Efficient Data Aggregation Methodology to Increase the Performance of Wireless Sensor Network Using Fuzzy Logic

[1]Kamlesh A.Waghmare, [2]Dr. P.N.Chatur
[1]Research Scholar, [2]Professor,
[1]CSE Department,
[1]Government College of Engineering, Amravati, India

Abstract : The multi hop wireless sensor network has the lossy links and energy resource constrained nodes. Energy efficiency is the most important constrained in WSN, in such network due to their constraints in energy consumption, memory and power resources, the performance optimization is a very big issues or challenging task in the wireless sensor networks. In this paper we used fuzzy based data aggregation methodology to select appropriate cluster head and non faulty node. The cluster head transmit the aggregated data from the cluster head to the sink node and removes the redundancy as well as unnecessary data forwarding. These techniques effectively select the cluster head and malicious node based on the system parameter and data aggregation process in the network. By simulation result we, show that our methodology has increase the throughput and packet delivery ratio with redundant packet drop and less energy consumption based on rate.

***IndexTerms* – Wireless Sensor Network (WSN), Aggregation, Cluster Head, Throughput.**

I. INTRODUCTION

This section brings out the motivation for efficient data collection methods in the wireless sensor network to reduce energy consumption. The research objectives and the major components of the proposed work are described.

Today, many infrastructural levels based applications are shifting to wireless networks such as an internet. This transformation is useful as it increases the outcome at the reduced cost[1,2]. But, along with it, there are many challenges such as data collection and energy consumption, hence providing researchers, a new and abundant platform technological platform names for Wireless Sensor Network (WSNs)[3]. The absolute essential factors associated with WSN are power or energy consumption, energy cost complexity and data collection [4,5]. Among all of them, the most significant function is data collection in a competent and well primed method. This process consisting different types of nodes such as source node for data collection from sensors and destination node collects it from source nodes. Such a technology is preferred from wired approach because it provides lot of flexibility in requisites of costs and efforts.[6,10]

Figure 1.1 shows that a Wireless Sensor Network is part of an Ad-Hoc network and an Ad-Hoc network also the part of a wireless network. Wireless Sensor Network has lots of limitations as compared to an Ad-Hoc network in term of data storage, data processing, an existing energy resource and so on[11,14]. Wireless Sensor Network is usually considered being energy limited because of sensor node operates with a small battery source and replacement of such kind of energy resource is not promising. Figure 1.1 shows wireless sensor networks are belonging to an Ad-Hoc network and the protocols or rules defined for Ad- Hoc network cannot be used similarly in Wireless Sensor Network [4,5,15,16,17]

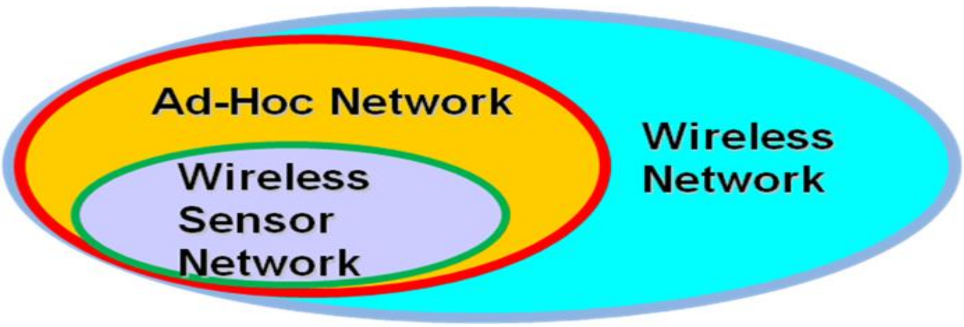

Figure 1.1 :Wireless Network [4]

1.1 Sensor Node Architecture

Figure 1.2 shows the sensor node architecture on a sensor board [8]. Here, we can see that each sensor consists of four main components, namely sensing unit, processing unit, transmission unit and power unit. Also, it has two alternative components that are position finding system and mobile component. It is worth noting that each sensor has limited resource in terms of energy, bandwidth, processing and memory which bring research challenges like routing, localization, etc[20-24].

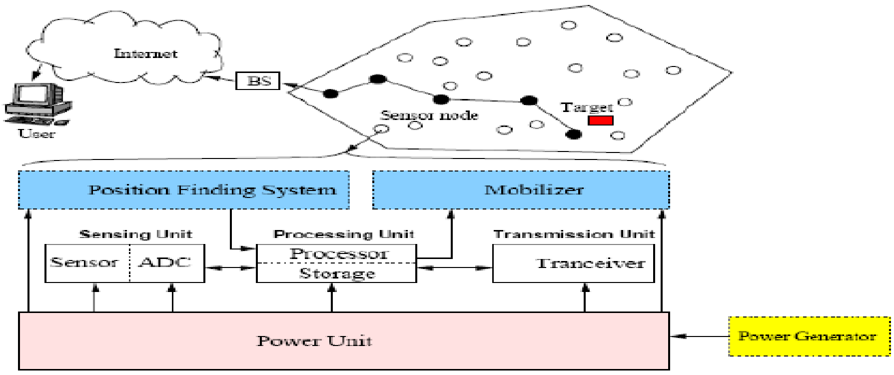

Figure 1.2: Sensor Node Architecture [8]

II. Literature Survey

Leandro A. Villas et.al.[2013] used a spatial correlation algorithm for efficient data collection. In that work they consider the problem of constructing a spatial correlation aware dynamic and scalable routing structure for data collection and aggregation in WSNs. Although there are some solutions for data aggregation in WSNs, most of them build their structures based on the order of event occurrence [29].

Abderrhimet. al. [2013] used a novel data aggregation scheme that exploits compressed sensing (CS) to achieve both recovery fidelity and energy efficiency in WSNs with arbitrary topology. They make use of diffusion wavelets to find a sparse basis that characterizes the spatial correlations well on arbitrary WSNs, which enables straightforward CS-based data aggregation as well as high-fidelity data recovery at the sink. Based on this scheme, they investigate the minimum-energy compressed data aggregation problem [32].

Weifa Liang *et.al*.[2013] used sensors for data gathering, they formulate a novel constrained optimization problem, namely, the capacitated minimum forest (CMF) problem, for the decision version of which they first show NP-completeness. They also devise approximation algorithms and provide upper bounds for their approximation ratios. Finally they evaluate the performance of the proposed algorithms through experimental simulation [33].

Table 2.1: Summary of data aggregations on clustering and data compression protocol of WSN in term of disadvantage and future scope

Author	Journal	Year	Methods	Disadvantages	Future Scope
Cheng Zhao[52]	IEEE JOURNAL	2015	T-CCDA (Treelet Based Cluster Compressive Data Aggregation	Tree based structure used for CH selection	Use Cluster based approach for CH Selection
Fen Zhou[66]	IEEE SENSOR JOURNAL	2016	FAM,HAM and Mixed Integer Linear programming	Location of the CH is pre computed	CH choosing a rely node from its adjacent
Mohammad Abu Alsheikhet. Al.	IEEE JOURNAL	2016	compressing neural networks	Training required for CH Selection and Data compression	Node may be self configurable
HasanHarb et. al.[70]	IEEE	2017	Aggregation at the CH using Distance Function	Repeated iteration	Low Message overhead
NitinGoyal et.al. [72]	ELSEVIER JOURNAL	2017	K-means and Round Based Clustering scheme	CH selected based on K value	Uniform node distribution
Wenliang Wu et. al [73]	IETE JOURNAL UNDER IEEE JOURNAL PUBLICATION	2017	Leach and I-Leach Routing protocol	Algorithm implemented on some node	Inter Cluster communication using TDMA

III. Energy Model for WSN

Energy consumption and energy modeling are important issues in designing and implementing of Wireless Sensor Networks (WSNs), which help the designers to optimize the energy consumption in WSN nodes. The first step is to reduce energy utilizationin WSNs havingprior knowledge about the sources of energy utilization. Therefore, to evaluate a communication protocol, precise energy model is required. Figure 1.3 shows the radio energy model for WSN.[11,34-40]

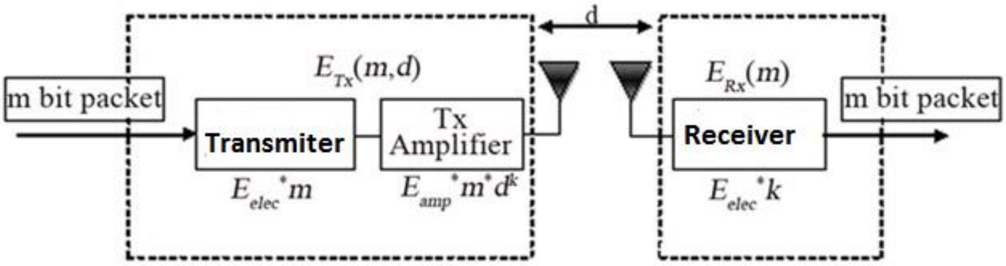

Figure 3.1: Radio Energy Model for WSN

In WSN locations of nodes are not specific because of which lot of the energy is dissipated throughout communication. If the distance between communicating nodes is less energy dissipation will be less and if more energy dissipations will be more. The above Figure 1.3 depicts the energy dissipation process.[12, 45-50] As per energy model shown in figure 1.3, for transferring m-bits of packets over a distance d in network, the total energy utilization by a single node is given by:

$$E_{Tx}(m,d) = E_{Tx-elec}(m) + E_{Tx-amp}(m,d) \qquad 3.1$$

$$E_{Tx}(m,d) = \begin{cases} m \times E_{elec} + (m \times E_{fs} \times d^2 & d < d_0 \\ m \times E_{elec} + (m \times E_{amp} \times d^4, d \geq d_0 \end{cases} \qquad 3.2$$

While the energy utilization for receiving that message is given by:

$$E_{Rx}(m) = m \times E\,(elec). \qquad 3.3$$

IV. Proposed Model

The aim of proposed algorithm is to minimize the energy consumption at the cluster level by forming an optimal data gathering chain. In a protocol is proposed based on three fuzzy parameters such as remaining battery power, mobility, and distance to base station to elect a super cluster head (SCH) among the CHs. But the major drawback of this protocol is that the lifetime of the network remains constant irrespective of the mobility of BS. The proposed methodology has improved the algorithm that extends the network lifetime 22% compared to LEACH. But, the proposed algorithm approaches to a single hop clustered WSN and may not scale well for larger applications.

Algorithm for Cluster head selection

1. Let N sensor node distributed randomly over A*A region where K clusters are assumed
2. N sensor nodes were divided into different level
3. Level should be numbered according to the distance of base station
4. Elect the cluster head at level based on fuzzy inference rule model
5. Apply if then else to elect cluster head
6. One sensor node with higher energy, distance to base station, node density, distance from node, distance from centered to base stationed Probability
7. Base station collect the aggregate data from cluster head

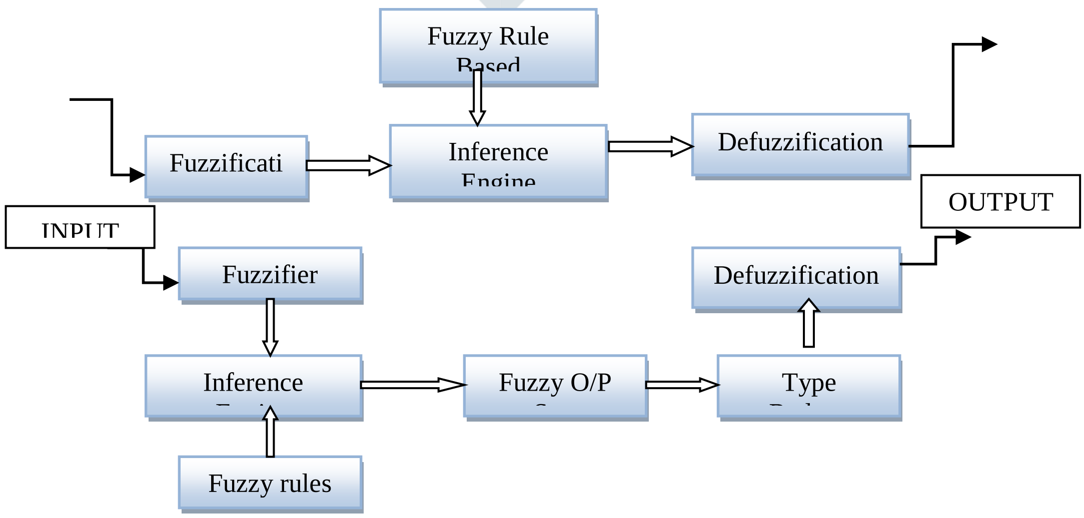

Figure 3.14: Block Diagram of Fuzzy Inference System

4.1 Proposed Model consist of four component

1. Fuzzifier : Translates inputs or crips values to fuzzy values
2. Fuzzification model: The inference engine combine rules and given mapping from input fuzzy set to output fuzzy sets
3. Type reducer or DeFuzzifier: The type reducer generate a type 1 fuzzy set on which is then converted to a numeric or through running the defuzzifier
4. Knowledge base- contain a set of fuzzy rules and membership function set known as data base

V. RESULTS AND DISCUSSION

In this section the simulation and performance of proposed method is analyzed and the result are conducted of various technique using MATLAB 7.10.0. The results of proposed technique are computed with the LEACH, PEGASIS and TEEN. The proposed methodology has been simulated and experimented for network size of 500 nodes.

Table 5.1: Simulation parameter

Parameters	Values
Simulator	MATLAB7.10.0
Number of Nodes	200
Topology	Random
Area size	100*100
Initial Energy	0.4J
Routing	Single Hope
Size of Packet	256
Proapagation Type	Amplifier

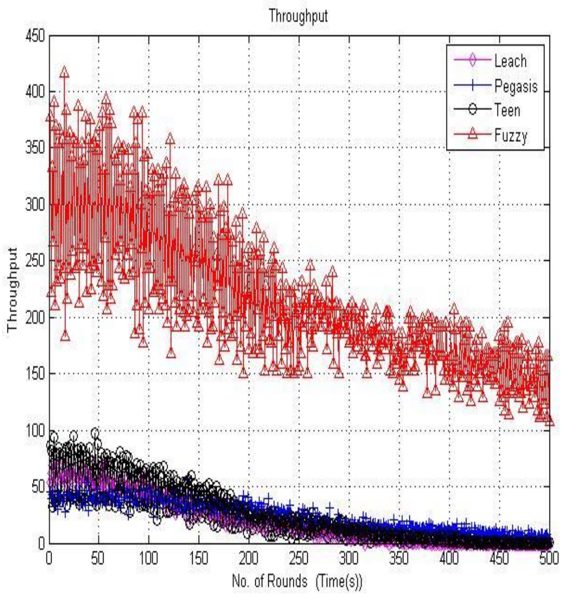

Figure 5.1 Throughput of the Proposed System

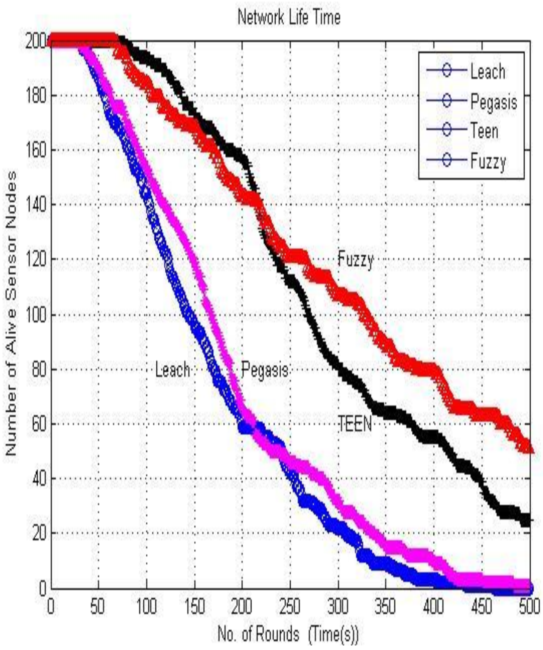

Figure 5.1 Lifetime of the proposed System

Figure 5.1 shows the total throughput of the network and it clearly shows that the throughput of the proposed methodology is increased. Figure 5.2 show the lifetime of network and it show that lifetime of proposed methodology is more as compare to the existing methodology.

Figure 5.4 Transmit and Receive rate

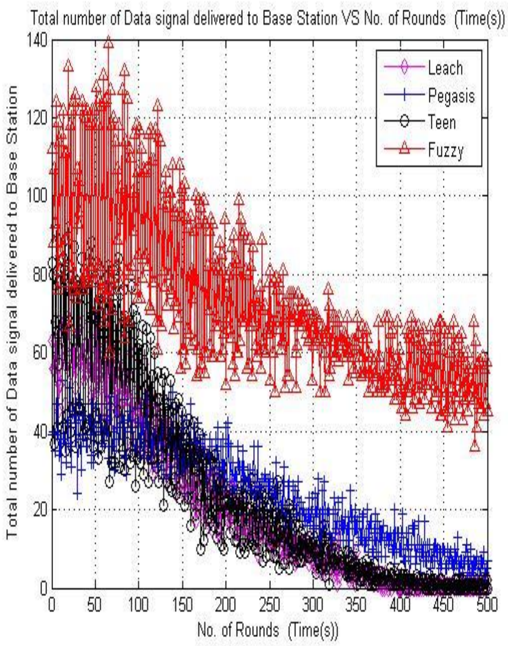

Figure 5.3 Total No of packet delivered to Base station

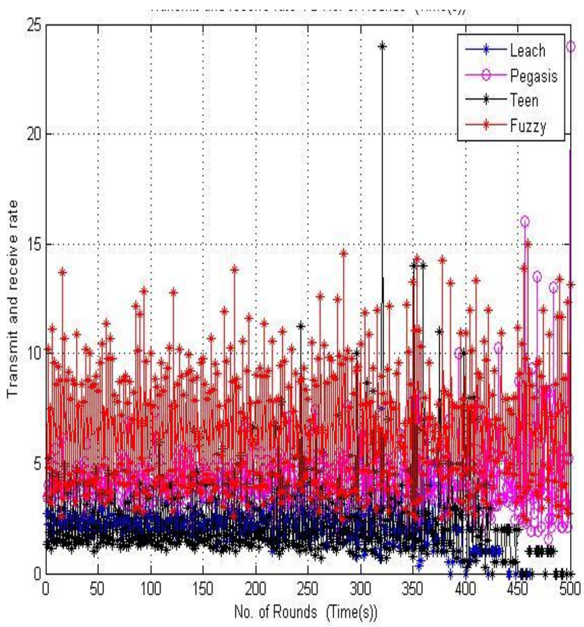

Figure 5.4 Transmit and Receive rate

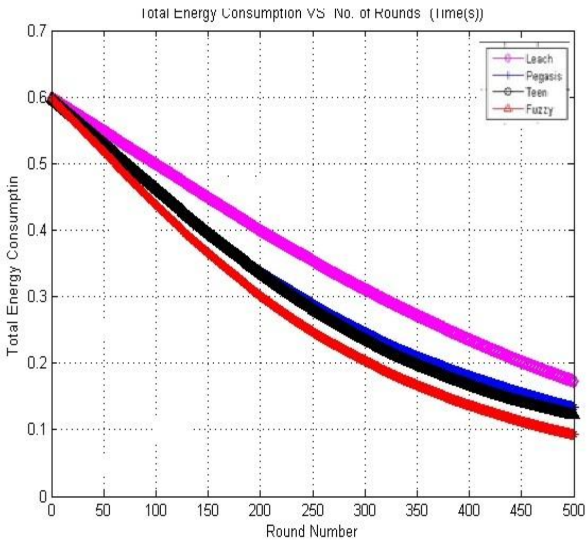

Figure 5.5 Total Energy Consumption

Our basic metric for packet delivery performance is based on the number of packet not successfully received at the base station or cluster head. Figure 5.3 shows that the implementation of total packet delivered to base station.

Figure 5.5 shows Network consumed energy in different rounds. As can be seen consumed energy by proposed methodology compared to LEACH, PEGASIS and TEEN in the lower rounds is less. Figure 5.5 represents Network Residual energy indifferent rounds It clear that Network Residual energy in Proposed Methodology in each round is less than LEACH, PEGASIS and TEEN Comparing the number of dead nodes per round between three algorithms is given in Figure 5.5. Our simulations were run for 500 times for each algorithm and a run time (The time it takes for half of the nodes die) was observed.

VI. CONCLUSION

Considering energy conservation in the design of WSNs, the challenges of attaining energy efficient solutions with data aggregation using fuzzy logic clustering are data compression using RLE. A novel unified framework for collaborative sensing and cooperative communication is proposed for resource constrained WSNs.

The basic LEACH, TEEN and PEGASIS protocol is a promising protocol and provides an opportunity to improve in various parts of the communication protocol so that the applicability of the protocol can be widely extended. In this research work, the entire sensor network is divided into number of levels and at each level, efficient Cluster Head is elected based on Mamdani Fuzzy logic Model. Six fuzzy parameter are consider such as battery power, distance to base station, node density, probability, distance from node and distance from centroid. Each Cluster Head sends the data the first level to the last level till it reaches at the base station. The novelty of the protocol utilizes the concept of MamdaniFuzzy Logic justifying that fuzzy logic model handles real time problems more accurately than any other probabilistic model. Again, Type 2 Fuzzy Logic Model handles the measured level of uncertainties more accurately than Type1 Fuzzy logic model.The throughput of the proposed methodology is higher as compare to the LEACH, PEGASIS and TEEN. Again it clarify that the throughput of proposed methodology 50% more than the LEACH, PEGASIS and TEEN.

REFERENCES

[1]. Q. Gao, Y. Zuo, J. Zhang and X. Peng, "Improving Energy Efficiency in a Wireless Sensor Network by Combining Cooperative MIMO With Data Aggregation," in *IEEE Transactions on Vehicular Technology*, vol. 59, no. 8, pp. 3956-3965, Oct. 2010.doi: 10.1109/TVT.2010.2063719

[2]. X. Li, Y. Wang and Y. Wang, "Complexity of Data Collection, Aggregation, and Selection for Wireless Sensor Networks," in *IEEE Transactions on Computers*, vol. 60, no. 3, pp. 386-399,March2011.doi: 10.1109/TC.2010.50

[3]. R. V. Kulkarni, A. Forster and G. K. Venayagamoorthy, "Computational Intelligence in Wireless Sensor Networks: A Survey," in *IEEE Communications Surveys & Tutorials*, vol. 13, no. 1, pp. 68-96, First Quarter 2011.doi: 10.1109/SURV.2011.040310.00002

[4]. H. Jiang, S. Jin and C. Wang, "Prediction or Not? An Energy-Efficient Framework for Clustering-Based Data Collection in Wireless Sensor Networks," in *IEEE Transactions on Parallel and Distributed Systems*, vol. 22, no. 6, pp. 1064-1071, June 2011.doi: 10.1109/TPDS.2010.174

[5]. H. Jiang, S. Jin and C. Wang, "Prediction or Not? An Energy-Efficient Framework for Clustering-Based Data Collection in Wireless Sensor Networks," in *IEEE Transactions on Parallel and Distributed Systems*, vol. 22, no. 6, pp. 1064-1071, June 2011.doi: 10.1109/TPDS.2010.174

[6]. P. Patil, V. H., S. Patil and U. Kulkarni, "Wireless Sensor Network for Precision Agriculture," *2011 International Conference on Computational Intelligence and Communication Networks*, Gwalior, 2011, pp. 763-766.doi: 10.1109/CICN.2011.169

[7]. C. Wang, H. Ma, Y. He and S. Xiong, "Adaptive Approximate Data Collection for Wireless Sensor Networks," in *IEEE Transactions on Parallel and Distributed Systems*, vol. 23, no. 6, pp. 1004-1016, June 2012.doi: 10.1109/TPDS.2011.265

[8]. PD. C. Hoang, R. Kumar and S. K. Panda, "Optimal data aggregation tree in wireless sensor networks based on intelligent water drops algorithm," in *IET Wireless Sensor Systems*, vol. 2, no.3,pp.282-292,September2012.doi: 10.1049/iet-wss.2011.0146

[9]. T. Zhang, D. Wang, J. Cao, Y. Q. Ni, L. Chen and D. Chen, "Elevator-Assisted Sensor DataCollection for Structural Health Monitoring," in *IEEE Transactions on Mobile Computing*, vol. 11, no. 10, pp. 1555-1568, Oct. 2012.doi: 10.1109/TMC.2011.191

[10]. J. Abouei, K. N. Plataniotis and S. Pasupathy, "Green modulations in energy-constrained wireless sensor networks," in *IET Communications*, vol. 5, no. 2, pp. 240-251, 21 Jan. 2011.doi: 10.1049/iet-com.2010.0472

[11]. J. Abouei, J. D. Brown, K. N. Plataniotis and S. Pasupathy, "On the Energy Efficiency of LT Codes in Proactive Wireless Sensor Networks," in *IEEE Transactions on Signal Processing*, vol. 59, no. 3, pp. 1116-1127, March 2011.doi: 10.1109/TSP.2010.2094193

[12]. Tslands R. Rocha, LuciPirmez, Flávia C. Delicato, ÉricoLemos, Igor Santos, Danielo G. Gomes, José Neuman de Souza, WSNs clustering based on semantic neighborhood relationships,Computer Networks(sciencedirect), Volume 56, Issue 5, 2012, Pages 1627-1645, ISSN 1389-1286, doi.org/10.1016/j.comnet.2012.01.014.

[13]. A. W. Gunst, M. P. van Haarlem and R. C. Vermeulen, "LOFAR: A digital aperture array radio telescope," *2011 URSI General Assembly and Scientific Symposium*, Istanbul, 2011, pp.1-1.doi: 10.1109/URSIGASS.2011.6051279

[14]. A. Prayati, "Wireless Technology Applications in Environment and Health: Network Design Challenges," in *IEEE Latin America Transactions*, vol. 10, no. 3, pp. 1853-1855,April2012.doi: 10.1109/TLA.2012.6222594

[15]. J. Kamenik and O. Theel, "Optimized data-available storage for energy-limited wireless sensor networks," *2011 IEEE 36th Conference on Local Computer Networks*, Bonn, 2011, pp.1011-1019.doi: 10.1109/LCN.2011.6115155

[16]. P. Wang and I. F. Akyildiz, "Spatial Correlation and Mobility-Aware Traffic Modeling for Wireless Sensor Networks," in *IEEE/ACM Transactions on Networking*, vol. 19, no. 6, pp.1860-1873,Dec.2011.doi: 10.1109/TNET.2011.2162340

[17]. Y. Huang and Y. Hua, "On Energy for Progressive and Consensus Estimation in Multihop Sensor Networks," in *IEEE Transactions on Signal Processing*, vol. 59, no. 8, pp. 3863-3875,Aug.2011.doi: 10.1109/TSP.2011.2144588

[18]. J. Chung, J. Kim and D. Han, "Multihop Hybrid Virtual MIMO Scheme for Wireless Sensor Networks," in *IEEE Transactions on Vehicular Technology*, vol. 61, no. 9, pp. 4069-4078,Nov.2012.doi: 10.1109/TVT.2012.2213620

[19]. Mustapha RedaSenouci, AbdelhamidMellouk, HadjSenouci, Amar Aissani, Performance evaluation of network lifetime spatial-temporal distribution for WSN routing protocols, Journal of Network and Computer Applications(sciencedirect),Volume 35, Issue 4, Pages 1317-1328, ISSN 1084-8045, 2012, doi.org/10.1016/j.jnca.2012.01.016.

[20]. H. Chen, G. Wang, Z. Wang, H. C. So and H. V. Poor, "Non-Line-of-Sight Node Localization Based on Semi-Definite Programming in Wireless Sensor Networks," in *IEEE Transactions on Wireless Communications*, vol. 11, no. 1, pp. 108-116, January 2012. doi: 10.1109/TWC.2011.110811.101739

[21]. J. Wang, Y. Yin, J. U. Kim, S. Lee and C. F. Lai, "A Mobile-Sink Based Energy- fficient Clustering Algorithm for Wireless Sensor Networks," *2012 IEEE 12th International Conference on Computer and Information Technology*,Chengdu, 2012, pp. 678-683. doi: 10.1109/CIT.2012.142

[22]. C. Wang, C. Jiang, S. Tang and X. Li, "SelectCast: Scalable Data Aggregation Scheme in Wireless Sensor Networks," in *IEEE Transactions on Parallel and Distributed Systems*, vol. 23, no. 10, pp. 1958-1969, Oct. 2012.doi: 10.1109/TPDS.2011.312

[23]. MiloudBagaa, YacineChallal, AbdelraoufOuadjaout, NoureddineLasla, NadjibBadache, Efficient data aggregation with in-network integrity control for WSN, Journal of Parallel and Distributed Computing (sciencedirect) Volume 72, Issue 10, 2012, Pages 1157-1170, ISSN 0743-7315, doi.org/10.1016/j.jpdc.2012.06.006.

[24]. HamedYousefi, Mohammad HosseinYeganeh, NaserAlinaghipour, Ali Movaghar, Structure-free real-time data aggregation in wireless sensor networks, Computer Communications (sciencedirect), Volume 35, Issue 9, 2012, Pages 1132-1140, ISSN 0140-3664,doi.org/10.1016/j.comcom.2011.11.007.

[25]. R. Chauhan and V. Gupta, "Energy Efficient Sleep Scheduled Clustering & Spanning Tree based data aggregation in wireless sensor network," *2012 1st International Conference on Recent Advances in Information Technology (RAIT)*, Dhanbad, 2012, pp. 536-541.doi: 10.1109/RAIT.2012.6194617

[26]. L. Xiang, J. Luo and C. Rosenberg, "Compressed Data Aggregation: Energy-Efficient and High-Fidelity Data Collection," in *IEEE/ACM Transactions on Networking*, vol. 21, no. 6,pp.1722-1735,Dec.2013.doi: 10.1109/TNET.2012.2229716

[27]. R. R. Rout and S. K. Ghosh, "Enhancement of Lifetime using Duty Cycle and Network Coding in Wireless Sensor Networks," in *IEEE Transactions on Wireless Communications*, vol. 12, no. 2, pp. 656-667, February 2013.doi: 10.1109/TWC.2012.111412.112124

[28]. C. Cheng, H. Leung and P. Maupin, "A Delay-Aware Network Structure for Wireless Sensor Networks With In-Network Data Fusion," in *IEEE Sensors Journal*, vol. 13, no. 5, pp. 1622-1631,May2013.doi: 10.1109/JSEN.2013.2240617

[29]. Leandro A. Villas, AzzedineBoukerche, Daniel L. Guidoni, Horacio A.B.F. de Oliveira, Regina Borges de Araujo, Antonio A.F. Loureiro, An energy-aware spatio-temporal correlation mechanism to perform efficient data collection in wireless sensor networks, Computer Communications, Volume 36, Issue 9, pp. 1054-1066, ISSN 0140-3664, 2013,doi.org/10.1016/j.comcom.2012.04.007.

[30]. Xuangou Wu, Yan Xiong, Wenchao Huang, Hong Shen, MingxiLi,An efficient compressive data gathering routing scheme for large-scale wireless sensor networks, Computers & Electrical Engineering (sciencedirect),Volume 39, Issue 6,2013,Pages 1935-1946, ISSN 0045-7906,doi.org/10.1016/j.compeleceng.2013.04.009.

[31]. X. Xu, R. Ansari and A. Khokhar, "Power-efficient hierarchical data aggregation using compressive sensing in WSNs," *2013 IEEE International Conference on Communications (ICC)*, Budapest, 2013, pp. 1769-1773.doi: 10.1109/ICC.2013.6654775

[32]. A. Maizate and N. E. Kamoun, "Enhanced passive clustering based on distance and residual energy for wireless sensor network," *2013 ACS International Conference on Computer Systems and Applications (AICCSA)*, Ifrane, 2013, pp. 1-8.doi: 10.1109/AICCSA.2013.6616416

[33]. W. Liang, P. Schweitzer and Z. Xu, "Approximation Algorithms for Capacitated Minimum Forest Problems in Wireless Sensor Networks with a Mobile Sink," in *IEEE Transactions on Computers*, vol. 62, no. 10, pp. 1932-1944,Oct.2013. doi: 10.1109/TC.2012.124

[34]. Y. Yun, Y. Xia, B. Behdani and J. C. Smith, "Distributed Algorithm for Lifetime Maximization in a Delay-Tolerant Wireless Sensor Network with a Mobile Sink," in *IEEE Transactions on Mobile Computing*, vol. 12, no. 10, pp. 1920-1930,Oct.2013. doi: 10.1109/TMC.2012.152

[35]. X. Wang, J. Wang, K. Lu and Y. Xu, "GKAR: A Novel Geographic K-anycast Routing for Wireless Sensor Networks," in *IEEE Transactions on Parallel and Distributed Systems*, vol. 24, no. 5, pp. 916-925, May 2013.doi: 10.1109/TPDS.2012.143

[36]. Y. Gu, Y. Ji, J. Li and B. Zhao, "ESWC: Efficient Scheduling for the Mobile Sink in Wireless Sensor Networks with Delay Constraint," in *IEEE Transactions on Parallel and Distributed Systems*, vol. 24, no. 7, pp. 1310-1320,July2013. doi: 10.1109/TPDS.2012.210

[37]. R. R. Rout and S. K. Ghosh, "Enhancement of Lifetime using Duty Cycle and Network Coding in Wireless Sensor Networks," in *IEEE Transactions on Wireless Communications*, vol. 12, no. 2, pp. 656-667, February 2013.

[38]. J. Wang, Y. Liu, Y. He, W. Dong and M. Li, "QoF: Towards Comprehensive Path Quality Measurement in Wireless Sensor Networks," in *IEEE Transactions on Parallel and Distributed Systems*, vol. 25, no. 4, pp. 1003-1013,April2014.doi: 10.1109/TPDS.2013.98

[39]. L. Bhasker, "Genetically derived secure cluster-based data aggregation in wireless sensor networks," in *IET Information Security*, vol. 8, no. 1, pp. 1-7, Jan.2014.doi: 10.1049/iet-ifs.2013.0133

[40]. S. Ji, R. Beyah and Z. Cai, "Snapshot and Continuous Data Collection in Probabilistic Wireless Sensor Networks," in *IEEE Transactions on Mobile Computing*, vol. 13, no. 3, pp. 626-637, March 2014. doi: 10.1109/TMC.2013.30

[41]. J. Ma, W. Lou and X. Li, "Contiguous Link Scheduling for Data Aggregation in Wireless Sensor Networks," in *IEEE Transactions on Parallel and Distributed Systems*, vol. 25, no. 7, pp.1691-1701,July2014.doi: 10.1109/TPDS.2013.296

[42]. F. Yuan, Y. Zhan and Y. Wang, "Data Density Correlation Degree Clustering Method for Data Aggregation in WSN," in *IEEE Sensors Journal*, vol. 14, no. 4, pp. 1089-1098, April 2014.doi: 10.1109/JSEN.2013.2293093

[43]. C. Li *et al.*, "Topology Analysis of Wireless Sensor Networks Based on Nodes' Spatial Distribution," in *IEEE Transactions on Wireless Communications*, vol. 13, no. 5, pp. 2454-2453,May2014.doi: 10.1109/TWC.2014.031714.130038

[44]. C. Wang, J. Shih, B. Pan and T. Wu, "A Network Lifetime Enhancement Method for Sink Relocation and Its Analysis in Wireless Sensor Networks," in *IEEE Sensors Journal*, vol. 14, no. 6, pp. 1932-1943, June 2014.doi: 10.1109/JSEN.2014.2306429

[45]. J. He, S. Ji, Y. Pan and Y. Li, "Constructing Load-Balanced Data Aggregation Trees in Probabilistic Wireless Sensor Networks," in *IEEE Transactions on Parallel and Distributed Systems*, vol. 25, no. 7, pp. 1681-1690, July 2014.doi: 10.1109/TPDS.2013.160

[46]. W. Xu, Q. Shi, X. Wei, Z. Ma, X. Zhu and Y. Wang, "Distributed Optimal Rate–Reliability–Lifetime Tradeoff in Time-Varying Wireless Sensor Networks," in *IEEE Transactions on Wireless Communications*, vol. 13, no. 9, pp. 4836-4847, Sept. 2014. doi: 10.1109/TWC.2014.2327955

[47]. Madhumathy P and Sivakumar D, "Enabling energy efficient sensory data collection using multiple mobile sink," in *China Communications*, vol. 11, no. 10, pp. 29-37, Oct. 2014. doi: 10.1109/CC.2014.6969791

[48]. H. F. Rashvand, A. Abedi, J. M. Alcaraz-Calero, P. D. Mitchell and S. C. Mukhopadhyay, "Wireless Sensor Systems for Space and Extreme Environments: A Review," in *IEEE Sensors Journal*, vol. 14, no. 11, pp. 3955-3970, Nov. 2014.doi: 10.1109/JSEN.2014.2357030

[49]. A. E. Zonouz, L. Xing, V. M. Vokkarane and Y. L. Sun, "Reliability-Oriented Single-Path Routing Protocols in Wireless Sensor Networks," in *IEEE Sensors Journal*, vol. 14, no. 11, pp. 4059-4068, Nov. 2014.doi: 10.1109/JSEN.2014.2332296

[50]. S. Guo, C. Wang and Y. Yang, "Joint Mobile Data Gathering and Energy Provisioning in Wireless Rechargeable Sensor Networks," in *IEEE Transactions on Mobile Computing*, vol. 13, no. 12, pp. 2836-2852, Dec. 2014.doi: 10.1109/TMC.2014.2307332

[51]. R. K. Tripathi, S. Dhuli, Y. N. Singh and N. K. Verma, "Analysis of weights for optimal positioning of base station in a Wireless Sensor Network," *2014 Twentieth National Conference on Communications (NCC)*, Kanpur, 2014, pp. 1-4.doi: 10.1109/NCC.2014.6811372

[52]. C. Zhao, W. Zhang, Y. Yang and S. Yao, "Treelet-Based Clustered Compressive Data Aggregation for Wireless Sensor Networks," in *IEEE Transactions on Vehicular Technology*, vol. 64, no. 9, pp. 4257-4267, Sept. 2015. doi: 10.1109/TVT.2014.2361250

[53]. B. Fateh and M. Govindarasu, "Joint Scheduling of Tasks and Messages for Energy Minimization in Interference-Aware Real-Time Sensor Networks," in *IEEE Transactions on Mobile Computing*, vol. 14, no. 1, pp. 86-98, Jan. 2015. doi: 10.1109/TMC.2013.81

[54]. Yaun Li and Lynne E.parker,"Nearest neighbor imputation using spatial temporal correlation in wireless sensor network*",elsver information fussion, Vol.* 15,pp. 64-69,2014, ISSN 1566-2535, doi.org/10.1016

[55]. SumedhaSirsikar, Samarth Anavatti,Issues of Data Aggregation Methods in Wireless Sensor Network: A Survey,Procedia Computer Science,Volume 49,2015,Pages 194-201,ISSN 1877-0509,doi.org/10.1016/j.procs.2015.04.244.

[56]. Y. Yao, Q. Cao and A. V. Vasilakos, "EDAL: An Energy-Efficient, Delay-Aware, and Lifetime-Balancing Data Collection Protocol for Heterogeneous Wireless Sensor Networks," in *IEEE/ACM Transactions on Networking*, vol. 23, no. 3, pp. 810-823, June 2015. doi: 10.1109/TNET.2014.2306592

[57]. H. Yousefi, M. Malekimajd, M. Ashouri and A. Movaghar, "Fast Aggregation Scheduling in Wireless Sensor Networks," in *IEEE Transactions on Wireless Communications*, vol. 14, no. 6, pp. 3402-3414, June 2015.doi: 10.1109/TWC.2015.2405060

[58]. F. El-Moukaddem, E. Torng and G. Xing, "Maximizing Network Topology Lifetime Using Mobile Node Rotation," in *IEEE Transactions on Parallel and Distributed Systems*, vol. 26, no. 7, pp. 1958-1970, 1 July 2015.doi: 10.1109/TPDS.2014.2329851

[59]. X. Liu Yanmin Zhu, Linghe Kong, Cong Liu,YuGu, Athanasios V. Vasilakos and Min-You Wu*et*, "CDC: Compressive Data Collection for Wireless Sensor Networks," in *IEEE Transactions on Parallel and Distributed Systems*, vol. 26, no. 8, pp. 2188-2197, 1 Aug. 2015.doi: 10.1109/TPDS.2014.2345257

[60]. M. Abo-Zahhad, S. M. Ahmed, N. Sabor and S. Sasaki, "Mobile Sink-Based Adaptive Immune Energy-Efficient Clustering Protocol for Improving the Lifetime and Stability Period of Wireless Sensor Networks," in *IEEE Sensors Journal*, vol. 15, no. 8, pp. 4576-4586,Aug.2015.doi: 10.1109/JSEN.2015.2424296

[61]. C. Tunca, S. Isik, M. Y. Donmez and C. Ersoy, "Ring Routing: An Energy-Efficient Routing Protocol for Wireless Sensor Networks with a Mobile Sink," in *IEEE Transactions on Mobile Computing*, vol. 14, no. 9, pp. 1947-1960, 1 Sept. 2015.doi: 10.1109/TMC.2014.2366776

[62]. Arumugam, G.S. &Ponnuchamy,"EE-LEACH: development of energy-efficient LEACH Protocol for data gathering in WSN", s,pringer EURASIP Journal on Wireless Communications and Networking,vol 75, pp.1-9,ISSN:1687-1499 2015, doi.org/10.1186/s13638-015-0306-5

[63]. A. R. Khan, N. Rakesh, A. Bansal and D. K. Chaudhary, "Comparative study of WSN Protocols (LEACH, PEGASIS and TEEN)," *2015 Third International Conference on Image Information Processing(ICIIP)*, Waknaghat, 2015, pp. 422-427.doi: 10.1109/ICIIP.2015.7414810

[64]. C. Wang, S. R. Hussain and E. Bertino, "Dictionary Based Secure Provenance Compression for Wireless Sensor Networks," in *IEEE Transactions on Parallel and Distributed Systems*, vol. 27, no. 2, pp. 405-418, 1 Feb. 2016.doi: 10.1109/TPDS.2015.2402156

[65]. F. Zhou, Z. Chen, S. Guo and J. Li, "Maximizing Lifetime of Data-Gathering Trees With Different Aggregation Modes in WSNs," in *IEEE Sensors Journal*, vol. 16, no. 22, pp. 8167-8177, 2016. doi: 10.1109/JSEN.2016.2609152

[66]. Elby K. Eldhose, G. Jisha,Active Cluster Node Aggregation Scheme in Wireless Sensor Network Using Neural Network,Procedia Technology,Volume 24, Pages 1603-1608,ISSN 2212-0173, 2016,https://doi.org/10.1016/j.protcy.2016.05.154.

[67]. S. Singh, S. Chand, R. Kumar, A. Malik and B. Kumar, "NEECP: Novel energy-efficient clustering protocol for prolonging lifetime of WSNs," in *IET Wireless Sensor Systems*, vol. 6, no.5,pp.151-157,102016.doi: 10.1049/iet-wss.2015.0017

[68]. KangkaChakravarty and Utpal Barman,"An Energy Balanced Algorithm of PEGASIS Protocol in WSN"International Journal of Computer Sciences and Engineering,Volume-4, Issue-7,pp.1-5,ISSN: 2347-2693Dec-2016

[69]. H. Harb, A. Makhoul, S. Tawbi and R. Couturier, "Comparison of Different Data Aggregation Techniques in Distributed Sensor Networks," in *IEEE Access*, vol. 5, pp. 4250-4263,2017.doi: 10.1109/ACCESS.2017.2681207

[70]. Quentin Bramas, SébastienTixeuil,"The complexity of data aggregation in static and dynamic wireless sensor networks,Information and Computation,Volume 255, Part 3, Pages 369-383,ISSN 0890-5401, 2017, doi.org/10.1016/j.ic.2016.12.004.

[71]. NitinGoyal, Mayank Dave and Anil Verma,"Data Aggregation in underwater wireless sensor network: Recent approaches and issues" Elsevere 2017 ISSN 1319-1578, https://doi.org/10.1016/j.jksuci.2017.04.007

[72]. W. Wu, N. Xiong and C. Wu, "Improved clustering algorithm based on energy consumption in wireless sensor networks," in *IET Networks*, vol. 6, no. 3, pp. 47-53, 5 2017.doi: 10.1049/iet-net.2016.0115

[73]. Y. Hu, Y. Niu, J. Lam and Z. Shu, "An Energy-Efficient Adaptive Overlapping Clustering Method for Dynamic Continuous Monitoring in WSNs," in *IEEE Sensors Journal*, vol. 17, no. 3, pp. 834-847, Feb.1, 1 2017. doi: 10.1109/JSEN.2016.2632198