Mobile Sink Adaptable Power Sentient Routing Schemes in Distributed Wireless Communication Systems

VINOD KUMAR VERMA
Department of Computer Science and Engineering
Sant Longowal Institute of Engineering and Technology
Longowal -148106, Sangrur, Punjab
INDIA
Vinod5881@gmail.com

Abstract: - Distributed wireless and mobile systems have attained the significant consideration for the research community due to their wider adoption nowadays. These systems serve as an integral part of our daily life applications. This research work explores the past contributions over the power-aware schemes for mobile networks. These schemes are namely: power-efficient gathering in sensor information systems (PEGASIS), stable election protocol (SEP), threshold sensitive energy efficient sensor network, TEEN, distributed energy-efficient clustering (DEEC) and low energy adaptive clustering hierarchy (LEACH) Moreover, a novel investigational analysis has been presented for these energy adaptive routing schemes on distributed mobile networks. Additionally, the factors affecting the performance of these systems have been elaborated in detail. Next, the outcomes from the investigations have been analyzed for the distributed mobile network systems. Finally, simulation explorations have been attached to validate the proposed comparative analysis.

Key-Words: - PEGASIS, TEEN, SEP, DEEC, LEACH energy, mobile, distributed, networks.

1 Introduction

Wireless mobile systems serve as a backbone for the all real-time applications used on a daily basis in different facets of life. The wider domains of these applications include education, healthcare, manufacturing, defense, environment, traffic control etc. The presence of a wide variety of devices in the wireless and mobile system adds the challenges of the heterogeneity for the researcher and designers. The evaluation parameters like power consumption, resource utilization, latency, scalability and network lifetime affect the performance of the deployed wireless and mobile system. To cope up with these challenges and constraints, innovative solutions are always needed to benefit these mobile systems and to attain the given objective. These solutions include mechanisms addressing the network design, routing scheme, coverage, mobility, battery capacity, etc. This paper investigated the existing energy adaptable schemes from rigorous explorations. This includes comprehensive explorations of existing mechanism and also proposed a policy to enhance the performance of these schemes

The structure of this paper has been expanded in the later sections. Section 2 highlighted the past work summation in distributed wireless and mobile systems. Further, section 3 presented the proposed mobile sink strategy for these systems. Next, section 4 elaborates the detailed scenario used for the experimentation. Section 5 illustrates the derailed investigational outcome of the designated approach through simulations. Eventually, conclusions have been described in the last section.

2 Past Work in Wireless and mobile Networks

The work done by the researchers and scientists in the direction of power-aware routing strategies are as follows. A proposal for the intelligent load balancing using K-Hop cluster-based approach was reported in reference [1]. This work has focused to address the energy consumption issue in WSNs. A cluster-based approach to address the energy issue was reported by Want et al. [2] for internet of things associated wireless sensor networks. A mesh-based solution for the emergency conditions in wireless mesh networks was suggested by Tawfik et al. [3]. Author in reference [4] reported the limitations of the wireless technology for the internet of things based on healthcare applications. A strategy to enhance the mobile and wireless networked system was presented by Youssef et al. [5]. This proposal specified an enhanced duty cycling protocol namely: Contiki-AMAC for the wireless sensor networks. Balico et al. [6] worked for the important performance parameters like routing and data aggregation for the high-speed sink in the wireless sensor networks. Sun et al. [7] presented a research approach focusing on efficient route guidance for vehicular wireless networks. Authors in reference [8] suggested an architecture for the next generation optical network focusing on the features namely: data aggregation, network processing and routing. Kim et al. [9] proposed a location-based approach for the separation and mobility management in the WSNs. For the cognitive WSNs, a solution was reported in the reference [10]. This research work considered the backward traffic difference estimation for the energy-efficient routing. Maleel et al. [11] represented comprehensive investigations for the reliability analysis in the wireless sensor networks specially focused around emergent applications for the internet of things. A strategy addressing the criteria of attitude has been explored by Ren et al. [12] for the dynamic routing in wireless sensor networks. Falcon et al. [13] proposed a policy for the robotic wireless sensor network focusing on mobility and energy efficiency. A methodology for the optimal routing using filer approach to eliminate false data for wireless sensor network was highlighted by Li et al. [14]. Zhao et al. [15] presented a solution for mobile data gathering with bounded hop relay for the wireless sensor networks. Hua et al. [16] in 2018 proposed a Wi-Fi-based person detection approach in the network domain for the benefit to adaptable and efficient solutions in the mobile system. Vinod Kumar Verma [17] presented a performance assessment of ad-hoc on demand distance vector routing (AODV) routing protocol over temperature constraints in the wireless sensor network. Verma et al. [18] reported terrain based explorations of AODV routing protocol with associated constraints in WSNs. Verma et al. [19] illustrated an analytical strategy for data aggregation approach in WSNs. Verma et al. [20] highlighted the significance of optimized battery models for different routing protocols namely: static, distance vector and on-demand using 802.11 enabled WSN. Verma et al. [21] presented the thorough estimations over sensor node distribution strategies and also associated the same with classical flooding routing protocol in WSNs. Authors in reference [22] reported the investigations for the trustworthiness with respect to the node increment factor in non-centric p-p networks. By reviewing these research efforts, it is observed that there is still a need to work in the direction of an efficient scheme for WSNs. The proposed scheme energy efficient region based scheme is described in the next section.

3 Mobile Sink Pliable Routing Scheme

In this section, an adaptive energy efficient transmission scheme has been described and implemented using the mobile sink for wireless sensor networks. We design and implemented multi-chain PEGASIS with mobile sink. The mobile sink position is stationed around the center of the four chains. It is observed that increments in a number of rounds reduce the energy consumption in our proposed model. It is observed that the normalized average energy analysis shows non-linear behaviour. It is analyzed that the number of alive nodes remains maximum at the beginning and minimum at the end of all the rounds. We observed that there is a strong relation among the dead nodes and the alive nodes in the PEGASIS protocol. Our proposed improvement is better as compared to the conventional PEGASIS evaluation as we incorporated the concept of chaining to find the energy and round based investigation of this protocol. We designed and implemented LEACH and improved (iLEACH) protocol for a comprehensive investigation. A comparative analysis of LEACH and iLEACH. iLEACH protocol performs better thn the LEACH protocols. This is due to the fact that we suggested an improvement in conventional LEACH protocol. This improvement varies the amount of energy consumption in the reception cycle of a node in the proposed model. The same concept of mobile sink has been implemented for the SEP, TEEN, DEEC protocols resulting in improved (iSEP), improved (iTEEN) and improved (iDEEC) respectively.

4 Experimental Scenario

The deployed scenario use MATLAB version 2010a with the WINDOWS operating system for the designing and implementation of the deployed model. The simulation scenario of the deployed network is depicted in figure 1. The experimental setup is depicted in figure 1. In figure 1, the circle shows the number of nodes deployed in a random manner. The tower symbol shows the base station and green circles represent the mobile sink position at a different time interval.

4.1 PEGASIS Investigations Parameters

We design and implemented multi-chain PEGASIS with mobile sink with the following parameters. The area for the deployed network remains 100 m × 100 m. The total numbers of nodes used are 100. We used transmission and reception energy per node equivalent to 50×10^{-9} J. Maximum round for the evaluation is taken as 5000. Data aggregation energy remains 5×10^{-9} J. Counter for the bits transmitted to the base station is set. The speed of the sink remains 50 m/s.

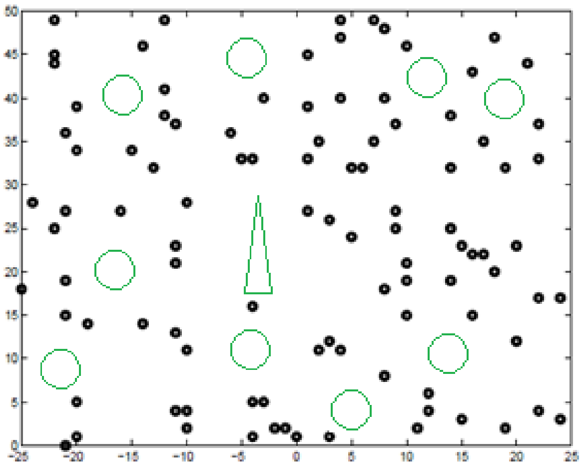

Figure 1: The Simulation Scenario

The calculation of energy is done on the basis of first, tenth, half and all the nodes respectively. Afterword, total energy in one round is computed. Alive nodes are identified and their chain is created for the investigations along with their alignments. Then the movement of sink is analyzed for region 1 chain formation. For the alive nodes, the sink distance is calculated with nodes and finding the last node. Chain formation is done for nodes. Subsequently; chain formation is done. Then calculation for finding minimum distance if it remains less than the threshold value is performed. Temporary leader node is selected. Afterward, chain leader selection process is performed. Further, the most optimal leader with the highest weight is selected. Then placing the leader in each round at the start of the chain array. The counter is set for child nodes of all nodes. Distance between leader and sink node is discovered. Energy calculation on the basis of child nodes of each node if only 1 child node. Any node having child consumes ERX equal to children are identified. Movement of the sink for the chain formation in region 2 is observed. This process continues at the end of the entire network including a number of rounds, nodes and regions.

4.2 LEACH Investigations Parameters

We used the following parameters in our proposed model. The diameter of sensor network 100 m, the distance of base station from the network 100 m, number of nodes 100, probability of a node to become cluster head 10 %.The .energy supplied to each node 0.5 J, transmitter energy per node 0.00000005 J, receiver energy per node 0.00000005 J, amplification energy $d < d_0$ 0.000000000001 J, amplification energy when $d > d_0$ 0.0000000000000013 J , Data Aggregation Energy 0.000000005. The no of rounds remained 3500. The distribution of nodes remains random in X and Y directions. Then the process continues and assigns to the nodes that have not been cluster head. Further, checking threshold and number of sleep nodes calculated. Apart from the above parameters, iLEACH protocols differ in the following parameters with respect to conventional LEACH protocol. The receiver energy per node remains 0.000000005 J and varies upto receiver energy per node 0.000000025 J. Only one condition is used *i.e.* the amplification energy remains amplification energy when $d < d_0$ 0.000000000001 J. The general simulation parameters of our proposed model are given in table 1.

4.3 TEEN AND iTEEN Parameters

In case of TEEN protocol, we used the following parameters. The nodes have been distributed randomly in X and Y axis. Initially, the number of nodes that have been cluster head is zero as there is no cluster head only nodes. The hard and soft threshold values are taken as 100 and 2 respectively. Earlier sense value is taken as zero. The percentage of advanced nodes and heterogeneity are set as zero. Counters have been set for the bits transmitted to base station and to cluster head with respect to each round. The network model is checked for the dead and sleep nodes. The energy dissipation distance is calculated. Selection of the adjoining head for the nodes is being done. Energy debauchery by associated cluster head is computed. Apart from the above parameters, iTEEN have following additional parameters responsible for the performance improvement of TEEN. The value of Emp has set as 0.0000000000000013 J. The values of counter for cluster head and cluster head per round are set as zero initially. The value of threshold is set as 0.00000000000001. The threshold value and the number of sleep nodes are checked periodically.

4.4 DEEC and iDEEC parameters

Initially, there is no cluster head, only nodes. Counters for bits transmitted to the base station and to the cluster head have been set respectively. Apart from the general parameters set for the DEEC protocol, iDEEC carries the following additional parameters. Every node has different energy so-called heterogeneous networks. There is no cluster head, only nodes at the beginning. Counters for the bits transmitted to base station and cluster head are set accordingly. One round remained equal to the value of the nearest integer. One modulus becomes equivalent to the remainder after computation. Dead count and sleep nodes are computed in the consistent manner thereafter.

4.5 SEP and iSEP parameters

Random election of normal nodes is computed. Random elections of advanced nodes have been done thereafter. Counter value for the cluster head is set to zero. Election probabilities for normal node and advanced nodes have been computed. Operations for the heterogeneous nodes and sub epochs have been calculated and imposed accordingly. Elections of cluster head for the normal nodes and cluster head for advanced nodes have been done. Computation of energy dissipation and energy dissipation distance has been performed. Cluster head selection for normal node computed. Energy dissipation by clustered member for transmission of packets is calculated. Also, energy dissipation in receiving is computed. Apart from the above parameter of SEP, iSEP contains the following additional parameters. Among all the nodes, ten nodes are advanced and rests of the nodes are normal. Random election of advanced nodes is done. ERX is set as 0.000000025, Efs is 0.000000000001 J *i.e.* amplification energy when d < d0. Election probability for normal nodes and advanced nodes has been computed as SEP is two levels heterogeneous. Operations for heterogeneous epoch and sub epoch have been calculated. Then, numbers of dead nodes, dead advanced nodes and dead normal nodes have been computed. Computations performed for the bits transmitted to base station, cluster heads and cluster heads per round. Checking for the dead nodes and sleep nodes done. Choice of group leads for the nodes done. Distance to cluster head to the base station and energy dissipation computed for the proposed framework. Then for the advanced nodes, distance to cluster head to base station and energy dissipation computed for the proposed framework. Further, the election for linked group leaders for the nodes and power debauchery computed.

5 Results and Findings

We made a comprehensive evaluation of PEGASIS, LEACH, SEP, DEEC and TEEN protocols. The improvement in the performance of these routing protocols is shown in the subsequent subsections

5.1 PEGASIS Analysis

We implemented multi-chain PEGASIS protocol with mobile sink. The mobile sink position is stationed around the center of the four chains. The Residual energy analysis corresponding to the rounds is shown in figure 2. The investigations show the slant decremented behavior in energy. It is observed that increments in rounds reduce the energy consumption in our proposed model.

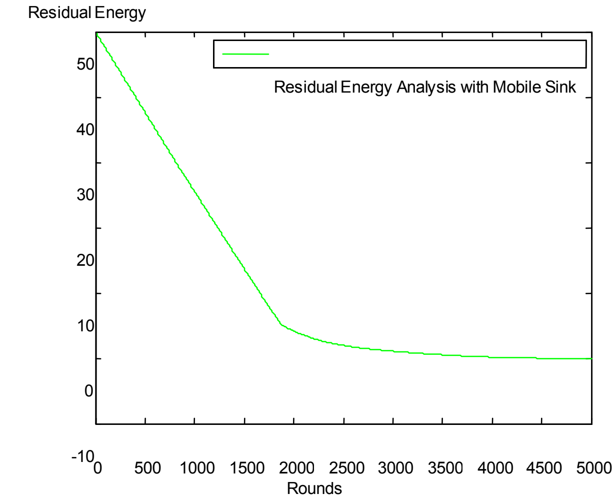

Figure 2: Residual energy versus rounds analysis

Next, we computed the normalized average energy per round as depicted by figure 3. It is observed that normalized average energy analysis shows non-linear behavior. Initially, it remains zero and then shows steeper behavior with respect to the individual node observations. In the proposed system, four chins are used and the position of the mobile sink node is placed at the center in the beginning. We extended the work reported in reference [15].

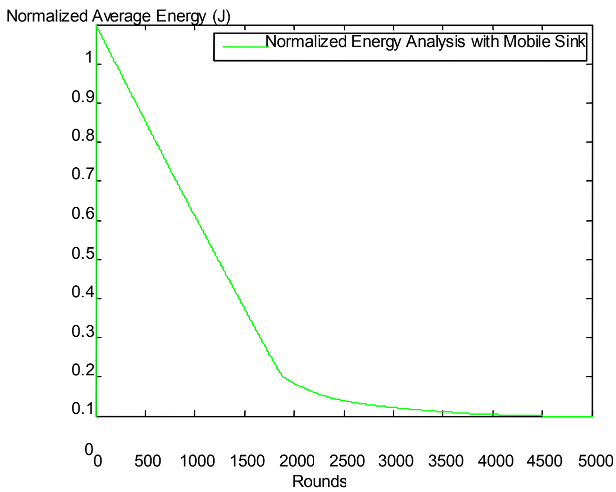

Figure 3: Normalized average energy versus rounds analysis

Further, we computed a number of alive nodes per round as shown in figure 4. It has been noticed that alive nodes remains maximum at the beginning and minimum at the end of all the rounds. The scenario shows steady behavior up to 1400 round afterward it decreases. Further, it remains steady for 1800 rounds. Lastly, it decreases at the end of rounds.

Lastly, Figure 5 depicts the dead nodes with rounds.

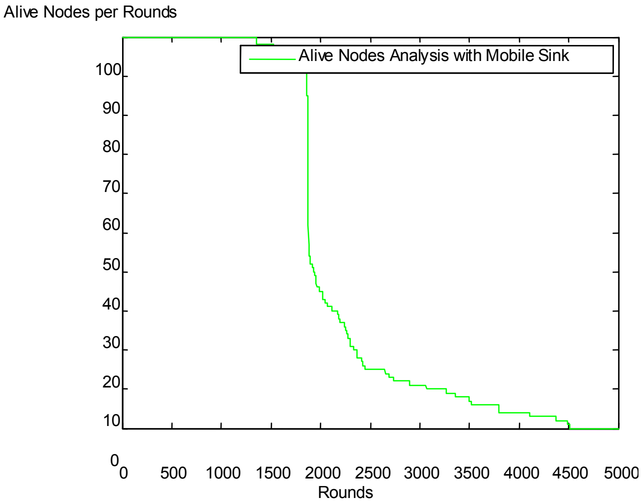

Figure 4: Alive node versus rounds analysis

The number of dead nodes shows reciprocal behavior as compared to the working nodes.

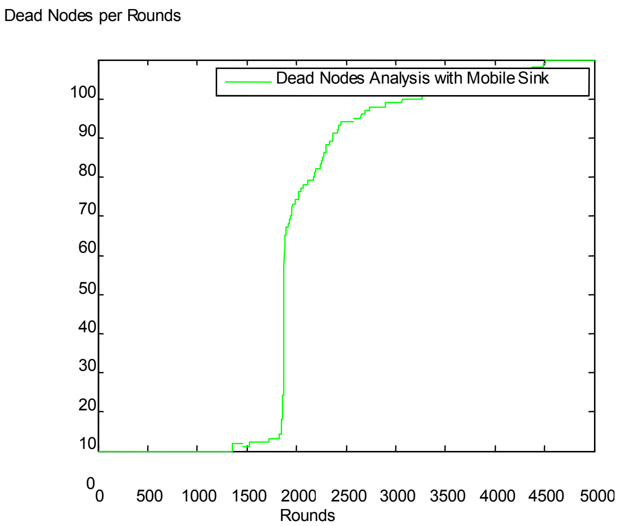

Figure 5: Dead node versus rounds analysis

The dead nodes remain minimum at the beginning of the rounds and increases with the increase in the number of the round in the proposed model. We observed that there is a strong relation among the dead nodes and the alive nodes in the PEGASIS protocol. Our proposed improvement is better as compared to the conventional PEGASIS evaluation as we incorporated the concept of chaining to find the energy and round based investigation of this protocol. This works on the consistent pattern of the results reported in references [17-18].

5.2. LEACH Investigational Analysis.

We design and implemented LEACH and iLEACH protocol for a comprehensive investigation. A comparative analysis of LEACH and iLEACH is depicted in figure 6. It is observed from figure 6 that the number of alive node remains constant in LEACH and iLEACH upto 1100 rounds. Afterwards,we found that the alive nodes remains more in iLEACH protocol. iLEACH protocol performs better than the LEACH protocols. This is due to the fact that we suggested an improvement in conventional LEACH protocol. This improvement varies the amount of power use in the reception cycle of node in the projected approach.

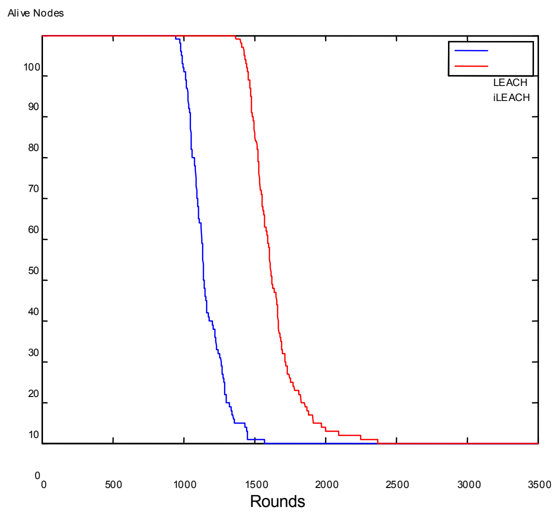

Figure 6: LEACH and iLEACH Evaluations

5.3. SEP Investigational Analysis.

Next, we implemented SEP and iSEP protocol for the evaluation of our proposed model. We observed that iSEP protocol remains more stable than the SEP protocol as shown in figure 7. The number of alive

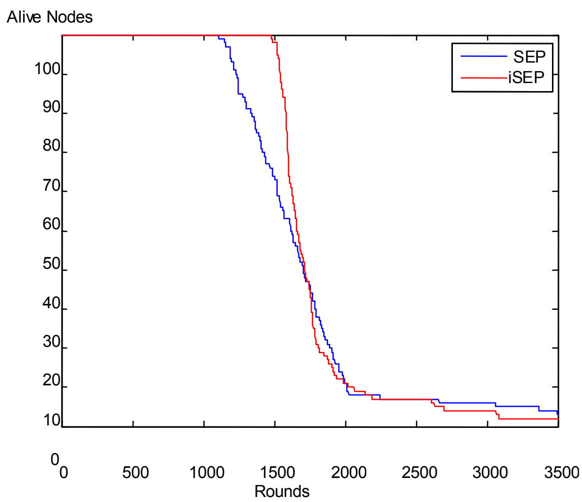

Figure 7: SEP and iSEP Evaluations

nodes in SEP protocol remains stable upto 1150 rounds and afterwards, it decreases up to 5000 rounds. Initially, all 100 nodes were alive and at the last only 4 nodes were alive. It is observed that iSEP performs better than the conventional SEP due to the improvements suggested in our proposed model.

This seems a good agreement with the result shown in references [18-20].

5.4. TEEN Protocol Investigational Analysis

Further, we investigated TEEN and iTEEN protocols for alive nodes as shown in figure 8. It is analyzed that alive nodes remains stable in iTEEN protocol upto 1700 rounds and afterwards it decreases. up to last round. The stability of alive nodes in SEP protocols remain on the consistent pattern of the iSEP protocol. We observed that SEP protocol in more stable in terms of alive nodes than the previous protocols.

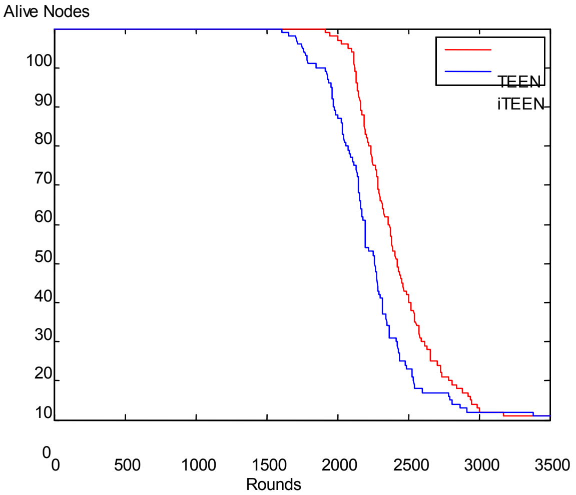

Figure 8: TEEN and iTEEN Evaluations

5.5. DEEC Analysis

Next, we implemented DEEC and iDEEC protocol for their comparative evolutions as shown in figure 9.

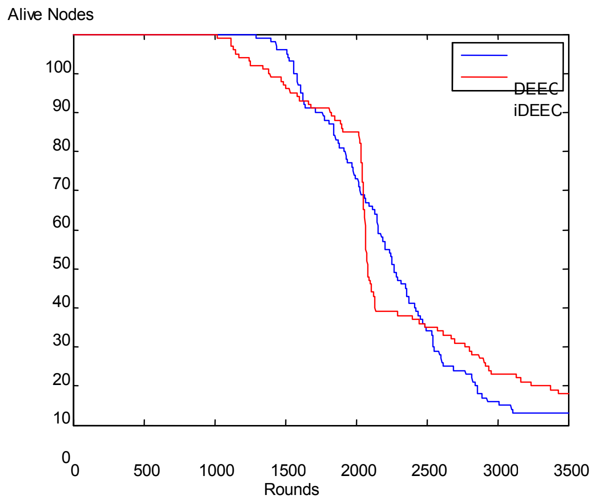

Figure 9: DEEC and iDEEC Evaluations

The DEEC protocol remains stable up to 1000 rounds and afterwards it declines up to last round. The iDEEC protocol is showing consistent behavior with the DEEC protocol. It is observed that at the last round iDEEC protocol performs better than the DEEC protocol. This is due to the improvement suggested in the proposed model for iDEEC protocol. We evaluated LEACH, SEP, TEEN and DEEC protocols over alive nodes investigations. It is observed that TEEN protocol is performing better than all the other protocols in terms of alive nodes stability. Also, our improvements suggested in our proposed model for all of these protocols added more stability to these protocols with reference to results in [21-25].

6 Conclusion

An inclusive investigational analysis have been made for PEGASIS, SEP, TEEN, DEEC and LEACH protocols over performance parameters namely, alive nodes, dead nodes and packets to base station (BS). We focused on the percentage of nodes serving as advanced nodes (m) and advanced nodes (a) with higher energy than the normal node in our investigations. We observed that iSEP protocol remains more stable than the SEP protocol. It is observed that iSEP performs better than the conventional SEP due to the improvements suggested in our proposed model. The stability of alive nodes in SEP protocols remains on the consistent pattern of the iSEP protocol. We investigated TEEN and iTEEN protocols for alive nodes. We observed that SEP protocol in more stable in terms of alive nodes than the previous protocols. We implemented DEEC and iDEEC protocol for their comparative evolutions. It is observed that at the last round iDEEC protocol performs better than the DEEC protocol. This is due to the improvement suggested in the proposed model for iDEEC protocol. We evaluated LEACH, SEP, TEEN and DEEC protocols over alive nodes investigations. It is observed that TEEN protocol is performing better than all the other protocols in terms of alive nodes stability. Also, the proposed improvements suggested in the deployed model added more stability to these protocols.

References:

[1] Mahmoud Mezghani. Intelligent Energy-Efficient Load Balanced Khalimsky-Based Routing Scheme for K-Hop Clustered WSNs, 2019 IEEE 19th International Conference on Sciences and Techniques of Automatic Control and Computer Engineering (STA), Year: 2019, Pages: 670 – 675.

[2] Zijing Wang ; Xiaoqi Qin ; Baoling Liu. An energy efficient clustering routing algorithm for WSN-assisted IoT. 2018 IEEE Wireless Communications and

Networking Conference (WCNC)Year: 2018, Pages: 1 - 6
[3] Tawfik Al-Hadhrami ; Faisal Saeed. NEARMesh: Network environment aware routing in a Wireless Mesh Network for emergency-response , IEEE 2017 International Conference on Research and Innovation in Information Systems (ICRIIS), Year: 2017, Pages: 1 – 6.
[4] Francisco Falcone. Exploring IoT Industry Applications: Limitations of Wireless Technology on Healthcare IoT, Year: 2017, IEEE Conference.
[5] Moataz F. Youssef ; Khaled M. F. Elsayed ; Ahmed H. Zahran. Contiki-AMAC — The enhanced adaptive radio duty cycling protocol: Proposal and analysis. IEEE 2016 International Conference on Selected Topics in Mobile & Wireless Networking (MoWNeT), Year: 2016, Pages: 1 – 6.
[6] Leandro N. Balico ; Horacio A.B.F. Oliveira ; Eduardo F. Nakamura ; Raimundo S. Barreto ; Antonio A.F. Loureiro. Routing and Data Aggregation toward a High Speed Sink in WirelessSensor Networks, IEEE 2015 International Conference on Distributed Computing in Sensor Systems. Year: 2015. Pages: 260 - 265.
[7] Yu Stephanie Sun ; Lei Xie ; Qi Alfred Chen ; Sanglu Lu ; Daoxu Chen Efficient route guidance in vehicular wireless networks 2014 IEEE Wireless Communications and Networking Conference (WCNC) Year: 2014, Pages: 2694 – 2699.
[8] Theofanis G. Orphanoudakis ; Chris Matrakidis ; Alexandros Stavdas. Next generation optical network architecture featuring distributedaggregation, network processing and information routing, IEEE 2014 European Conference on Networks and Communications (EuCNC), Year: 2014, Pages: 1 – 5.
[9] Jinho Kim ; Jun Lee ; Hyoeng Kyu Kang ; Dae Sun Lim ; Choong Seon Hong ;Sungwon Lee, An ID/Locator Separation-Based Mobility Management Architecture for WSNs. IEEE Transactions on Mobile Computing, Year: 2014 Volume: 13 , Issue: 10, Pages: 2240 – 2254.
[10] George Mastorakis ; Constandinos X. Mavromoustakis ; Athina Bourdena ;Evangelos Pallis. An energy-efficient routing scheme using Backward Traffic Difference estimation in cognitive radio networks. 2013 IEEE 14th International Symposium on "A World of Wireless, Mobile and Multimedia Networks" (WoWMoM), Year: 2013, Pages: 1 – 6.
[11] Nourhene Maalel ; Enrico Natalizio ; Abdelmadjid Bouabdallah ; Pierre Roux ;Mounir Kellil. Reliability for Emergency Applications in Internet of Things, 2013 IEEE International Conference on Distributed Computing in Sensor Systems, Year: 2013, Pages: 361 – 366.
[12] Fengyuan Ren ; Jiao Zhang ; Yongwei Wu ; Tao He ; Canfeng Chen ; Chuang Lin. Attribute-Aware Data Aggregation Using Potential- Based Dynamic Routing in Wireless Sensor Networks, IEEE Transactions on Parallel Distributed Systems. Year: 2013 Volume: 24 , Issue: 5, Pages: 881 - 892.
[13] Rafael Falcon ; Hai Liu ; Amiya Nayak ; Ivan Stojmenovic. Controlled Straight Mobility and Energy-Aware Routing in Robotic Wireless Sensor Networks. 2012 IEEE 8th International Conference on Distributed Computing in Sensor Systems. Year: 2012, Pages: 150 – 157.
[14] Jianzhong Li ; Lei Yu ; Hong Gao ; Shuguang Xiong. Grouping-Enhanced Resilient Probabilistic En-Route Filtering of Injected False Data in WSNs, IEEE Transactions on Parallel and Distributed Systems. Year: 2012 Volume: 23 , Issue: 5, Pages: 881 - 889.
[15] Miao Zhao ; Yuanyuan Yang, Bounded Relay Hop Mobile Data Gathering in Wireless Sensor Networks, IEEE Transactions on Computers, Year: 2012 Volume: 61 , Issue: 2, Pages: 265 – 277.
[16] Hua Huang, Shan Lin (2018) WiDet: Wi-Fi Based Device-Free Passive Person Detection with Deep Convolutional Neural Networks - 2018, MSWiM 2018.
[17] Vinod Kumar Verma. Performance Assessment of AODV Routing Protocol over Temperature Constraints in Wireless Sensor Network. Published in proceeding of 11th WSEAS International Conference on Electronics, Hardware, Wireless and Optical Communication (EHAC '12), Recent Researches in Communications, Electronics, Signal Processing and Automatic Control, pp. 74-77, ISBN: 978-1-61804-069-5, Cambridge, United Kingdom (UK), February 22- 24, 2012.
[18] Vinod Kumar Verma, Surinder Singh, N. P. Pathak, Terrain Investigations of AODV Routing Protocol over Temporal Constraints in Wireless Sensor Network. Published in

proceeding of 1[1th] WSEAS International Conference on Electronics, Hardware, Wireless and Optical Communication (EHAC '12), Recent Researches in Communications, Electronics, Signal Processing and Automatic Control, Isbn: 978-1-61804-069-5, Cambridge, United Kingdom (UK), February 22- 24, 2012.

[19] Vinod Kumar Verma, Surinder Singh, and N.P. Pathak. Analytical Event Based Investigations Over Delphi Random Generator Distributions for Data Dissemination Routing Protocols in Highly Dense Wireless Sensor Networks. Published in Wireless Personal Communications: An International Journal © Springer Science + Business Media New York 2015.

[20] Vinod Kumar Verma, Surinder Singh and N.P. Pathak. Optimized Battery Models Estimation for Static, Distance Vector and On-Demand Based Routing Protocols over 802.11 Enabled Wireless Sensor Networks, Published in Wireless Personal Communications: An International Journal, © Springer Science + Business Media New York 2014.

[21] Vinod Kumar Verma, Surinder Singh, and N.P. Pathak. Comprehensive Event Based Estimation of Sensor Node Distribution Strategies using Classical Flooding Routing Protocol in Wireless Sensor Networks. Published in Wireless Networks: The Journal of Mobile Communication, Computation and Information. Volume 20, pp.2349-2357. © Springer Science + Business Media New York 2014.

[22] Vinod Kumar Verma. Simulative Exploration of Power Trust and Reputation Model over Power Node Augmentation Factor in Distributed Peer to Peer Networks. Published in WSEAS 18th International Conference on Automatic Control, Modelling & Simulation (ACMOS '16), VENICE, ITALY. Jan. 29- 31, 2016.

[23] Vinod Kumar Verma. Pheromone and Path Length Factor Based Trustworthiness Estimations in Heterogeneous Wireless Sensor Networks, Published in IEEE Sensors Journal, Year: 2017, Volume: 17, Issue: 1, Pages: 215 - 220, DOI: 10.1109/JSEN .2016. 2627041, ISSN: 1530-437X.

[24] Vinod Kumar Verma, Surinder Singh, and N.P. Pathak. Towards comparative evaluation of trust and reputation models over static, dynamic and oscillating wireless sensor networks. Published in Wireless Networks: The Journal of Mobile Communication, Computation and Information. February 2017, Volume 23, Issue 2, pp 335–343. © Springer Science +Business Media New York 2017. ISSN: 1022-0038 (Print) 1572-8196 (Online).

[25] Vinod Kumar Verma. Klimis Ntalians, S. Singh, N.P. Pathak. Data Proliferation Based Estimations over Distribution Factor in Heterogeneous Wireless Sensor Networks. ELSEVIER Computer Communications - The International Journal for the Computer and Telecommunications Industry, 124 (2018) 111–118. ISSN: 0140-3664. June 2018, Elsevıer Scıence Netherlands