ISSN (Print) : 0974-6846
Indian Journal of Science and Technology, Vol 9(45), DOI: 10.17485/ijst/2016/v9i45/106150, December 2016 ISSN (Online) : 0974-5645

A Co-Operative Based Inter-Cluster Communication to Optimize Network Life Time in WSN

L. Rajesh[1] and C. R. Byra Reddy[2]

[1]Visvesvaraya Technological University Research Scholar, Bangalore, Karnataka –560091, India; l.rajeshprasad@rediffmail.com

[2]Bangalore Institute of Technology, KR Road, V V Puram, Bengaluru, Karnataka –560004, India; byrareddycr@yahoo.co.in

Abstract

Wireless Sensor Networks (WSNs) consist of a large number of low-cost, low-power and intelligent sensor nodes and one or more sinks or base stations. Those nodes are small in size and can perform many important functions, including event sensing, information processing, and data communication. WSNs can be employed in wide military applications and civilian scenarios. Sensing the signal and transmission of those signal require lots of energy which reduces the life time of sensor node, which affects the overall network life time. So for saving the energy a better mechanism is required which can improve the overall network life time. Many research works are going in this field for improving the network life time. For Energy saving a large network is divided in to some cluster from one hop to another hop, where a hop contains a Cluster Head (CH) which is chosen by the Base Station (BS) and a Cluster Member (CM), which can communicate with CH. Clusters, can save the energy due to less distance communication factor. CH communicates with BS. LEACH (Low Energy Adaptive Clustering Hierarchy) is very popular clustering mechanism, but it also has some draw backs. So a better mechanism for energy saving and to improve the life time of network is needed. Here author proposed a new idea called Mutual relay node clustering protocol. Here author analyses the network life time in terms of number of rounds and overall energy consumption and compare with currently existing Leach protocol.

Keywords: Inter-Cluster, Intra-Cluster, Mutual, Rounds

1. Introduction

The time for technological growth and survival on the world mainly dependent with the electrical equipment and dependency on these equipment increases very rapidly. Our home want, business need or environmental need to biological for each scenario, human beings are dependent on these new technologies. WSN is also a part of it. In WSN large numbers of sensor nodes are deployed in the network, these devices are capable of sensing signal and are programmable to do some task. These small devices are very useful in gathering environmental data; it helps in military operation, at the time of disaster or health operation, tracking etc. By selecting a location, where target can approach the region of sensor nodes were it is deployed, if target entering in the WSN region sensor node start sensing the signal and collect the information and send it to the BS which is far from the sensor network. Cost of these devices are very low but it require continuous power supply, because these devices are inbuilt with battery which not rechargeable in most of the case, not replaceable also, so it get discharge and die,

*Author for correspondence

the rate of failure of sensor node due to power supply is a biggest problem[1]. The WSN sensor nodes are less mobile in nature, it cannot move frequently like Ad hoc network. In WSN enough nodes are required for collecting more accurate data, tracking information or for maintaining the network connectivity. These nodes can communicate with neighbor nodes and exchange of information takes place. Sensing the signal and transmission of those signal require more energy, which reduce the life time of sensor node and it also affects the overall network life time. For saving the energy, a better mechanism is required which can improve the overall network life time[2]. Many works are going on in this field for improving the network life time. LEACH protocol became very popular for the clustering the network and improving the network life time but LEACH protocol also has some loop holes and not up to the mark.

The basic functionality of clustering mechanism is dividing the large network in small-small cluster where each cluster has their own CH and CM and one BS which may be located inside or outside the network. Selection process of CH, each node sends their information like energy level, position BS etc. On the basis of these detail BS chooses number of CH and give them ID. Then the CH broadcast this ID in the network. Other member of network checks the best feasible CH on the basis like, the distance from CH and chooses one CH as their head. By this manner different member join different CH and forms a cluster. After that CM can directly communicate with other CM and CH. CM transmit their data to the CH, CH collecting data and process it and can communicate directly or indirectly to the base station[3]. In this case CM can save their energy because, the direct communication with BS sensor node lose their energy very fast due to distance factor. The Energy consumption can be divided into two parts, nodes can utilize energy for communication and sensing the signal within the cluster and in other case node can utilize energy in communication with other cluster node. For avoiding the communication error or packet failure here author calculate the Packet Failure Probability (PFP) based on probability factor, author schedule the cluster node for transmission of data. This establishes a relationship between active node and energy consumption, the Energy consumption and sensor active node rate also depends on network node density.

For the best result analysis author compare the obtained result with existing "Energy-Efficient Cooperative Transmission for Simultaneous Wireless Information and Power Transfer in Clustered WSN" by author Songtao Guo, in which its shows that our obtained result is performing better. Rest of the organization of paper is as follows in section two WSN clustering mechanism is discussed from various previous works. In section third proposed system with network design and PFP is discussed. In last section overall summary of the paper work is concluded.

2. Related Work

Various researches are ongoing for the saving of energy consumption in WSN. In[4] author give idea about energy aware routing protocol in WSN, before forwarding packet from one node to another, by considering the available energy of sensor nodes. In Energy Aware Directed Diffusion (EADD) protocol a node which has more energy response time is fast in comparison with node which has less energy. It is useful in balancing the energy distribution in a network, to achieve energy efficiency by reducing duplicate message. In[5] author defined the stability of network in terms of energy consumption and lifetime of network. Cluster may overlap each other and packet collision in the network also happen, for the avoidance of these factors, Multi-hop energy efficient LEACH protocols given, but are not robust clustering techniques. I[6] multiple sensor nodes can join or leave the cluster at a same time, while existing work has only one node can join or leave at a time. By using concept of time complexity, author tries to achieve the goal. However about energy consumption author not to be concerned which a major issue in WSN. In[7] a multi-hop LEACH algorithm is proposed, it is similar to the LEACH, and selection process of CH is same as LEACH. Difference is that if BS is far away or beyond the range in that case CH may behave as a relay node for transmission of the information. The demerits of LEACH concept is that, all nodes are identical in energy level or size. Life time problem of sensor network covered in[8], every sensor has non negative weight and computation is done based on the node which is minimum weight. In[14], author achieves the network lifetime of WSN in coverage of target or any specific things. In[15] problem faced at the time of dividing the network and make cluster in WSN is discussed and comparison of clustering algorithm is done based on their network size, residual energy, hop distance, CH distribution delay. In[16] author calculated the function for minimizing the distance between intra-cluster called fitness function, it minimize the distance between cluster node and CH. Through this function energy efficiency of network also increases. For the selection of CH all the sensor node send their residual energy level and location information to the sink. At that time network congestion is high because transmission in bulk and it also leads to unnecessary energy consumption.

3. Proposed System

3.1 Network Design

Here author consider WSN with random number of sensor node which is deployed in a sensor field. Sensor network is divided into a set of cluster where each cluster has it CH. Author consider mutual relay between the clusters so cluster has also Mutual Cluster Head (MCH). A cluster contains CH with cluster member, where cluster head behave as a sink for CM and for cluster head BS is a sink. A basic architecture of WSN is CM senses the signal or based on basic operation on that prepare information and send it to the CH. Now cluster head collect all the information from number of CM and perform its own calculation prepare a result and send it to the base station.

Now a modified WSN architecture is describe as, after formation of CH author proposed a concept for mutual node which is worked for mutual relay between inter-cluster and intra-cluster, and names it as MCH. For selection of MCH CM send their information to the cluster head or inform that previously it will be a MCH or not. It only takes one bit extra overhead for the CM at the time of joining the cluster after election of new cluster head. Based on signal strength and minimum communication distance, if number of MCH candidate is less than CH only considers the signal strength for selecting the MCH.

Figure1 shows that there is one sensor network and it has two clusters with name Y and Z. BS residing outside the Sensor network and named as BS. In a cluster there is a cluster head named as CH and for better communication mechanism with inter cluster communication cluster head choose some mutual relay cluster node named as MCH. Communication between cluster node and cluster head within the cluster is known as intra-cluster communication and communication between two clusters is known as inter-cluster communication.

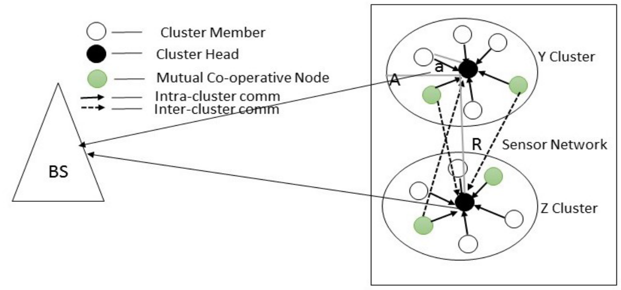

Figure 1. Cluster design mechanism.

3.2 Symbol and Notation Used

Table 1. Summary of notation

Notation	Description
A	Maximum radius of cluster
a	Distance between cluster head and cluster member
d	Average density of randomly deployed sensor node in the network
T	Packet Length
J	Number of cluster member
σ	Received SNR at the receiving node
Q	Consumption of energy per bit for intra-broadcasting transmission
R	Distance between two cluster heads
X_{eb}	Average bit failure rate
X^x	PFP
X^x_{avg}	Average PFP
$X_n(n)$	Probability that n nodes decode packet correctly
n_{avg}	Average number of nodes that decode packets
X^x_{all}	Total PFP for both inter and intra communication

3.3 System Design

For heavy traffic condition, CDMA multichip network is used and sensor node randomly deployed in the network with average density d. Probability of finding j nodes in a forwarding cluster $c1$ with cluster radius A can be given as

$$\frac{e^{-d\pi A^2}(d\pi A^2)^j}{j!} \tag{1}$$

So a CH may get the j number of cluster member. Here we can take $Y\ and\ Z$ as a two cluster, if communication between cluster Y member node and CH is going on it is called intra-cluster communication. In this CH can broadcast a message for mutual relay but for communication with other cluster CH and MCH relay form a virtual antenna to communicate with cluster head of Z. Here we are considering that the CH known its channel condition and MCH in a same cluster. Cluster head is only supposed to receive the inter-cluster transmitted data.

3.4 PFP

Here packet transmission by the sensor nodes is defined in terms of intra-cluster and inter-cluster packet transmission, it is not necessary that packet which is transmitted is properly decoded by the cluster node for this we are analyzing PFP.

3.4.1 Type 1 PFP

In Intra-cluster broadcasting communication, the sensor nodes communicate within the cluster. When CH nodes broadcast some message it is not necessary that all member nodes decode that message packet properly. For avoiding this we find PFP and average number of packet which is decoded by the nodes. Inside the cluster, a is the distance between cluster head and CM where a is less than or equal to maximum radius of cluster A. The density of continuous random variable can be calculated as

$$f_a(a) = 2a/A^2 \tag{2}$$

In intra-cluster wireless transmission, loss of energy follows the Free-space path loss. Here distance between nodes is less hence it follows square-law path loss. CM that receives signal which is broadcasted by CH at some a distance which may contain some noise, then received $SNR\ \sigma$ at the receiving node can be given as

$$\sigma = \frac{PQ|t|^2}{a^2 M_0} \tag{3}$$

Where P the antenna gain in cluster is is, t is the channel gain between cluster node and CH, white Gaussian noise power at the receiver is M_0. Consumption of energy per bit for intra-broadcasting transmission is Q.

Average bit failure rate when Q is energy consumption and a is the distance between CH and members node of cluster.

$$X_{eb} = \frac{a^2 M_0}{4PQ} \tag{4}$$

From [8] PFP X^x can be expressed as

$$X^x = (1-(1-X_{eb})^T) \tag{5}$$

Value of X_{eb} is very small so we can consider the overall result of TX_{eb} were T is the packet length. Now by using equation (2) we can find average PFP in a cluster as

$$X_{avg}^x = \int_0^A TX_{eb}.2a/A^2.da \tag{6}$$

Put X_{eb} from equation (4)

$$X_{avg}^x = \int_0^A T.\frac{a^2 M_0}{4PQ}.2a/A^2.da \tag{7}$$

$$X_{avg}^x = {TM_0A^2}/{8PQ} \tag{8}$$

Cluster head and members of clusters are independent; members of cluster independently decode the message packet. Probability that n nodes properly decode the message by using the equation (1) and concept of binomial distribution and n is uniform number $n = 0,1,2,\ldots..$ is

$$X_n(n) = \sum_{j=n}^{\infty} \binom{j}{n} \frac{e^{-d\pi A^2}(d\pi A^2)^j}{j!} (X_{avg}^x)^{j-n} (1-X_{avg}^x)^n \tag{9}$$

Now find the average number of node that properly decode the message packet in a cluster is

$$n_{avg} = \sum_{n=0}^{\infty} n * X_n(n) \tag{10}$$

$$n_{avg} = d\pi A^2(1-X_{avg}^x) \tag{11}$$

3.4.2 Type 2 PFP

Communication between two clusters is known as inter-cluster communication and usually distance between two clusters is more than radius of a cluster. Here communication between Y and Z cluster is taken as shown in Figure 1. Network among the cluster has orthogonal property, for this average Signal to noise Ratio (SNR)[9] received by the relay node can be given as

$$\sigma_{1avg} = \left(\frac{PQ_1}{R^2 M_0}\right) \tag{12}$$

Where inter cluster distance is R which transmitter to receiver end distance from center of two cluster. Q_1 is the transmission energy required by the node for each bit transmission, it is assumed that each node require the same energy Q_1.

We assume perfect channel knowledge at the receiver[11,12]. Due to orthogonal property of channel the effective received SNR value can be given as

$$X_{eb1} = \left(\sum_{i=1}^{M_0} |h_i|^2 \sigma_{1avg}\right) \tag{13}$$

Where h_i denotes the channel gain between ith transmission node. With chi-square distribution, σ_1 can be subject to $2m$ degree off freedom[13].

Average bit failure probability for inter-cluster transmission is X_{eb1} and it is very small ($< 10^{-4}$), and therefore PFP can be given as

$$X_1^x = 1 - (1 - X_{eb1})^T \approx TX_{eb1} \tag{14}$$

3.4.3 Type 3 PFP in overall mutual relay communication

PFP obtained from both type1 and type 2 communications based on that overall average PFP can be given as

$$X_{all}^x = \sum_{n=0}^{\infty} P_n(n) * X_1^x$$

$$= \sum_{n=0}^{\infty}\left(\left(\sum_{j=n}^{\infty}\binom{j}{n}\frac{e^{-d\pi A^2}(d\pi A^2)^j}{j!}\left(X_{avg}^x\right)^{j-n}\left(1 - X_{avg}^x\right)^n\right) * X_1^x\right) \tag{15}$$

Based on exponential function series representation we can get

$$\left(\sum_{j=n}^{\infty}\frac{\left(d\pi A^2 X_{avg}^x\right)^{j-m}}{(j-m)!}\right) = e^{d\pi A^2 X_{avg}^x} \tag{16}$$

Hence,

$$X_{all}^x = e^{d\pi A^2\left(X_{avg}^x - 1\right)} \times \sum_{n=0}^{\infty}\left(\frac{\left(d\pi A^2 - d\pi A^2 X_{avg}^x\right)^n}{n!} * X_1^x\right) \tag{17}$$

3.4.4 Energy Consumption

Energy consumption of whole network can be calculated as energy consumption in intra-cluster communication and energy consumption in inter-cluster communication. CH of the cluster consumes U average energy per bit

$$U_{intra} = S\left((1+\delta)U + U_t + \sigma\pi A^2 U_r\right) \tag{18}$$

Where δ represent the transmission efficiency of power amplifier. U_t *and* U_r denote the transmitter and receiver circuit energy.

Energy consumption for inter-cluster mutual relay communication for $n_{avg} + 1$ including CH

$$U_{inter} = S\left((1+\delta)(n_{avg}+1)U_1 + (n_{avg}+1)U_t + U_r\right) \tag{19}$$

Now overall energy consumption,

$$U_{total} = U_{intra} + U_{inter} \tag{20}$$

Life time of network depends on energy consumption by the CM and CH.

4. Result and Analysis

The system environment used is windows 8.1 enterprises 64-bit operating system with 4GB of RAM. We have used sensoria simulator which is based on C# programming and used dot net framework 4.0 visual studios 2010. We have conducted simulation study on following parameter for network lifetime and packet transmission delay and compare it with existing one and have varied node size by 400,600,800.

Table 2. Network parameter for simulation of the WSN

N/W Parameter	Value
Size of N/W	40m*40m (meters)
Number of Sensor nodes	400,600,800
BS location	1m*1m (meters)
Length of Data packet (T)	2000 bits
Initial energy of sensor nodes	0.1 J
Radio energy dissipation	50 nj/bit
Data packet delay	0.1ms
Idle energy consumption	50 nj/bit
Amplification energy	100 pj/bit/m2
Transmission speed	100 bits/s
Bandwidth	5000 bits/s

In Figure 2, it is shows that packet transmission delay for number of node 400,600 and 800 is shown. For 400 nodes delay for Leach is 170ms, and 136ms is taken by our proposed model. For 600 nodes delay for Leach is 195ms and for our proposed model it takes 172ms. Leach takes 200ms and 184ms is taken by our proposed model when number of nodes are 600. From figure 2 we can the delay of proposed approach is reduced by 19%, 12% and 8% over $LEACH$ protocol when node is equal to 400, 600 and 800 respectively.

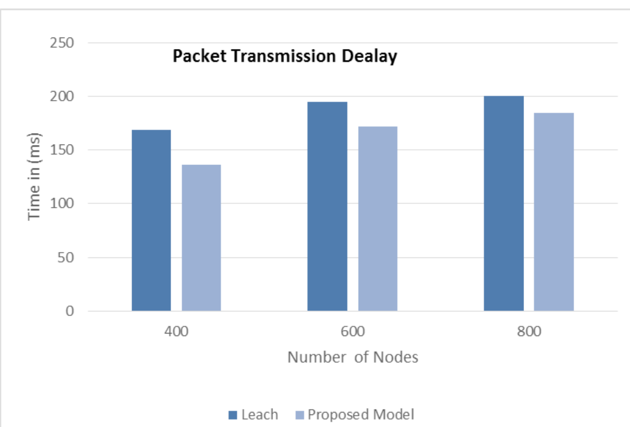

Figure 2. Packet transmission delay.

In Figure 3, WSN network life time analysis is done for different-different number of nodes and comparison is done between existing and proposed model. From figure it is clear that our proposed model network life time increases as number of nodes increases but for existing model network lifetime is decreases as number of nodes is increased. Here percentage of lifetime increment between existing and proposed is can be given, for 400 nodes proposed model is 13.82% better than exiting, when number of nodes are 600 it performed 58.34% better than existing and for 800 nodes percentage is 75.13%. All percentage of network lifetimes is done on the basis of time taken by proposed or existing model at 400,600 and 800 nodes.

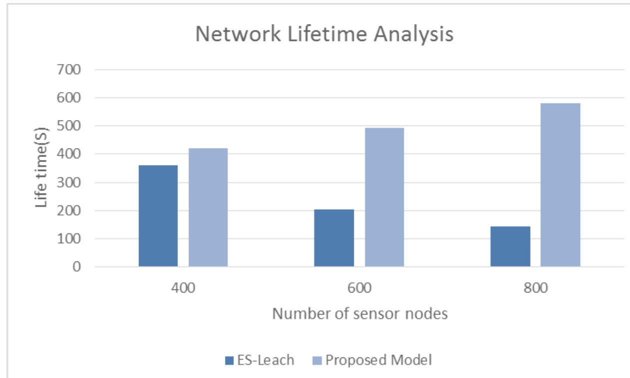

Figure 3. WSN network lifetime.

In Figure 4, Network Energy and number of rounds for 400 nodes is showing ES-Leach ended up with 200 rounds and our model ended up with 209 rounds. Here 4% more round for our proposed model.

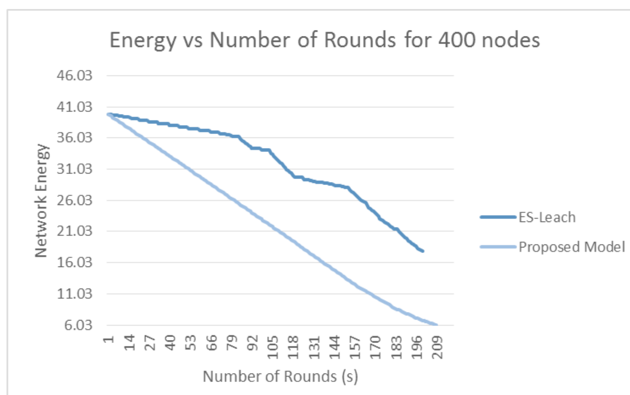

Figure 4. Energy Vs Number of rounds.

In Figure 5, the network energy and number of rounds for 600 nodes here we can see that Leach protocol number of round end at the 127 iteration only while our proposed model go up to the 148 rounds. Hence 17% more rounds for 600 nodes.

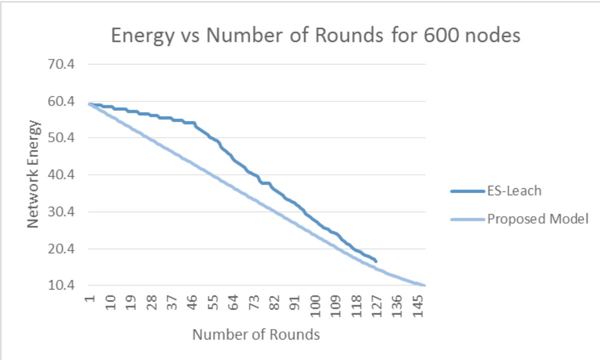

Figure 5. Energy Vs Number of rounds.

In Figure 6, 800 nodes are analyze in a network in terms of energy and number of rounds where Leach end up with 93 rounds only while our proposed model with 115 rounds. Here 22% more rounds for 800 nodes, so that, for more number of nodes percentage numbers of rounds increases for proposed model.

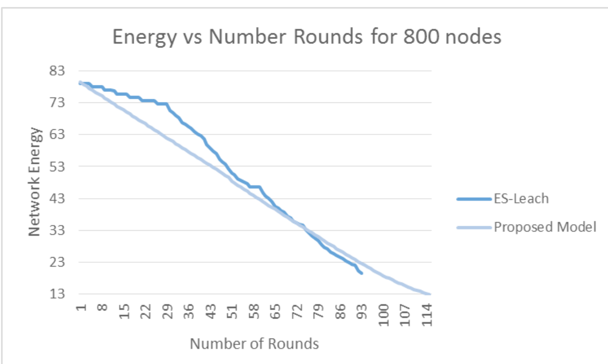

Figure 6. Energy Vs Number of rounds.

From Figure 7, analysis shows that the node decay rate is fast for Leach when compared with our proposed Model.

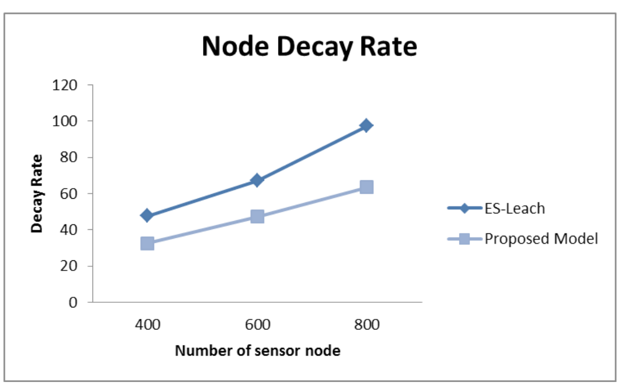

Figure 7. Node decay rate.

5. Conclusion and Future

As WSN is a very fast growing technology but suffer with limited power supply due to which how to reduce the overall energy consumption in a network is our goal. For this here author used concept of mutual relay transmission and different mechanism of communication within WSN network. Our proposed mutual relay communication improved the lifetime of network by over 13.8% for 400 node, 58.34% more efficient for 600 nodes and 75.13% for 800 nodes. Which shows that as number of nodes increases our proposed system lifetime also increases but existing system lifetime decreases as number of node in system increases. For packet delay our proposed model also performs better. We are also analyzing the number of round in network for 400, 600 and 800 nodes our model performance increased with network size like for 400 nodes it perform 4% better than ES-Leach and for 600 and 800 it performed 17% and 22% more number of rounds respectively. Node decay rate is reduced for our proposed model when compared with existing *LEACH*. In future we are going to work on Energy Bounded Model based on PFA.

6. References

1. Cheng CT, Tse CK, Lau FCM. An energy-aware scheduling scheme for WSN, in IEEE Transactions on Vehicular Technology. 2010 Sep; 59(7):3427–44.
2. Vaidya R, Dandekar DR. Comparison of SPAN and LEACH protocol for topology control in WSN, Signal Processing Image Processing and Pattern Recognition (ICSIPR), 2013 International Conference on, Coimbatore; 2013. p.20–3.
3. Jianyin L.Simulation of improved routing protocols LEACH of WSN, Computer Science and Education (ICCSE), 7th International Conference on, Melbourne, VIC; 2012. p.662–6.
4. Choe J, Kim K. EADD: EADD for WSN, parallel and distributed processing with applications, ISPA '08. International Symposium on, Sydney, NSW; 2008. p.779–83.
5. Sharma V, Saini DS. Performance investigation of advanced multi-hop and single-hop energy efficient LEACH protocol with heterogeneous nodes in WSN, Advances in Computing and Communication Engineering (ICACCE), Second International Conference on, Dehradun; 2015. p.192–7
6. Zeb A, Islam AKMM, Komaki S, Baharun S. Multi-nodes joining for dynamic cluster-based WSN, Informatics, Electronics and Vision (ICIEV), International Conference on, Dhaka; 2014. p.1–6.

7. Sharma V, Saini DS. Performance investigation of advanced multi-hop and single-hop energy efficient LEACH protocol with heterogeneous nodes in WSNs, Advances in Computing and Communication Engineering (ICACCE), 2015 Second International Conference on, Dehradun; 2015. p.192–7.
8. Zuniga M, Krishnamachari B. Analyzing the transitional region in low power wireless links, sensor and ad hoc communications and networks. IEEE SECOND. First Annual IEEE Communications Society Conference on; 2004. p.517–26
9. Paulraj A, Nabar R, Gore D. Introduction to space-time wireless communications, cambridge, U.K.: Cambridge University; 2003.
10. Cui S, Goldsmith AJ, Bahai A. Energy-efficiency of MIMO and cooperative MIMO techniques in sensor networks, IEEE Journal on Selected Areas in Communications. 2003 Aug; 22(6):1089–98.
11. Laneman JN, Wornell GW. Distributed space-time coded-protocols for exploiting cooperative diversity in wireless networks, IEEE Transactions on Information Theory. 2003 Oct; 49(10):2415–25.
12. Sirkeci-Mergen B, Scaglione A. “Randomized distributed space-time coding for cooperative communication in self organized networks,” in Proceedings of IEEE Signal Processing Advances in Wireless Communications; 2005 Jun. p.500–4.
13. Proakis JG. Digital communications. New York: McGraw-Hill; 2000.
14. Cardei M, Thai MT, Li Y, Wu W. Energy-Efficient Target Coveragenin WSNs. IEEE INFOCOM; 2005.
15. Boyinbode O, Le H, Mbogho A, Takizawa M, Poliah R. A survey on clustering algorithms for WSNs. In Proceedings of 2010 13th International Conference on Network-Based Information Systems, Takayama, Japan;2010 Sep 14–16. p. 358–64.
16. Latiff NMA, Tsemenidis CC, Sheriff BS. Energy-aware clustering for WSNs using particle swarm optimization, The 18th Annual IEEE International Symposium on Personal. Indoor and Mobile Radio Communications, Athens, Greece; 2007 Sep 3–7. p.1–5.