

Fuzzy based Stable Clustering Protocol for Heterogeneous Wireless Sensor Networks

Akshay Verma^{#1}, Tarique Rashid^{*2}, Prateek Raj Gautam^{*3}, Sunil Kumar^{*4}, Arvind Kumar^{#5}

[#]Department of Electronics and Communication Engineering
 Motilal Nehru National Institute of Technology, Allahabad (India)

¹Akshayv.verma49@gmail.com, ⁵arvindk@mnnit.ac.in

²tariquerashid@gmail.com, ³prateekrajgautam@gmail.com, ⁴rel1516@mnnit.ac.in

Abstract- In this paper a novel Fuzzy based Stable Clustering Protocol (FSCP) for Heterogeneous Wireless Sensor Network (WSN) is proposed. The major focus of protocol is on network coverage and lifetime enhancement. It is observed that not only energy of sensor nodes but also the cluster heads distances affect both network coverage and network lifetime. In this protocol, fuzzy logic with cluster head update rule is implemented to improve network coverage, throughput and network lifetime under multilevel heterogeneous network. For optimum number of cluster heads, probabilities of cluster heads are decided by fuzzy logic in which fuzzy logic selects CHs which have plenty of energy and satisfy distance criteria. Along this CH update rule also removes the unfavorable scenario of no CHs. These two factors, fuzzy logic and CH update rule better enhances the network performance when it is compared with LEACH, SEP, DEEC and EDCS protocol. Through simulation, it is justified that network coverage is improved by 17.50 % than EDCS protocol.

Keywords: WSN, Network coverage, Fuzzy logic, Stability period, Network lifetime.

1. INTRODUCTION

A network with optimal number of low cost and small size sensor nodes, which are deployed in area for specific or generalized application, creates a wireless sensor network (WSN). In recent days, Because of numerous application WSN is spreading very fast. There are many ways to route network data to destination like chain routing, grid routing, concentric routing, direct transmission or cluster routing. It is surveyed that for minimum energy consumption with effective routing, cluster routing is better than others routing techniques [1]. So major focus has been given to cluster routing. From survey [2], It is observed that most of cluster algorithms focus on network lifetime [3] but the network coverage of these protocols is very less. There are very few papers which have work on both network coverage along with network lifetime [4]. Network coverage (stability factor) is first evolved by Stable Election Protocol (SEP) [7]. It enhances the network stability along with network lifetime. It is the extension of Low Energy Adaptive Clustering Hierarchy (LEACH) protocol under two level heterogeneous network. It scaled the priori probability (p_{opt}) used by LEACH protocol [6] eq. (1). In SEP, network coverage along with throughput improves but it does not provide the optimal solution in terms of multilevel heterogeneity. A further extension of multilevel solution is provided by Distributed Energy Efficient Clustering (DEEC) [8]. It employs the concept of weight average energy for the selection of CHs by which the performance of network under two level eq. (2) as well as multilevel eq. (3) heterogeneous network improved drastically. Since it employs the concept of weight average energy of current round but does not include the effect of previous round weight average energy for selection of CHs, therefore to include the effect of previous round weight average energy EDCS protocol is implemented by Zhen HONG [9]. EDCS protocol includes the weight average energy of previous round with current round weight average energy, which enhances the stability period of network slightly more than that of DEEC. The major contribution of EDCS protocol is in modifying the average residual energy which include both current average residual energy and previous average residual energy concept together eq. (4, 5). EDCS protocol focuses only on average energy of sensor nodes but it does not include the effect the distance of sensor nodes from BS. Since energy of sensor nodes is also affected by distance of node from BS eq. (6). This motivate us for further enhancement of network coverage. With the help of fuzzy logic and CH update rule, network coverage and network lifetime improved much as compare to EDCS protocol.

$$p = \begin{cases} \frac{p_{opt}}{(1 + a * m)} & \text{if normal nodes} \\ \frac{p_{opt}(1 + a)}{(1 + a * m)} & \text{if advanced nodes} \end{cases} \quad 1$$

$$pp_i(r) = \begin{cases} \frac{E_i(r)}{(1+am)\bar{E}(r)} & \text{if } i \in \text{normalnode} \\ \frac{p_{opt}(1+a)E_i(r)}{(1+am)\bar{E}(r)} & \text{if } i \in \text{advancenode} \end{cases} \quad 2$$

$$p_i(r) = \frac{p_i N(1+a)E_i(r)}{(N + \sum_{i=1}^N a_i)\bar{E}(r)} \quad 3$$

$$\bar{E}_{ideal}(r) = \frac{1}{N} E_{total} \left(1 - \frac{r}{R}\right) \quad 4$$

$$\bar{E}(r) = \alpha \bar{E}_{ideal}(r) + (1 - \alpha) \times \left\{ \bar{E}(r-1) - \frac{1}{N} \sum_{i=1}^N \bar{E}_i(r) \right\} \quad 5$$

$$E_{Tx}(i) = \begin{cases} l.E_{elec} + l.\epsilon_{fs}.d^2 & d < d_o \\ l.E_{elec} + l.\epsilon_{mp}.d^4 & d \geq d_o \end{cases} \quad 6$$

Here N is the number of sensor nodes, r is simulation round, R is the maximum number of round for which network simulated, a is extra energy factor, m is fraction of advance nodes, $E_i(r)$ is the residual energy of sensor node i for a round particular round r. $\bar{E}(r)$ is the average residual energy, $p_i(r)$ is the probability of sensor node i. $\bar{E}_{ideal}(r)$ is the ideal average residual energy, $\alpha \in (0, 1)$ is the weighted coefficient. $\bar{E}(r-1)$ is the previous round average residual energy.

Proposed paper is organized as follows – Section-II provides the detail of proposed FSCP protocol. Section-III justified the performance of FSCP protocol with LEACH, SEP, DEEC and EDCS protocol. And finally conclusion is drawn in Section-IV.

II. FSCP (FUZZY BASED STABLE CLUSTERING PROTOCOL) MODEL

A WSN with cross section $M \times M$ is deployed with N number of sensor nodes Fig.1. Under multilevel heterogeneous network, let E_i be the initial energy of deployed node i. E_{max} is the maximum energy sensor node from deployed nodes. Base station is located at center (50,50) and let the distance of normal nodes from BS are d_{i_BS} . If maximum distance from BS is d_{max} then fuzzy inputs are given in eq. (7, 8). Based on these two inputs fuzzy rule will decide which node will be more probable than others. The outcome of fuzzy input is fed as crisp input to the network and same thresholding is applied as EDCS protocol eq. (9). Fuzzy rule with its input output membership function has been indicated in Fig. 2(a, b, c and d).

$$E_{norm}(i) = \frac{E_i}{E_{max}} \quad 7$$

$$d_{norm}(i) = \frac{d_{i_BS}}{d_{max}} \quad 8$$

$$T(i) = \begin{cases} \frac{p_i}{1 - p_i \bmod \left(r, \frac{1}{p_i}\right)} & \text{if } i \in G \\ 0 & \text{otherwise} \end{cases} \quad 9$$

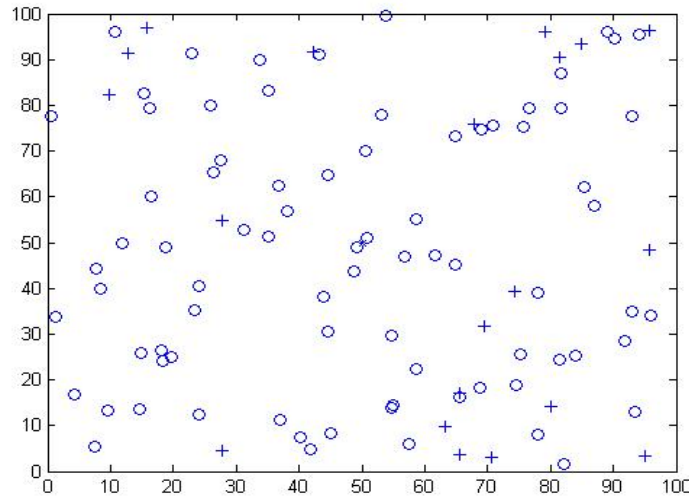
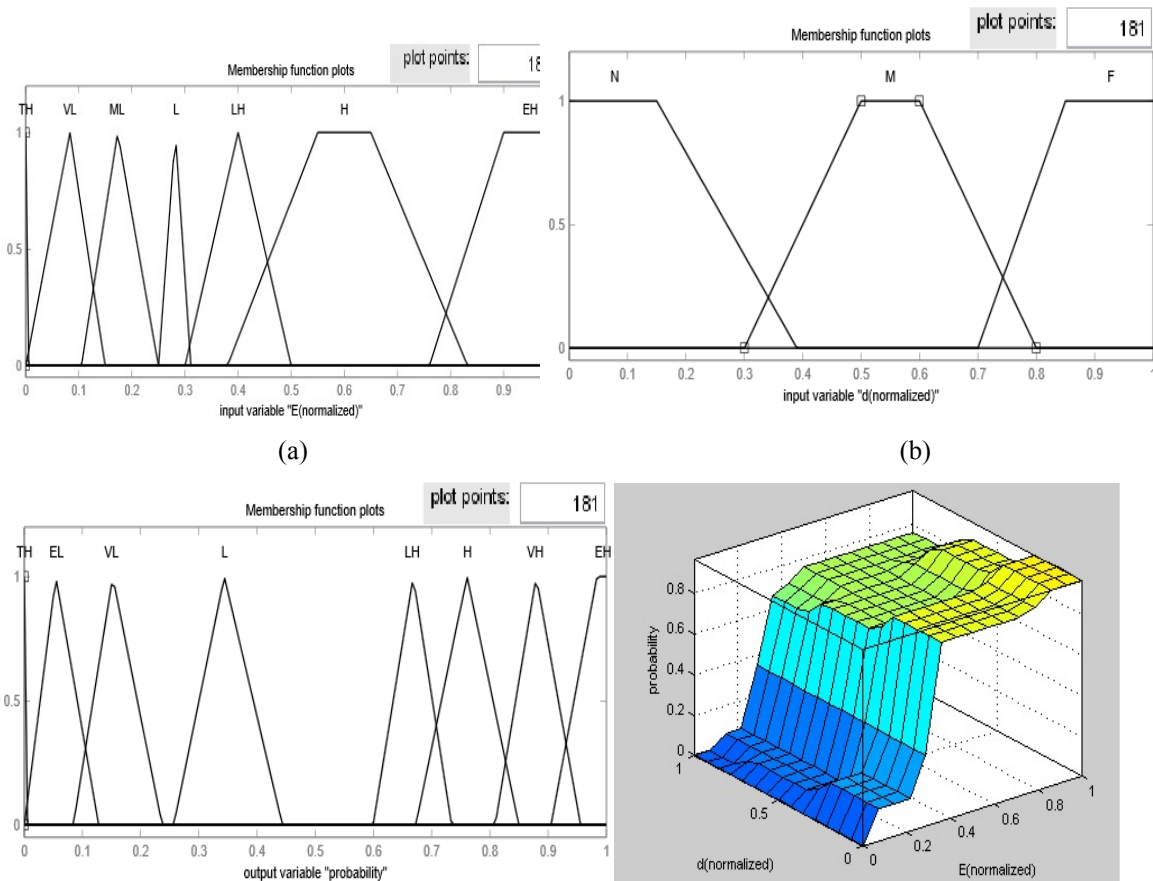


Fig. 1 Random deployment of 100 nodes with BS at center

For CHs selection, Mamdani model [10] is used in fuzzy rule because it is acceptable worldwide for variable input parameters. Modeling of fuzzy rule is based on two factor, (i) Normalized energy of sensor nodes (E_{norm}) and (ii) normalized distance (d_{norm}). In fuzzy rule, crisp input ($E_{norm}(i)$, $d_{norm}(i)$) are converted into fuzzy input. These fuzzified input applied to inference rule as given in Fig. 2 (d) and the outcome of fuzzy rule will be treated as probability of CHs selection. Based on these probabilities and CHs threshold eq. [9], certain nodes will undergo in CH selection process. It provides optimum solution in terms of CHs probability for each node. Since network is multilevel heterogeneous and each node has different probability, at the end stage of simulation, there may be the chance that most of the nodes which are having less probability will not undergo in CHs selection process. It creates unfavorable scenario for network. To overcome this, CH update rule is necessary for proper clustering unless optimum number of nodes (given in eq. (9) [7]) are selected as CH. Flow chart of the network is shown in Fig. 3.



(c)(d)

Fig. 2: (a) E_{norm} Input membership function (b) d_{norm} Input membership function (c) $p_{(i)}(r)$ output membership function (d) Fuzzy rule for CHs selection.

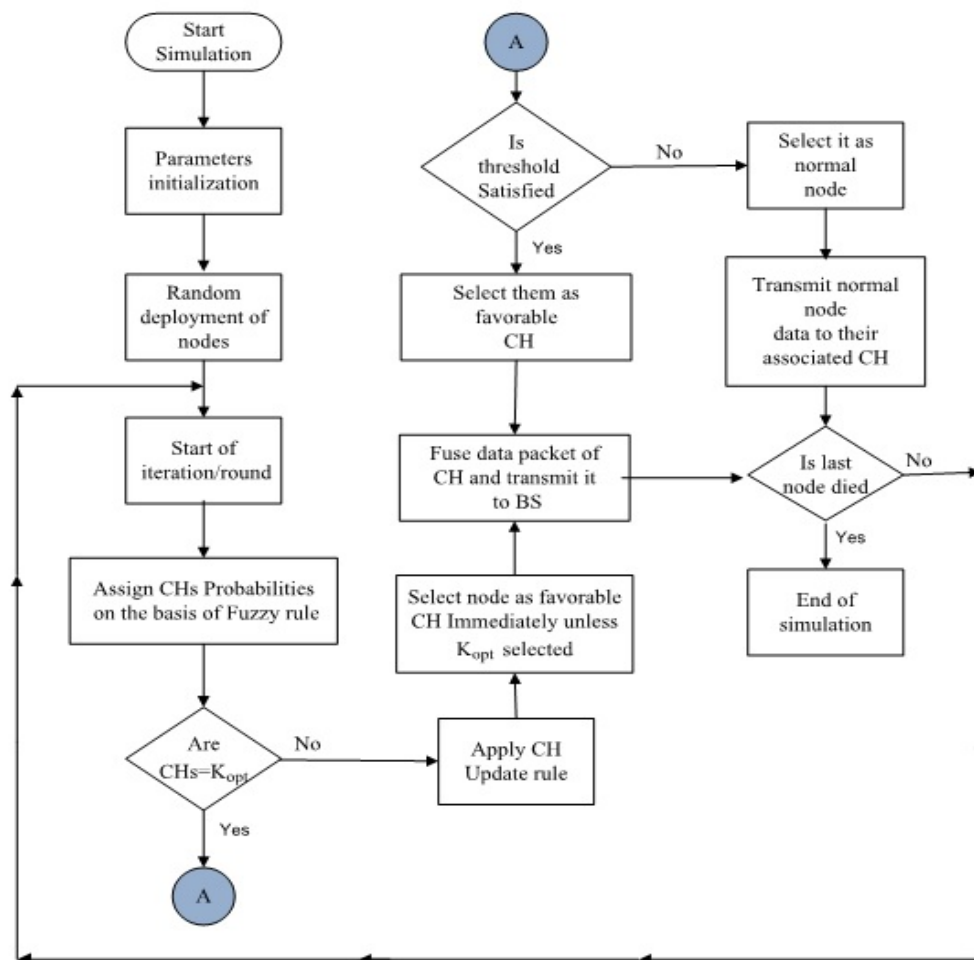


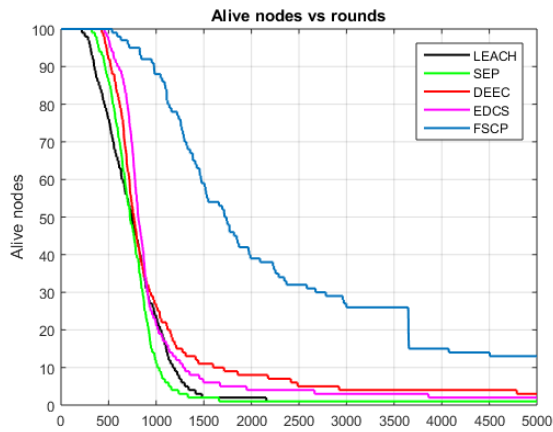
Fig.3.Flow chart of network

III. SIMULATION PARAMETERS AND RESULTS

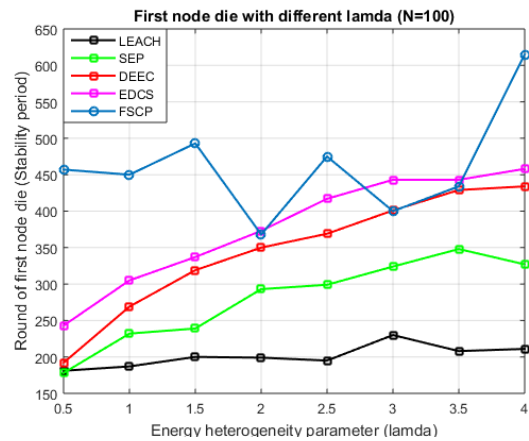
To compare the performance of proposed FSCP with LEACH, SEP, DEEC and EDCS protocols, same network parameters has been taken as EDCS protocol [9]. Parameters are indicated in Table-I [9]. Fig.4 (a) shows the alive node vs round. It indicates that life time of the network with stability period (17.50 % improvement over EDCS) is much better than existing protocol ([6] – [9]). Fig. 4 (b) shows the FSCP stability period comparison with ([6] – [9]) protocols. It indicates that under multilevel heterogeneous network with different energy heterogeneity parameter (λ), FSCP stability period is much improved over EDCS. At some points in energy heterogeneity parameter (λ , 2.3 and 3.5) performance of FSCP is not better but overall performance is remarkably improved. Fig. 4 (c, d) compares the die-up of alive nodes at 10%, and 50% it shows that life time FSCP is improved with network coverage. Also for different energy heterogeneity parameter (λ), packet received at BS are much better in comparison to existing protocol ([6] – [9]) Fig. 4 (e and f). Therefore, through MATLAB simulation it is depict that overall performance of proposed FSCP is much better than other protocols ([6] – [9]).

TABLE I Simulation Parameters of WSNs

| Parameters | Values |
|--|--------------------------------------|
| Network Size | 100*100 square meter |
| Total Number of Node (N) | 100 |
| Energy (E_o) | 0.25 J |
| Location of Base Station (BS) | (50,50) |
| Transmitter/Receiver Energy (E_{elec}) | 5 nJ/bit/m ² |
| Transmit Amplifier (ϵ_{fs}) | 10 pJ/bit/m ² |
| If ($d_{ch,bs} < d_o$) . | |
| Transmit Amplifier (ϵ_{mp}) | 0.0013 pJ/bit/m ⁴ |
| If ($d_{ch,bs} \geq d_o$) | |
| Data Aggregation Energy(E_{DA}) | 5 nJ/bit/message |
| d_o | $\sqrt{\epsilon_{fs}/\epsilon_{mp}}$ |
| Data packet size | 500 Bytes |
| Packet header size | 25 Bytes |
| Broadcast packet size | 25 Bytes |
| Request packet size | 25 Bytes |
| Round | 5 TDMA |
| α | 0.5 |



(a)



(b)

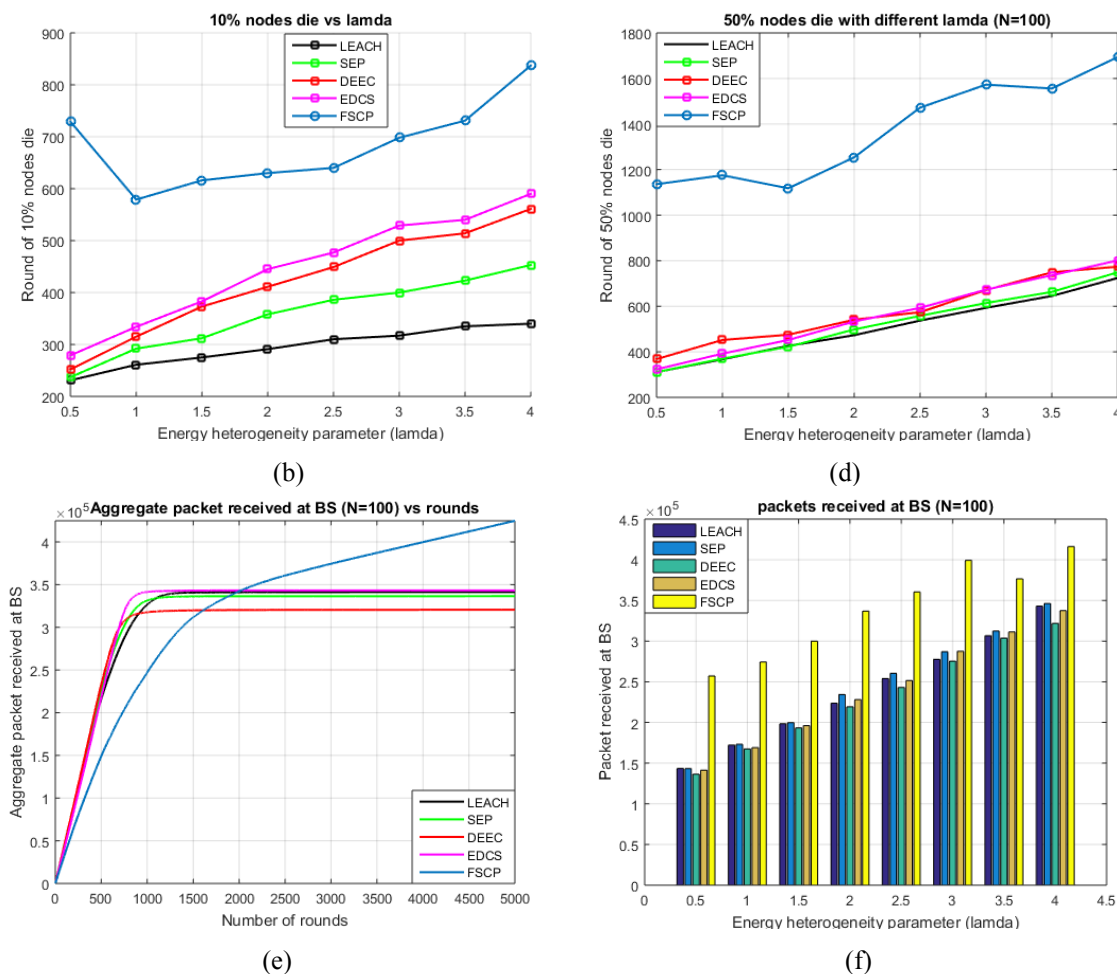


Fig. 4: (a) Alive node vs round (b) Stability period vs Energy heterogeneity parameter (lambda) (c) 10% node die up vs Energy heterogeneity parameter (lambda) (d) 50% node die up vs Energy heterogeneity parameter (lambda) (e) Packet received at BS vs round (f) Packet received at BS vs Energy heterogeneity parameter (lambda)

IV. CONCLUSION

In this paper, FSCP (Fuzzy based Stable Clustering Protocol) for multilevel heterogeneous WSN is proposed. In FSCP, Fuzzy logic with CH update rule enhances the network coverage and network lifetime under different energy heterogeneity parameters. This improvement in network coverage also enhances the throughput at BS. This is because of synchronous energy consumption of sensor nodes after employing the balance effect of normalized energy and normalized distance. Simulation results justified that overall network performance is better than existing protocols LEACH, SEP, DEEC and EDCS.

REFERENCES

- [1] K. Akkaya and M. Younis, "A survey on routing protocols for wireless sensor networks," *Ad Hoc Netw.*, Vol. 3, No. 3, pp. 325–349, 2005.
- [2] J.-S. Lee and W.-L. Cheng, "Fuzzy-logic-based clustering approach for wireless sensor networks using energy predication," *IEEE Sensors J.*, Vol. 12, No. 9, pp. 2891–2897, Sep. 2012.
- [3] Tyagi, Sudhanshu, and Neeraj Kumar. "A systematic review on clustering and routing techniques based upon LEACH protocol for wireless sensor networks." *Journal of Network and Computer Applications* Vol. 36, No. 2, pp. 623-645, 2013.
- [4] Afsar, M. Mehdi, and Mohammad-H. Tayarani-N. "Clustering in sensor networks: A literature survey." *Journal of Network and Computer Applications* Vol. 46, pp. 198-226, 2014.
- [5] Singh, Santar Pal, and S. C. Sharma. "A survey on cluster based routing protocols in wireless sensor networks." *Procedia Computer Science* Vol. 45, pp. 687-695, 2015.
- [6] W.R. Heinzelman, A.P. Chandrakasan, H. Balakrishnan, "An application- specific protocol architecture for wireless microsensor networks", *IEEE Transactions on Wireless Communications* Vol. 1, No. 4, pp. 660–670, 2002.
- [7] G. Smaragdakis, I. Matta, A. Bestavros, "SEP: A Stable Election Protocol for clustered heterogeneous wireless sensor networks," In *Proceeding of Second International Workshop on Sensor and Actor Network Protocols and Applications (SANPA 2004)*, Vol. 3, 2004.
- [8] L. Qing, Q. Zhu, and M. Wang, "Design of a distributed energy-efficient clustering algorithm for heterogeneous wireless sensor networks," *Comput. Commun.*, Vol. 29, No. 12, pp. 2230–2237, 2006.
- [9] Zhen, Hong, Yu Li, and Gui-Jun ZHANG. "Efficient and dynamic clustering scheme for heterogeneous multi-level wireless sensor networks." *Acta Automatica Sinica* 39.4 (2013): 454-460.
- [10] Ben-Mubarak, M. A., Ali, B. M., Noordin, N. K., Ismail, A., & Ng, C. K., Fuzzy logic based self-adaptive handover algorithm for mobile WiMAX. *Wireless Personal Communications*, Vol. 71, No.2, pp. 1421– 1442, 2013.

AUTHOR PROFILE

Akshay Verma received M.Tech degree in Electronics and Communication Engineering from National Institute of Technology Jalandhar, Jalandhar, India in 2016. He is currently pursuing Ph.D. degree with Motilal Nehru National Institute of Technology Allahabad, Allahabad, India. His research interest includes energy efficient routing algorithm designing in wireless sensor networks.

Tarique Rashid received M.Tech degree in Electronics and Communication Engineering from Motilal Nehru National Institute of Technology Allahabad, Allahabad, India in 2014. He is currently pursuing Ph.D. degree with Motilal Nehru National Institute of Technology Allahabad, Allahabad, India. His research interest includes energy efficient routing algorithm for Intra body sensor networks.

Prateek Raj Gautam received M.Tech. degree in Electronics and Communication Engineering from Harcourt Butler Technological Institute Kanpur, India in 2011. He is currently pursuing Ph.D. degree with Motilal Nehru National Institute of Technology Allahabad, Allahabad, India. His research interest includes energy optimization for wireless sensor network, Image Processing, CDMA and IDMA.

Sunil Kumar received M.Tech. degree in Electronics and Communication Engineering from Harcourt Butler Technological Institute Kanpur, India in 2011. He is currently pursuing Ph.D. degree with Motilal Nehru National Institute of Technology Allahabad, Allahabad, India. His research interest includes energy optimization for wireless sensor network.

Arvind Kumar received M.E and Ph.D. degree from Motilal Nehru National Institute of Technology Allahabad, Allahabad. He is currently an Assistant Professor with Department of Electronics and Communication Engineering, Motilal Nehru National Institute of Technology Allahabad, Allahabad, India. He has published more than 18 papers in various journal and conference.