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# A Effective Cross layer Multi-hop Routing Protocol for Heterogeneous Wireless Sensor Network

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**ABSTRACT**

In today's scenario to solve the real world problem heterogeneous wireless sensor is necessary. It consists of different sensor with different sensing capability and different energy level. Routing is important task in HWSN from energy dissipation point of view. In HWSN many routing protocols were proposed but many protocols are for single hop communication between cluster head and sink. Here we have designed multi-hop routing protocol for HWSN, which will be energy efficient and also solve the problem of hot spot using unequal clustering. To make this protocol more energy efficient cross layer information exchange approach is used. Using cross layer communication this protocol will get residual energy, quality of link and neighboring nodes information and this information is used in cluster head selection. Moreover there is no need to do broadcast of residual energy for every round because of RDA (regular data acquisition) nodes. We can predict the energy consumption of node, which will conserve the energy using Energy Efficient Fuzzy Based Cross Layer Protocol (EEFCLP). This proposed protocol can achieve longer sensor lifetime and more energy efficiency.



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## 1. INTRODUCTION

Due to advancement in technological field of wireless sensor network, the concept of heterogeneous wireless sensor network is originated. HWSN is a network of node having different capabilities. Capabilities can be defined in terms of energy, sensing, coverage, deployment, link and computational heterogeneity. Such type of heterogeneity can prolong the network lifetime, improve the reliability and decrease the latency [1].

Energy is the main concern in WSN. Large amount of energy is required for communication between sink node and sensor node that is why routing is important issue in WSN [2]. As per the researchers hierarchical routing is better than flat routing for HWSN [3]. In Hierarchical routing again we are having two types first is single hop and second is multi-hop hierarchical routing. Currently routing using clustering is popular area of research in HWSN. In this clustered multi-hop routing cluster members transmit their data to the cluster head and then intermediate cluster head will relay that data to base station. In addition to multi-hop routing energy efficiency can be achieved using cross layer information exchange [4]. For example, use of RSSI information from neighboring nodes physical layer to decide next hop in route. Here in this case if signal is weak from that neighboring node then it should not be selected as a next hop on that route.

In this paper heterogeneous wireless sensor network with energy and sensing heterogeneity is considered. To prolong the network lifetime and increase the reliability cross layer approach with energy prediction for multi-hop clustering is proposed.

In [5] author proposed CCBE algorithm to extend network lifetime. Here network should be divided into different hexagonal structured cluster. CHs are selected from cluster members based on CH optimal distance and residual energy. Drawback of this method is that they have considered all nodes are homogeneous. During end to end transmission CCBE creates additional overhead of control packets and unbalanced utilization of nearest node of sink.

In [6] paper presents Fuzzy and Ant Colony Optimization based MAC/ Routing cross layer protocol. They have used cross layer approach for cluster head selection where residual energy, quality of communication link and number of neighboring nodes are used. They have addressed hot spot problem also. For inter-clustering routing they have used cross layer. Problem with this method is that, it designed for homogeneous WSN and they are just rotating the role of cluster head according to the value of CAPABILITY which is not suitable for heterogeneous wireless sensor network.

In [7] author proposed Energy efficient clustering using energy prediction mechanism. They have used different energy level sensors with different monitoring objects. For cluster head selection residual energy of nodes is predicted instead of broadcasting it in every round, also they used communication cost. But the problem with this method is single hop communication between cluster head and base station and in much real time application single hop communication is not suitable.

In [8] proposed energy dissipation forecast and clustering management protocol. They have used new model of HWSN contains energy and computation heterogeneity. It is also based on energy prediction, for that energy consumption of two types of CH nodes in the previous round is used. Cluster head selection is based on energy dissipated forecast. If node has higher forecasted residual energy it will be selected as CH. But in this method they have taken only two types of heterogeneous nodes and another drawback is single hop communication between cluster head and sink node.

In [9] three types of nodes are used, normal node, advanced node and super nodes to create HWSN. There is energy difference in between these three nodes but author need to consider the percentage of advanced and super nodes in a network. In cluster head selection, all three nodes have their own probability. MCR gives good performance in terms of load balancing, stability, and energy efficiency. However MCR used only distance to calculate multi-hop route. Therefore hot spot problem occurred because they have not considered energy factor while selecting next hop.

In [10] author proposed a distributed energy efficient unequal clustering routing protocol (DE U). Cluster head selection is based on time. For multi-hop route next node, they have considered optimal forwarding hops, residual energy, communication cost of inter and intra cluster. But again this protocol is designed for homogeneous wireless sensor network.

In WSN, communication between sensor nodes consumes more energy than sensing or other operation like processing [11]. Due to that many researchers are working on energy efficient routing. Many hierarchical clustering protocols have been proposed for HWSN.

A Secure & Efficient Audit Service Outsourcing method designed to prevent the fraudulence of prover [12]. An efficient mechanism on probabilistic queries and periodic verification is proposed to reduce the audit costs per verification and implement abnormal detection timely [13].

The link level congestion occurs when more than one sensor node tries to acquire the channel at same time. In case of link-level congestion, all the nodes attempt to send traffic on the link simultaneously. It results in packet collisions. Furthermore, due to link-level congestion, the link utilization is reduced. To avoid all the above-mentioned effects of congestion, congestion must be controlled or avoided in an effective way [14]. Heterogenous network have budding to improve network lifetime and also provide sophisticated quality network. Due to limited power battery will exhausted. Thus, energy efficient routing protocol needs to allocate the balance energy burden between the sensor nodes [15].

## 2. RESEARCH METHOD

The growing interest in real time application heterogeneous sensor wireless sensor network imposes new challenges in network lifetime, stability, scalability and reliability. Multi-hop cross layer protocol is proposed to handle all said issues. Proposed system is divided in to three components.

- Network Setup
- Cluster head Selection
- Clustering
- Multi-hop routing

### 2.1. Network Setup

We present our HWSN model with different sensors which having different initial energy and different monitoring objects and N number of sensor nodes are randomly distributed in MxM area in circular fashion and BS is at centre. Then afterword nodes will be organized into layers using message sent by BS which contains ID, timing information and (x, y) coordinates. Then each node calculates its distance from BS using radio Propagation model and finds its layer.

$$dis(x) = \sqrt[4]{\frac{P_{BSt}G_{BSt}\ G_{xr}\ h_{BSt}^2\ h_{xr}^2}{P_{xr}L}} \tag{1}$$

Where $P_{\mathrm{BSt}}$ and $P_{xr}$r is power, GBSt and Gxr is gain, hBSt and hxr is height above ground for BS transmitting antenna and node x receiving antenna respectively. L is path loss. Each node uses the calculated distance to find its layer as discussed next. The first layer is a circular ring with centre at BS and radius as Rmax m. The second layer is a circular ring with centre at BS, outer radius of Rmax x 2 m and inner radius of Rmax x (2-1) m.

Then every normal node will send message to get the information of their neighbors in the same layer and store information in neighborhood table which contains ID, layer number, location. The network will use RDA (regular data acquisition nodes) Example nodes monitoring temperature, wind direction, humidity. Then every node will calculate the distance between nodes according to signal strength received using the relationship between transmission energy and received signal strength shown in (3).

$$\mathrm{E}_{\mathrm{y,x}}^{\mathrm{rec}} = \frac{\mathrm{K}}{\mathrm{d}_{\mathrm{x,y}}^{\alpha}} \mathrm{X}\ \mathrm{E}_{\mathrm{x}}^{\mathrm{tran}} \tag{2}$$

$$\mathrm{d}_{\mathrm{x,y}}^{\alpha} = \frac{\sqrt[\alpha]{K}\mathrm{X}\mathrm{E}_{\mathrm{x}}^{\mathrm{tran}}}{\mathrm{E}_{\mathrm{y,x}}^{\mathrm{rec}}} \tag{3}$$

$\mathrm{E}_{\mathrm{x}}^{\mathrm{tran}}$ is node x transmission energy and node y detects received signal strength $\mathrm{E}_{\mathrm{y,x}}^{\mathrm{rec}}$ where $K$ is a constant, $\mathrm{d}_{\mathrm{x,y}}^{\alpha}$ is the relative distance between node x and node y. $\alpha$ is distance-energy gradient, and its value varies from 1 to 6 according to the physical environment in which the sensor networks operate.

All nodes in the networks are marked by the only integer value, which is each node's ID. The information stored in the routing table includes the distance between the node and its neighboring nodes, cluster head node's ID, the distance to the cluster head, the current energy, and predicted energy consumption

### 2.2. Cluster head selection

Nodes take their own decision to be or not to be cluster head using Fuzzy inference system with Mamdani model. It depends on residual energy, nodes nearness with neighborhood nodes and link quality indicator. Every node will find these three values and send to nodes in communication range. Nodes neighborhood nearness should have lesser value and Link quality indicator should have higher value and higher residual energy so that node will be selected as a cluster head. Residual energy can get it from physical layer for first round then nodes neighborhood nearness can be calculated using eq.(4) and link quality indicator which describe the packet reception quality can achieved by radio chip and it is an average of link quality indicator of links between node and neighbors in its transmission range. Thus each node will calculate capability of nodes within its transmission range using above three things. Node which having highest capability value will be selected as cluster head.

$$\mathrm{NNR(x)} = \frac{1}{N_{TR}} \left( \sum_{y=1}^{y=N_{TR}-1} d(x,y) \right) \tag{4}$$

In eq (4) $N_{TR}$ is total number of nodes within transmission range and layer of x, d(x, y) is distance between node x and y. To become a cluster head, node should have more nodes in its transmission range to decrease intra-cluster communication cost and consequently should have a lesser value of NNR(x). In next rounds new node need to be selected as cluster head. So it is necessary to re-evaluate energy factor. There is no need to broadcast all things which are used for cluster head selection because nodes are fixed and RDA. RDA nodes packet size is also fixed and they are sending data in fix interval of time. So here energy consumption prediction is useful for RDA nodes. In r-1 round, it takes ny times for any node y to send messages with a length ly to cluster head node x and the distance between x and y is dxy

$$E_{y_{r-1\_consume}} = \begin{cases} n_y(l_y \ E_{elec} + l_y \varepsilon_{fs} \ d_{x,y}^2 \ ), & d_{x,y} < d_0, \\ n_y(l_y \ E_{elec} + l_y \varepsilon_{mp} \ d_{x,y}^4 \ ), & d_{x,y} \geq d_0, \end{cases} \quad (5)$$

According to current energy of node y and above formula, the residual energy of node y can be predicted at beginning of r round

$$E_{y_{r\_prediction}} = E_{y_{r-1}} - E_{y_{r-1\_consume}} \quad (6)$$

Node y also determine whether its current residual energy is close to residual energy predicted in last round with the help of tolerance factor given in eq.(7)

$$Q = \left| 1 - \frac{E_{y_{r\_prediction}}}{E_{yr}} \right| \quad (7)$$

If Q is less than constant $\varepsilon$, the energy predication error can be tolerated. In the initial phase of r round, node y does not broadcast its energy information and the remaining nodes update node y energy information in the routing table according to calculation results.

### 2.3. Clustering

Clustering means arrangement of nodes into groups. Cluster head selected in the previous step send message within Radv radius using non persistent CSMA MAC protocol to advertise their role, which contains ID and header. It uses radius Radv to reach to nodes within its layer.

$$R_{adv}(ch_x) = \left[ \left\{ \left\{ 1 - w \frac{d_{max} - d(ch_x, BS)}{d_{max} - d_{min}} \right\} \left\{ \frac{(E_{cu})ch_x}{(E_{in})ch_x} \right\} \right] R_{adv}^{maxi} \quad (8)$$

Where, dmax and dmin is maximum and minimum distance between nodes and BS respectively, d(chx , BS) is distance between chx and BS, Ecu and Ein are chx's current energy and initial energy, $R_{adv}^{maxi}$ is maximum advertisement radius. We decides degree of inequality in cluster size and is kept between 0 and 0.99

Cluster head which are near to BS will have lesser value of Ravd and which are far away will have lager value of Ravd. Due to that small cluster will be formed near the BS which will preserve the energy of cluster nodes near the BS. Using received signal strength each normal node will select its cluster head. Nodes then send message to cluster head to confirm the membership of cluster. Then using TDMA, cluster head will setup schedule for intra cluster communication.

### 2.4. Multi-hop Routing Using Energy Efficient Fuzzy Based Cross Layer Protocol (EEFCLP)

This is the communication between cluster head and base station. In this phase also cross layer communication is used. Each cluster head broadcast message which contains ID, residual energy, location, Packet Reception Rate to reach to nodes within two layers. Then every cluster head will define one set which contains probable relay cluster nodes.

$$PR_{CH}(s_x) = \{ s_y \mid d(s_x, s_y) \leq m \ \times R_{adv}(s_x); d(s_y, BS) < d(s_x, BS) \} \quad (9)$$

Where m is minimum integer to let $PR_{CH}(s_x)$ contain at least one item and is set to 2 x Rmax m for simulations done in paper. Probable relay cluster head selection ensures that data is forwarded in right direction towards MS

This probable relay cluster head set will ensure that data is forwarded in right direction. So determine path Ant Colony Optimization is used. Ants determine relay cluster head node according following formula

$$Pr_{xy}^k = \frac{[\tau_{xy}(t)]^\alpha [\eta_{xy}]^\beta}{\sum_{s \in PR_{CH}(s_x)} [\tau_{xs}(t)]^\alpha [\eta_{xs}]^\beta} \quad (10)$$

Where $Pr_{xy}^{k}$ is probability with which ant k decides to move from node Sx to node Sy. $PR_{CH}(s_x)$ is set from which relay cluster head is to be chosen by kth ant, $\tau_{xy}$ (t) is the pheromone trail value of edge (Sx, Sy) and ηxy is the heuristic information value defined in eq.(11).

$$\eta_{xy} = \frac{RE_y}{\sum_{s \in PR_{CH}(s_x)} RE_s} \times \frac{1}{d^2(S_x, S_y) + d^2(S_y, BS)} \times \frac{PRR_y}{\sum_{s \in PR_{CH}(s_x)} PRR_s} \quad (11)$$

Cluster head with following properties will be selected as relay node.

1. High PRR (Packet Reception Ration)
2. High RE( Residual energy)
3. Near the current cluster head
4. Near the base station

Ants passing through nodes collect path information and reach to base station. Then base station analyzes data after arrival of kth ant. Information collected by kth ant is {(S0,d(s0,s1)), (S1,d(s1,s2)), (S2,d(s2,s3)),.., (Sm-1,d(sm-1,sm))}. Then the worthiness of path is estimated and conveyed to update pheromone trail value.

## 3. RESULTS AND ANALYSIS

Using the Network Simulation (ns-2), the simulation environment is set up for improving the energy conservation mechanism in the heterogeneous sensor network. Following Table 1 shows the simulation setup.

Table 1. Similation Parameters Details

| Simulation Parameter | Range |
|---|---|
| Channel | Wireless |
| Antenna | Two Ray Ground / Omni Directional |
| Layer | MAC – Cross Layer |
| Model | Energy Model |
| Simulation Range | 1000 x 1000 |
| Number of Nodes | 67 |
| Algorithm | Energy Efficient Fuzzy Based Cross Layer Protocol (EEFCLP) |
| Simulation Metrics | Packet Delivery Rate |
| | Average Delay |
| | Throughput |
| | Energy Consumed |
| | Network Lifetime |

The newly proposed Energy Efficient Fuzzy based Cross layer Protocol (EFCLP) is incorporated in the heterogeneous sensor networks and the results are analyzed using the simulation metrics. Viz. Packet Delivery Rate, Average Delay, Throughput, Energy Consumed and Network Lifetime. Simulation analyses figure 1 to 5 shows that the proposed Energy Efficient Fuzzy based Cross layer Protocol performs better in terms of all simulation metrics when compared with the existing protocols.

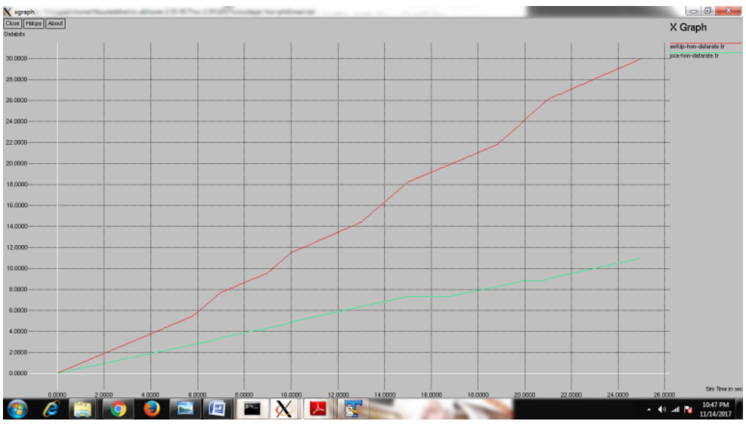


Figure 1: Performance Analysis – Packet Data rate

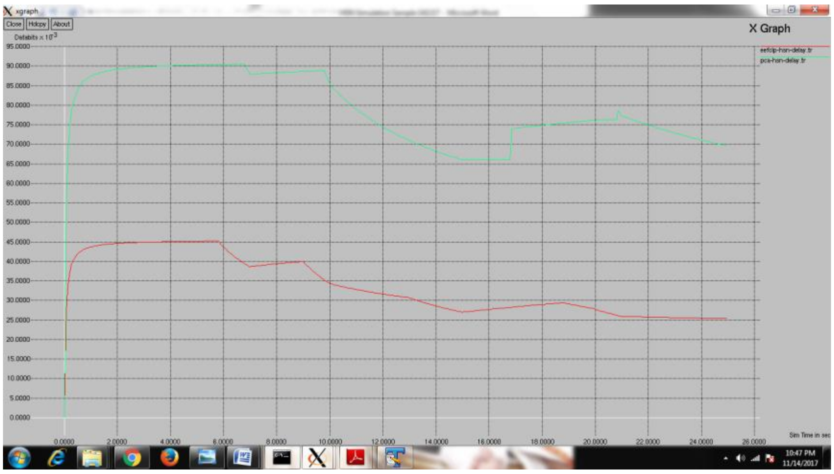


Figure 2: Performance Analysis – Delay

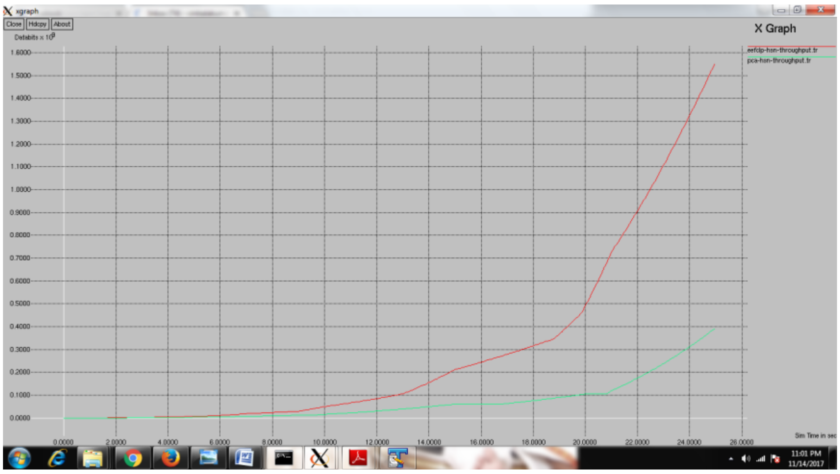


Figure 3: Performance Analysis – Throughput

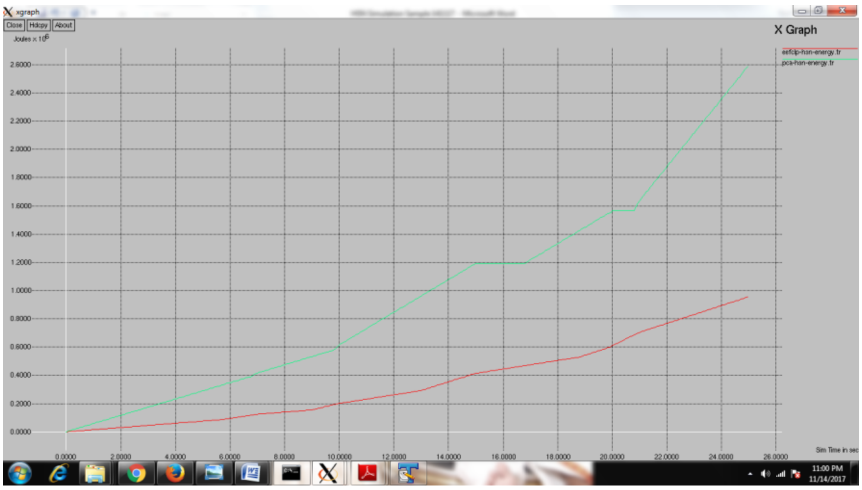


Figure 4: Performance Analysis – Energy Conserved

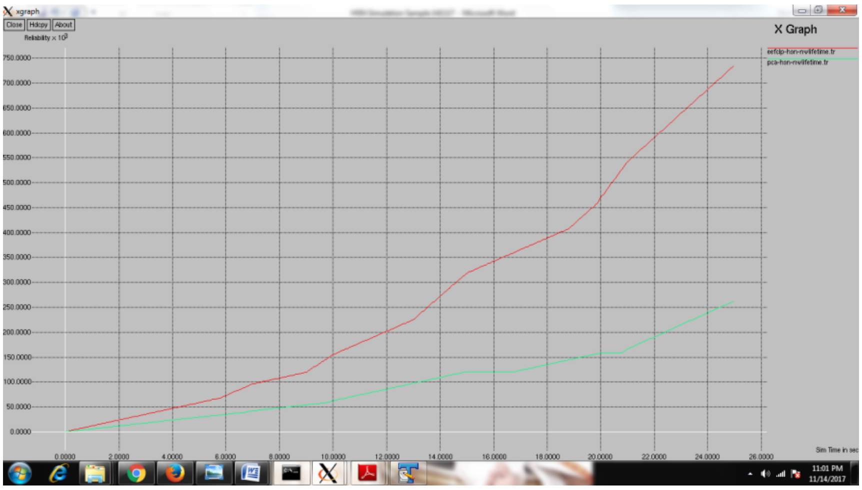


Figure 5: Performance Analysis – Network Lifetime

## 4. CONCLUSION

In this paper we have proposed an effective way to use energy constraint sensor node with the help of energy prediction mechanism for heterogeneous model of network which contains heterogeneous node with different initial energy and different monitored objects. Real time application and nodes used in HWSN needs an energy efficient, scalable, reliable routing protocol. Due to this requirement proposed protocol combines the idea of cross layer information exchange and energy prediction mechanism to increase the life time. RDA nodes used to report data regularly and length of data is also fix therefore we can easily calculate energy consumption prediction and it will avoid broadcast of residual energy. These methods also handle hierarchical clustering with multi hop to avoid energy hole by using unequal clustering.

## REFERENCES


[1] Dietrich and F. Dressler, “On the lifetime of wireless sensor networks,” *ACM Transactions on Sensor Networks*, vol. 5, no. 1, pp. 5:1–5:39, 2009.

[2] Henry Ohiani Ohize, “Emerging Issues in Wireless Sensor Network,” *Journal of Software & Automation*, pp . 11-15, 9 April 2011

[3] Mhatre, V., & Rosenberg, C., “*Homogeneous vs heterogeneous clustered sensor networks: a comparative study*”, In Communications, 2004 IEEE International Conference, vol. 6, pp. 3646-3651, 2004.

[4] B. Kechar, A. Louzani, L. Sekhri, and M. Khelfi, “*Energy Efficient Cross-Layer MAC Protocol for Wireless Networks*,” in Proc. of the 2nd International Workshop on Verification and Evaluation of Computer and Communication Systems, July 2008.

[5] Mammu, A. S. K., Hernandez-Jayo, U., Sainz, N., & de la Iglesia, I., "Cross-layer cluster-based energy-efficient protocol for wireless sensor networks." *Sensors*, vol. 15, no. 4, pp. 8314-8336, 2015.

[6] Gajjar, S., Sarkar, M., & Dasgupta, K., “FAMACRO: Fuzzy and ant colony optimization based MAC/routing cross-layer protocol for wireless sensor networks”, *Procedia Computer Science*, vol. 46, pp. 1014-1021, 2015.

[7] Peng, J., Liu, T., Li, H., & Guo, B., “Energy-efficient prediction clustering algorithm for multilevel heterogeneous wireless sensor networks”, *International Journal of Distributed Sensor Networks*, vol. 9, no. 2, pp. 1-8, 2013.

[8] Haibo, Zhou, Wu Yuanming, and Xie Guangzhong. "*EDFM: A Stable Election Protocol Based on Energy Dissipation Forecast Method for Clustered Heterogeneous Wireless Sensor Networks.*" 2009 5th International Conference on Wireless Communications, Networking and Mobile Computing, 2009, pp. 1-4.

[9] D.Kumar,T.C.Aseri,andR.B.Patel,“Multi-hopcommunicationrouting(MCR) protocol for heterogeneous wireless sensor networks,” *International Journal of Information Technology, Communications and Convergence*, vol. 1, no. 2, pp. 130–145, 2011.

[10] Jiguo Yu, , Yingying Qi, GangWang, Qiang Guo, Xin Gu, “An Energy-Aware Distributed Unequal Clustering Protocol for Wireless Sensor Networks”, *International Journal of Distributed Sensor Networks* , vol. 7, no. 1, July 2011

[11] Han, Guangjie Jiang, Xu Qian, Aihua Rodrigues, Joel J P C Cheng, Long, “A Comparative Study of Routing Protocols of Heterogeneous Wireless Sensor Networks”, *The ScientificWorld Journal*, pp. 1-11, 2014.

[12] Prakash, G., Vyas, B., & Kethu, V. R., “Secure & Efficient Audit Service Outsourcing For Data Integrity In Clouds”, *International Journal of MC Square Scientific Research*, vol. 6, no. 1, pp. 5-60, 2014.

[13] Awadalla, M. H. A., “Heuristic Approach for Scheduling Dependent Real-Time Tasks”, *Bulletin of Electrical Engineering and Informatics*, vol. 4, no. 3, pp. 217-230, 2015.

[14] Manisha R. Dhage, Srikanth Vemuru, "Routing Design Issues in Hetrogeneous Wireless Sensor Network", *International Journal of Electrical and Computer Engineering*, vol. 8, no. 2, 2018.
[15] Tamizharasi, A., Selvathai,j.j., Kavi priya, A., Maarlin, R., Harinetha, M., "Energy aware heuristic approach for cluster head selection in wireless sensor network", *Bulletin of Electrical Engineering and Informatic's* vol. 6, no. 1, pp. 70-75, 2017.