A Simulated Study of Transmission Probability in Cluster Formation Phase for Wireless Sensor Network

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ABSTRACT
Wireless sensor nodes serve as both sensing and routing devices which are generally employed to send data from the primary source node to the destination node (or sink node). There are distinct procedures that wireless sensor networks (WSN) takes when put into operation to route traffic leading to Cluster Head (CH) election and cluster formation. This paper presented a simulated study of transmission probability in cluster formation phase for wireless sensor network. There are several strategies employed in selecting the value of node transmission probability to become a cluster head (CH). The fixed transmission probability scheme has been studied in this paper due to its simplicity, ease of implementation and being commonly considered as means of the random access strategy. The simulation study was carried out in MATLAB environment to examine the effect of changing value of fixed transmission probability. Simulation results show that by proper selection of a value for the fixed transmission probability, the energy efficiency of the nodes can be improved and the WSN life prolonged.

Keywords: Cluster Head, Energy Efficiency, Transmission Probability, WSN.

1.0 INTRODUCTION
As ad-hoc networks, sensor nodes in Wireless Sensor Networks (WSNs) are broadly spread in an area of concern for real time extraction of data. These nodes serve as both sensing and routing devices. Several sensor nodes may be employed to send data from the primary source node to the destination node; for example, in multi-hop communication. The destination node is described as a sink node. The procedures that the WSN takes when put into operation to route traffic are Cluster Head (CH) election and cluster formation (Murugan and Pathan, 2016).

Clustering is a normal process for achieving efficient and scalable performance in sensor networks. When nodes are clustered into groups, energy is saved and aid distribution of control over the network In order to form clusters, sensor nodes must first elect a CH for each cluster. Nodes that are not CHs in the WSN find the closest CH within range and become cluster members. The nodes in a cluster only communicate with one and another and the CH. Data sensed by a node is transmitted to its CH. The CH is accountable for all routing and communication external to the cluster. This brings about energy savings over a “flat” topology, where every node must determine the route from source to sink node (base station). All the nodes in the WSN either choose to become a CH or join a cluster as a cluster member. An exception is the sink node. The sink node is always a cluster member in the WSN. It is never elected to be a CH (Heinzelman et al., 2000).

Any sensor in the WSN may be chosen to become a CH with a predetermined probability p when the network is installed. There is not an optimal number of CHs for a WSN. For each topology the clustering process must guarantee that no nodes become separated and that there are no more clusters than required as surplus clusters decrease the energy savings produced from clustering. There are two distinct phases in cluster based WSN configuration: cluster formation phase and steady state phase. In the cluster formation phase, all the active nodes (the nodes that detect the event) transmit a packet among one and another so as to be part of the event cluster. However, in this phase, it is not possible to know in advance the number of nodes that detected the event as such transmission cannot be scheduled. For the steady state phase, once the event cluster is formed, all the nodes in the event cluster transmit their data packets to the CH and the CH transmits the accumulated data packet to the base station and there is schedule time of data transmission for sensor nodes using Time Division Multiple Access (TDMA) protocol (Rivero-Angeles, 2014).

In this paper, the effectiveness of a WSN to conserve energy has been examined by iterative simulation of fixed transmission probability for optimal performance. The fixed transmission probability is considered in the study.

2.0 STRATEGIES FOR SELECTING TRANSMISSION PROBABILITY

The issue of selecting the transmission probability in the formation of cluster has been largely neglected in literature (Verna, 2015 and Montielet al., 2017). Selecting the transmission probability in cluster formation phase can be achieved using different strategies such as Maximum success (MAXS) transmission probability or optimal transmission probability, adaptive transmission probability, and fixed transmission probability (Montiel et al., 2017).

The transmission probability that optimizes the successful transmission probability is used in MAXS transmission probability. The probability that a node transmits a packet without experiencing a collision is referred to as the successful transmission probability. This strategy requires that all nodes in the WSN should know the exact number of nodes that are able to potentially transmit in the next time slot (Montiel et al., 2017). However, this strategy is not feasible in practical systems due to the fact that there is no easy way to know the precise number of nodes inside the surveyed area, since it is frequently not fixed. Also, the evaluation of MAXS transmission probability scheme is only of theoretical interest.

The fixed transmission probability technique involves selection of an appropriate value for the transmission probability and the value is kept constant all through the cluster formation phase. Unlike the MAXS scheme, this approach is very simple and easily implemented in practical systems. This technique offers good performance once the transmission probability is suitably selected for some specific conditions. The disadvantage of this strategy is that in WSN, the conditions of the systems are highly variable as a result of the death of nodes (nodes that consumed all their battery energy or are destroyed during the normal operation of WSN) and to new node addition.

Adaptive transmission probability scheme is such that the transmission probability is adjusted in accordance with the outcome of the previous slot. This scheme offers the advantage of constantly adapting to the varying conditions of the WSN such as death of nodes and addition of new nodes. It also provides much closed performance to MAXS. However, like MAXS, the scheme depends on the number of transmissions in current time slot to evaluate the value of the transmission probability, and as such the perception of the outcome in current time slot can be drastically changed by noisy channel effect (Montiel et al., 2017; Rivero-Angeles, 2014).

3.0 MODELING METHOD

The modeling of the network was done in MATLAB based on the following assumptions made for the network topology and operation:

- Setting the simulation: the WSN model used for simulation purpose in this paper has a dimension of 100m×100m (10000 square metre) representing the network field consisting of N number of sensor nodes.
- Placement of nodes: the nodes are randomly distributed all over the network field.
- Sending of data: the nodes always have data to transmit to the sink node.
- Placement of sink node: the sink (base station) positioned for this purpose is in the x and y coordinates given by (x, y) = (25m, 75m).

The flowchart for the implementation of the WSN model in MATLAB is based on the information provided in Figure 1. The designed model is shown in Figure 2, and the simulation parameters in Table 1.

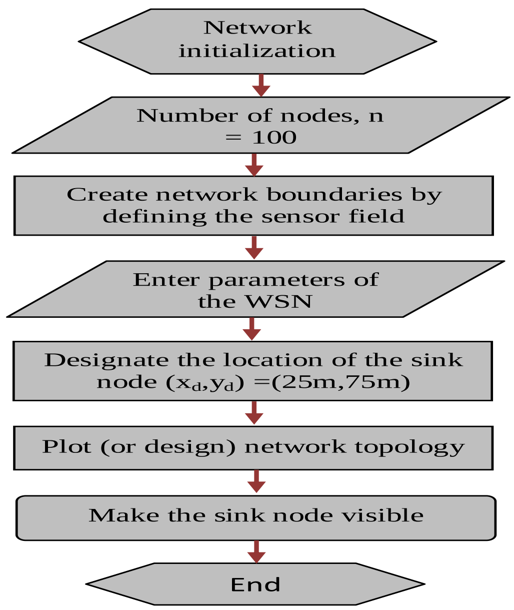

Figure 1: Flowchart of WSN Topography Design.

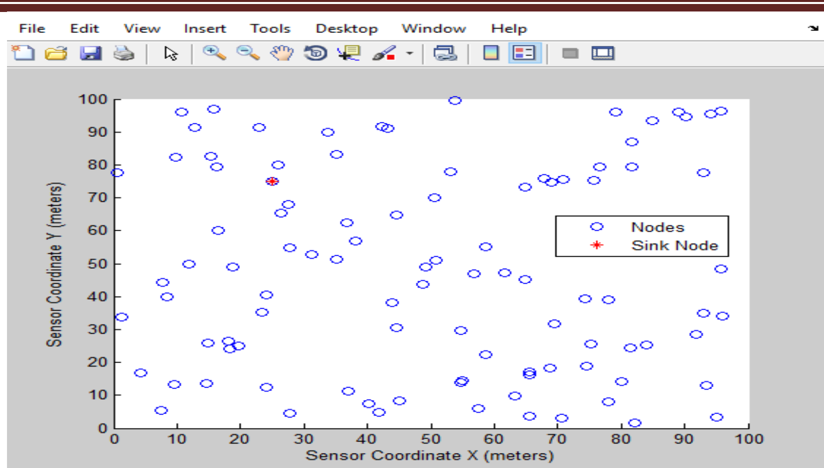

Figure 2: Random Sensor Wireless Network Coded in MATLAB.

Table 1: Simulation Parameters.

Parameter	Value
No. of sensors	100
Area	100m by 100m square
Transmit power	5.0×10^{-9}W
Receive power	5.0×10^{-9}W
Processing power	5.0×10^{-9}W
Initial Energy of sink node	2.0 J
Initial Energy of Each node	2.0 J
Traffic generation messages	5,000 to 20,000
No of threshold nodes	20
Sink node coordinate	(x,y) = (25m, 75m)

During the operation of the network, the threshold value T_h for a sensor node SN (i) to belong to a cluster is given by:

$$T_h = \frac{p}{1 - p \times (\mathrm{mod}(rnd, 1/p))}, \quad \text{otherwise } T_h = 0 \qquad (1)$$

where p is the desired fraction or percentage of CH, rnd is the current round number.

Given that E_i is the energy of i-th sensor node, SN(i) during the current round operation, and the average energy $\bar{E}$ calculated for each round (rnd) and is given by:

$$\bar{E}(rnd) = E_o[1 + s(q + s_o r)]\left(1 - \frac{rnd}{R}\right) \qquad (2)$$

And $$R = \frac{E_T}{E_{rnd}} = \frac{N \times E_o[1 + s(q + s_o r)]}{E_{rnd}} \qquad (3)$$

Energy dissipated by i-th sensor node SN(i) in a cluster while transmitting data to cluster head (CH) is given by:

$$E_i = E_{elec} \times k + E_{amp} \times k \times SN(i) \times d_{tch}^2 \tag{4}$$

Where d_{tch} is the distance between the i-th sensor node, SN(i) in a cluster transmitting data to the CH and is given by:

$$d_{tch} = \sqrt{(d_{chx} - d_{SN(i)x})^2 - (d_{chy} - d_{SN(i)y})^2} \tag{5}$$

The energy dissipated by cluster head node while transmitting data to sink node with respect to SN(i) is given by:

$$E_{i\text{-}ch} = (E_{elec} + E_{DA}) \times k + E_{amp} \times k \times SN(i) \times d_{t\sin k}^2 \tag{6}$$

where d_{tsink} is the distance between the sink and the CH and is given by:

$$d_{tsink} = \sqrt{(d_{sinkx} - d_{SN(i)x})^2 - (d_{sinky} - d_{SN(i)y})^2} \tag{7}$$

where x and y mean the horizontal and vertical coordinates of the WSN.

The energy dissipation for CH during reception is:

$$E_{RX} = (E_{elect} + E_{DA}) \times k \tag{8}$$

The total round energy dissipated E_{rnd} is the sum of all the energy dissipated by i-th sensor node SN(i) in the network during transmission and reception.

4.0 SIMULATION RESULTS

Results obtained from the simulation carried out in MATLAB for different values of transmission probabilities - P (%) of cluster head (CH) election are hereby presented. The simulation plots are presented in figures 3 to 6. Tables 2 to 5 are the analysis report of operational nodes per transmission, operational nodes per rounds, average energy consumed by a node per transmission and energy consumed per transmission.

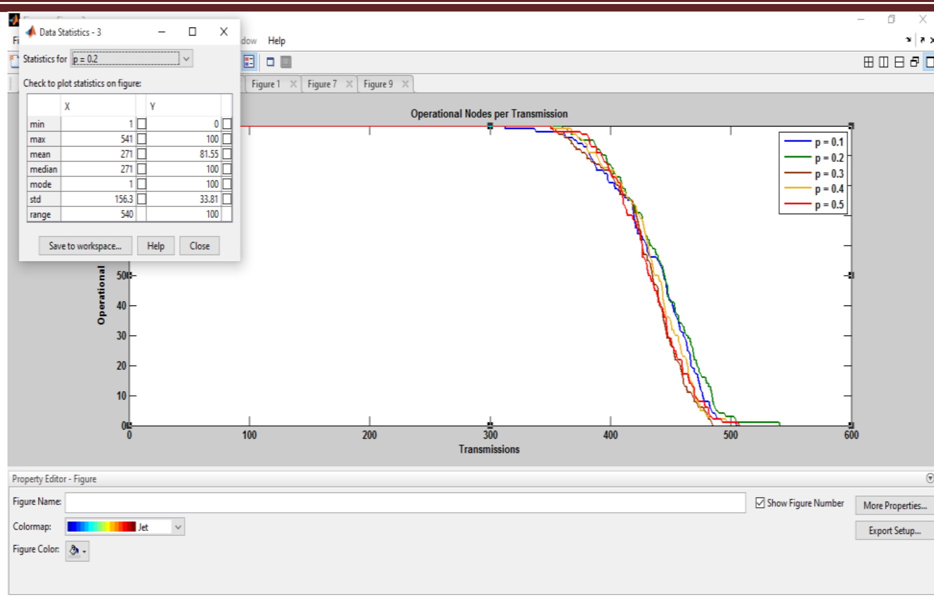

Figure 3: Operational Nodes per Transmission with Respect to Probability.

Table 2: Analysis of Operational Nodes per Transmission.

P (%)	Transmission	Operational nodes
10	505	100
20	541	100
30	485	100
40	506	100
50	507	100

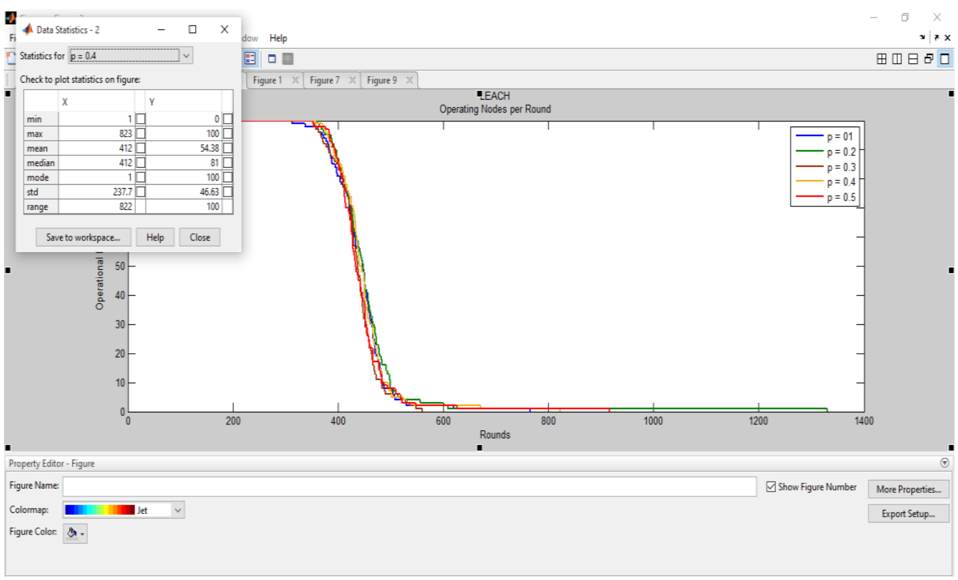

Figure 4: Operational Nodes per Rounds with Respect to Probability.

Table 3: Analysis of Operational Nodes per Rounds.

P (%)	Round	Operational node
10	765	100
20	1331	100
30	561	100
40	823	100
50	917	100

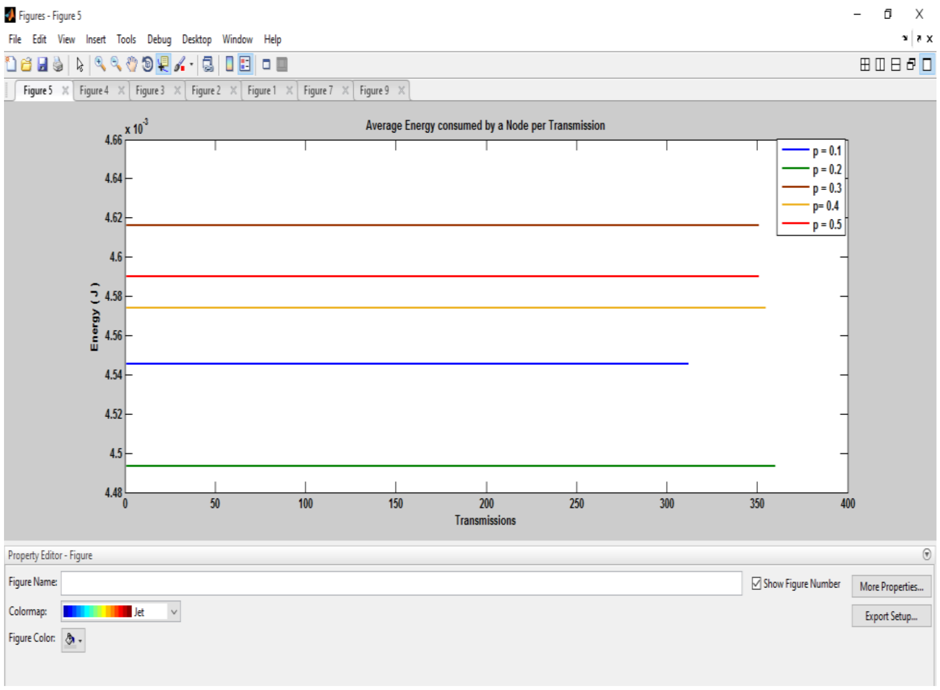

Figure 5: Average Energy Consumed by a node per Transmission in Terms of Probability.

Table 4: Analysis of Average Energy Consumed by a Node per Transmission.

P (%)	Transmission	Average energy (J)
10	312	0.004545
20	360	0.004493
30	351	0.004616
40	355	0.004574
50	351	0.004590

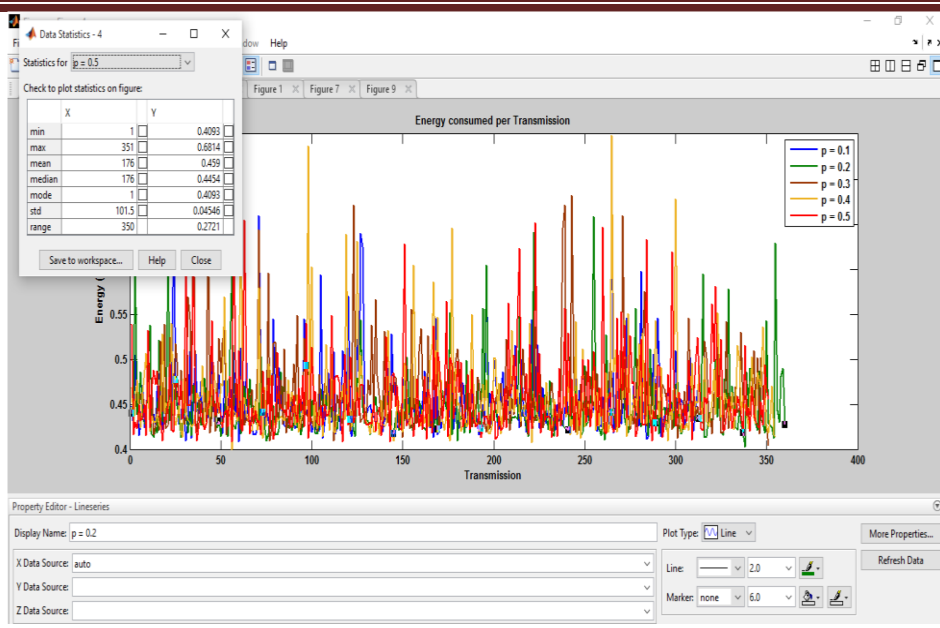

Figure 6: Energy Consumed per Transmission with Respect to Probability.

Table 5: Analysis of Energy consumed per Transmission.

P (%)	Transmission	Energy (J)
10	312	0.6647
20	360	0.6589
30	351	0.6823
40	355	0.7483
50	351	0.6814

From Tables 2 to 5, it can be deduced that the probability of a sensor node becoming a cluster head at 20% provided the most effective performance in all cases. In Table 2, the probability at 20% offers the highest transmission (541). In Table 3 it gives the highest round of operation (that is from transmission to reception and vice-versa), which is 1331. Despite the fact that the probability taken at 20% provided the highest transmission and round time operation of nodes, it can be seen that in this case the average energy consumed by each nodes and the entire energy consumed by nodes during operations were less (that is, 0.004493 J and 0.6589 J) compared to other probability conditions. What this means is that by taking a probability of 20%, the energy efficiency of the wireless sensor network nodes with sink node privacy is enhanced.

CONCLUSION

In this paper, different transmission probability values have been selected and utilized based on fixed transmission probability to determine the value that will provide optimal performance in Wireless Sensor Network (WSN) operation. MATLAB program and simulations conducted were used to analyze the fixed transmission probability performance of WSN. The simulation underscores the need to experimentally determine the transmission probability value that should be selected when assigning it to nodes in WSN.

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