IOT Based Sensor Monitoring System for Smart Complex and Shopping Malls

Vipul Narayan(✉) and A. K. Daniel

Department of Computer Science and Engineering, Madan Mohan Malaviya University, Gorakhpur, U.P., India
vipulupsainian2470@gmail.com

Abstract. Wireless Sensor Network (WSN) plays a significant role in smart offices/workplaces and academic research nowadays. Due to the vast range of technologies research is being conducted in the domain such as environmental monitoring, human safety, military operations, intelligent remote monitoring, shopping malls, smart complex, healthcare etc. Clustering is a technique through which the efficiency of network is enhanced. Two Stage Energy Efficient Routing Protocol (TS-EERP) is proposed, which divides the network into different levels. Increasing the number of Cluster Head (CH) nodes at various levels improves the Residual Energy (RE) of cluster nodes/nodes. The aim of the paper is to develop an efficient CH selection mechanism based on maximum RE of Sensor Node (SN) and minimum Base Station (BS) distance. The proposed protocol works in two steps as follows: The data is collected from smart offices in the first step and from residential buildings in the next step. The collected data is aggregated by the Cluster head(s) and transmit to the BS in the Internet of Things (IoT) based network. The simulation performance of the proposed protocol improves the lifetime of the network compared to the SEP protocol.

Keywords: Cluster head selection · IoT · Lifetime · Residual Energy · Sensor Network

1 Introduction

The future internet aim is to integrate a wide range of wireless and wired technology together for smart living. In [1] author discussed IoT consists of a large network to links a wide range of objects and entities. The sensor nodes are used for continuously monitoring of objects in the network. The WSN plays a significant role in various places as military and non-military domains, climate forecasting, environmental monitoring, smart buildings, shopping malls, smart offices, smart cities and military surveillance etc. In the current decade sensors with essential characteristics like smaller size, cheaper cost and intelligent processing system made this easily possible. In [2] author discussed around 5 billion smart devices are connected together in the future days. According to the survey, around 30 billion objects will be connected to IoT devices by 2022. This gives up several opportunities for IoT research in a variety of disciplines. The SN performs the data collection task and transmits to CH node. The aggregation of data is performed by CH node and transmit it to BS shows in Fig. 1.

C. T. Calafate et al. (Eds.): MONAMI 2021, LNICST 418, pp. 344–354, 2022.
https://doi.org/10.1007/978-3-030-94763-7_26

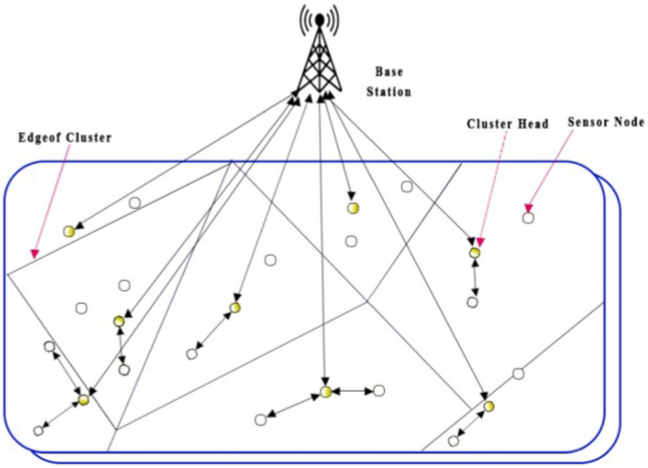


Fig. 1. Architecture of WSN.

The wireless interface characteristic of the sensor allows them to connect and establish a wireless network. In [3] author discussed the architecture of WSN is influenced by important factors as cost, hardware and limited battery power. The homogeneous and heterogeneous nodes are used in the network. Sensor node battery replacement is a difficult task in the network. The various node deployment techniques are used to cover the monitoring area by using optimum SN in the network. In [4] authors discussed deterministic and random node deployment schemes. The nodes have limited battery power for performing tasks in the network. The various energy optimization techniques are used to enhanced node residual energy and improved network performance.

The network lifetime is improved by using clustering techniques. The number of SN are grouped to form clusters in the network. The single node in an individual cluster serves as a CH, while the remaining SN acts as a cluster member of the network. The aggregation of data is performed by CH nodes and transmits to BS. In [5] authors discussed hybrid routing techniques to solve the issues in the IoT based network. The normal node sent data to BS directly while the advanced node through the clustering process and enhanced network performance. The proposed Two Stage Energy Efficient Routing Protocol for IoT based WSN. The network area is partitioned into regions and sub regions. The RE of Cluster nodes/nodes is improved by increasing Cluster Head (CH) nodes at various levels in the network. The TS-EERP protocol performed its operation in two steps: In the first step, it collects the data from the smart offices and in the second step collects data from the residential buildings.

The research article is structured as follows: Sect. 2 elaborates the previous research work. Two Stage Energy Efficient Routing Protocol is discussed in Sect. 3. Simulation results are discussed in Sect. 4 and Conclusion and Future directions in the last section.

2 Related Work

In [6] authors discussed the evolution of IoT and play a significant role to boost up the demand of internet users all across the world. The IoT makes people's lives easier and works smarter. The distribution of SN is random in the network area. The SN have limited battery power, computational capacity, and communication range. The SN is one of the major components of IoT devices. The SN are placed anywhere and consist of a large quantity of data to process for communication among devices in the network. In [7] authors discussed three types of network communication as direct communication, multi-hop communication and cluster-oriented communication. The Clustering technique is performed either statically/dynamically and data is transmitted to BS. The various routing protocols are used to route data in the sensor network. In [8] author discussed LEACH protocol. The protocol works for homogenous nodes and follows single-hop communication for data transmission tasks in the network. The protocol uses clustering and an efficient CH selection mechanism for optimal energy utilization in the network.

The IoT plays a vital for connecting smart devices to cloud infrastructure. To improve the efficiency of IoT-based applications, several routing protocols are introduced. The data transmission tasks consume more energy in the network therefore to develop a routing protocol for the WSN is an important task. The integration of WSN with IoT devices plays an important role in every aspect of life. In [9] authors investigated a good solution for data collection and processing tasks in the smart complexes/buildings for the IoT based wireless network. The solution is modeled for IoT devices and simulated in the Cooja simulator. The proposed solution performed efficient utilization of energy in the IoT based smart building and complexes. In [10] author survey the IoT based building management system for optimum use of resources and efficient energy management systems for smart complex/malls. The edge computing is also widely used to minimize the energy issues in the IoT based network and improve network performance. In [11] author discussed selection of CH plays an important role in the clustering algorithm. The CH node is responsible for the data fusion process and data processing task in the network. The energy consumption is more in the network when the BS is situated outside the network. The replacement of dead CH nodes consumes more energy in the network and the performance of network is degraded.

In [12] author discussed LEACH centralized with chain protocol. The protocol used a centralized clustering technique to minimize delay in the network and enhanced network performance compared to the LEACH protocol.

In [13] author discussed the working principle of the Centralized LEACH protocol. The steady phase of the protocol is different compared to LEACH protocol. The SN is equipped with a global positioning system for tracking objects in the network. The CH election is based on a threshold value and keeps a record of the previously selected CH. The protocol improves the performance of the system and enhanced network lifetime. In [14] authors discussed Multi-hop LEACH (MH-LEACH) protocol for data transmission to BS. The data is collected by the SN and forwarded to the respective zonal CH. The CH-to-CH communication in the zonal region which enhanced RE of CH node and improves performance of the system. In [15] author discussed Advance Zonal Rectangular LEACH (ARZ-LEACH) protocol. The network area is categorized

into advanced clusters, rectangular clusters and zonal clusters to maintain the load inside the network and enhanced network lifetime. In [16] introduced SEP protocol which uses Normal nodes (NN) and Advanced nodes (AN). The weighted probability is used for CH selection in the protocol. The protocol improves stability and improves network performance.

In [17] author introduced Enhanced Stable Election Protocol. The protocol uses three-level architecture and intermediate SN. The AN have more energy than NN in the network. The heterogeneity level is improved by adding one more layer and improves network performance.

In [18] author proposed multi-hop routing with stable election (MR-SEP) protocol. The MR-SEP protocol divides the network into multiple cluster levels. The minimum BS distance is used as a criterion for CH selection and requests member SN to join the CH. The top layer CH works as super CH for lower layer and increase the network performance.

In [19] introduced HEED protocol and CH is selected based on RE of node and proximity principal. The protocol minimizes network overhead and enhances the network life span. In [20] introduced Energy Efficient Density Control (EEDCA) method in which the CH selection criteria are based on node position and RE of SN. The EEDCA protocol maintains a table of its neighboring SN and transmits data to BS.

The TS-EERP protocol uses the following performance metrics:

(i) Stability Period: The time span in which all the SN cover the region of interest until dead of first SN in the network.
(ii) Network lifetime: The time period in which all nodes cover the region of interest until the death of all SN.
(iii) Throughput: The packets successfully transmitted to BS.

3 Proposed Two Stage Energy Efficient Routing Protocol (TS-EERP)

The proposed TS-EERP protocol divides the network into multiple regions and sub regions. The CH is selected by using SN maximum node RE and minimum BS distance. The random number is chosen and compares to a threshold value. If the selected number is less to the threshold value the SN acts as a CH in the network, while the other node acts as a CM in the network. The CH-to-CH communication takes place in the network which enhanced the RE of SN and the lifetime of the network.

The proposed protocol works in two stages: In the first step data is collected from smart offices in one cluster and in the second step data is collected from residential buildings. The collected data is aggregated by CH nodes and transmitted to BS in the IoT-based network (Figs. 2 and 3).

The automation of smart homes and offices is widely used in corporate offices, shopping malls, shopping complexes, etc. in various places nowadays. The goal of the automation process is to integrate new technology with IoT devices for easy control in smart home appliances such as fans, lights, refrigerators, television, electric induction,

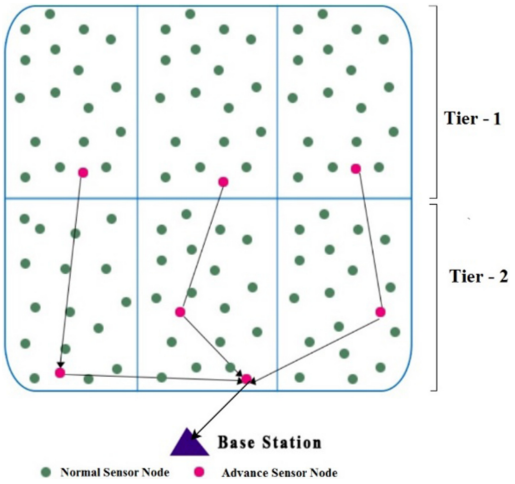


Fig. 2. The two-stage energy efficient routing protocol.

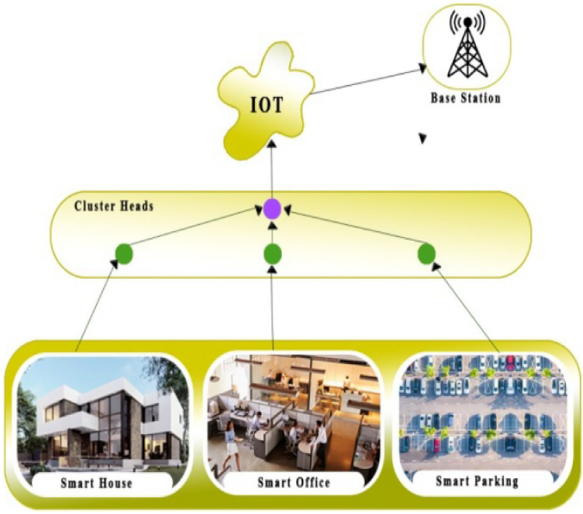
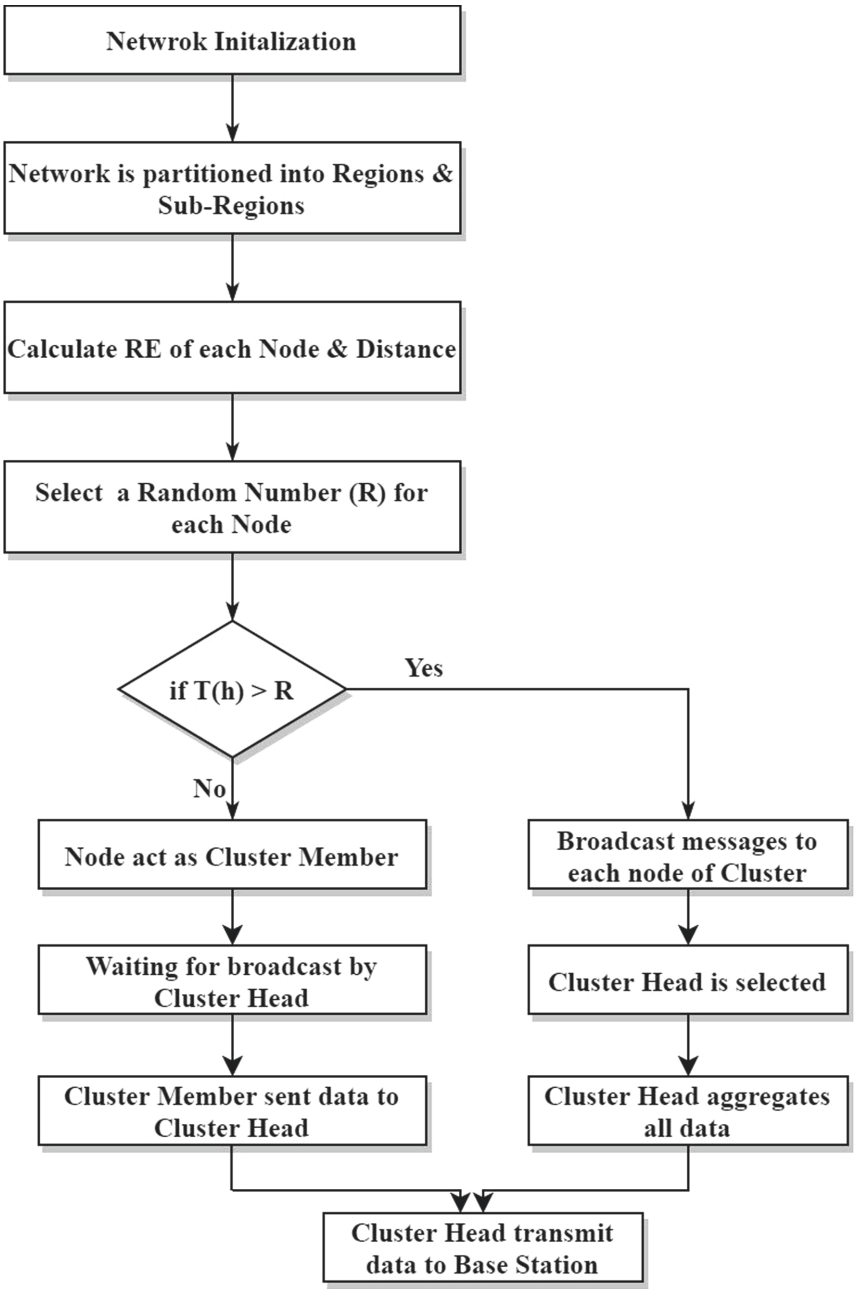


Fig. 3. IoT applications.

smart doors, smart windows, gas detections, light monitoring, and air conditioners. The automation process saves power consumption and improves the standard of living.



The working of the proposed Two Stage Energy Efficient Routing Protocol as follows:

3.1 Setup Phase

The network area is partitioned into regions and sub-regions. The responsibility of BS for dividing the network region into two tiers/stages. Tier 1 is away from the BS and Tier 2 is closer to BS.

3.1.1 Cluster Formation

The SN are randomly deployed in the network, and cluster formation takes place. Each SN is assigned a unique identification number based on the location information and join its adjacent nodes cluster only.

3.1.2 Cluster Head Selection

The CH selection process in the proposed TS-EERP protocol is based on maximum node RE and minimum BS distance as parameters. The threshold value is compared to a randomly generated value. The AN are selected as cluster heads and broadcast messages to all NN in the network to join and become CHs member nodes. The CH-to-CH communication takes place in the network. The aggregation of data by CH nodes and transmit it to BS.

TS-EERP Algorithm

Initialization: N = Sensor Nodes, D = Distance, CH = Cluster Head, CM = Cluster Member, RE = Residual Energy, BS = Base Station, T_h = Threshold, R = Random Number.

```
CH_Selection ()
BEGIN
Divide Area into Regions and Sub-Regions.
for (i=1; i ≤ N; i++)
Calculate Di, REi
Calculate Ri = Rand ()
if (Th> Ri)
    Broadcast (msg_To_Ni)
    Select (CH)
    Aggregate (data)
    Transmit (BS)
  else
    Select (CM)
    Broadcast (CH_msg)
    Sent (CM_data_to_CH)
  end if
end for
END
```

3.2 Steady State Phase

The Time Division Multiple Access slots for each node for communication purposes. The SN use predetermined allocated TDMA slot to communicate with their corresponding cluster leaders and the rest of SN is kept in the sleep state during the unallocated time.

4 Simulation Results and Validation

Matlab software is used for simulation purposes. The software provides a good framework for data virtualization, algorithms and simulating various parameters. The heterogeneous nodes are used for the simulation purpose in terms of alive nodes, cluster head per round and no. of packet successfully transmitted to BS. The two-tier architecture for the data transmission in the network. The CH-to-CH communications take place in the network and data is transmitted to BS.

Network Designing Assumptions and Key Parameters. The 150 nodes are randomly deployed in the (150,150) m^2 area for simulation purposes. The nodes are placed static after random distribution in the network. The simulation is performed for 6000 rounds of packet transmission. The position of BS is somewhere outside the area of the network. The CH selection probability and advanced nodes are 10% in the network.

The following assumptions for the proposed protocol.

1. The nodes distributed are random and static in nature.
2. The heterogeneous nodes are used for designing the protocol.
3. The node battery power is limited and BS supplies power continuously.
4. The collision and noise factors are ignored in the system.
5. The advanced node worked as CH in the network and transmitted the packet to BS (Table 1).

Table 1. Key parameters.

Parameters	Values
Number of SN	100
Network area	(150,150) m^2
Free model ($E\,fs$)	10 pJ//bit//m^2
Multipath model (E_{amp})	0.0013 pJ/bit/m^4
Initial level battery (E_0)	0.5 J
Electronic circuitry (E_{RX})	50 nJ//bit
Data aggregation (E_{DA})	10 nJ/bit

The simulation result shows SEP protocol first packet drop at 1199 rounds and proposed protocol at 2999 rounds. The lifetime of the SEP protocol is 4049 rounds and the proposed TS-EERP is 5059 rounds show is Fig. 4.

The CH selection plays an important role to improve the energy efficiency of the WSN. The number of SN to become CH in the TS-EERP protocol is greater initially and remains same for some time as compared with SEP protocol. The simulation performance

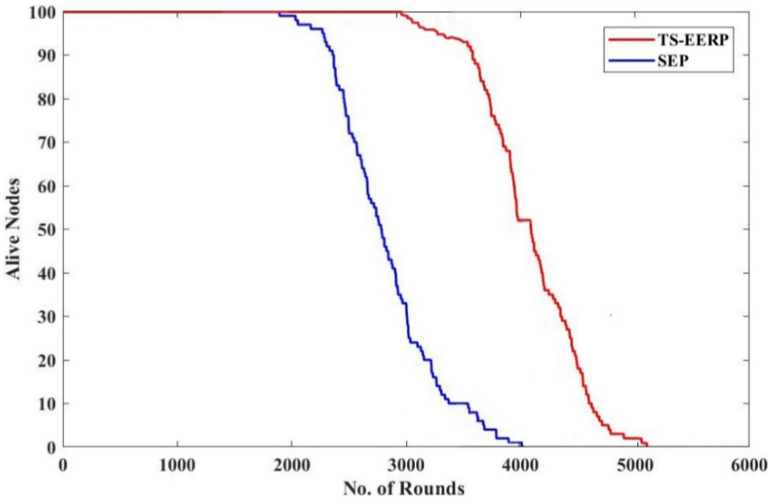


Fig. 4. Alive node number.

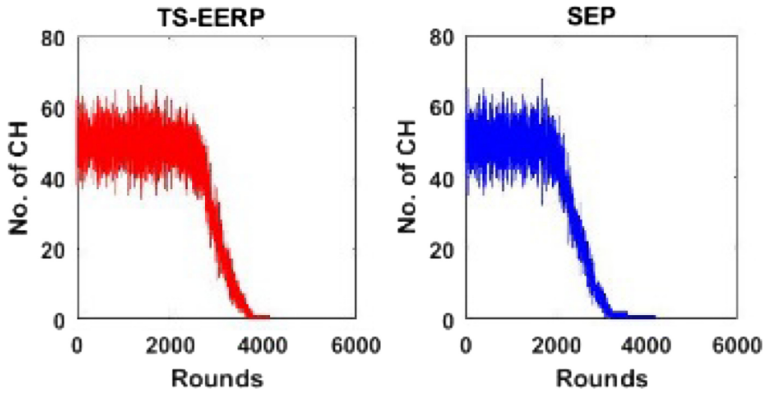


Fig. 5. Number of CH per round.

of the TS-EERP protocol shows improvement in stability number of CH per round and enhanced network lifetime compared to the SEP protocol show in Fig. 5.

The TS-EERP protocol successfully transmits 2.1×10^4 packets to BS whereas SEP transmits 1.5×10^4 packets to BS. The TS-EERP protocol shows enhancement in packet transmission to BS compared to SEP show in Fig. 6.

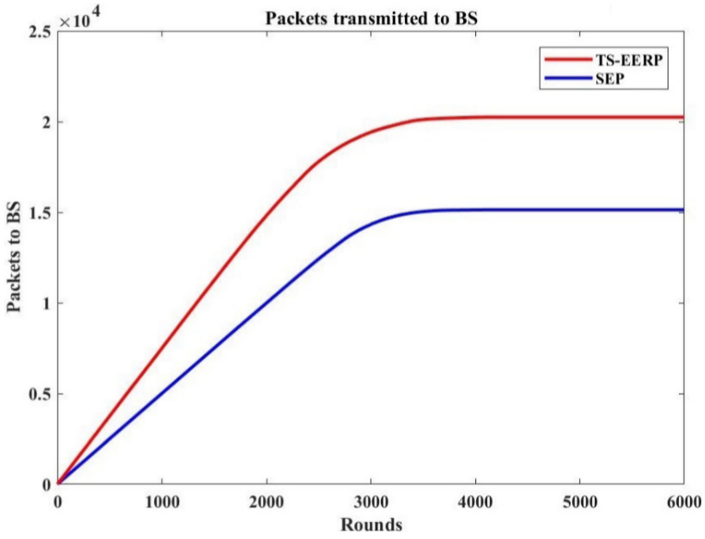


Fig. 6. Packet successfully transmitted to BS.

5 Conclusion and Research Directions

The proposed protocol increases the number of cluster head nodes at different levels to enhance node residual energy and the performance of the system. The data is collected from the smart offices in the first cluster, and for residential buildings in the second cluster and transmitted to BS. The simulation performance of the proposed protocol show enhancement in network lifetime compared to the SEP protocol. The three-level hierarchical network architecture will be developed in the future for an efficient CH selection process for large network area to increase network lifetime.

References

1. Chauhan, J., Goswami, P.: An integrated metaheuristic technique-based energy aware clustering protocol for Internet of Things based smart classroom. Mod. Phys. Lett. B **34**(22), 2050360 (2020)
2. Paunikar, V.L., et al.: A user authentication scheme of Iot devices using blockchain-enabled fog nodes. Int. J. All Res. Writ. **1**(11), 19–22 (2020)
3. Narayan, V., Daniel, A.K.: Multi-tier cluster based smart farming using wireless sensor network. In: 2020 5th International Conference on Computing, Communication and Security (ICCCS). IEEE (2020)
4. Narayan, V., Daniel, A.K.: A novel approach for cluster head selection using trust function in WSN. Scalable Comput. Pract. Exp. **22**(1), 1–13 (2021)
5. Chaturvedi, P., Daniel, A.K.: A hybrid scheduling protocol for target coverage based on trust evaluation for wireless sensor networks. In: IAENG Int. J. Comput. Sci. **44**(1) (2017)
6. Atzori, L., Iera, A., Morabito, G.: Understanding the Internet of Things: definition, potentials, and societal role of a fast-evolving paradigm. Ad Hoc Netw. **56**, 122–140 (2017)

7. Chaturvedi, P., Daniel, A.K.: A novel approach for target coverage in wireless sensor networks based on network coding. In: Ray, K., Sharma, T.K., Rawat, S., Saini, R.K., Bandyopadhyay, A. (eds.) Soft Computing: Theories and Applications. AISC, vol. 742, pp. 303–310. Springer, Singapore (2019). https://doi.org/10.1007/978-981-13-0589-4_28
8. Bhagat, A., Geetha, G.: Optimization of LEACH for developing effective energy-efficient protocol in WSN. In: Khanna, A., Gupta, D., Bhattacharyya, S., Snasel, V., Platos, J., Hassanien, A.E. (eds.) International conference on innovative computing and communications. AISC, vol. 1059, pp. 195–206. Springer, Singapore (2020). https://doi.org/10.1007/978-981-15-0324-5_17
9. Plageras, A.P., et al.: Efficient IoT-based sensor BIG Data collection–processing and analysis in smart buildings. Future Gener. Comput. Syst. **82**, 349–357 (2018)
10. Harkare, A., Potdar, V., Mishra, A., Kekre, A., Harkare, H.: Methodology for implementation of building management system using IoT. In: Suma, V., Bouhmala, N., Wang, H. (eds.) Evolutionary Computing and Mobile Sustainable Networks. LNDECT, vol. 53, pp. 939–948. Springer, Singapore (2021). https://doi.org/10.1007/978-981-15-5258-8_86
11. Chugh, A., Panda, S.: Strengthening clustering through relay nodes in sensor networks. Procedia Comput. Sci. **132**, 689–695 (2018)
12. Boubiche, D.E., Bilami, A.: HEEP (Hybrid Energy Efficiency Protocol) based on chain clustering. Int. J. Sensor Netw. **10**(1–2), 25–35 (2011)
13. Kumar, S.A., Ilango, P., Dinesh, G.H.: A modified LEACH protocol for increasing lifetime of the wireless sensor network. Cybern. Inf. Technol. **16**(3), 154–164 (2016)
14. Neto, J.H.B., et al.: MH-LEACH: a distributed algorithm for multi-hop communication in wireless sensor networks. In: ICN 2014, pp. 55–61 (2014)
15. Khan, M.K., et al.: Hierarchical routing protocols for wireless sensor networks: functional and performance analysis. J. Sens. (2021)
16. Smaragdakis, G., Matta, I., Bestavros, A.: SEP: a stable election protocol for clustered heterogeneous wireless sensor networks. In: Second International Workshop on Sensor and Actor Network Protocols and Applications (SANPA 2004), vol. 3 (2004)
17. Islam, M.M., Matin, M.A., Mondol, T.K.: Extended Stable Election Protocol (SEP) for three-level hierarchical clustered heterogeneous WSN, pp. 43–43 (2012)
18. Kaur, H., Sharma, H., Manu, G.: Multi-hop Routing SEP (MR-SEP) for clustering in wireless sensor network. Int. J. Eng. Technol. Manage. Appl. Sci. **2**(3), 54–65 (2014)
19. Yang, M., Yang, D., Huang, C.: An improved HEED clustering algorithm for wireless sensor network. J. Chongqing Univ. **35**(8), 101–106 (2012). Chongqing Daxue Xuebao (Ziran Kexue Ban)
20. Meddah, M., Haddad, R., Ezzedine, T.: An energy-efficient and density control clustering algorithm for wireless sensor network. In: 2017 13th International Wireless Communications and Mobile Computing Conference (IWCMC). IEEE (2017)