

A New Algorithm for Cluster Leader Selection in Wireless Sensor Networks

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Abstract—Nowadays sensors play nearly a crucial play in our daily live. Because of their important impacts like investigation of non-reachable places for human kind, etc. Sensor networks consist of tiny sensors that can be homogenous or heterogeneous. Sensors will not mangle by human so they have to be self- management. Most of Sensors works with low-producer-power like battery. In this paper, we propose a new solution to cluster sensor nodes in Wireless Sensor Networks.

Index Terms—Fuzzy Logic, WSN, Clustering, IoT

I. INTRODUCTION

Wireless Sensor Networks are widely used in various civil and military related applications. One of the most challenging issues is to manage nodes in environments that basically cannot be reachable or when its not possible to replace their power source. Many of WSN nodes today are supplied with rechargeable lithium ion/polymer batteries and polycrystalline cells to charge them by ambiance sunlight radiation. They include variety of sensors such as temperature, humidity, motion detection, light, UV or IR sensors. A pico-power microcontroller manages the node and a cmos low power transceiver provides the communication layer. However, the most hesitating part is to recover the captured information from dead nodes and to guarantee the transmission of captured data safely to the base station.

II. RELATED WORK

Qi Dong and Donggang Liu in [1] describes a new and novel distributed cluster head leader selection algorithm based on symmetric key operations that has three main characteristics: cluster nodes are consistent in cluster leader selection, relatively resistant against attackers which means attackers do not have any impact on benign nodes for cluster leader election decisions, and finally is a fault tolerant algorithm which recover messages that maybe lost or be changed via malicious attacks. Puneet Azad, etc in [2] present a new cluster head election algorithm that is based on fuzzy rule and also considered three main characteristics: remaining energy of nodes, number of neighbors, and distance from the base station or sink node and compare the proposed method with distributed hierarchical agglomerative clustering and show it has better performance in network life time Dilip Kumar in [3] introduce a new

distributed stable algorithm that is used for cluster head election. The presented algorithm, DSCHE, is based on weighted probability, consider two aspects: remaining energy and the average energy of network, he showed that the algorithm is more stable and has better performance in comparison of conventional ones. One of the main drawbacks of this algorithm is the volume of data packets sent to Base Station rather than some of the known algorithms. Sohail Jabbar in [4] introduced a multilayer algorithm for clustering. It means it consider three centralized and distributed algorithms in order that it will reduce the number of cluster head candidates. to achieve this goal it use centralized algorithm or we can use distributed one. It also reduces message exchange and use communication architecture and design architecture.

III. USING FUZZY INFERENCE SYSTEMS IN CLUSTERING

Fuzzy logic is a useful decision-making system, without need to full information about the environment. On the other hand the normal control mechanisms generally require accurate and complete information about the environment [5]. Fuzzy logic can make decisions based on a variety of environmental parameters, combining them according to predefined rules are used. Some clustering algorithms are used fuzzy logic to overcome the problem of uncertainty in wireless sensor networks. The fuzzy clustering algorithm (FCA) is use fuzzy logic to combine different parameters to select a cluster head. In accordance with a de-fuzzy output of system, they report the chances of cluster head that is achieved with IF-THEN rules [6-21]. A node will be a cluster head if it has the most chance to their adjacent nodes. Fuzzy logic methods can be distributed or centralized. In this paper, we try to use the fuzzy system to solve the problems of previous systems and presented the optimal algorithm to select the cluster head [71-90]. The proposed clustering algorithm is based on LEACH which functionality and reliability is improved by fuzzy systems. LEACH Protocol is one of the first and most famous hierarchical protocols that is Provided for wireless sensor networks [6-9]. In this protocol, Network activity is divided into time periods (Figure 5). At the beginning of each period, selected number of nodes as a

$$T(n) = \begin{cases} \frac{P}{1 - P \times (r \bmod \frac{1}{P})}, & \text{if } n \in G \\ 0, & \text{otherwise} \end{cases}$$

cluster head randomly. For this purpose, each node produces a random number between 0 and 1 [10]. If this number is less than the $T(n)$ that is achieved using Equation 3, the node as cluster head is introduced. In relation (1), P is ratio of the number of clusters and the total number of network nodes, r is number of Course, and G is the numbers of nodes in the $1/P$ previous are not selected as cluster head [11-18, 91-108].

After defining the cluster head node, other nodes based on the received signal strength from each cluster head, decide to become a member of each cluster. Cluster head node divided the range of their responsibilities into several time slices (Figure 1). This time slices are sharing based on TDMA mechanism between members of cluster [19-24]. In each time slices, cluster head communicate with one Clusters members and receives its information packets [25]. In every some time slices, Cluster head sends received Information from its members to the central node. In order to distribute the load on different nodes after a period, for the beginning of a new era, cluster head based on the mechanism described above are changed [26-30]. In short, the LEACH algorithm is as follows:

A. Notification phase (advertising):

Each sensor selects a random value between 1 -0. If the random number is less than a threshold $T(n)$, in this case, the node selects itself as a cluster head. While the P is percent of needed cluster head, r is number of current period And G is a fraction of the nodes that is not be a cluster head in the $1/P$ last period. Using this threshold, each node in each $1/P$ period will be a cluster head. In the first round all nodes can be cluster head with probability P [31]. In the next period increases the probability of selection nodes that are not selected as the cluster head. The method presented in this study, this possibility is described by fuzzy inference system that continues to be expressed in detail below, will be calculated [32]. Each node is selected as cluster head node sends a message broadcast to the other. All cluster heads send their announcement messages with the same energy.

ADV = nodes ID + distinguishable header

After this stage, the non-cluster head node, choose their cluster head which they belong. If a non-cluster head node receives several announcement messages will be join to the close cluster head. (Closely is detected by the strength of the received signal). In the same case a cluster head to be selected randomly.

B. Cluster formation Phase

In this phase, each node after determined that is which cluster to it belongs must deliver this issue to the cluster head of that cluster [33-35].

Join-REQ = nodes ID + cluster-head ID + header

C. Forming phase schedule

At this stage, cluster head received all Members join messages and based on the number of them, constitute a TDMA schedule and send information for each node.

D. Data transfer phase

After the clusters were formed and fixed TDMA, Data transfer can be started. Each Non-cluster head node radio device, it can be turned off until the time of notification that node. In the proposed method the amount of chance of each node to parent (phase announcement) is calculated using a fuzzy system [42, 60]. Fuzzy system that is used is Mamdani type, with three inputs and one output. The defuzzification of output is used to find the center of mass method, which is the most popular method among seven defuzzification of the output [36, 41, 62-90]. Overview fuzzy system and its features can be seen in Figure 2.

$$T(n) = \begin{cases} \frac{P}{1 - P \times (r \bmod \frac{1}{P})}, & \text{if } n \in G \\ 0, & \text{otherwise} \end{cases}$$

Membership functions for the fuzzy system have been obtained experimentally and testing and optimization. Inputs and outputs are defined as follows:

a) *The first input (residual energy)*: Show the remaining amount of energy of each node. Whatever the amount of energy is higher can send and receive more information and lifetime is higher.

b) *The second input (neighbors)*: Shows the number of each node neighboring. Nodes that have more neighbors will have a better chance of be parent [36, 37]. The proposed method is calculated based on the number of neighbors. In this method, the following formula is used:

$$N = 1 - e^{-\gamma\pi R^2}$$

Where, R is the radius of the neighborhood and the $0.01 = \gamma$. In the algorithm running neighbor radius is considered 15 meters. The third input (centrality): show the distance of a node from the central node. Less distance a better chance of becoming a parent will make. Output (chance): combine three input value by fuzzy rules defined, the chance of a node for

become parent node being obtained fuzzy system output. Input and output membership functions in Figure (3) are observed [38-40, 42].

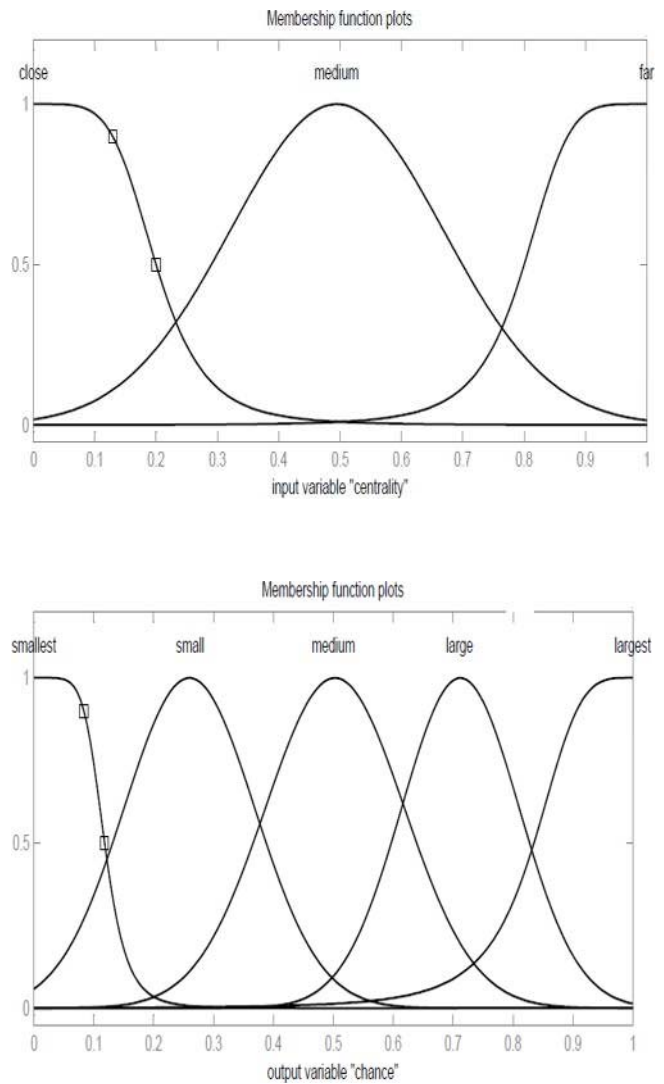
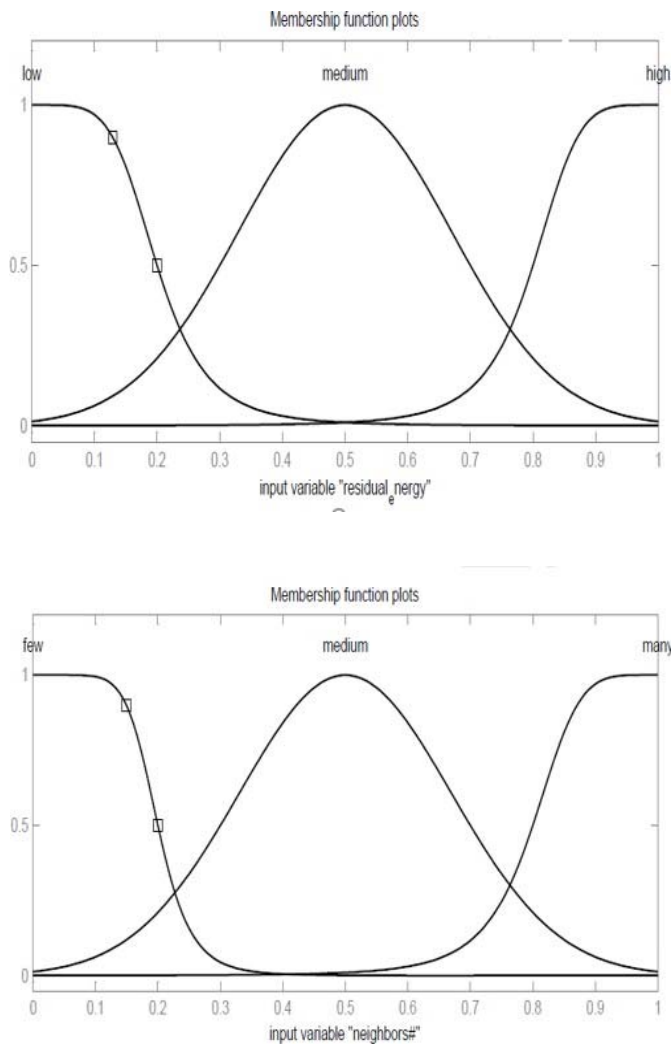


Fig. 1. Figure 3 - (a), (b) and c) input membership functions, (d) output membership function of the fuzzy system

Input values are defined by fuzzy rules, which combined to produce output. For this fuzzy system are defined 18 laws as follows: 1. If (residual energy is low) and (neighbors is few) and (centrality is far) then (chance is smallest) 2. If (residual energy is medium) and (neighbors is few) and (centrality is far) then (chance is smallest) 3. If (residual energy is low) and (neighbors is medium) and (centrality is far) then (chance is smallest) 4. If (residual energy is low) and (neighbors is few) and (centrality is medium) then (chance is smallest) 5. If (residual energy is low) and (neighbors is medium) and (centrality is medium) then (chance is small) 6. If (residual energy is medium) and (neighbors is medium) and (centrality is far) then (chance is small) 7. If (residual energy is high) and (neighbor is many) and (centrality is close) then (chance is largest) 8. If (residual energy is high) and (neighbors is medium) and (centrality is close) then (chance is large) 9. If (residual energy is medium) and (neighbors is many) and (centrality is close) then (chance is large) 10. If (residual energy

is high) and (neighbors is many) and (centrality is medium) then (chance is large) 11. If (residual energy is medium) and (neighbors is medium) and (centrality is medium) then (chance is medium) 12. If (residual energy is medium) and (neighbors is many) and (centrality is medium) then (chance is medium) 13. If (residual energy is medium) and (neighbors is medium) and (centrality is close) then (chance is medium) 14. If (residual energy is medium) and (neighbors is medium) and (centrality is far) then (chance is medium) 15. If (residual energy is medium) and (neighbors is few) and (centrality is medium) then (chance is medium) 16. If (residual energy is medium) and (neighbors is many) and (centrality is medium) then (chance is medium) 17. If (residual energy is low) and (neighbors is medium) and (centrality is medium) then (chance is medium) 18. If (residual energy is high) and (neighbors is medium) and (centrality is medium) then (chance is medium)

An example of how to combine inputs to produce an output is observed in Figure (4) and (5) [90-101].

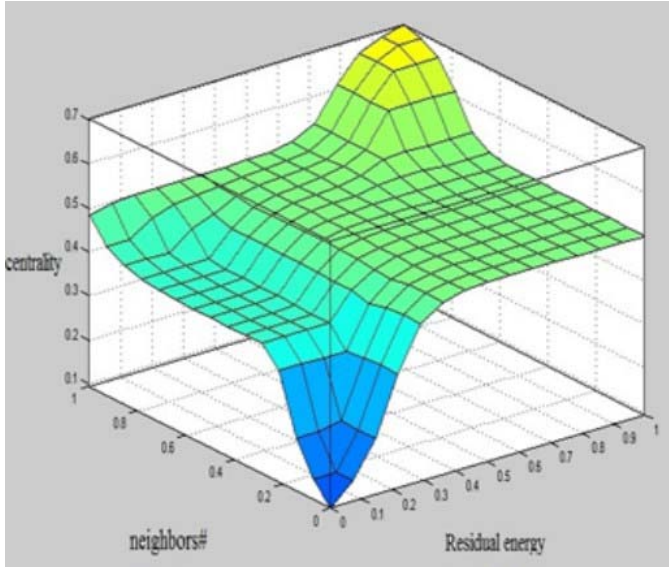


Fig. 2. Figure 4 the combination of input parameters

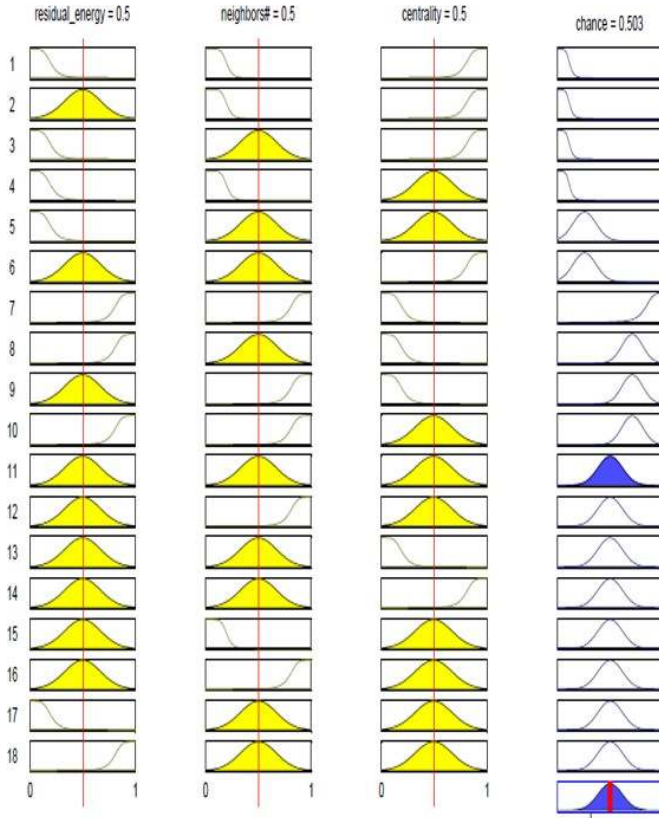


Fig. 3. Figure 5 the combination of inputs to produce outputs

To examine design methods, a network with 100 nodes consider that are randomly distributed. Other network parameters to be entered in the following the proposed algorithm:

xm=100; ym=100; sink.x=0.5*xm; sink.y=0.5*ym; n=100
p=0.1; Eo=0.5; ETX=50*0.000000001;
ERX=50*0.000000001; Efs=10*0.000000000001;
Emp=0.0013*0.000000000001; EDA=5*0.000000001;

IV. NETWORK MODEL

At first, we will explain the characteristics of the used system model. First we expressed our assumptions about the Network Model. As review the designed method:

- 1) A network with 100 nodes and a random distribution.
- 2) Network will consider in the 100m 100m.
- 3) Base station coordinates [50.50] is considered.
- 4) The amount of initial energy is equal 0.5 Joule.
- 5) And the initial probability is assumed to be 0.1.
- 6) All sensor nodes have the same energy in the arrangement stage.
- 7) All nodes and sink after the arrangement are fixed.
- 8) All sensor nodes have the same computing power; memory and energy or homogeneous in terms of form.
- 9) The distance between nodes can be calculated based on the intensity of the received signal.
- 10) Therefore sensor nodes do not need to be aware of their exact location.

V. RADIO ENERGY MODEL

Radio energy model for k-bit packet transmission, In the distance d meter, In the simulations is as follows: As well

$$E_{Tx}(k, d) = \begin{cases} k * E_{elec} + k * \epsilon_{fs} * d^2, & d < d_0 \\ k * E_{elec} + k * \epsilon_{mp} * d^4, & d \geq d_0 \end{cases}$$

as radio energy model to receive a k-bit packages, is as follows: Depending on the distance, the consumed energy has been expressed in channel model by fs and mp. Eelec is the amount of energy required to run the transmitter circuit or receiver. Radio parameters used in the simulation are set as follows: Eelec=50 nJ/bit EDA=5 nJ/bit/report fs=10 J/bit/m2 mp=0.0013 J/bit/m4

Algorithms for different numbers of repeats, is examined. After about 1,000 around the optimal cluster head, will be achieved.

$$E_{Rx}(k) = E_{elec} * k$$

For evaluation, we compare it with Leach algorithm and FCA solution from remaining energy evaluation metric and number of live nodes.

VI. CONCLUSION AND FUTURE WORK

In this paper a new algorithm was proposed for routing in WSNs. Then a comprehensive evaluation, discussion, comparison with other methods was done. One of the drawback

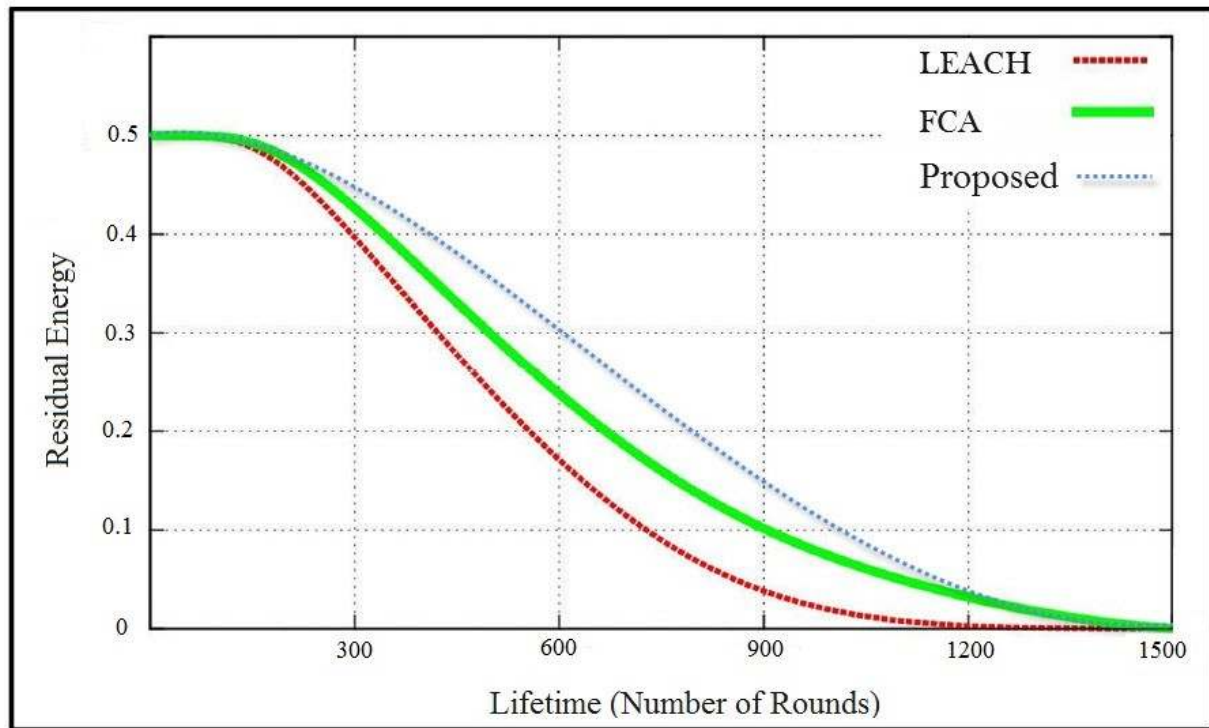


Fig. 4. Remaining energy

of this method is this it will not considering the privacy and security. One possible future work is that we can use other technologies such as machine learning methods in order to enhance clustering selection method.

VII. CONFLICT OF INTEREST

No potential conflict of interest was reported by the authors

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REFERENCES

- [1] H. Ghayvat, S. Mukhopadhyay, X. Gui, and N. Suryadevara, "Wsn-and iot-based smart homes and their extension to smart buildings," *Sensors*, vol. 15, no. 5, pp. 10 350–10 379, 2015.
- [2] Akkaya K. and Younis M., (2005), "A survey on routing protocols for wireless sensor networks", in: Proceedings of the Elsevier Ad Hoc Network Journal, pp. 325-349.
- [3] Akyildiz I.F., Su.W, Sankarasubramaniam Y. and Cayirci E. (2002), "A survey on sensor networks", in: Proceedings of the IEEE Communication Magazine, Vol. 40, pp. 102-114
- [4] Al-Karaki J. N. and Kamal A. E., (2004), "Routing techniques in wireless sensor networks: a survey". In: Proceedings of the IEEE Wireless Communications, Vol. 11, pp. 6-28.
- [5] Amis A., Prakash R., Vuong T., and D. Huynh, March(2000), "Max-Min D-Cluster Formation in Wireless AdHoc Networks," IEEE INFOCOM.
- [6] Baker D.J., Ephremides A., (1981), "The architectural organization of a mobile radio network via a distributed algorithm", IEEE Transactions on Communications, COM-29 (11), pp. 1694–1701
- [7] Chan H., Perrig A., (2004), "ACE: An emergent algorithm for highly uniform cluster formation", Proceedings of the 1st European Workshop on Sensor Networks (EWSN).
- [8] Chatterjee M., Das S. K., and Turgut D., (2002), "WCA: A Weighted Clustering Algorithm for Mobile Ad Hoc Networks," *Clustering Computing*, vol. 5, pp. 193–204.
- [9] Demirbas M., Arora A. and Mittal V., (2004), "FLOC: A fast local clustering service for wireless sensor networks, in Proc. of Workshop on Dependability Issues in Wireless AdHoc Networks and Sensor Networks (DIWANS04), Florence, Italy.
- [10] Ding P., Holliday J., Celik A., (2005), "Distributed energy efficient hierarchical clustering for wireless sensor networks", Proceedings of the IEEE International Conference on Distributed Computing in Sensor Systems (DCOSS'05).
- [11] Estrin D., Xu Y., Heidemann j. (2001), Geography-Informed Energy Conservation for Ad Hoc Routing. In Proceedings of the 7th Annual International Conference on Mobile Computing and Networking (MobiCom), Rome, Italy pp 70–84.
- [12] Fan X. and Song Y., (2007), "Improvement on LEACH protocol of wireless sensor network," IEEE Sensor Communication, pp 260–264.
- [13] Godbole v.,(2012), "Performance Analysis of Clustering Protocol Using Fuzzy Logic for Wireless Sensor Network", IAES International Journal of Artificial Intelligence (IJ-AI) Vol. 1, No. 3, ISSN: 2252-8938, pp. 103-111.
- [14] Goldsmith A.J. and Wicker S.B. , (2002), "Design challenges for energy-constrained ad hoc wireless networks", in: Proceedings of the IEEE Wireless Commun, pp. 8–27.
- [15] Guang Feng Li, Taieb Z., (2007), "A ring-structured energy-efficient clustering architecture for robust communication in wireless sensor networks", International Journal of Sensor Networks, Volume 2.
- [16] Heinzelman W. R., Kulik J., and Balakrishnan H. , (2000), "Adaptive Protocols for Information Dissemination in Wireless Sensor Networks". Proceedings of the 5th Annual International Conference on Mobile Computing and Networking, pages 174–185. ACM, Seattle, WA.
- [17] Heinzelman W., chandrakasan A. and Balakrishnan H., (2000), "Energy-efficient communication protocol for wireless mi-crosensor network", in: Proceedings of the IEEE System Sciences, pp.1-10.
- [18] Hill J. and Culler D. , (2002), "Mica: A wireless platform for deeply embedded networks", in: Proceedings of the IEEE Micro., Vol. 22, no. 6, pp. 12-24.
- [19] Huynh T. T. and Hong C. S. , (2005), "Prolonging network lifetime via intra-

- cluster routing in wireless sensor networks", in: Proceedings of the ICMU2005, pp. 162-167.
- [20] Ilyas M. and Mahgoub I. (2005), "Handbook of Sensor Networks: Compact Wireless and Wired Sensing Systems", in: Proceedings of the CRC Press, London, Washington, D.C.
- [21] Janakiram D., Venkateswarlu R. Nitin S., (2005), "A survey on programming languages, middleware and applications in wireless sensor networks", in: Proceedings of the IITM-CSE-DOS-2005-04.
- [22] Jiang H., Sun Y., Sun R., and Xu H., (2013), "Fuzzy-Logic-Based Energy Optimized Routing for Wireless Sensor Networks", International Journal of Distributed Sensor Networks Volume 6, pp 1-9.
- [23] Kahn J.M., Katz R.H. and Pister K.S.J., (1999), "Next century challenges: mobile networking for smart dust", in: Proceedings of the ACM MobiCom 99, Washington, USA, pp. 271-278.
- [24] Kumar S., Kumar M., Sheeba V. S., Kashwan K. R., (2012), "Cluster Based Routing Algorithm Using Dual Staged Fuzzy Logic in Wireless Sensor Networks" Journal of Information & Computational Science 9(5), pp.1281-1297
- [25] Loscri V., Morabito G., and Marano S. , (2005), "A two-level hierarchy for low-energy adaptive clustering hierarchy", Proceedings of IEEE VTC Conference 2005, Vol. 3, pp. 1809-1813.
- [26] Gheisari, M., Esnaashari, M. (2017). A survey to face recognition algorithms: advantageous and disadvantageous. Journal Modern Technology & Engineering, 2(1), 57-65.
- [27] Gheisari, M., Baloochi, H., Gharghi, M., & Khajehyousefi, M. (2012). An Evaluation of Two Proposed Systems of Sensor Data's Storage in Total Data Parameter. International Geoinformatics Research and Development Journal.
- [28] GHEISARI, M.. Design, Implementation and Evaluation of SemHD: a New Semantic Hierarchical Sensor Data Storage. Indian Journal of Innovations and Developments, [S.I.], p. 115-120, mar. 2012.
- [29] M. Gheisari et al., "NSSSD: A new semantic hierarchical storage for sensor data," 2016 IEEE 20th International Conference on Computer Supported Cooperative Work in Design (CSCWD), Nanchang, 2016, pp. 174-179.
- [30] M. Gheisari, G. Wang and M. Z. A. Bhuiyan, "A Survey on Deep Learning in Big Data," 2017 IEEE International Conference on Computational Science and Engineering (CSE) and IEEE International Conference on Embedded and Ubiquitous Computing (EUC), Guangzhou, 2017, pp. 173-180
- [31] M. Jafari, J. Wang, Y. Qin, M. Gheisari, A. S. Shahabi and X. Tao, "Automatic text summarization using fuzzy inference," 2016 22nd International Conference on Automation and Computing (ICAC), Colchester, 2016, pp. 256-260.
- [32] Gheisari, Mehdi. "The Effectiveness of Schema Therapy Integrated with Neurological Rehabilitation Methods to Improve Executive Functions in Patients with Chronic Depression." Health Science Journal 10.4 (2016).
- [33] Gheisari, M., A. R. Bagheri, and Damavand Branch. "SHD: a New Sensor Data Storage." In 5th international symposium on advances in science & technology. 2011
- [34] Gheisari, Mehdi, and Mehdi Esnaashari. "Data Storages in Wireless Sensor Networks to Deal With Disaster Management." Emergency and Disaster Management: Concepts, Methodologies, Tools, and Applications. IGI Global, 2019. 655-682
- [35] Rezaeiye, Payam Porkar, et al. "Agent programming with object oriented (C++)." Electrical, Computer and Communication Technologies (ICECCT), 2017 Second International Conference on. IEEE, 2017.
- [36] Gheisari, Mehdi, et al. "MAPP: A Modular Arithmetic Algorithm for Privacy Preserving in IoT." Ubiquitous Computing and Communications (ISPA/IUCC), 2017 IEEE International Symposium on Parallel and Distributed Processing with Applications and 2017 IEEE International Conference on. IEEE, 2017.
- [37] Ashourian, Mohsen, Mehdi Gheisari, and Ali Hashemi. "An Improved Node Scheduling Scheme for Resilient Packet Ring Network." Majlesi Journal of Electrical Engineering 9.2 (2015): 43.
- [38] Khajehyousefi, Mehdi, et al. "A Comparison with Three Proposed Sensors Data's Storages." International Conference on Advanced Computer Theory and Engineering, 4th (ICACTE 2011). ASME Press, 2011
- [39] Fakhimi, Esmaeil, et al. "Design Two Sensor Data Storages." International Conference on Advanced Computer Theory and Engineering, 4th (ICACTE 2011). ASME Press, 2011
- [40] Gheisari, Mehdi. "Design, implementation and evaluation of SemHD: a new semantic hierarchical sensor data storage." Indian Journal of Innovations and Developments 1.3 (2012): 115-120.
- [41] Sharifzadeh, Manaf, Kaveh Bashash,, Shahram Bashokian, and mehdi gheisari. "A Comparison with two semantic sensor data storages in total data transmission." arXiv preprint arXiv:1401.7499 (2014).
- [42] Rezaeiye, Payam Porkar, et al. "Statistical method used for doing better corneal junction operation." Advanced Materials Research. Vol. 548. Trans Tech Publications, 2012
- [43] Fazli, Mojtaba Sedigh, Keykhosrow Keshavarzi, and Saeed Setayeshi. "Designing a hybrid neuro-fuzzy system for classifying the complex data, application on cornea transplant." Proceedings on the International Conference on Artificial Intelligence (ICAI). The Steering Committee of The World Congress in Computer Science, Computer Engineering and Applied Computing (WorldComp), 2013.
- [44] Shahram Ghanizadeh , Mojtaba Sedigh Fazli, Application of Genetic Algorithm on Heat Exchanger Network Optimization, Research Journal of Applied Sciences, Engineering and Technology 6(18): 3378-3383, 2013
- [45] W. Yang, G. Wang, K.-K. R. Choo, and S. Chen, "Hepart: A balanced hypergraph partitioning algorithm for big data applications," *Future Generation Computer Systems*, vol. 83, pp. 250-268, 2018.
- [46] F. Kache and S. Seuring, "Challenges and opportunities of digital information at the intersection of big data analytics and supply chain management," *International Journal of Operations & Production Management*, vol. 37, no. 1, pp. 10-36, 2017.
- [47] G. Wang, "Special Section on Security, Privacy and Anonymity of Internet of Things Forward," *IEICE transaction on information ans systems*, vol. E99D, no. 8, pp. 1964-1965, AUG 2016.
- [48] P. Porkar, M. Gheisari, G. H. Bazyari, and Z. Kaviyanjahromi, "A comparison with two sensor data storages in energy," in *International Conference on Computer and Computer Intelligence (ICCCI 2011)*. ASME Press, 2011.
- [49] P. P. Rezaeiye and M. Gheisari, "Performance analysis of two sensor data storages," in *Proceedings of 2nd International Conference on Circuits, Systems, Communications & Computers (CSCC)*, 2011, pp. 133-136.
- [50] E. M. Gheisari, M., "A survey to face recognition algorithms: advantageous and disadvantageous," *Journal Modern Technology & Engineering*, 2017.
- [51] P. P. Rezaeiye, M. Fazli, M. Sharifzadeh, H. Moghaddam, and M. Gheisari, "Creating an ontology using protege: concepts and taxonomies in brief," *Advances in Mathematical and Computational Methods*, vol. 1, no. 3, pp. 115-120, 2012.
- [52] T. M. da Costa, "Opp_jot an ontology-based privacy preservation approach for the internet of things," Ph.D. dissertation, Universite' Grenoble Alpes, 2017.
- [53] C. Perera, A. Zaslavsky, P. Christen, and D. Georgakopoulos, "Context aware computing for the internet of things: A survey," *IEEE Communications Surveys & Tutorials*, vol. 16, no. 1, pp. 414-454, 2014.
- [54] Z. Bousalem and I. Cherti, "Xmap: A novel approach to store and retrieve xml document in relational databases." *JSW*, vol. 10, no. 12, pp. 1389-1401, 2015.
- [55] E. I. Tatli, "Extending p3p/appel for friend finder," in *Mobile Data Management, 2007 International Conference on*. IEEE, 2007, pp. 243-247.
- [56] M. Olurin, C. M. Adams, and L. Logrippo, "Platform for privacy preferences (p3p): Current status and future directions," *2012 Tenth Annual International Conference on Privacy, Security and Trust*, pp. 217-220, 2012.
- [57] M. Compton, P. Barnaghi, L. Bermudez, R. Garca-Castro, O. Corcho, S. Cox, J. Graybeal, M. Hauswirth, C. Henson, A. Herzog, V. Huang, K. Janowicz, W. D. Kelsey, D. L. Phuoc, L. Lefort, M. Leggieri, H. Neuhaus, A. Nikolov, K. Page, A. Passant, A. Sheth, and K. Taylor, "The ssn ontology of the w3c semantic sensor network incubator group," *Web Semantics: Science, Services and Agents on the World Wide Web*, vol. 17, pp. 25 - 32, 2012.
- [58] S. Sharma, K. Chen, and A. Sheth, "Toward practical privacy-preserving analytics for iot and cloud-based healthcare systems," *IEEE Internet Computing*, vol. 22, no. 2, pp. 42-51, Mar 2018.
- [59] H. Mahdikhani and R. Lu, "Achieving privacy-preserving multi dot-

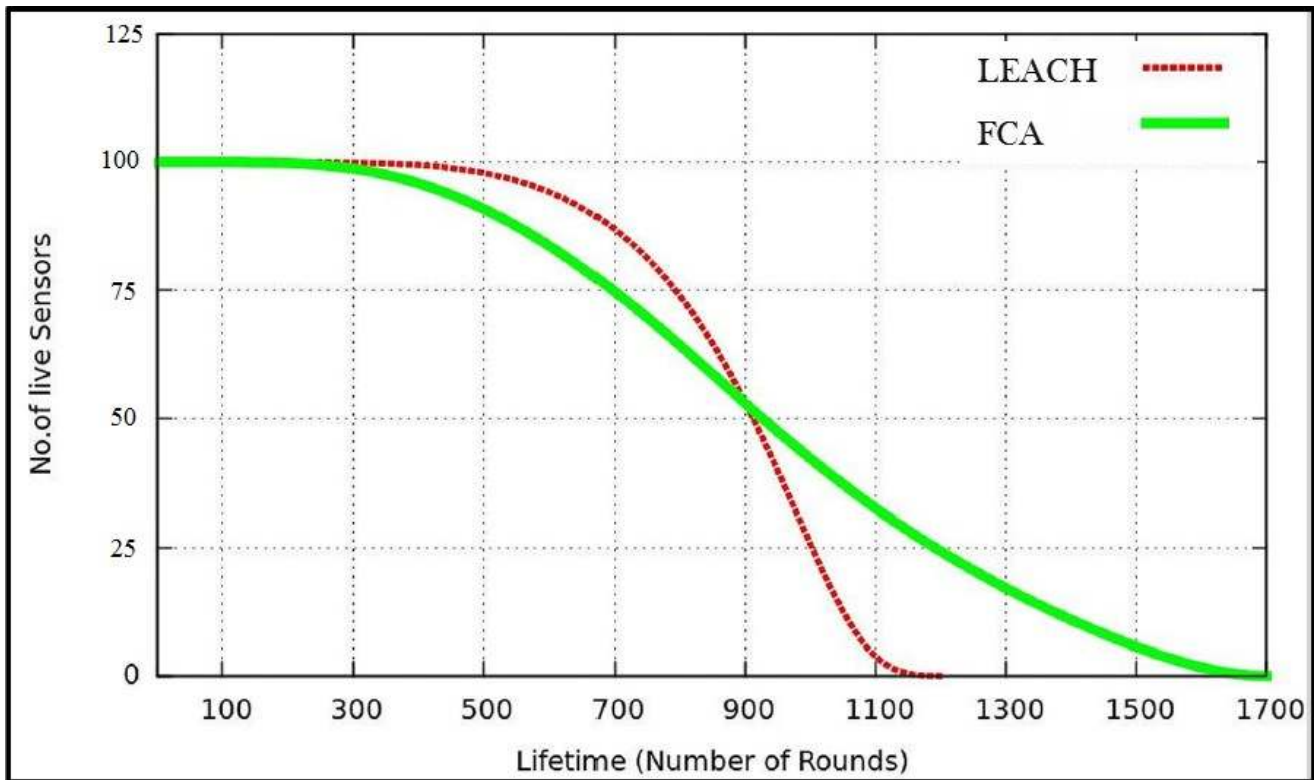


Fig. 5. Live nodes

- product query in fog computing-enhanced iot," in *GLOBECOM 2017 - 2017 IEEE Global Communications Conference*, Dec 2017, pp. 1–6.
- [60] M. Tao, J. Zuo, Z. Liu, A. Castiglione, and F. Palmieri, "Multi-layer cloud architectural model and ontology-based security service framework for iot-based smart homes," *Future Generation Computer Systems*, vol. 78, no. Part 3, pp. 1040 – 1051, 2018.
- [61] T. Peng, Q. Liu, and G. Wang, "A multilevel access control scheme for data security in transparent computing," *Computing in Science Engineering*, vol. 19, no. 1, pp. 46–53, Jan 2017.
- [62] E. Jajaga and L. Ahmedi, "C-swrl: Swrl for reasoning over stream data information," in *Proceedings of the 11th IEEE International Conference on Semantic Computing (ICSC 2017)*, San Diego, CA, January, 2017.
- [63] O. Mazhelis, A. Hmlinen, T. Asp, and P. Tyrvinen, "Towards enabling privacy preserving smart city apps," in *2016 IEEE International Smart Cities Conference (ISC2)*, Sept 2016, pp. 1–7.
- [64] L. Atzori, A. Iera, and G. Morabito, "The internet of things: A survey," *Computer networks*, vol. 54, no. 15, pp. 2787–2805, 2010.
- [65] M. C. Choi, H. Cha, H. B. Park, and J. K. Yoo, "Combined base transceiver station and base station controller handoff," Sep. 13 2011, uS Patent 8,019,348.
- [66] A. Klose and A. Drexler, "Facility location models for distribution system design," *European journal of operational research*, vol. 162, no. 1, pp. 4–29, 2005.
- [67] S. Peng, G. Wang, and D. Xie, "Social influence analysis in social networking big data: Opportunities and challenges," *IEEE Network*, vol. 31, no. 1, pp. 11–17, January 2017.
- [68] B. Brech, J. Jamison, L. Shao, and G. Wightwick, "The interconnecting of everything," *IBM Corp*, pp. 1–6, 2013.
- [69] W. H. O. C. for Health Development, *Hidden Cities: unmasking and overcoming health inequities in urban settings*. World Health Organization, 2010.
- [70] M. Gheisari, A. Bagheri, and D. Branch, "Shd: a new sensor data storage," in *In 5th international symposium on advances in science & technology*, 2011, pp. 10–19.
- [71] M. Sharifzadeh, K. Bashash, S. Bashokian *et al.*, "A comparison with two semantic sensor data storages in total data transmission," *arXiv preprint arXiv:1401.7499*, pp. 96–102, 2014.
- [72] M. Gheisari, G. Wang, M. Z. A. Bhuiyan, and W. Zhang, "Mapp: A modular arithmetic algorithm for privacy preserving in iot," in *2017 IEEE International Symposium on Parallel and Distributed Processing with Applications and 2017 IEEE International Conference on Ubiquitous Computing and Communications (ISPA/IUCC)*, Dec 2017, pp. 897–903.
- [73] M. Gheisari, "The effectiveness of schema therapy integrated with neurological rehabilitation methods to improve executive functions in patients with chronic depression," *Health Science Journal*, vol. 10, no. 4, 2016.
- [74] M. Jafari, J. Wang, Y. Qin, M. Gheisari, A. S. Shahabi, and X. Tao, "Automatic text summarization using fuzzy inference," in *2016 22nd International Conference on Automation and Computing (ICAC)*, Sept 2016, pp. 256–260.
- [75] M. Ashourian, M. Gheisari, and A. Hashemi, "An improved node scheduling scheme for resilient packet ring network," *Majlesi Journal of Electrical Engineering*, vol. 9, no. 2, p. 43, 2015.
- [76] H. Kargupta, S. Datta, Q. Wang, and K. Sivakumar, "On the privacy preserving properties of random data perturbation techniques," in *ICDM 2003*. IEEE, 2003, pp. 99–106.
- [77] R. Kannan and S. Vempala, "Randomized algorithms in numerical linear algebra," *Acta Numerica*, vol. 26, pp. 95–135, 2017.
- [78] J.-P. Fox, "Randomized item response theory models," *Journal of Educational and Behavioral statistics*, vol. 30, no. 2, pp. 189–212, 2005.
- [79] J. Kraft and L. Washington, *An Introduction to Number Theory with Cryptography*. Chapman and Hall/CRC, 2018.
- [80] H. A. S. M. Touhidul, J. Qingshan, L. Jun, L. Chengming, and C. Lifei, "An effective value swapping method for privacy preserving data publishing," *Security and Communication*

- Networks*, vol. 9, no. 16, pp. 3219–3228. [Online]. Available: <https://onlinelibrary.wiley.com/doi/abs/10.1002/sec.1527>
- [81] C. Stergiou and K. E. Psannis, “Recent advances delivered by mobile cloud computing and internet of things for big data applications: a survey,” *International Journal of Network Management*, vol. 27, no. 3, 2017.
- [82] M. Gheisari, “Design, implementation and evaluation of semhd,” *Indian Journal of Innovations and Developments*, pp. 115–120, March 2012.
- [83] A. Botta, W. De Donato, V. Persico, and A. Pescapé, “Integration of cloud computing and internet of things: a survey,” *Future Generation Computer Systems*, vol. 56, pp. 684–700, 2016.
- [84] D. Johnson, *Digital Camera*. McGraw-Hill/Osborne, 2003.
- [85] J.-T. Chang, “Compact camera module with lens array,” Oct. 16 2012, uS Patent 8,289,409.
- [86] C. C. Aggarwal and S. Y. Philip, “A general survey of privacy-preserving data mining models and algorithms,” in *Privacy-preserving data mining*. Springer, 2008, pp. 11–52.
- [87] H. Ebad, T. Antignac, and D. Sands, “Sampling and partitioning for differential privacy,” in *2016 14th Annual Conference on Privacy, Security and Trust (PST)*, Dec 2016, pp. 664–673.
- [88] V. Estivill-Castro and L. Brankovic, “Data swapping: Balancing privacy against precision in mining for logic rules,” in *DaWaK*, vol. 99. Springer, 1999, pp. 389–398.
- [89] S. Bechhofer, “Owl: Web ontology language,” in *Encyclopedia of Database Systems*. Springer, 2009, pp. 2008–2009.
- [90] M. Gheisari, A. A. Movassagh, Y. Qin, J. Yong, X. Tao, J. Zhang, and H. Shen, “Nsssd: A new semantic hierarchical storage for sensor data,” in *IEEE 20th International Conference on Computer Supported Cooperative Work in Design (CSCWD)*, May 2016, pp. 174–179.
- [91] E. GhadakSaz, M. R. Amini, P. Porkar, and M. Gheisari, “Design, implement and compare two proposed sensor data storages named semhd and ssw,” *From Editor in Chief*, p. 78, 2012.
- [92] E. T. Chen, “The internet of things: Opportunities, issues, and challenges,” in *The Internet of Things in the Modern Business Environment*. IGI Global, 2017, pp. 167–187.
- [93] M. Alirezaie, J. Renoux, U. Kckemann, A. Kristoffersson, L. Karlsson, E. Blomqvist, N. Tsiftes, T. Voigt, and A. Loufi, “An ontology-based context-aware system for smart homes: E-care@home,” *Sensors*, vol. 17, no. 7, 2017.
- [94] M. Tao, K. Ota, and M. Dong, “Ontology-based data semantic management and application in iot- and cloud-enabled smart homes,” *Future Generation Computer Systems*, vol. 76, no. Supplement C, pp. 528–539, 2017.
- [95] J. H. Gennari, M. A. Musen, R. W. Ferguson, W. E. Grosso, M. Crubézy, H. Eriksson, N. F. Noy, and S. W. Tu, “The evolution of protégé: an environment for knowledge-based systems development,” *International Journal of Human-computer studies*, vol. 58, no. 1, pp. 89–123, 2003.
- [96] N. Nethravathi, V. J. Desai, P. D. Shenoy, M. Indiramma, and K. Venugopal, “A brief survey on privacy preserving data mining techniques,” *Data Mining and Knowledge Engineering*, vol. 8, no. 9, pp. 267–273, 2016.
- [97] J. Joy and M. Gerla, “Differential privacy by sampling,” *arXiv preprint arXiv:1708.01884*, pp. 10–36, 2017.
- [98] A. Solanas, F. Sebé, and J. Domingo-Ferrer, “Micro-aggregation-based heuristics for p-sensitive k-anonymity: one step beyond,” in *Proceedings of the 2008 international workshop on Privacy and anonymity in information society*. ACM, 2008, pp. 61–69.
- [99] G. De Giacomo, D. Lembo, M. Lenzerini, A. Poggi, and R. Rosati, “Using ontologies for semantic data integration,” in *A Comprehensive Guide Through the Italian Database Research Over the Last 25 Years*. Springer, 2018, pp. 187–202.
- [100] C. Golbreich and A. Imai, “Combining swrl rules and owl ontologies with protégé owl plugin, jess, and racer,” in *7th International Protégé Conference, Bethesda, MD*, 2004.
- [101] X. Xing, D. Xie, and G. Wang, “Energy-balanced data gathering and aggregating in wsns: A compressed sensing scheme,” *International Journal of Distributed Sensor Networks*, vol. 11, no. 10, p. 585191, 2015.
- [102] B. research report, “Iot security threat map,” [Online]. Available: <http://www.beechamresearch.com/download.aspx?id=43>, [Accessed May 2017], 2017.
- [103] M. Markovic, “Data protection techniques, cryptographic protocols and pki systems in modern computer networks,” in *Systems, Signals and Image Processing, 2007 and 6th EURASIP Conference focused on Speech and Image Processing, Multimedia Communications and Services. 14th International Workshop on*. IEEE, 2007, pp. 13–24.
- [104] S. Pearson, “Taking account of privacy when designing cloud computing services,” in *Software Engineering Challenges of Cloud Computing, 2009. CLOUD’09. ICSE Workshop on*. IEEE, 2009, pp. 44–52.
- [105] M. Gheisari and M. Esnaashari, “Data storages in wireless sensor networks to deal with disaster management,” *IGI-Global*, p. 196222, 2018.
- [106] M. F. Khan, G. Wang, M. Z. A. Bhuiyan and X. Li, “Wi-Fi Signal Coverage Distance Estimation in Collapsed Structures,” 2017 IEEE International Symposium on Parallel and Distributed Processing with Applications and 2017 IEEE International Conference on Ubiquitous Computing and Communications (ISPA/IUCC), Guangzhou, 2017, pp. 1066–1073.
- [107] Muhammad ARIF, Guojun WANG*, Valentina Emilia BALAS, Secure VANETs: Trusted Communication Scheme between Vehicles and Infrastructure Based on Fog Computing, *Studies in Informatics and Control*, ISSN 1220-1766, vol. 27(2), pp. 235-246, 2018.