A Novel Energy efficient Surface water Wireless Sensor Network Algorithm

B.Meenakshi
Research Scholar, Department of Information Technology, MIT Campus
Anna University Chennai,
Chennai-44, India
E-Mail : meenakruthi@gmail.com

P. Anandhakumar
Associate Professor, Department of Information Technology, MIT Campus
Anna University Chennai, Chennai-44, India
E-mail: anandh@mitindia.edu

Abstract— Maintaining the energy of sensors in Wireless Sensor Network (WSN) is important in critical applications. It has been a challenge to design wireless sensor networks to enable applications for oceanographic data collection, pollution monitoring, offshore exploration, disaster prevention, assisted navigation and tactical surveillance applications. WSN consists of sensor nodes which sense the physical parameters such as temperature, humidity, pressure and light etc and send them to a fusion center namely Base Station (BS) from where one can get the value of physical parameters at any time. Requirement of monitoring the environment might be anywhere, like middle of the sea or under the earth where man cannot go often to recharge the batteries which supplies the sensing device, transceiver and memory unit in the sensor node. So the usage of the battery power must be judicious in WSN. Earlier attempts have been made to prolong the network lifetime, but still it is a challenging task. In this paper we propose a Novel Energy efficient Surface water Wireless Sensor Network Algorithm (NES-WSN) to optimize the energy consumption by WSN. The present work concentrates on energy saving of sensor nodes when they are deployed in the surface of the sea water. Whenever the sea surface temperature increases there will be a power loss which is reduced by clustering the nodes and by transferring data through multihop routing. Experimental results show that due to increase in temperature there is a definite power loss and it can be minimized by using NES-WSN algorithm definitely.

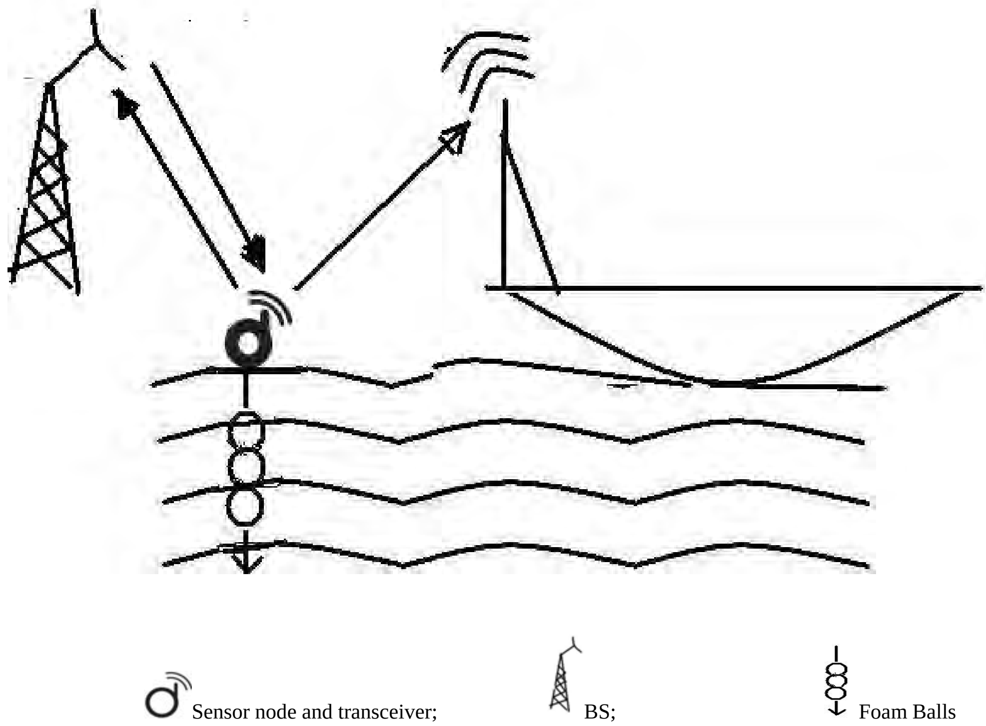
Keywords WSN; Base Station; Network Lifetime; power loss; clustering;

I. INTRODUCTION

The lifetime of a sensor network can be defined as the duration from the deployment of the network to the time when the first or the last sensor runs out of energy. One of an energy-efficient technique to extend the lifetime of a sensor network is clustering. To extend the sensor lifetime, it is often coupled with the data aggregation. Each cluster selects one node as the cluster head. The data gathered from the sensors are forwarded to the cluster head first, and then to the sink. The cluster heads can aggregate the data from the sensors to minimize the amount of the data to be forwarded to the sink. Clusters can be organized hierarchically when the network size increases. The application of wireless sensor networks to the underwater domain has huge potential for monitoring the health of river and marine environments [1],[2]**.**The ocean alone cover 70% of our planet and along with rivers and lakes are critical to our well-being. Monitoring marine environment is difficult and costly. A human can't go and stay for longer time under water to collect such data. NES-WSN Algorithm is designed to collect oceanographic data in efficient manner. This work is the extension of our previous Two Cluster Head Energy efficient Wireless Sensor Network (TCHE-WSN) algorithm [3]

Our work is to propose an idea of doing WSN on the surface of sea so as to get information about the sea pollution, sea roughness etc and also to communicate with the fisherman. In Fig-1, one such sensor node is shown (for clarity purpose). Like this 'n' number of nodes are deployed. Sensor node is to sense the information like oxygen level, or CO_2 level so as to know the availability of fish. The sensed information is conveyed to BS through transceivers. From BS information can be sent to satellite. Like this arrangement so many BSs can be linked through internet. The zigbee transceivers can be fixed with the Fisherman's boat. In definite time intervals the nodes which act as CH (Cluster Head), collects the information from their CMs (Cluster Members), aggregate the data and send them to BS. This leads the communication between the fisherman and sea shore so that they could get information about fish availability, sea roughness etc. If there is a possibility of communication with sea shore then the fisher man could avoid crossing the border of one country in the sea area. Our proposed work can help to develop such network.

Figure 1. Node communicates with BS and transceiver in the boat.



II. RELATED WORK

Wendi Rabiner Heinzelman et al. compared direct communication, Minimum Transmission Energy (MTE) method with his Low Energy Adaptive Clustering Hierarchy (LEACH)[4] In direct communication nodes can send information directly to the Base Station (BS). In case of direct communication, if BS is far away from node, the life of the battery reduced sooner. In MTE method, the node which has minimum transmission energy to transfer data is chosen to receive data from all other nodes and transfer data to BS. Here the node nearer to BS dies out quickly. Commonly used WSN architecture is by grouping nodes into clusters and the selected Cluster Head (CH) communicates with BS. Changing the CH periodically is a must so as to reduce the stress on the same node since CH is communicating with all other nodes constantly and also with BS. LEACH is implemented in two phases. (i) Set up phase. (ii) Steady state phase. In set up phase the clusters are framed and for each cluster, CH is selected. LEACH uses coordination so as to enable scalability and robustness for dynamic networks, and combine data fusion into routing protocol to reduce amount of information transferred to BS. LEACH saves energy 8 times than MTE routing and direct transmission.

M. J. Handy et al. in his L-DCHS (LEACH with Deterministic CH selection) [5] increased the lifetime of a network. The threshold value is modified by including the remaining energy level available in each node.

Linping Wang et al. improved the L-DCHS algorithm in IEAL algorithm (Improved Energy-efficient Algorithm based on L-DCHS) [6] by making the nodes to know about the location of other nodes, secondly by appointing two CHs. The MCH (Master CH) is elected by calculating the threshold value. The node factor is sent to MCH by all the nodes belong to the same cluster. The MCH select the VCH (Vice CH) which is having highest node factor. The cluster maintenance is done by watching the current energy of the MCH and VCH. If the current energy of MCH is less than 2 times the energy threshold value then the new cluster is formed with new CHs. It is observed that in IEAL the lifetime improvement of WSN is 19.8% for HND (Half Node Dies) and 6.7% for LND (Last Node Dies).

Further the energy improvement is done in NEAW (Novel Energy-efficient Algorithm for WSN) [7] by splitting the total area into 3 regions. The 3 regions have different MCH and VCH whose functions are heterogeneous. The far VCH nodes send data to BS through multi hop. MCH receives data from all nodes and send them to VCH. VCH is responsible for compressing the data and send to BS. The NEAW has 8.6% delays at time when the first node die, 24.2% improvement when there are half of the nodes alive, in comparison to L-DCHS. Moreover, NEAW can achieve even a 14.3% increase in LND.

WSN used for many real time applications. Many projects are going on throughout the world which uses the WSN to collect much more useful data. Few of them are listed in Table-1

TABLE-1 VARIOUS WSN PROJECTS

Sl.No	Project Name and Place	Purpose
1	WINSOC project, Idukki, Kerala state, India[8]	Landslide detection
2	SmartDetect, IISC, Bangalore, India [9],[10],[11].	Intruder detection
3	ComonSense Net(CSN) project, Karnataka, India[12]	Agricultural Management
4	MpWiNodeZ, Douro[13]	Precision viticulture, Grape Field.

III. PROPOSED ALGORITHM: NES-WSN ALGORITHM

Our proposed NES-WSN Algorithm includes the following phases of works

- Nodes Deployment
- Cluster Formation
- CH selection
- Routing
- Energy Maintenance

A. Nodes Deployment

The wireless sensor nodes are deployed on the surface of the sea. On the surface of the sea the sensor nodes are deployed by tying a weight on the sensor with rope whose length little bit more than sea depth [14]. The sensors are also attached with foam balls so that they can float on the surface [15]. Each and every node is a transceiver. The node senses the information and passes them to BS. The communication between node and BS follows NES-WSN Algorithm, which made the same efficiently. Figure 1. shows how the sensor node floats on the sea surface and communicate with BS and with transceiver in fisherman's boat. Figure 2 shows the actual scenario created.

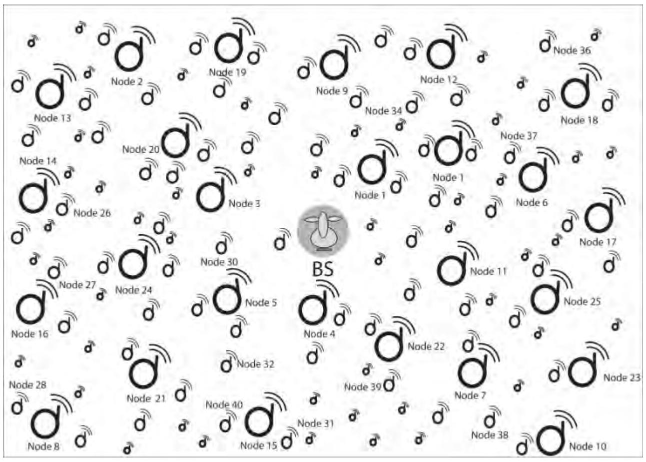


Figure 2. Actual scenario created

B. Cluster Formation and CH selection

The activities of the network during cluster formation are depicted in Figure 3. BS broadcasts the message to all nodes asking for their host_id and remaining energy. The nodes receiving message from BS, sends the Acknowledgement, host_id and remaining energy. The BS creates a table whose columns are host_id, TF (Time Factor), remaining energy and region. The region is decided by TF. The remaining energy is updated by Energy Maintaining Module (EMM) in Mac layer (as shown in Figure. 4). The processes involved in cluster formation and CHs selection are implemented by altering the process model (Figure 5.) in the OPNET. OPNET is a network simulator used here to implement the NES-WSN algorithm.

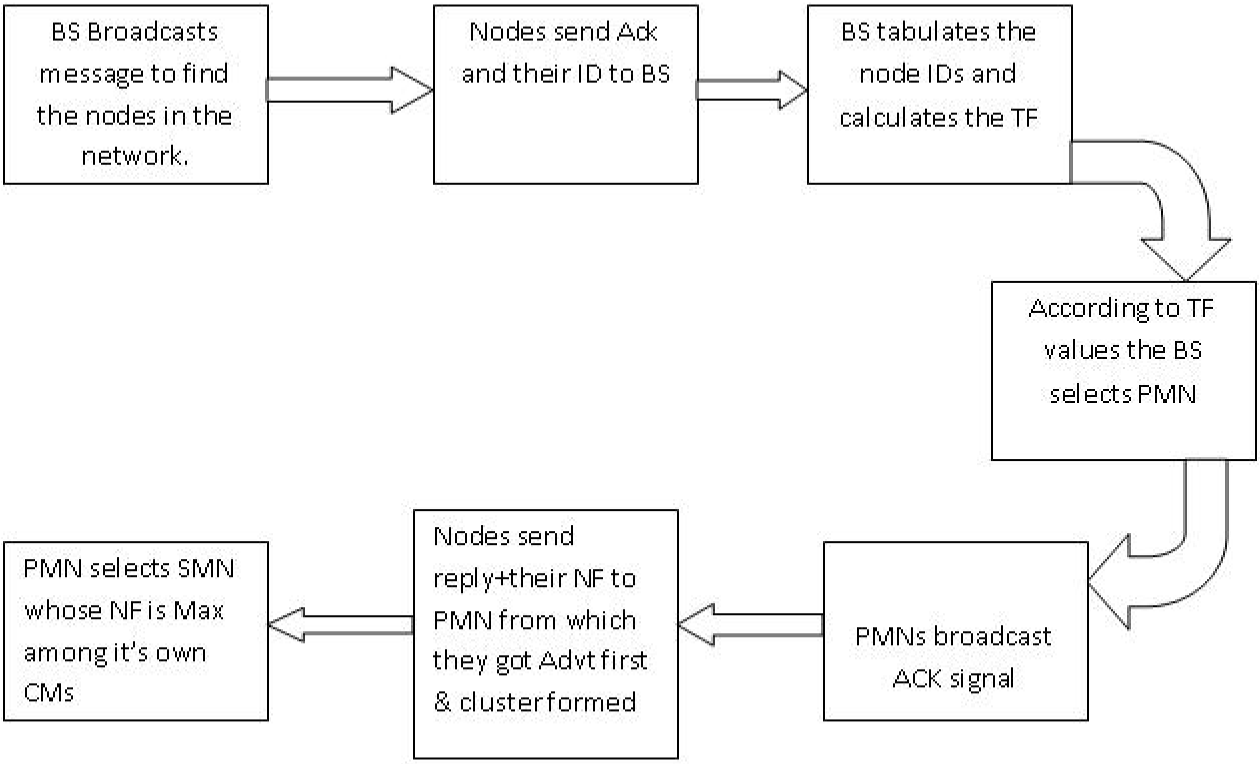


Figure 3. Illustration of Cluster formation and CHs selection

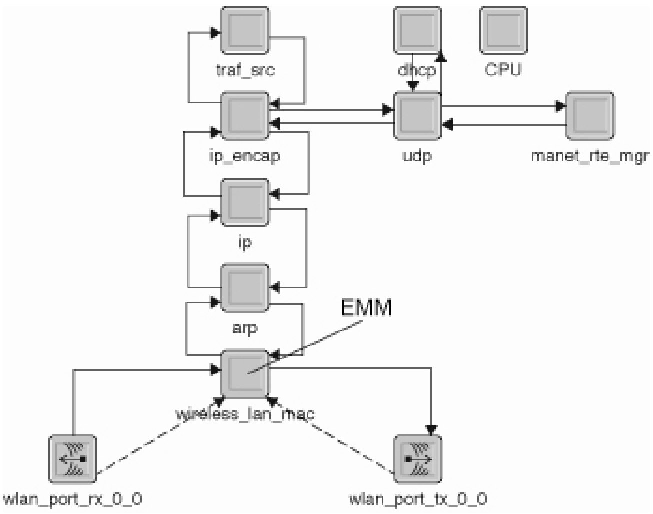


Figure 4. Node model of individual sensor nodes in WSN

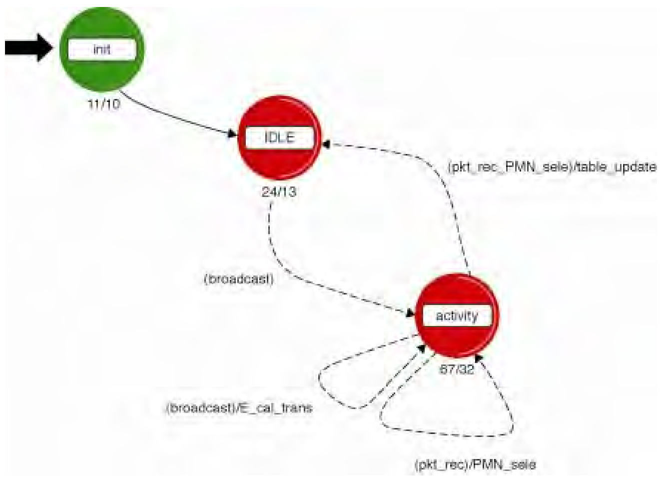


Figure 5. The Process model of BS

In the process model of BS there are three FSM (Finite State Machines). Among these three states the init state alone is a forced state (green in color). The other two states are unforced states (red in color). In the forced state the enter executives and exit executives will get executed and then move to next state. In unforced state enter executive will get executed first and will wait for interrupts before executing the exit executives. BS executes four functions namely

- Broadcast()
- Table_update()
- Region_split()
- PMN_selection().
- SMN_selection().

1. *Broadcast()*

All initializations are done in init state, and then BS broadcasts the message to find the nodes in the surroundings. After receiving the message the nodes reply. The reply from the nodes are received by BS and the pmn_sele() function gets executed. Whenever the pmn_sele condition is satisfied then the table_update() function is executed.

2. *Table update()*

Whenever the BS sent the broadcast information to the node the time (t_1) was noted and tabulated. After receiving the acknowledgement from the node the acknowledgement received time (t_2) was also tabulated. For all the nodes in the network the TF (t) is calculated using (1).

$$t = (t_2 - t_1) \qquad \rightarrow (1)$$

In the table the TF, random number received, and threshold values for all the nodes are entered as shown in Table-II.

TABLE-II TABLE CREATED AND UPDATED BY BS

Sl.No	Node_ID	Time t_1	Time t_2	TF= t_2- t_1	Random no. recvd.	Threshold value recvd.	Region	Status of node (PMN or SMN or CM)

Nodes generate a random number and calculate a threshold value T_N and send them to BS. T_N is calculated by (2).

$$T_{N(i)} = \frac{P}{1 - P\left(r \bmod \left(\frac{1}{P}\right)\right)}\left[\frac{E_{rem}(i)}{E_{max}(i)} + \left(r_{n_{ch}}\ div\left(\frac{1}{P}\right)\right)\left(1 - \frac{E_{rem}(i)}{E_{max}(i)}\right)\right] \rightarrow (2)$$

P-> percentage of CH among nodes 'n';

i->represents for any i^{th} node;
r-> round no.;
r_{n_ch}->no. of rounds for which the node is not being CH;
Threshold value includes remaining energy of i_{th} node and maximum energy of the node. Threshold value calculated for the nodes which are not selected as PMN for the last (1/P) rounds by using equation (2), otherwise its value taken as zero. BS compares the random number with T_N and selects P number of PMNs whose random number generated is less than the T_N.[5],[6],[7]

3. Region split()

The total coverage area is divided into three regions based on TF. Region I is the area where TF is less than (TF_{max}/3). Region II's TF is between (TF_{max}/3) and (2*TF_{max}/3). The region whose TF above (2*TF_{max}/3) is region III. By separating the coverage area, the CH's energy dissipation in transmitting data to BS is reduced. The pseudo code for splitting the region is given in Table-III

TABLE III PSEUDO CODE FOR REGION SPLIT FUNCTION

```
Region_split()
{
If (Node.TF<=TFmax/3) then
Region=1;
Elseif (TFmax/3<=Node.TF<= 2*TFmax/3) then
Region=2;
Else
Region=3
Endif;
}
```

4. PMN_selection()

The total number of PMNs (Primary Master Node) in a network is decided by the value of P, the number of Cluster heads. Among this P% of cluster heads $1/3^{rd}$ of the P% is selected from each region. Since the TF of the nodes near the BS is very less, and chances to be selected as PMN are more for nearby nodes. To avoid energy drain out of nearby nodes $1/3^{rd}$ of the nodes from each region are selected. The pseudo code for splitting the region is given in Table IV

TABLE IV PSEUDO CODE FOR PMN SELECTION FUNCTION

.

```
PMN_selection()
{
For node=1 to n
{
If (node.random_no<node.threshold_value) <and> (node.region=1) then
Node=PMN.region1;    //selected as PMN of region 1
PMN.region1++;          // PMN of region 1 incremented by 1
If (PMN.region1>P/3) then  end;
End;
If (node.random_no<node.threshold_value) <and> (node.region=2) then
Node=PMN.region2;    //selected as PMN of region 2
PMN.region2++;          // PMN of region 2 incremented by 1
If (PMN.region2>P/3) then  end;
End;
If (node.random_no<node.threshold_value) <and> (node.region=3) then
Node=PMN.region3;    //selected as PMN of region 3
PMN.region3++;          // PMN of region3 incremented by 1
If (PMN.region3>P/3) then  end;
End;
```

5 SMN_selection()

BS sent the selection message (as PMN), altered id and table containing information about all nodes in network to all selected PMNs. Now the control is taken over by the PMNs. All PMNs broadcast an advertisement signal which is received by all the nodes in the network. The node will reply to only one PMN from whom it receives advertisement signal first. While sending acknowledgement to PMN's advertisement signal the node will also send its node factor (NF). After the fixed time interval the PMN selects one node from its own cluster as SMN (Secondary Master Node) whose NF is maximum.

$$NF(i) = \frac{E_{rem}(i)}{TF(i)} \rightarrow (3)$$

Where NF(i) is the node factor of i^{th} node. E_{rem} (i) is the remaining energy in i^{th} node. TF(i) is the Time Factor of i^{th} node. NF is high for nodes having more remaining energy and for nodes taking less time to communicate with BS. Now the cluster is formed with two CHs namely PMN and SMN.

C . ROUTING

PMN allocate fixed time interval for all nodes of its own cluster for every round. PMN follows Time Division Multiple Access (TDMA), to avoid effects due to multi-path and fading [16]. The sensed data of the node is sent in its allotted time to PMN. The collected data passed to BS was different for various regions. The first region PMNs collects the data from their CMs and aggregates the data then pass to BS directly. The second region PMNs aggregates the data and pass to their own SMNs. The second region SMNs collect data from their own PMNs and also the SMNs of third region aggregate the entire data and pass to SMNs of first region from where the data is passed to BS. The routing in the NES-WSN algorithm is shown in Table V

TABLE V ROUTING

Region:1 CM→PMN(reg-1)→BS
Region:2 CM→PMN(reg-2)→SMN(reg-2)→SMN(reg-1)→BS
Region:2 CM→PMN(reg-3)→SMN(reg-3)→SMN(reg-2)→->SMN(reg-1)BS

C. ENERGY MAINTENANCE

In previous algorithms, the CHs are changed for every round of operation. But in NES-WSN algorithm calculation overhead by implementing the algorithm for each round is reduced. The change of CH is done only after every 100 rounds of operation. Whenever the node transmits or receives there is a definite energy loss [4],[5],[6],[7] in the node given by (4) and (5)

$$E_{trans}(k,d) = E_{trans_{elec}}(k) + E_{trans_{amp}}(k,d) = KE_{elec} + k\mathcal{E}_{amp}d^2 \rightarrow (4)$$

$$E_{recv}(k) = E_{recv_{elec}}(k) = kE_{elec} \rightarrow (5)$$

$$E_{trans}(k,d) = E_{trans\_elec}(k) + E_{trans\_amp}(k,d) = kE_{elec} + k\varepsilon_{amp}d^2 \rightarrow (3.1)$$

Where E_{trans} (k, d) is the energy required to transmit k bits over distance d. Here the distance decided by the Time Factor (TF). TF is the summation of time duration to send the message from BS to node (t_1) and got reply from node to BS (t_2). The distance d is calculated using (6)

$$d = (t_2 - t_1) * V \rightarrow (6)$$

Where E_{trans_elec} (k) is the electrical energy required for transmitting k bits which is equal to kE_{elec}. The energy spent for amplifying k bits to transmit over d distance is E_{trans_amp} (k, d) and is equal to $k\varepsilon_{amp}d^2$. Energy required to receive k bits is E_{recv} (k) and is equal to kE_{elec}. Velocity of radio signals is V and is equal to 300km/sec

$$E_{rem} = E_{init} - (E_{trans} + E_{recv}) \rightarrow (7)$$

We imposed Energy Maintaining module (EMM) in MAC layer which keeps a record of the remaining energy of each and every node. Equation (7) is used by EMM to calculate remaining energy after each and every round of operation [3], [4],[5],[6],[7].

Whenever temperature increases beyond 25^{o}C, the received Signal Strength decreases. So the nodes should spend more energy to receive the week signals. The power loss in dBm due to rise in temperature [17] is given by (8).

$$P_L(T) = 0.1996(T - 25) \rightarrow (8)$$

P_L(T)->Power Loss due to Temperature in dBm;

T->Temperature in ^{0}C;

Generally the surface temperature of the sea in Bay of Bengal Ocean near Tamilnadu sea shore is around 27^{o}C to 29^{o}C. The slope of (8) gives the rate of change of power loss (9) due to change in temperature.

$$\frac{dP_L(T)}{dT} = 0.1996 \rightarrow (9)$$

Power Loss in mW=10^(0.1996/10)mW=1.047032mW=1.047032J/sec.--> (10)

Energy loss due to increase in temperature beyond 25^{o}C is equal to ,

E_L(T)=((power Loss in J/sec) X (Total number of bits)) / (Range in bits/sec)→(11)

For Zigbee the range is 54Mbps.

The EMM(Energy Maintaining Module) will check the remaining energy levels of PMNs and SMNs. Energy threshold value ($E_{threshold}$) was set in the algorithm which is twice that of energy required to pass data to BS. If remaining energy of SMN is less than $E_{threshold}$ then PMN will redo the procedure of SMN selection from its own cluster. But the remaining energy of PMN is less than $E_{threshold}$ then cluster reformation is to be carried out.

D. .EXECUTION:

The data taken for simulation is given in Table VI.

TABLE VI THE DATA TAKEN FOR SIMULATION.

Parameter	Value
The Number of Nodes	100
Initial Energy of individual nodes	0.5 Joules
Distance, d	1meter.
E_{elec}	50nJ/bit
ε_{amp}	100PJ/bit/sq.meter

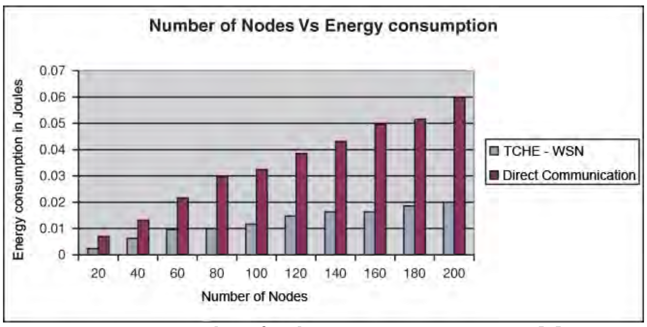


Figure 6. Number of nodes Vs Energy consumption [3]

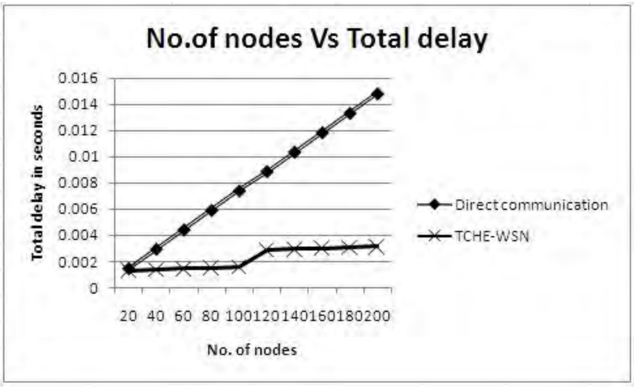


Figure 7. Number of nodes Vs Total delay [3]

The average percentage of energy saving when two CHs are selected is 36.46501817% , Percentage reduction delay is 4.8922775595% in TCHE-WSN[3]. For each and every round only 5% of the total number of nodes that are PMNs in region1 and SMNs of region2 and region3 will collect the information from all other nodes and communicate them to BS. So the average energy saving is 36.46501817%. The energy saving during communication process by sensor node will lead greater effects in battery life, since energy spent during communication is more compare to other works like sensing, aggregating etc. The delay also considerably reduced when two CHs are selected. In this proposal, we have analyzed the remaining energy of sensor nodes when energy loss due to increase in surface temperature also taken into account.

$$E_{rem} = E_{init} - (E_{trans} + E_{recv} + E_L(T)) \rightarrow (12)$$

$E_L(T)$ is calculated using equation(1). Fig-8 shows the remaining energy for 100 nodes for various numbers of bits. When numbers of bits increases the remaining energy reduces soon. When energy losses due to increase in temperature is taken into account the remaining energy for various number of bits is shown in Figure 9. The effect of temperature increase over remaining energy is shown in Figure 10. Whenever the number of bits increases the energy loss due to temperature increase is more which is shown in Figure 11.

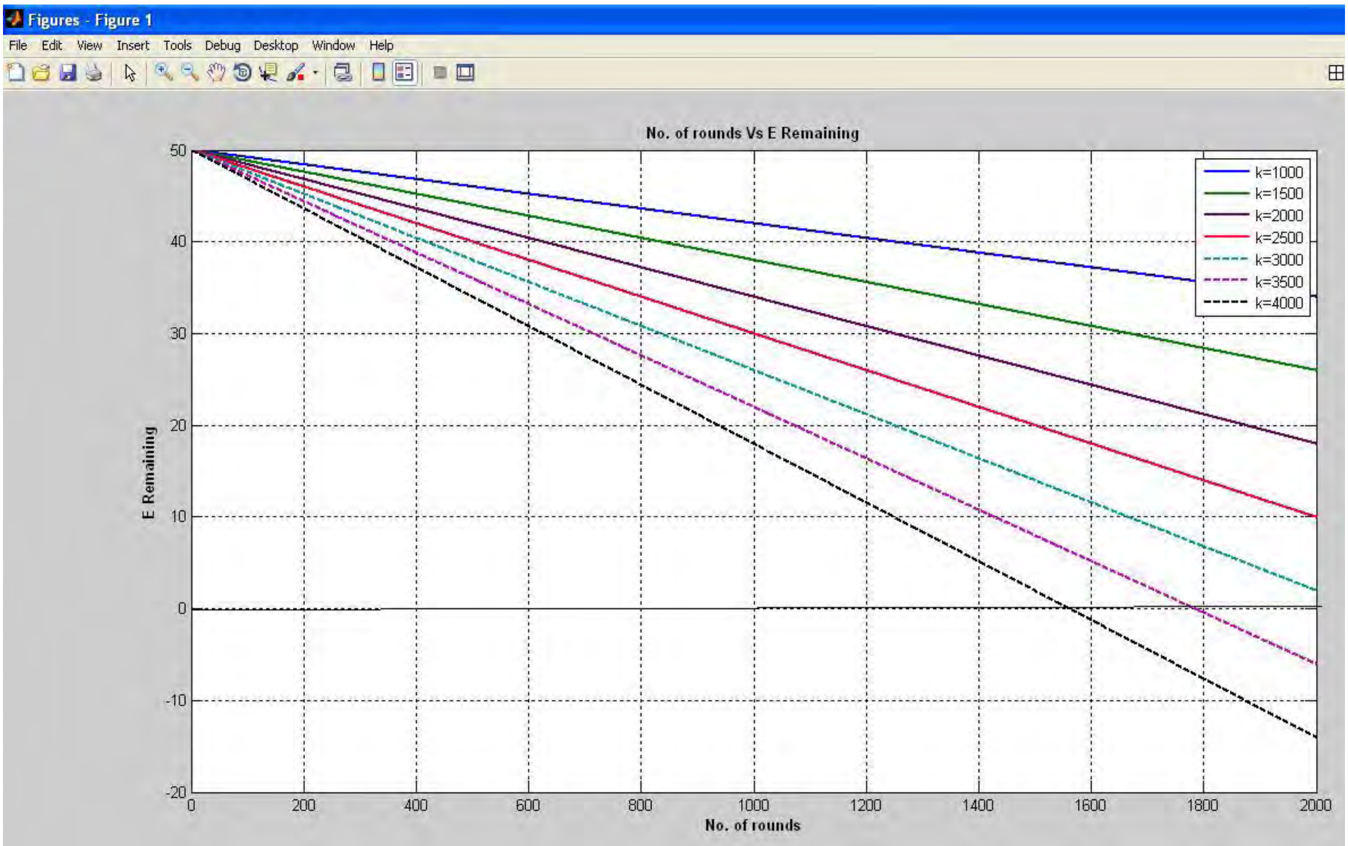


Fig-8 Energy remaining without energy loss due to increase in temperature for various numbers of bits

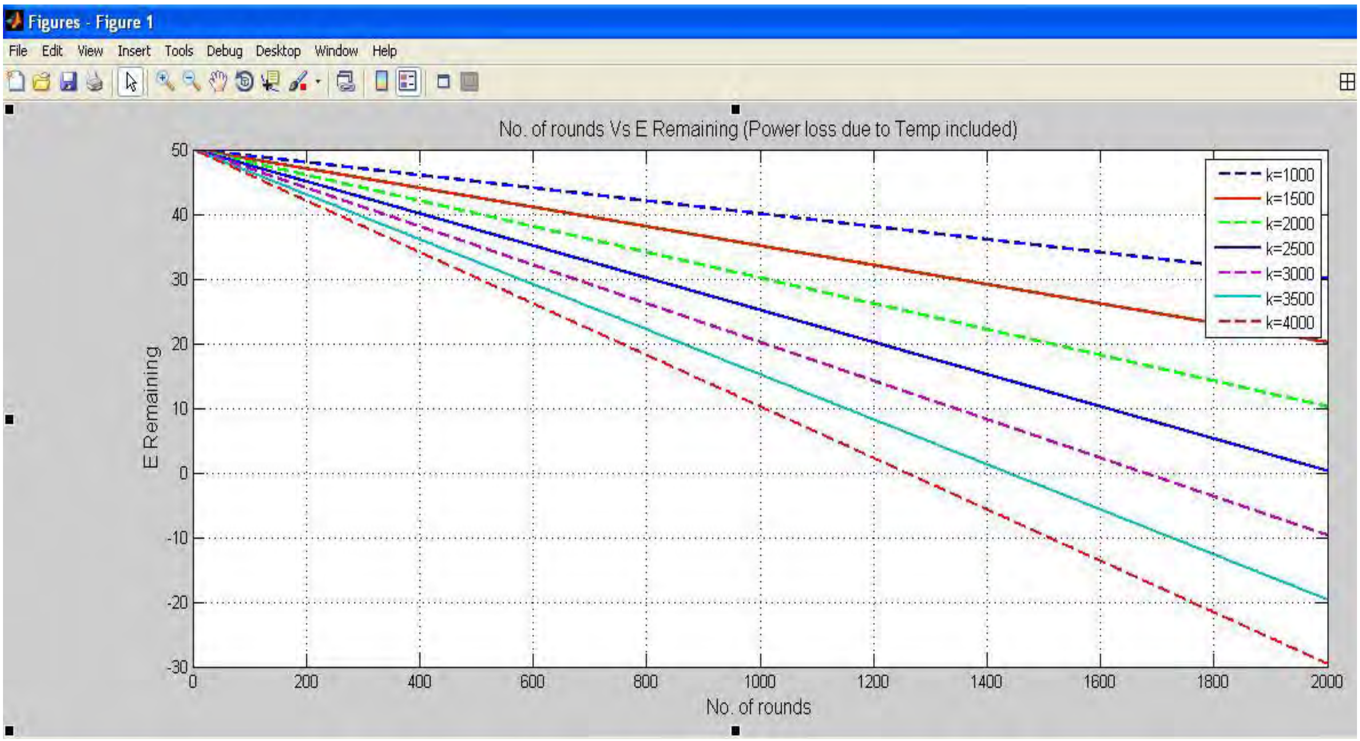


Fig-9 Energy remaining with energy loss due to increase in temperature for various numbers of bits

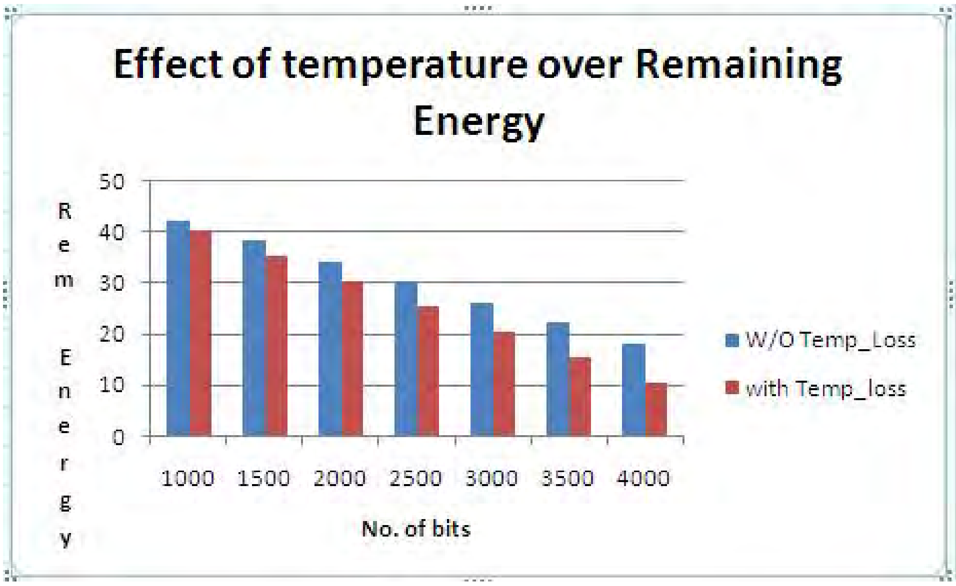


Fig-10 Effect of temperature over energy loss for various numbers of nodes

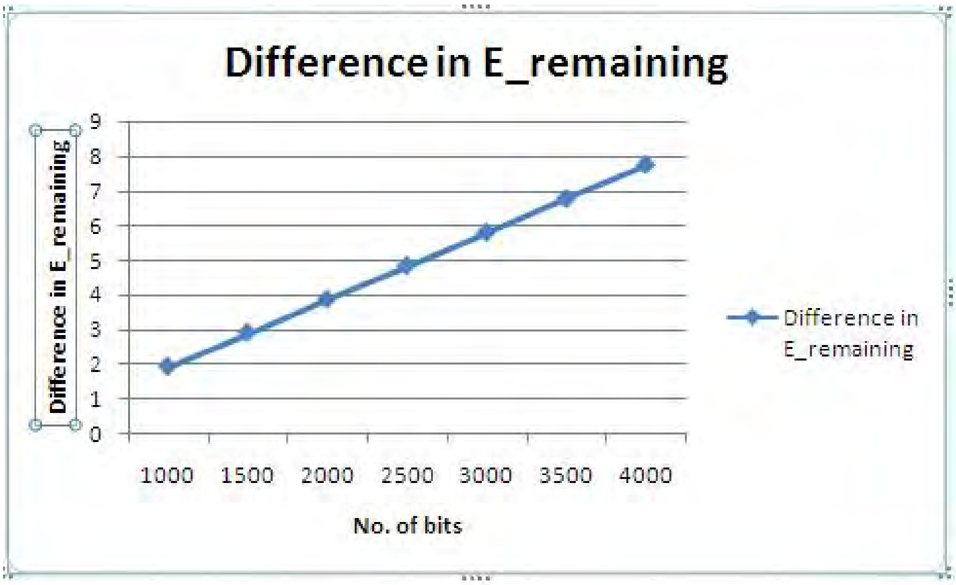


Fig-11 Difference in energy remaining with and without energy loss due to increase in temperature

CONCLUSION

Thus we conclude that in the case of wireless communication the time taken for the packets to be sent and received is the main factor. The remaining energy decreases with increase in the number of days after deployment of the nodes. The Energy deterioration of WSN is still a subject of interest, because of the challenges involved in it. The average energy saving is 36.46 and the delay is reduced by 4.89% when two CHs are selected. After every 100 rounds the algorithm is implemented to form cluster and CHs there is an increment in delay (Figure 7) but the delay is less than direct communication. NES-WSN algorithm is a reliable algorithm for surface water applications. The scope of this algorithm is on the higher side even when the network area increases. The algorithm is designed by keeping the Energy loss due to increase in temperature as a major factor. Even though clustering mechanism is an older one, the usage of second CH (here SMN) increases the battery life of sensor nodes. The impact of increment in temperature over remaining energy is discussed in this paper. Definitely the NES-WSN algorithm will be suitable for surface water applications and will prolong the lifetime of sensor nodes.

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B.Meenakshi received the B.E. degree in Electrical and Electronics Engineering from the Alagappa Chettiar college of Engineering and Technology, Madurai Kamaraj University, India, in 1990, the M.E. degree in Applied Electronics from the Hindustan college of Engineering and Technology, Anna University, Chennai, India in 2005. She is currently pursuing the Ph.D. degree in Information and Communication Engineering, Anna University, Chennai, India. Her research interests include wireless networks, sensor networks, network performance evaluation, and Energy Analysis of wireless networks.

P.Anandhakumar received his B.E degree in Electronics and Communication Engineering from the Government College of Engineering, Salem, India in the year 1994. He obtained his M.E degree in Computer Science and Engineering from Government College of Technology, Coimbatore, India in 1997 and PhD degree in computer science and Engineering from Anna University, Chennai in 2006.He is the distinguished Professor of Department of Information Technology, Madras Institute of Technology, Chennai, India. His research areas include Mobile computing, Image processing, Robotics, Pervasive computing. His research work has been published in many journal papers and numerous conference papers.