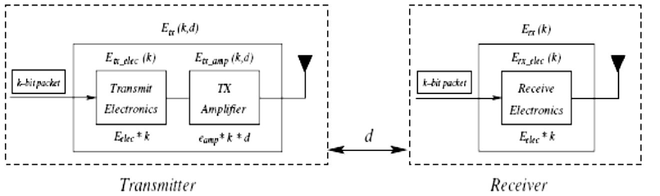


Figure 1. The Simplified energy model [1]

The energy consumption model can be simplified for a transmitter–receiver pair a distance *d* apart as follows:

$$Ec = Etx(k, d) + Erx(k) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

where *Etx(k, d)* and *Erx(k)* are the energy consumption of the transmitter and the receiver, respectively.

## 3. Our Simulation

In this simulation, we use NS-2 version 2.34 (ns-allinone-2.34). as simulator. Energy model that we used is energy model on NS-2. Other parameters are MAC, simulation area, numbers of nodes. MAC we used 802.15.4 for WSN. We deploy in area 500 x 500. In our scenarios, we used 9, 25, 64, 100, 225, 400, and 625 number of nodes for each deployment topology : grid, array and random. Main parameters on NS-2 that we used can be seen at table 1.

TABLE I
WSN PARAMETERS CONFIGURATION

| No | Parameter | Value |
|---|---|---|
| 1 | Channel Type | Channel/WirelessChannel |
| 2 | Propagation | Propagation/TwoRayGround |
| 3 | Network Interface Type | Phy/WirelessPhy/802_15_4 |
| 4 | Mac | Mac/802_15_4 |
| 5 | IfqType | Queue/DropTail/PriQueue |
| 6 | Antenna Type | Antenna/OmniAntenna |
| 7 | Routing | AODV |
| 8 | Topography | FLAT |
| 9 | Idle Power | 0.2 |
| 10 | Rx Power | 1.0 |
| 11 | Tx Power | 2.0 |
| 12 | Sleep Power | 0.0 |
| 13 | Initial Energy | 1000 |
| 14 | Area | 500 x 500 |

Traffic that we loaded is CBR with rate 100Kb and packet size 100. Traffic is send by first node to the end node, for example at networks with 100 nodes, traffic is send by node 0 to the node 99.

The examples of simulations for 25 nodes can be seen at figures 2, 3, and 4. In that simulation, we can seen for each deployment topology.

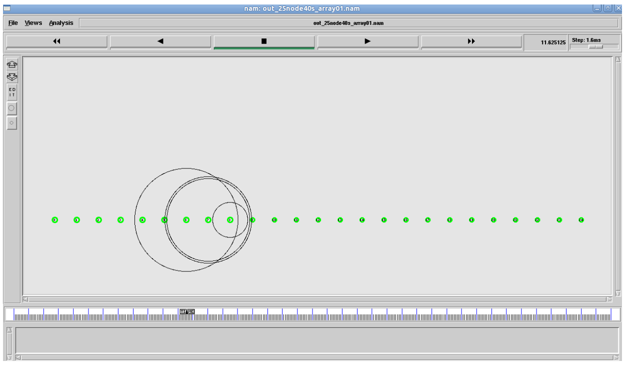

Figure2.Simulation of 25 nodes, array topology

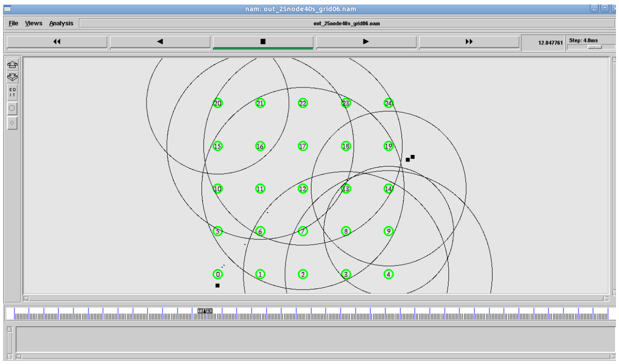

Figure3.Simulation of 25 nodes, grid topology

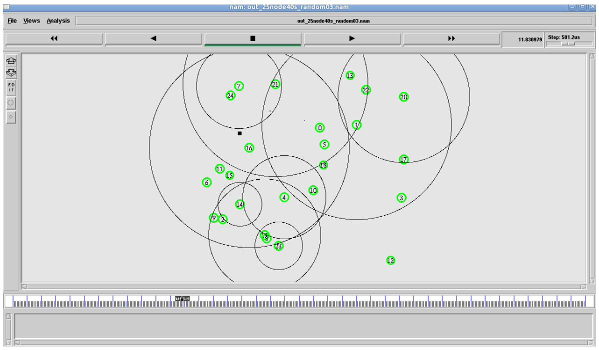

Figure4.Simulation of 25 nodes, random topology

## 4. Experimental Result

We perform 21 test on the same traffic. The test consist of three different deployment topologies and seven of nodes. Than, we analyze the trace-file for calculate the consumption for each test. The total energy consumption is aggregate of energy consumption for each node.

In Figure 5 show the energy consumption for 9 nodes. It can be seen that array topology consume the lowest energy.

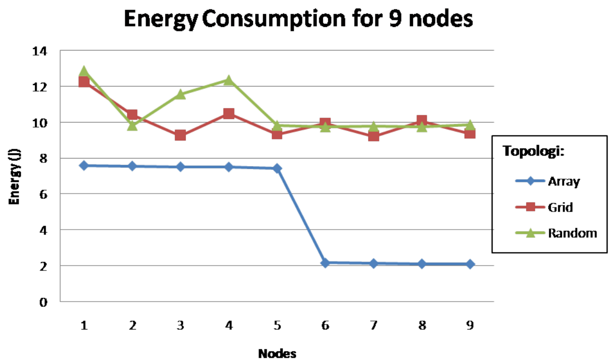


Figure 5. Energy consumption for 9 nodes

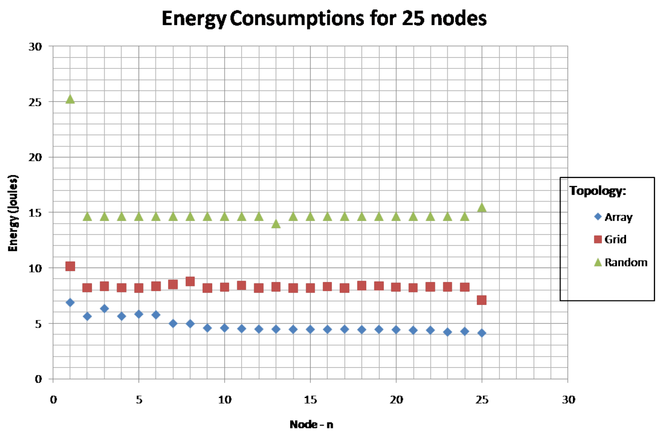


Figure 6. Energy consumption for 25 nodes

Figure 6 until 11 show the energy consumption for 25, 64, 100, 225, 400, and 625 nodes. In each figure indicates that array topology deployment is better than other topology.

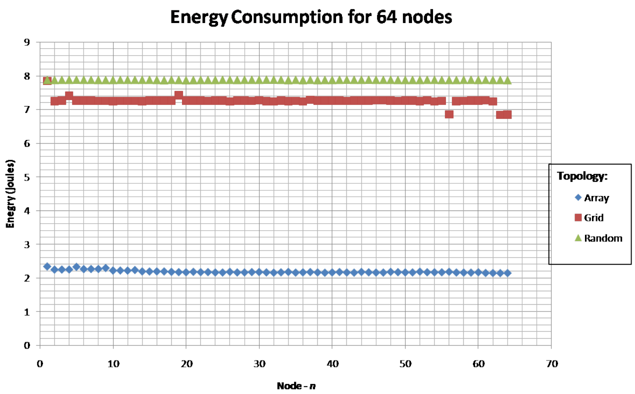


Figure 7. Energy consumption for 64 nodes

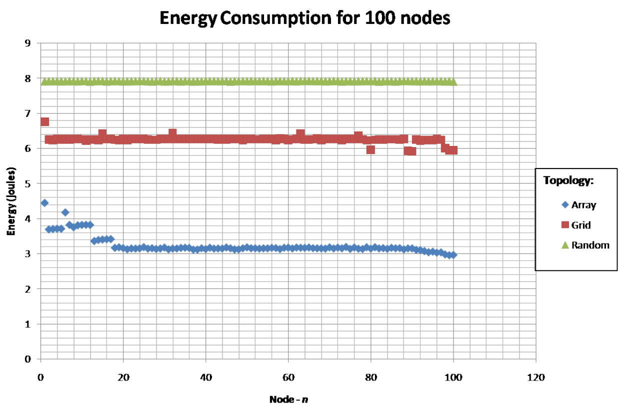


Figure 8. Energy consumption for 100 nodes

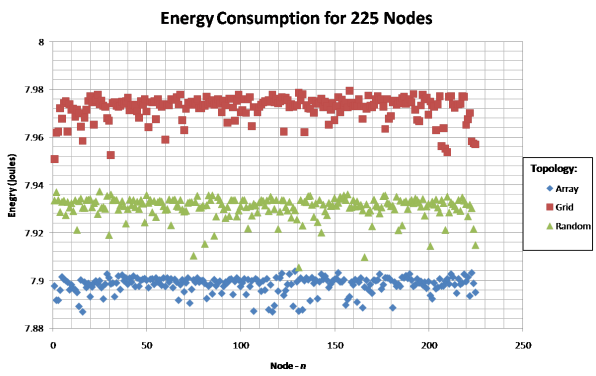


Figure 9. Energy consumption for 255 nodes

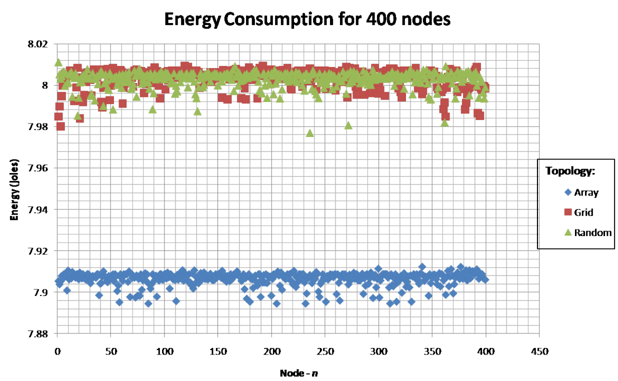


Figure 10. Energy consumption for 400 nodes

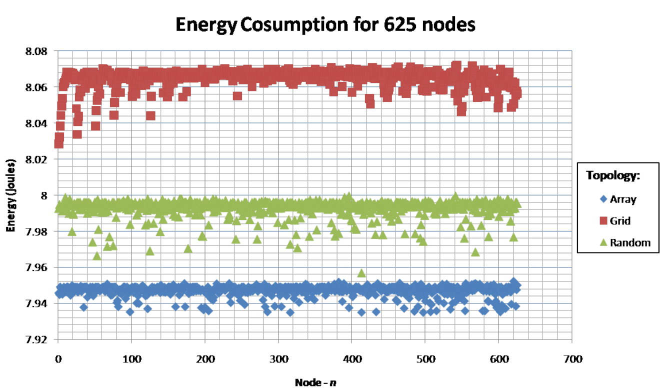


Figure 11. Energy consumption for 625 nodes

In table 2 indicates the average energy consumption for each topology and each number of nodes. Array topology array indicates the best result, 0,560%, then grid topology 0,799% and the last is random topology 0,935%. That's mean that array topology consume the lowest energy.

TABLE II
Topology Average Energy Consumption

| Number of nodes | Topology | | | | | |
|---|---|---|---|---|---|---|
| | Array | | Grid | | Random | |
| | Energy (j) | % | Energy (j) | % | Energy (j) | % |
| 9 | 5.127141 | 0.513 | 10.03382 | 1.003 | 10.63261 | 1.063 |
| 25 | 4.870636 | 0.487 | 8.326291 | 0.833 | 15.0975 | 1.510 |
| 64 | 2.180871 | 0.218 | 7.248263 | 0.725 | 7.882718 | 0.788 |
| 100 | 3.238816 | 0.324 | 6.252485 | 0.625 | 7.908721 | 0.791 |
| 225 | 7.898222 | 0.790 | 7.972196 | 0.797 | 7.930723 | 0.793 |
| 400 | 7.906364 | 0.791 | 8.00293 | 0.800 | 8.002836 | 0.800 |
| 625 | 7.946978 | 0.795 | 8.064755 | 0.806 | 7.992625 | 0.799 |
| Averages | 5.595575 | 0.560 | 7.985821 | 0.799 | 9.349677 | 0.935 |

Figure 12 is graphic of average energy consumption. For every number of nodes, array topology show the best result, then follow by grid topology and random topology.

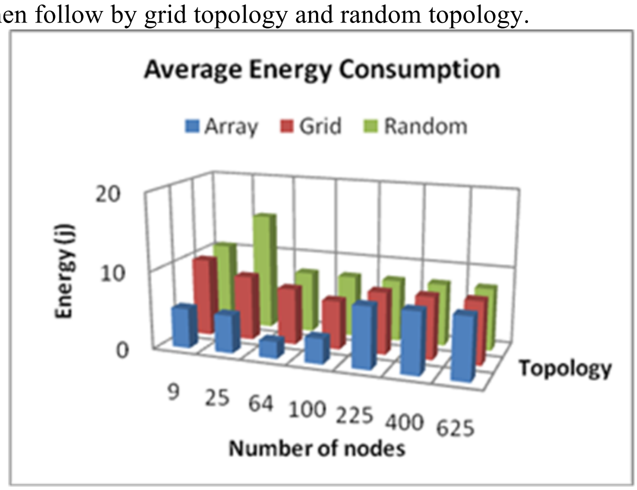


Figure 12. Average Energy Consumption

Total energy consumption for each number of nodes and topology can be seen at Figure 13. As indicated at Figure 13, the total energy consumption is linear with number of nodes. It's mean that more numbers of nodes coresspond to the greater of energy consumption.

According to the Wei Li [13], the main objective of the minimum-power sensor deployment problem is to deploy the sensors in order to (*i*) successfully send all data to the sink (feasibility), and (*ii*) minimize the power consumption of the whole network (optimality). The minimum-power sensor deployment problem can be formulated as an optimization problem which minimizes the total communication power consumption by controlling on each link $j$ the *locations of sensor nodes* $x_{s(j)}$ and $x_{t(j)}$ and the *data rate* $f_{m\,j}$ from each source $m = 1, \ldots, M$.

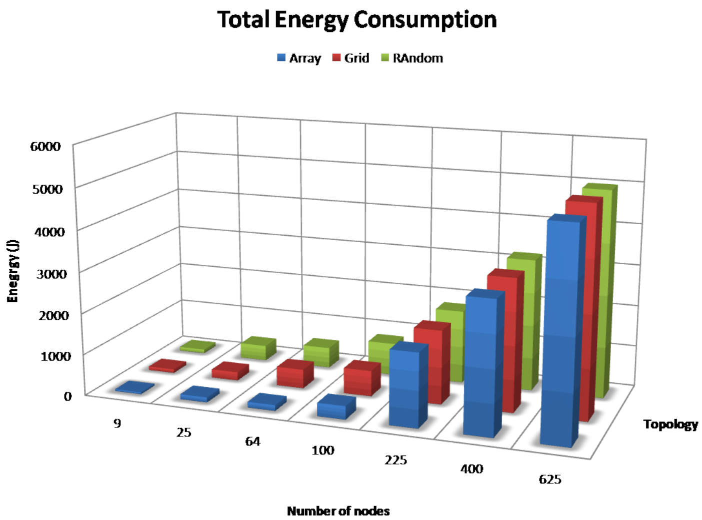

Figure 13. Total energy consumption

In [13], a minimum-power topology was proposed based on the assumption that there is no constraint on the number of intermediate sensor nodes. Under this assumption, the most energy-efficient path between a data source and the sink is a multi-hop link in a straight line, and the minimum power topology is constructed by building such a path for each data source in the network. This topology consumes the least power since each data flow *rm* takes the shortest path toward the sink and by optimizing the hop number, the power consumption on this shortest path is also minimized.

Based onthat research, furtherstrengthensour resultsthat thetopologyarrayindeedconsumethe leastenergy. Basically,an arraytopologyisamulti hoplinkinastraightline.

## 5. Conclusion

Based on our experiment, the array topology indicate the best result, 0.560%, follow by grid topology with 0.799% and the last is random topology 0.935%. It is mean that array topology consume the lowest energy than other topologies.

Total energy consumption is linear with the number of nodes. It's mean that more numbers of nodes correspond to the greater of energy consumption

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