An Ephemeral Analysis on Network Lifetime Improvement Techniques for Wireless Sensor Networks

Rekha V S, Siddaraju

Abstract: *Wireless Sensor Network is used in an extensive assortment of applications like enemy vehicle motion detection, surveillance of the environment. For the network to be operational and for longer maintenance of WSN low-cost sensor nodes are the need of the hour. There are many constraints in the WSN network like deployment constraints, energy constraints and hardware constraints which must be handled in a careful manner in order to improve network lifetime. To improve the network lifetime there are techniques which come under beam forming, connectivity factor, coverage and harvesting factors. In this paper, the survey is done on the innumerable delineations of network lifetime and the methods which can help in improving the network lifetime. Battery Level management during the routing process as well as approaches to identify and reduce the number of dead nodes will also improve lifetime.*

Index Terms: ***Wireless Sensor Network, Energy Dissipation, Residual energy.***

I. INTRODUCTION

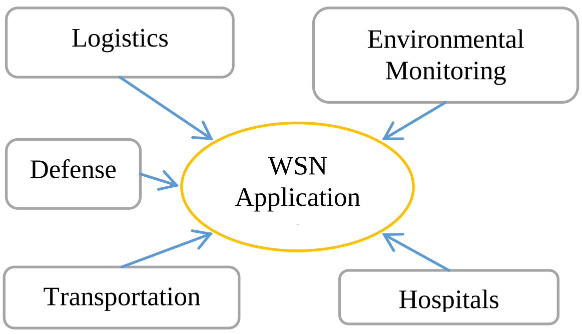

Figure1: Span of WSN Applications

Figure1 shows the span of wireless sensor networks. As shown in the fig the WSN are used in various applications like logistics, environmental monitoring, defense applications, transportation and hospitals as described in the literature [1] –[4]. Networks can be said as the formation of nodes into a single layer or spread it across multiple layers. When nodes are in single layer algorithms such as AODV, DSDV, DSR are the best suited for route discovery.

When the nodes are spread across multiple layers then algorithms like LEACH and SEP are used to ensure the data delivery. Figure2 shows the placement of the nodes in the single area and figure3 shows the nodes placement across multiple layers.

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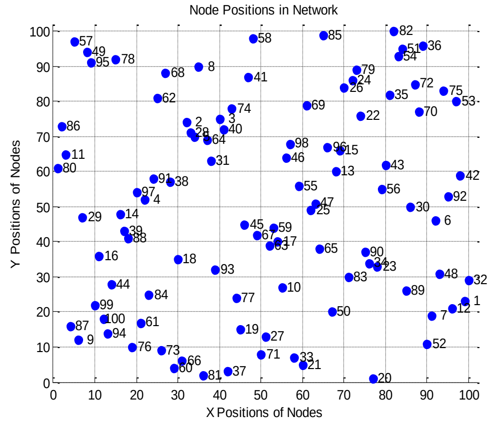

Figure2: Nodes Spread in Single Layer

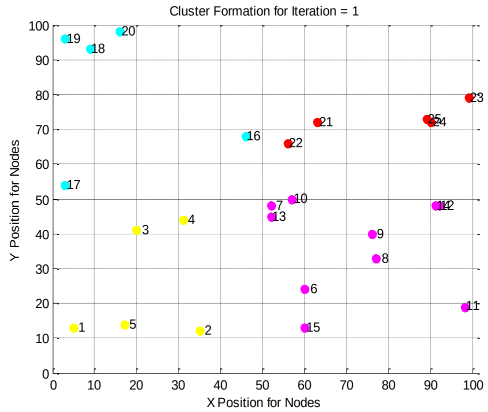

Figure3: Multi-Layer Spreading of Nodes

Consider the WSN network in which the nodes are spread in the area of 100 X 100 limits. Each of the 100 nodes is spread in the area of 100 X 100. The node is represented by unique Id and cannot be the same for two nodes in the network. The node 9 is located at (9,11) position and in a similar fashion Node 82 is present at (85,100). Like this, all the 100 nodes are present in the same layer but at different positions. The topology is present in figure2. Similarly consider the WSN network in which the nodes are spread across multiple layers. As shown in figure3 the nodes are spread in four different layers. Each of the layers is equal in size. Layer 1 has the following endpoints

$$x_{start} = 1, x_{end} = 50, y_{start} = 1, y_{end} = 50$$

Layer2 has the following endpoints

$$x_{start} = 51, x_{end} = 100, y_{start} = 1, y_{end} = 50$$

Layer 3 has the following endpoints

$x_{start} = 1, x_{end} = 50, y_{start} = 51, y_{end} = 100$

Layer 4 has the following endpoints

$x_{start} = 51, x_{end} = 100, y_{start} = 51, y_{end} = 100$

Layer1 has the nodes {Node1 till Node5}, Layer 2 has the nodes {Node6 till Node 15}, Layer 3 has the nodes {Node16 to Node20} and finally Layer 4 has the nodes {Node21 to Node25}.

The remainder of the artifact is organized as streams. Section II deliberates the process of updating the battery levels for the nodes. Section III describes few applications of WSN. Section IV describes the definition of Network Lifetime and then improvement techniques for Network Lifetime.

II. BATTERY UPDATE PROCESS

When a node participates in routing then the energy of the node comes down. Initially, all the nodes will have the same energy level during network formation. The updated energy level of the node can be computed using equation1;

$$U_{Energy} = C_{Energy} - E_{consumed} \qquad (1)$$

Where,

C_{energy} = current energy

$E_{consumed}$ = energy consumption

The energy consumed depends upon the transmission energy, amplification energy, distance between two nodes and attenuation factor

$$E_{consumed} = 2 \text{ X } E_{tx} + E_{amp}\ d^{\chi} \qquad (2)$$

Where,

E_{tx} = transmission energy

E_{amp} = amplification energy

d = distrance between nodes

χ = attunuation factor

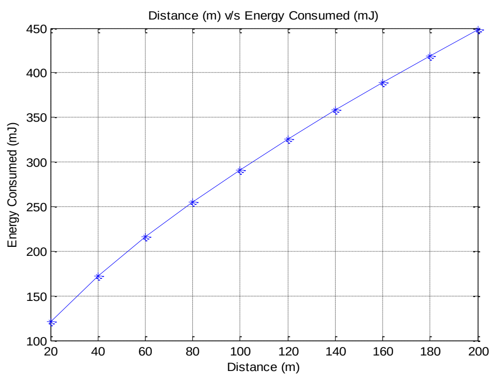

Figure4: Distance Energy Dependence

As shown in equation 2 there is a dependency between the energy consumption and distance both are directly proportional. The distance is varied in terms of 20m increment and energy dissipation is shown in figure4. The above figure is obtained by making use of values in table1;

Parameter Name	Parameter Value
Energy Transmitted	20 mJ
Energy Generation	10 mJ
Attenuation factor	0.7

Table1: Energy Consumption Inputs

The nodes can be classified after the energy dissipation into dead nodes or alive nodes using the scaling factor and the region of convergence for energy levels is described in figure5.

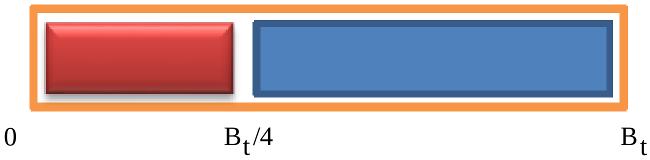

Figure5: Battery Level Scale

When the battery level of the node is less than 4 times the initial energy $B_t/4$ then node will behave like a dead node. The initial energy of the mote for the WSN network is B_t. The lifetime ratio is defined using the following equation 3;

$$LR = \frac{\text{Nodes Battery} >= \frac{B_t}{4}}{\text{Nodes Battery} < \frac{B_t}{4}} \qquad (3)$$

III. APPLICATIONS OF WSN

WSN are used in a extensive variety of applications and are also very much helpful for humanity. They have been used to perform the detection for the amount of exposure to dust and ultra-violet rays for garment workers [5] and then report to the control center. Electromyogram (EMG) sensor can detect the muscle strain and then send it over the network, Wireless Body Area Network (WBAN) are used in such cases and the data can be sent to the expert doctor who is remotely located.

The WSN is used to detect the precision agriculture and then used for transmission of information over narrowband channels. It has an electromagnetic façade end which is used for maintenance of radiation efficiency [6] which has random dissipative characteristics. G. Pradeebaa, Nandita Lavanis describes two algorithms which use relay nodes [7] are arranged in the format of 1-D and responsible for sending packets towards the destination. In order to improve network lifetime rather than using all nodes, one can use a subset of nodes. This helps in energy reduction and improves network lifetime and also the nodes are switched between sleep and non-sleep mode.

IV. NETWORK LIFETIME AND GLOSSARY OF IMPROVEMENT TECHNIQUES

Network Lifetime (NL) has been defined in different ways by various authors. Dietrich and F. Dressler [8] define the NL as an entity to maintain specific objective function or entity to maintain full functionality of the application for which WSN is used. WSN is defined as a set containing nodes and each node has a battery limitation. The energy consumption happens rapidly depending upon whether the nodes participate in the various activities. The time at which the battery of a certain number of nodes gets depleted drastically is defined as NL [9]-[10]. The time at which first node residual energy falls below the threshold is also defined as NL [11]-[13]. Network lifetime can be prolonged via nodal energy balancing which improves message delivery rate [36]. The summary of exact definitions for Network Lifetime is given in table2. There are many techniques through which the NL can be optimized and a glossary is provided in figure6.

A. Energy Harvesting

The energy for the nodes is generated by making use of kinetics, solar power and thermal technology to improve NL. The energy efficiency will improve if energy storage and energy harvesting are taken into consideration for routing decisions as presented by G. Martinez, S. Li [20]. The QoS can be improved by using energy reaping techniques from ambient bases and reduces the battery failures affecting QoS. Pradip Kumar Sharma [21] proposes energy harvesting based smart Homes and will help to transmit data in an

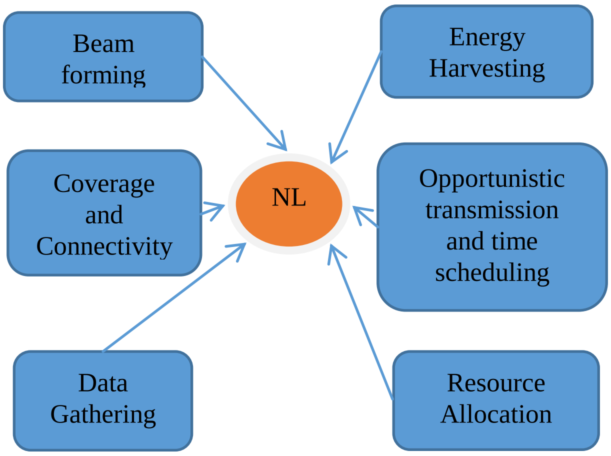

Figure6: Glossary for NL Improvement

efficient manner. Florian Strakosch [22] describe that EH can be used to power WSN when energy source has drained out completely. The frequency of energy source replacements will be reduced using Energy Harvesting. There are various policies presented by Y. He, X. Cheng, W.[23] have provided methods for the optimal offline process with energy harvesting Samuel Perez [24] have worked on use cases in which renewable energy generators are used to reduce EC and also to achieve high NL. Based on EH patterns the communication rate is adaptively adjusted. The NL can be improved based on a reduction in energy consumption and also power outages can be avoided. Greg Jackson, Simona Ciocoiu, Julie A. McCann [25] have provided duty cycle optimizations, power transmission and reduction in data rates with the help of energy generation using solar devices.

B. Resource Allocation

Resource Allocation is needed to satisfy various entities like node placement, throughput maximization, route discovery, control/data packets scheduling, reliability and rate adaptation. R. Madan, S. Cui, S. Lall [26] describes that multiple constraints like power allocation, energy depletion and link that few nodes can be made active or inactive to achieve energy efficient routes to maximize NL in a dynamic topology. Takanobu Otsuka are used for monitoring of weather conditions. The nodes will perform the detection of water quality in rivers. For such detections, the sensor needs more energy consumption. The energy depletion can be condensed by performing switching between active to idle modes at regular levels.

C. Beam Forming

Beamforming is done with the help of sensor antennas. It is used to direct the main radiation towards the valid user and side lobes towards unwanted users. Beamforming helps in increasing the transmission distance by directing selective beams towards the right receiver.

Zhe Wang, Lingjie Duan [27] can be used for transmission for a faraway base station by making use of energy efficient collaborative scheme satisfying QoS requirement along with NL maximization and has proposed an optimal solution to increase Life Time of WSN. By making use of beamforming reduction of ED is achieved with the improvement of NL. Zhe Wang, Lingjie Duan, Rui Zhang [27] proposes adaptive directional wireless power transfer (AD-WPT) method using power beacons (PBS) to perform energy beamforming and power can be supplied using electromagnetic waves to improve NL. Rong Du, Ayça Özçelikkale [28] propose energy beam forming scheme whose performance is better than other beam forming schemes even for optimized routing and maximization of minimum sampling rate is done with low energy consumption of node. The data cannot be relayed by sensors when they have critical battery levels and collaborative beamforming is used to group closely situated sensor motes to ease the stream of traffic capacity.

D. Data Gathering

The sensing data is variable in nature and reconstruction of such a data must be accurate. Adaptive Compressive Data Gathering Scheme which adjusts the prediction value based on changes in the trending data from sensors. The reconstruction accuracy is achieved through Proportional Integrative Derivative (PID) and Stagewise Orthogonal Matching Pursuit (StOMP).

Om Jee Pandey [29] provide an objective function with the aim of reducing localization error and increasing bandwidth for Mobile ubiquitous LAN extensions (MULEs). Kavita R. Kakde, Mahesh Kadam [30] describe that small memory, limited energy, and computation complexity are the major constraints on WSN and they propose tree-cluster data gathering method which makes use of tree and zone-based protocols to decrease EC and prolong NL.

When WSN is used for weather monitoring it has features of low-rank, temporal firmness, and relative rank firmness. The weather data has both spatial and temporal variations. The authors Kun Xie, Lele Wang [31] provide MC-Weather technique in which WSN collects data from different locations and make use of cross sample model, matrix completion and uniform time slot which reduces the cost of sensing, computation, and communication. When the amount of data load is more NL reduces. The battery power can be increased to reach difficult terrains and improve NL.

Saurav Ghosh, Sanjoy Mondale [32] proposes a method in which a cluster of dominating the set of nodes is created and chains are generated with the help of ant colony optimization (ACO). The CH is selected based on combination function with residual energy and distance as the parameters. This helps the end user to improve NL.

E. Coverage and Connectivity

When WSN is used for agriculture applications then each sensor is assigned a different job and reliable coverage is critical for such applications. X. Deng, B. Wang [33] describe an algorithm for achieving NL maximization by proving reliable coverage in the convex region.

Saad Talib Hasson [34] provides a technique for classification of terrain with the help of transmitted data and by taking a minimum number of nodes for the transmission process. The nodes are deployed using a topology which can provide great coverage, decent connectivity and reliability thereby improving NL. This technique is helpful for military and civilian applications which make use of WSN IOT.

Z. Lu, W. W. Li, and M. Pan [35] proposed that subsets of nodes can be used to maximize NL and can help in monitoring the target data with the help of sleep mode schedulers.

Q. Zhao and M. Gurusamy [16] performs the scheduler approach makes use of active sensor mote to provide permanent coverage of a specific intention region for the entire duration and the detection data must be sent to destination mote with the help of multi-hop message. The NL can be maximized if the coverage of the aim area and a subset of sensors which are coming in between within the subsets.

F. Opportunistic Transmission and Time Scheduling

The attenuation of time, position and frequency of the signal is called Fading. The controlling station gathers the information from the motes deployed in the area. The sensed information is captured by intermediate motes that fall under the path to the destination. The nodes that are responsible for relaying are under sleep state at few instances. The sleep scheduling and joint routing can improve the NL by 29% compared to fix sleep schedule. The reduction in energy consumption can handle a huge amount of traffic load as describe that by adjusting power with respect to Channel State Information and residual energy of WSN nodes one can increase the NL. It provide a method which monitors channel quality in a continuous fashion and then the transmission is allowed when quality exceeds the threshold value. When the packets arrival time/rate is not regular then few nodes can be made to awake and few of them can be made to sleep using scheduler which improves NL. As cited in the various techniques for NL improvement most of the papers speak about Sleep Scheduling, energy harvesting either through a solar source or through EM waves. Collaborative beamforming technique, obtaining proper connectivity in difficult terrains helps in improving lifetime.

Our future work suggests a method in which the existing routing approaches can be modified to execute a genetic process at regular intervals to identify few dead nodes in the network to maintain a balance between NL and RF Cost. Once the dead nodes are recognized then energy harvesting is used to recover few of the dead nodes. The selection of the cluster head is done with the help of residual energy, packet load, and distance to base station and the cluster heads are rotated by performing the sleep schedule to improve NL. Achyutha Prasad N, C D Guruprakash [38] the effect of MGTEB-FR accomplishes better as compared to several propagation channel models with respect to network lifetime.

Authors	Network Lifetime Definition
J. Chen, J. Li, and T. Lai, M. Najimi, A. Ebrahimzadeh, S. Andreoli, and A. Fallahi	The time beyond which only certain nodes are operational [9]-[10]
D. Tian and N. D. Georganas	The time duration beyond which there is no event detection ratio [14]
B. C˘arbunar, A. Grama, J. Vitek, and O. C˘arbunar	The time at which packet delivery ratio is less than a threshold [15]
Q. Zhao and M. Gurusamy	The time at which WSN loses its coverage [16]
S. Soro and W. Heinzelman	The time duration for the cluster head to lose its energy completely [17]
M. Bhardwaj and A. P. Chandrakasan	The time duration beyond which an area is not concealed by even a single mote [18]
E. B. Hamida and G. Chelius	Time beyond which last data packet cannot be delivered to sink or time beyond which the data collection will fail [19]
Achyutha Prasad N and C D Guruprakash	The interval at which first dead sensor mote occurs in the network [37].

Table2: Network Lifetime Definitions in Literature

CONCLUSION

The network lifetime maximization taxonomy has provided a lot of research attention to make WSN work in a seamless fashion with battery constraints. The paper commences by proving the applications of WSN, broad overview on kinds of topologies in which the WSN nodes can work, battery updating process, the definition of NL and NL maximization methods with each method having its own objective function. The different network lifetime techniques can be taken up in optimizing WSN network depending on QoS requirements and energy constraints.

REFERENCES

1. Akyildiz, W. Su, Y. Sankarasubramaniam, and E.Cayirci, “A Survey on Sensor Networks”, IEEE Commu. Mag., vol.40, no. 8, pp. 102-104, August 2002
2. D. Puccinelli and M. Haenggi, “Wireless sensor networks: Applications and challenges of ubiquitous sensing,” IEEE Circuits and Systems Magazine, vol. 5, no. 3, pp. 19–31, September 2005.
3. V. Potdar, A. Sharif, and E. Chang, "Wireless sensor networks: A survey," in Advanced Information Networking and Applications Workshops, International Conference on 2009, pp. 636-641.
4. Jan Bauer, Nils Aschenbruck, "Design and implementation of an agricultural monitoring system for smart farming", 2018 IoT Vertical and Topical Summit on Agriculture - Tuscany (IOT Tuscany),8-9 May 2018.
5. Elisa Giovanelli; Alina Plesca; Riccardo Stefanelli; Daniele Trinchero,'Dynamic wireless sensor networks for the real-time safeguard of workers exposed to physical agents in constructions sites',2013 IEEE Topical Conference on Wireless Sensors and Sensor Networks (WiSNet),20-23 Jan. 2013.
6. Abel Rodriguez de la Concepcion; Riccardo Stefanelli; Daniele Trinchero, 'Adaptive wireless sensor networks for high-definition monitoring in sustainable agriculture', 2014 IEEE Topical Conference on Wireless Sensors and Sensor Networks (WiSNet), Year: 2014, Page s: 67 – 69.
7. G. Pradeebaa; Nandita Lavanis, "Network lifetime

improvement using routing algorithm with sleep mode in wireless sensor network", 2016 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET), 23-25 March 2016.
8. Dietrich and F. Dressler, "On the lifetime of wireless sensor networks," ACM Transactions on Sensor Networks, vol. 5, no. 1, pp. 1–39, February 2009.
9. J. Chen, J. Li, and T. Lai, "Trapping mobile targets in wireless sensor networks: An energy-efficient perspective," IEEE Transactions on Vehicular Technology, vol. 62, no. 7, pp. 3287–3300, September 2013.
10. M. Najimi, A. Ebrahimzadeh, S. Andargoli, and A. Fallahi, "Lifetime maximization in cognitive sensor networks based on the node selection," IEEE Sensors Journal, vol. 14, no. 7, pp. 2376–2383, July 2014.
11. Y. Chen and Q. Zhao, "On the lifetime of wireless sensor networks," IEEE Communications Letters, vol. 9, no. 11, pp. 976–978, November 2005.
12. J. W. Jung and M. Weitnauer, "On using cooperative routing for lifetime optimization of multi-hop wireless sensor networks: Analysis and guidelines," IEEE Transactions on Communications, vol. 61, no. 8, pp. 3413–3423, August 2013.
13. C. Cassandras, T. Wang, and S. Pourazarm, "Optimal routing and energy allocation for lifetime maximization of wireless sensor networks with nonideal batteries," IEEE Transactions on Control of Network Systems, vol. 1, no. 1, pp. 86–98, March 2014.
14. D. Tian and N. D. Georganas, "A coverage-preserving node scheduling scheme for large wireless sensor networks," in Proceedings of the 1st ACM international workshop on Wireless sensor networks and applications (WSNA), Atlanta, GA, USA, September 2002, pp. 32–41.
15. B. C˘arbunar, A. Grama, J. Vitek, and O. C˘arbunar, "Redundancy and coverage detection in sensor networks," ACM Transactions on Sensor Networks (TOSN), vol. 2, no. 1, pp. 94–128, February 2006.
16. Q. Zhao and M. Gurusamy, "Lifetime maximization for connected target coverage in wireless sensor networks," IEEE/ACM Transactions on Networking, vol. 16, no. 6, pp. 1378–1391, December 2008.
17. S. Soro and W. Heinzelman, "Prolonging the lifetime of wireless sensor networks via unequal clustering," in IEEE International Parallel and Distributed Processing Symposium, Denver, CO, April 2005.
18. M. Bhardwaj and A. P. Chandrakasan, "Bounding the lifetime of sensor networks via optimal role assignments," in IEEE International Conference on Computer Communications (INFOCOM'02), vol. 3, NY, USA, June 2002, pp. 1587–1596.
19. E. B. Hamida and G. Chelius, "Strategies for data dissemination to mobile sinks in wireless sensor networks," IEEE Wireless Communications, vol. 15, no. 6, pp. 31–37, December 2008.
20. G. Martinez, S. Li, and C. Zhou, "Multi-commodity online maximum lifetime utility routing for energy-harvesting wireless sensor networks," in IEEE Global Communications Conference (GLOBECOM'14), Austin, TX, December 2014, pp. 106–111.
21. Pradip Kumar Sharma, Young-Sik Jeong, Jong Hyuk Park, "EH-HL: Effective Communication Model by Integrated EH-WSN and Hybrid LiFi/WiFi for IoT", IEEE Internet of Things Journal, Volume: 5, Issue: 3, June 2018.
22. Eric Schneider, Faouzi Derbel, Florian Strakosch, "Energy harvesting and management of continuously powered WSNs", 14th International Multi-Conference on Systems, Signals & Devices (SSD), 28-31 March 2017.
23. Y. He, X. Cheng, W. Peng, and G. L. Stuber, "A survey of energy harvesting communications: Models and offline optimal policies," IEEE Communications Magazine, vol. 53, no. 6, pp. 79–85, June 2015.
24. Samuel Perez, Juan Antonio Cordero Fuertes, Marceau Coupechoux, "ODMAC++: An IoT communication manager based on energy harvesting prediction", IEEE 28th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC) 8-13 Oct. 2017.
25. Greg Jackson, Simona Ciocoiu, Julie A. McCann, "Solar Energy Harvesting Optimization for Wireless Sensor Networks", GLOBECOM 2017 - 2017 IEEE Global Communications Conference, 4-8 Dec 2017.
26. R. Madan, S. Cui, S. Lall, and A. Goldsmith, "Modeling and optimization of transmission schemes in energy-constrained wireless sensor networks," IEEE/ACM Transactions on Networking, vol. 15, no. 6, pp.1359–1372, December 2007.
27. Zhe Wang, Lingjie Duan, Rui Zhang, "Adaptively Directional Wireless Power Transfer for Large Sensor Networks", IEEE Global Communications Conference (GLOBECOM), Year: 2015, Pages: 1 – 6.
28. Rong Du, Ayça Özçelikkale, Carlo Fischione, Ming Xiao, "Towards Immortal Wireless Sensor Networks by Optimal Energy Beamforming and Data Routing", IEEE Transactions on Wireless Communications, Year: 2018, (Early Access), Pages: 1 – 1.
29. Om Jee Pandey, Akshay Mahajan, Rajesh Mahanand Hegde, "Joint Localization and Data Gathering Over a Small-World WSN With Optimal Data MULE Allocation", IEEE Transactions on Vehicular Technology, Year: 2018, Volume: 67, Issue: 7, Pages: 6518 – 6532.
30. Kavita R. Kakde; Mahesh Kadam,'Performance analysis of tree cluster-based data gathering for WSNs', 2017 International Conference on Intelligent Computing and Control (I2C2),23-24 June 2017.
31. Kun Xie, Lele Wang, Xin Wang, Gaogang Xie, Jigang Wen, "Low Cost and High Accuracy Data Gathering in WSNs with Matrix Completion", IEEE Transactions on Mobile Computing, Year: 2018, Volume: 17, Issue: 7, Pages: 1595 – 1608.
32. Saurav Ghosh, Sanjoy Mondal, Utpal Biswas, "Efficient data gathering in WSN using fuzzy C means and ant colony optimization", 2016 International Conference on Information Science (ICIS), Year: 2016, Pages: 258 – 265.
33. X. Deng, B. Wang, W. Liu, and L. Yang, "Sensor scheduling for multi-modal confident information coverage in sensor networks," IEEE Transactions on Parallel and Distributed Systems, vol. 26, no. 3, pp.902–913, March 2015.
34. Saad Talib Hasson, Abd Al-Nasir Riyadh Finjan, "A suggested Angles-based sensors deployment algorithm to develop the coverages in WSN", 2nd International Conference on Inventive Systems and Control (ICISC), Year: 2018, Pages: 547 – 552.
35. Z. Lu, W. W. Li, and M. Pan, "Maximum lifetime scheduling for target coverage and data collection in wireless sensor networks," IEEE Transactions on Vehicular Technology, vol. 64, no. 2, pp. 714–727, February 2015.
36. Achyutha Prasad N, C D Guruprakash, "An ephemeral investigation on energy proficiency mechanisms in WSN", 3rd International Conference on Applied and Theoretical Computing and Communication Technology (iCATccT), IEEE ISBN : 978-1-5386-1144-9, pp. 180-185, December 2017.
37. Achyutha Prasad N, C D Guruprakash, "A Relay Node Scheme for Energy Redeemable and Network Lifespan Enhancement", 4th International Conference on Applied and Theoretical Computing and Communication Technology(iCATccT), IEEE ISBN: 978-1-5386-7706-3, pp. 284-292, September 2018.
38. Achyutha Prasad N, C D Guruprakash, "A Relay Node Scheme of Energy Redeemable and Network Lifespan Enhancement for Wireless Sensor Networks and its Analysis with Standard Channel Models", International Journal of Innovative Technology and Exploring Engineering (IJITEE), ISSN: 2278-3075 vol. 8, issue. 5, pp. 605-612, March 2019.

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