Journal of Research Proceedings

JRP

Under the delegate of "Journal of Research Proceedings," we anchor a bimonthly electronic journal enclosing the diverse realms of the educational research field. JRP is providing a platform for the researchers, academicians, professionals, practitioners, and students to impart and share knowledge in the form of high quality empirical and theoretical research papers, case studies, literature reviews, and book reviews.

JRP Publications
www.i-jrp.com
journalrp.editor@gmail.com
9353189468

BRE-LEACH: An Advance LEACH Protocol to Increase Efficiency of WSN

Saurav Kumar Thakur[1], Ujwal Kumar[2], Rohindra Nath Shah[3], Rajeev Kumar Roy[4], Prof. Rashmi K T[5]

CSE Department, Sri Krishna Institute of Technology, B'lore-560090, India[1234]

Assistant Professor, CSE Department, Sri Krishna Institute of Technology, B'lore-560090, India[5]

ABSTRACT:

The Wireless Network, abbreviated as (WSN), is a relatively new technology that is proving to be quite useful in commercial and defense applications wherein energy is now the most important component. This work introduces BRE-LEACH (Balanced Residual Energy-LEACH), a novel method for the LEACH (Low Energy Adaptive Clustering Hierarchy) algorithm. To improve lifetime of the network by reducing energy loss, three aspects must be considered: cluster heads, proximity to the BS (Base Station), and multi-hop. The fundamental factor in the cluster head (CH) choice technique is residual energy, which is used to make lower sensor networks serving as a CH since they require more energy than just a regular node. The BRE-LEACH determines the best route by selecting the CH with the highest residual energy and the highest efficiency to the BS as the roots CH, which clear and consistent from those other CHs and sends it to the BS. The inter is used by the furthest CHs to get to the core CH. Our suggested protocol, BRE-LEACH, extends communication range by 55.73 percent in comparison to the Leach algorithm, according to simulation findings in MATLAB.

KEYWORDS: WSN, LEACH, CH, BS, BRE-LEACH.

I. INTRODUCTION

WSN is indeed an adhoc network of several sensor nodes, that are segments and sub capable of autonomously collecting physical parameters from the surroundings like heat, humidity, and so forth and transmitting them to a collectors. Nowadays, the WSN is powered by batteries in several military and commercial applications, and due of its tiny size, battery capacity is limited, so energy conservation is essential. In practise, charging or replacing the cells isn't really possible [1-2]. As a result, scientists are developing for practical solutions to this challenge. Many techniques are provided, with the majority of them focusing on route. There are three types of communication algorithms: information protocols (SPIN, COUGAR, etc.) and location-based protocols (MECN, SMECN, GEAR)and hierarchical protocols (LEACH, PEGASIS, TEEN, etc.). In recent years, a variety of studies have looked at hierarchical model in the Wireless communication from various perspectives. The Suggested technique is the very first electricity cluster - based routing system with data fusion, and it is the foundation for other hierarchy protocols [3-5].

Because the dynamic choice in LEACH causes a highly fragmented that naturally effects the lifetime of the network, this research presented in a new methodology based on the remaining power of each and every node in a network for enhance the estimation of the CHs. As a result, our procedure designated the CH with the largest power consumption and the shortest path to the BS as the roots CH, and other CHs used multi-hop to approach this root. This charge combines the data from the CHs and transfers it to the BS [6-8].

BACKGROUND STUDY

The Leach is the first and foremost widely used hierarchy routing protocol, allowing machine learning via clustering, in which nodes provide data to the CH, and the CH aggregates and compresses data before sending it straight to the BS. Heinzelman created the LEACH technique in 2000. [9]. During the clusters creation phase, each node selects a random value between 0 and 1, if this value is smaller than that of the predefined threshold T, that network is designated as a CH (n).
Numerous LEACH-based algorithms, including V-LEACH, have been developed to address many of the system's flaws. V-LEACH is an enhanced version of the Leach algorithm that creates a new representations. [10-13]
By using uneven classification approach [14], the researcher proposes a DUCA clustering method that produce real cluster - head and eliminate cluster major criteria to manage power burden [15]. Clustering of DUCA computers created closer to the base station were smaller in size than cluster farther away from the Base station. The BS estimated the clustering diameter and located its centre using the equation, then broadcasted messages to entire network to generate groups of uneven size.
The main goal of E-LEACH is to improve the CH identification algorithm by avoiding lower power consumption nodes and higher spent energy nodes as CH. It works in the same way as LEACH, allowing the root node to be chosen from among the CHs with the highest power consumption, as well as the data from other CHs to be merged and sent to the collectors [16].
By calculating the power degradation of various CHs, the LEACH-TLCH extends the lifetime of entire network. LEACH is used to select the CHs and build the cluster. If CH0s energy consumption may be less than the energy content of all nodes, or the separation among CH & BS is higher than the increase length, the clusters gets established. in this case, this CH could choose a network from its group as a supplementary CH, and this node must have the most energy. If not, this CH will not require additional CH.

II. METHODOLOGY

1 .LEACH

LEACH is the contraction of the low energy adaptive clustering hierarchy. It is a clustering routing protocol introduced by W. Heinznlman. The group of nodes that form the cluster is organized by this protocol. Once the cluster is created in the WSN, one node is selected as CH among all the nodes by taking the node with the highest energy and minimum distance to BS as the criteria [17].

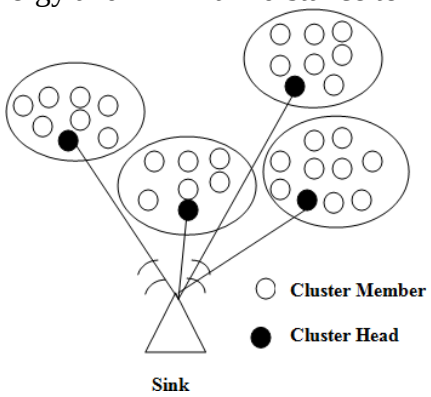

FIGURE 1: CLUSTERING IN LEACH

Wherever a node has data to send, it first analyses the route to the node to which the data has to be sent. On setting the target, the sending node in the cluster forwards the appropriate information to its cluster head ( ) as shown in fig 1. Similarly, all the cluster members ( ) in the network sends the appropriate information or data packets to CH for communication with nodes over the communication line. The CH receives data and sends or forwards the aggregated data packets to BS and the collected information is compressed.

This compressed data is forwarded to the base station. Since CH is responsible for forwarding the data sent by all the nodes, it runs out of the deposited energy rapidly than the other nodes. Once the CH's energy becomes null, it is no longer capable of performing the task. Thus, the CH is said to be the dead node. On CH becoming a dead node, a sub-CH is selected, which is the second-highest energy node in the cluster, whose energy is measured in 'joules'.
LEACH aligns the nodes randomly in the network and also deposits an equal amount of energy in terms of joules to the randomly arranged nodes in the network. Practically, 5 out of 100 nodes are capable to become the CH. The collisions within the cluster and between the clusters can be controlled by adopting CSMA/CD techniques like TDMA-MAC.

1. Phases of LEACH

The LEACH operates in 2 phases scilicet, the first setup phase and the second one is the steady phase. The formation of cluster and selection of CH is carried out in the setup phase and the processing of data and its transmission to the base station is carried out in a steady phase.

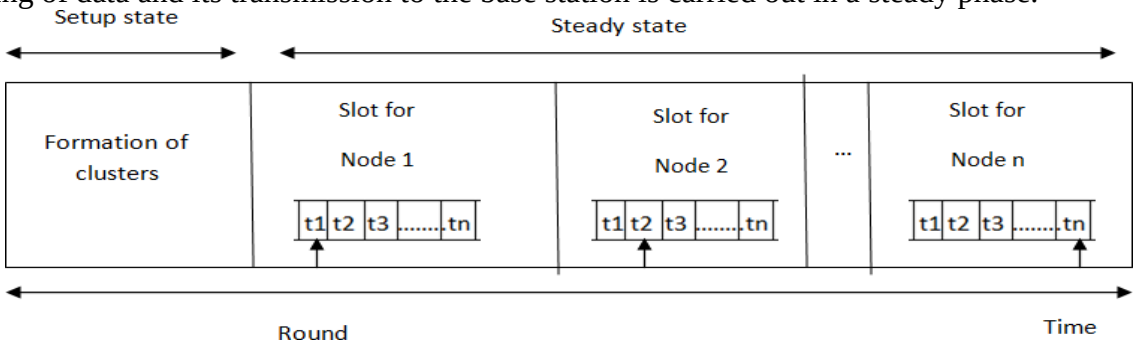

FIGURE 1: PHASES OF LEACH

The phases of LEACH are shown in figure 2. The clusters are formed during the setup phase. The TDMA slots are allotted for all the nodes during the steady-state. The node1 is allotted timeslot 't1', the node2 is allotted the timeslot 't2' and the node n is allotted timeslot 'tn' as depicted in the upper arrow in fig 2. The nodes send the packet during the allotted time slot.

Setup Phase

The cluster head is selected among the nodes with the probability 'P'. This election process is done by calculating the threshold energy value T(n). The T(n) relies on the percentage of CH probability selection. The 'r' is the present round. 'G' represents the node group, which was not elected as CH in

$$T(n) = \begin{cases} \dfrac{P}{1-P\,(r*\mathrm{mod}\,(1/P))} & ;\ n \in G \\ 0 & ;\ \text{else} \end{cases} \qquad \ldots\ldots\ldots(1)$$

the previous 1/P rounds [18].
Where,

P = The probability to become cluster head
r = Current round
n = Node
G = Node group

Every sensor node in the network wishes to gain the position of CH and possess the probability value in the range (0,1). Then T(n) is computed as illustrated in equation 1. If the probabilistic value selected by the nodes is less than that of T(n), then, for the particular round, the specific nodes emerge as CH [19].

Steady Phase
The nodes in the sensor network which aren't elected as CH do sense the data and forward the aggregated data to the CH in the allotted TDMA time slot. The CH sends the data received to the base station after a certain period, when the CH loses all its energy, a new CH is selected after completion of specific prioritized rounds, the new cluster head is chosen by returning to the setup phase. To avoid interference in sensor nodes, CDMA communication techniques are adopted.

2. **Algorithm**

Setup phase:

1. CN => r
2. If r > T(n) then, CH = CN else, go to step1
3. CH => G; id(CH), join_adv
4. A (j) -> CH (j); id(A(i)), id(CH(j)), join_req
5. CH (j) -> A(i) : id(CH(j)), <t(i), id(A(i))

Steady phase:

1. A(i) -> CH(j): id(A(CH(j))), info
2. A(i) -> CH(j): id(A(CH(j))), info

The various symbols used here are:

1. CN: Candidate node to become the cluster head.
2. r: random variable (0 > r > 1).
3. T(n): Threshold value.
4. CH: cluster head.
5. G: All nodes in the network.
6. id: Identification number.
7. Join_adv: Request to join the cluster.
8. A: normal node.

3. **Proposed LEACH (P-LEACH)**

A proposed LEACH protocol is implemented in a wireless cluster comprising of a CH, a gateway mode, base station, and cluster members [20]. Consider the WSN with the 100 nodes, which are positioned randomly in a 100*100 Sq. area, initially, CH is chosen by evaluating the node having the highest amount of energy in joules. The 0.5 is the assigned probability to the nodes to become CH in the wireless network in 100 rounds [21].
The cluster is organized and cluster members start sending data to CH and CH forwards it to the base station in the case of LEACH, CM sends the data to the nearest destination node, which is either a gateway or base station. This procedure has the superiority of reducing the load at the CH [22-24].

Consider the example scenario, where the network of 100*100 Sq. m. is created with 100 nodes in random positions within the network area. The network consists of two clusters, namely, cluster1 and cluster2.The nodes existing in the network are known as members. Every node in the respective clusters forwards the data to the respective cluster head in the network. Then the cluster head aggregates all the data received from cluster members, then forwards it to the gateway node, which is positioned at the center of the network area i.e., (50,50). The gateway node receives the data in the allotted time slot, then forwards it to the base station. Thus, the energy and bandwidth are saved [25-27].

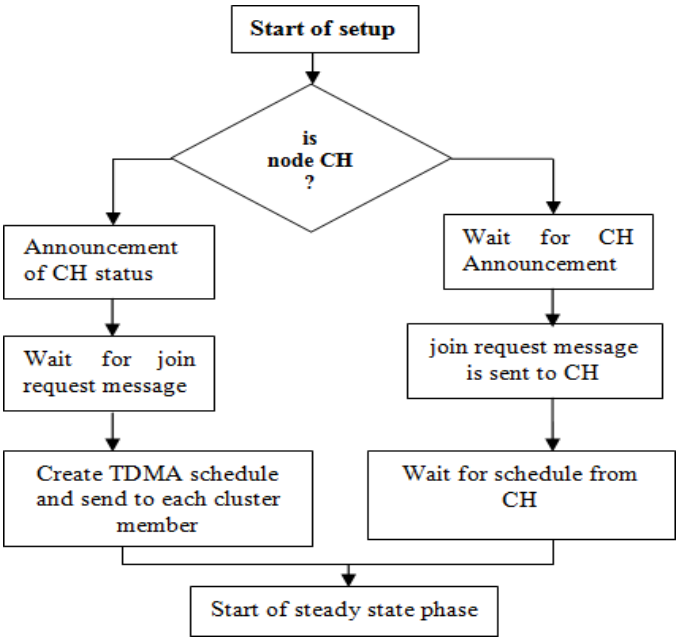

FIGURE 1: FLOWCHART OF SETUP PHASE OF LEACH

The flowchart of the setup phase of LEACH is shown in figure 3. The operation of the setup phase begins with the checking of whether the node is a cluster head or cluster member [28-31]. If the node is a cluster member, then it waits for the broadcast message of announcement of cluster head for that cluster [32-36]. On receiving the broadcast message, the cluster member sends a 'join request' message to the cluster head and waits for the cluster head to assign the time slot for data transmission. If the node is cluster head, then the node is announced as 'cluster head' to all the cluster members. The cluster head sits ideal until a 'join request' is encountered by its member to join the cluster. Once the cluster head is announced, the TDMA schedule is created and sent to all cluster members to send data I allotted time slots to the cluster head [30-32].

III. IMPLEMENTATION

The network congestion leads to the loss of data packets as the packet undergoes collision. To overcome this hurdle for maximum data transfer, the LEACH protocol is implemented. The following description interprets the implantation of protocol LEACH.

A. Network formation

A network is framed in an area of 100*100 sq. m by using the MATLAB simulation tool. The nodes are randomly created and positioned, where all the nodes are sensor nodes. The sink node is the base station node, which is positioned at (50,120). Gateway (GW) node act as an intermediate node between cluster head and sink node located at the position of (50,50). Two clusters isolate the

network into two segments namely, region R1 and region R2. A cluster is built up of several nodes randomly. All the nodes are initialized with an equal amount of energy of 0.5 joules.

Table 1: Boundaries of clusters

Cluster region R1	Cluster region R2
0<= x <30 ,0<=y<80	50<=X<70, 0<=y<30
30<x<=50, 0<=y<30	70<=X<100, 0<y<=80
30< x <=50, 70<= y < 80	50<x<=70, 70<y<80

B. Cluster formation

The network is viewed as a 2D rectangular plane with x & y coordinates governing the position of sensor nodes and boundaries of clusters with in the network.

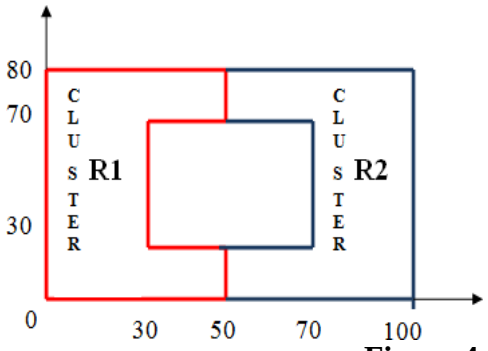

Figure 4: Cluster regions

The two clusters are configured in the network and are shown in figure 4. The coordinate values of the clusters i.e., the cluster boundaries are tabulated in table 1.

C. Cluster head selection

Among all the nodes, one node is elected as cluster head in each round. The number of rounds for CH selection is initialized to be 3000. The probability to become cluster head is initialized as 0.5. the threshold T (n) is measured by [33]:

$$T(n) = \begin{cases} \dfrac{P}{1-P\,(r*\mathrm{mod}\,(1/P))} & ; \; n \in G \\ 0 & ; \; \text{else} \end{cases} \qquad \ldots\ldots\ldots(2)$$

Where,

n: ranges between [0,1].
p: is the probability to become CH.
r: is the ongoing round.
The CH is elected according to this equation.

D. Distance calculation and protocol selection

If the assigned energy of the node is greater than 0, the node is considered to be an alive node, and packets are transferred to the respective base station. The reference distance d0 is found by [37-42].

$$E_{TX}(k,d) = \begin{cases} K \times E_{elec} + K \times E_{fs} \times d^2, & \text{if } d \le d_0 \\ K \times E_{elec} + K \times E_{mp} \times d^4, & \text{if } d \ge d_0 \end{cases} \quad \text{.....(3)}$$

$$d_0 = \sqrt{\frac{E_{mp}}{E_{fs}}} \quad \text{.....(4)}$$

Where,

Efs = Energy for free space routing.
Emp = Energy for multipath routing.
Eelec = Energy consumed to transmit or receive data.
d0 = Reference distance.
d = Distance from cluster head to base station.
K = Number of packets.

The distance from the cluster head node to the base station node is calculated. If this distance is found to be greater than d0 (d > d0) then multipath routing protocol (Emp) is incorporated, otherwise, free space routing protocol (Efs) is applied for routing (d <= d0).

E. Calculation of dead nodes and alive nodes

The node that has run out of all the energy will not be proficient in performing communication and routing is said to be a dead node, whose energy, E<0. The dead node flag dead_dir is initialized as '0'. The energy of the nodes is continuously monitored. In the process, the node with E <= 0 is considered to be a dead node, and the flag dead_dir is incremented by one to take the count of dead nodes.

At the end of all the rounds, the alive nodes are counted by finding the absolute difference between the total quantity of nodes in the network and dead nodes. These alive nodes are those nodes that are actively participating in the communication and routing [43-48].

F. Packet transmission to sink node

In the case of proposed LEACH, if the communication node is close to the sink node, the data packet can be directly transferred to the sink instead of routing it to sink via CH, taking into consideration the distance between node and sink as illustrated in equation 5.

$$dist = sqrt((Node_{X\text{-}pos} - Sink_{X\text{-}pos})^2 - (Node_{Y\text{-}pos} - Sink_{Y\text{-}pos})^2 \quad \text{.....(5)}$$

Where,

Nodex-pos – Location of the node concerning the x-axis.
Nodey-pos– Location of the node concerning the y-axis.
Sinkx-pos – Location of sink node concerning the x-axis.
Sinky-pos – Location of sink node with respect to y-axis.
dist> do – Multipath routing.
dist< do – Free space routing.

G. Packet transmission to the gateway

The gateway node act as a mediator between sink and CH to transfer the packet. Here, the data packets are directly transferred to the GW node instead of routing via CH, by taking the distance between node and GW as illustrated in equation 6 [39].

$$dist = sqrt((Node_{X\text{-}pos} - GW_{X\text{-}pos})^2 - (Node_{Y\text{-}pos} - GW_{Y\text{-}pos})^2 \quad \ldots\ldots(6)$$

Where,

Nodex-pos – Location of node with respect to x-axis.
Nodey-pos – Location of node with respect to y-axis.
GWx-pos– Location of gateway node with respect to x-axis
GWy-pos – location of gateway node with respect to y-axis
dist> d0 – Multipath routing.
dist< d0 – Free space routing.

IV. CONCLUSION

Clustering is the proficient plan for organizing the network by aggregating the data from the nodes in the network. The network is compiled into clusters, in which one node is designated as cluster head (CH) for each clustering the sensor network. Once the sensor node transmits lump data to the BS. This results in wastage by adopting the load balancing technique at various intervals.
The simulation of the wireless sensor network is carried out in the MATLAB tool. A hundred nodes are positioned randomly in 100*100 sq. m area. The network is split into two clusters and a cluster head is selected for each cluster. The graphical analysis of the death of several nodes concerning the number of rounds, number of alive nodes concerning the number of rounds, and energy of nodes concerning the number of rounds are carried out. The proposed LEACH operates in such a way that the energy of the nodes is preserved for a longer time than that of the existing LEACH and the network lifetime is considerably expanded. Thus, the proposed LEACH is found to be more efficient than the existing LEACH.

REFERENCES

[1] Puttamadappa, C., and B. D. Parameshachari. "Demand side management of small scale loads in a smart grid using glow-worm swarm optimization technique." Microprocessors and Microsystems 71 (2019): 102886.
[2] Prabu, S., M. Lakshmanan, and V. Noor Mohammed. "A multimodal authentication for biometric recognition system using intelligent hybrid fusion techniques." Journal of medical systems 43, no. 8 (2019): 1-9.
[3] S. Shanthi, Padmalaya Nayak, Sujatha Dandu: “Minimization Of Energy Consumption In Wireless Sensor Network By Using A Special Mobile Agent.”, In Ashleigh S. Boyd, Editor, Immunological Tolerance, Volume 1899, Pages 359-368. Springer New York, New York, NY, 2019.
[4] Hu, Liwen, Ngoc-Tu Nguyen, Wenjin Tao, Ming C. Leu, Xiaoqing Frank Liu, Md Rakib Shahriar, and SM Nahian Al Sunny. "Modeling of cloud-based digital twins for smart manufacturing with MT connect." Procedia manufacturing 26 (2018): 1193-1203.
[5] Dwivedi, R., Dey, S., Chakraborty, C. and Tiwari, S., 2021. Grape disease detection network based on multi-task learning and attention features. IEEE Sensors Journal.
[6] Shivappriya, S. N., S. Karthikeyan, S. Prabu, R. Pérez de Prado, and B. D. Parameshachari. "A modified ABC-SQP-based combined approach for the optimization of a parallel hybrid electric vehicle." Energies 13, no. 17 (2020): 4529.
[7] Patil Anil Kumar And Dr. P M Hadalagi: “Survey Of Routing Protocols In Wireless Sensor Networks”, Page 10.

[8] Subramani, Prabu, Ganesh Babu Rajendran, Jewel Sengupta, Rocío Pérez de Prado, and Parameshachari Bidare Divakarachari. "A block bi-diagonalization-based pre-coding for indoor multiple-input-multiple-output-visible light communication system." Energies 13, no. 13 (2020): 3466.
[9] Kumar, M. Keerthi, B. D. Parameshachari, S. Prabu, and Silvia liberata Ullo. "Comparative Analysis to Identify Efficient Technique for Interfacing BCI System." In IOP Conference Series: Materials Science and Engineering, vol. 925, no. 1, p. 012062. IOP Publishing, 2020.
[10] Chunyao Fu, Zhifang Jiang, W. E. I. Wei, Ang Wei: "An Energy Balanced Algorithm Of LEACH Protocol In WSN". International Journal Of Computer Science Issues (IJCSI), 10(1):354, 2013.
[11] Babu, N.V., 2014. Design and performance analysis of clustering mechanisms for wireless sensor networks.
[12] Vu, D.L., Nguyen, T.K., Nguyen, T.V., Nguyen, T.N., Massacci, F. and Phung, P.H., 2020. HIT4Mal: Hybrid image transformation for malware classification. Transactions on Emerging Telecommunications Technologies, 31(11), p.e3789.
[13] Liu, Bing-Hong, Ngoc-Tu Nguyen, Van-Trung Pham, and Yue-Xian Lin. "Novel methods for energy charging and data collection in wireless rechargeable sensor networks." International Journal of Communication Systems 30, no. 5 (2017): e3050.
[14] W.R.Heinzelman, A.Chandrakasan, And H. Balakrishnan: "Energy-Efficient Communication Protocol For Wireless Microsensor Networks", In Proceedings Of The 33rd Annual Hawaii International Conference On System Sciences, Volume Vol.1, Page 10, Maui, HI, USA, 2000. IEEE Comput. Soc.
[15] Alka Singh And Sandeep Kade: "LEACH Based Energy Efficient Routing Protocol For WSN", International Conference On Electrical, Electronics, And Optimization Techniques (ICEEOT) – 2017.
[16] Lingappa, H., Suresh, H. and Manvi, S., 2018. Medical image segmentation based on extreme learning machine algorithm in kernel fuzzy c-means using artificial bee colony method. Int. J. Intell. Eng. Syst, 11, pp.128-136.
[17] Rashmi Jain And Manali Kshirsagar: "Analysis Of Setup Energy Of Leach Protocol For Wireless Sensor Network", International Journal Of Scientific & Engineering Research, Volume 7, Issue 5, May-2017 ISSN 2229-5518.
[18] Parameshachari, B. D., Rashmi P. Kiran, P. Rashmi, M. C. Supriya, Rajashekarappa, and H. T. Panduranga. "Controlled partial image encryption based on LSIC and chaotic map." In ICCSP, pp. 60-63. 2019.
[19] Yassin: "Improvement On LEACH Protocol Of Wireless Sensor Network (VLEACH)", International Journal Of Digital Content: Technology And Its Applications, 3(2), 2009.
[20] Layla Aziz, Said Raghay, HananeAznaoui, And Abdellah Jamali: "A New Enhanced Version Of VLEACH Protocol Using A Smart Path Selection", International Journal Of GEOMATE, 12(30): 28-34, 2017.
[21] Prabu, S., Balamurugan, V. and Vengatesan, K., 2019. Design of cognitive image filters for suppression of noise level in medical images. Measurement, 141, pp.296-301.
[22] Nguyen, Ngoc-Tu, and Bing-Hong Liu. "The mobile sensor deployment problem and the target coverage problem in mobile wireless sensor networks are NP-hard." IEEE Systems Journal 13, no. 2 (2018): 1312-1315.
[23] Muhammad, L.J., Algehyne, E.A., Usman, S.S., Ahmad, A., Chakraborty, C. and Mohammed, I.A., 2021. Supervised machine learning models for prediction of COVID-19 infection using epidemiology dataset. SN computer science, 2(1), pp.1-13.
[24] S. B. Bore Gowda and G. Nayak Subramanya DUCA: "An approach to Elongate the lifetime of wireless sensor nodes.", In Kanad Ray, S. N. Jain, Sumit Srivastava, and Anirban Bandyopadhyay, editors, Engineering Vibration, Communication and Information Processing, volume 478, page 329-337. Springer Singapore, Singapore, 2019.

[25] Rajendran, Ganesh B., Uma M. Kumarasamy, Chiara Zarro, Parameshachari B. Divakarachari, and Silvia L. Ullo. "Land-use and land-cover classification using a human group-based particle swarm optimization algorithm with an LSTM Classifier on hybrid pre-processing remote-sensing images." Remote Sensing 12, no. 24 (2020): 4135.
[26] Bilal Jan, Haleem Farman, Huma Javed, Bartolomeo Montrucchio, Murad Khan, And Shaukat Ali: Energy Efficient Hierarchical Clustering Approaches In Wireless Sensor Networks: A Survey. Wireless Communications And Mobile Computing, 2017:1-14, 2017.
[27] J. Xu, N. Jin, X. Lou, T.Peng, Q. Zhou, And Y. Chen: "Improvement Of Leach Protocol For Wsn", In 2019 9th International Conference On Uzzy System And Knowledge Discovery, Pages 2174-2177, May 2012.
[28] Jia Xu And Ning Jin, "Improvement Of LEACH Protocol For WSN", 9th International Conference On Fuzzy Systems And Knowledge Discovery, 2017
[29] Malka N. Halgamuge And SiddeswaraMayura Guru: "Energy Efficient Cluster Formation In Wireless Sensor Networks", IEEE, 2018.
[30] Parameshachari, B.D., Panduranga, H.T. and liberata Ullo, S., 2020, September. Analysis and Computation of Encryption Technique to Enhance Security of Medical Images. In IOP Conference Series: Materials Science and Engineering (Vol. 925, No. 1, p. 012028). IOP Publishing.
[31] Ngo, T.D., Bui, T.T., Pham, T.M., Thai, H.T., Nguyen, G.L. and Nguyen, T.N., 2021. Image deconvolution for optical small satellite with deep learning and real-time GPU acceleration. Journal of Real-Time Image Processing, pp.1-14.
[32] Hemalatha, K. L., SUNILKUMAR MANVI, and HN SURESH. "ADAPTIVE WEIGHTED-COVARIANCE REGULARIZED KERNEL FUZZY C MEANS ALGORITHM FOR MEDICAL IMAGE SEGMENTATION." Journal of Theoretical & Applied Information Technology 95, no. 14 (2017).
[33] Babu, R.G., Maheswari, K.U., Zarro, C., Parameshachari, B.D. and Ullo, S.L., 2020. Land-Use and Land-Cover Classification Using a Human Group-Based Particle Swarm Optimization Algorithm with an LSTM Classifier on Hybrid Pre-Processing Remote-Sensing Images. Remote Sensing, 12(24), p.4135.
[34] Shahriar, Md Rakib, SM Nahian Al Sunny, Xiaoqing Liu, Ming C. Leu, Liwen Hu, and Ngoc-Tu Nguyen. "MTComm based virtualization and integration of physical machine operations with digital-twins in cyber-physical manufacturing cloud." In 2018 5th IEEE International Conference on Cyber Security and Cloud Computing (CSCloud)/2018 4th IEEE International Conference on Edge Computing and Scalable Cloud (EdgeCom), pp. 46-51. IEEE, 2018.
[35] Nayak, Jithendra PR, K. Anitha, B. D. Parameshachari, Reshma Banu, and P. Rashmi. "PCB Fault detection using Image processing." In IOP Conference Series: Materials Science and Engineering, vol. 225, no. 1, p. 012244. IOP Publishing, 2017.
[36] Hemalatha, K. L., S. M. Ashitha, and S. R. Meghana. "Design and implementation of modified FCM in the detection of brain tumor." Int. J. Adv. Sci. Res. Eng 3, no. 4 (2017): 2850-2858.
[37] Nguyen, N.T., Liu, B.H., Chu, S.I. and Weng, H.Z., 2018. Challenges, designs, and performances of a distributed algorithm for minimum-latency of data-aggregation in multi-channel WSNs. IEEE Transactions on Network and Service Management, 16(1), pp.192-205.
[38] Rajendrakumar, Shiny, and V. K. Parvati. "Automation of irrigation system through embedded computing technology." In Proceedings of the 3rd International Conference on Cryptography, Security and Privacy, pp. 289-293. 2019.
[39] Nguyen, Tu N., Bing-Hong Liu, Nam P. Nguyen, and Jung-Te Chou. "Cyber security of smart grid: attacks and defenses." In ICC 2020-2020 IEEE International Conference on Communications (ICC), pp. 1-6. IEEE, 2020.[39]
[40] F. Ding, G. Zhu, M. Alazab, X. Li, and K. Yu, "Deep-Learning-Empowered Digital Forensics for Edge Consumer Electronics in 5G HetNets", IEEE Consumer Electronics Magazine, doi: 10.1109/MCE.2020.3047606.

[41] W. Zeng, Z. Guo, Y. Shen, A. K. Bashir, K. Yu, Y. D. Al-Otaibi, and X. Gao, "Data-Driven Management for Fuzzy Sewage Treatment Processes Using Hybrid Neural Computing", Neural Computing and Applications, https://doi.org/10.1007/s00521-020-05655-3.
[42]
[43]
[44] S. Chen, L. Zhang, Y. Tang, C. Shen, R. Kumar, K. Yu, U. Tariq, and A. K. Bashir, "Indoor Temperature Monitoring Using Wireless Sensor Networks: A SMAC Application in Smart Cities", Sustainable Cities and Society, vol. 61, p. 102333, July 2020
[45] K. Yu, L. Tan, M. Aloqaily, H. Yang, and Y. Jararweh, "Blockchain-Enhanced Data Sharing with Traceable and Direct Revocation in IIoT", IEEE Transactions on Industrial Informatics, doi: 10.1109/TII.2021.3049141.
[46] K. Yu, L. Lin, M. Alazab, L. Tan, B. Gu, "Deep Learning-Based Traffic Safety Solution for a Mixture of Autonomous and Manual Vehicles in a 5G-Enabled Intelligent Transportation System", IEEE Transactions on Intelligent Transportation Systems, doi: 10.1109/TITS.2020.3042504.
[47] K. Yu, M. Arifuzzaman, Z. Wen, D. Zhang and T. Sato, "A Key Management Scheme for Secure Communications of Information Centric Advanced Metering Infrastructure in Smart Grid," IEEE Transactions on Instrumentation and Measurement, vol. 64, no. 8, pp. 2072-2085, August 2015.
[48] Z. Guo, K. Yu, Y. Li, G. Srivastava, and J. C. -W. Lin, "Deep Learning-Embedded Social Internet of Things for Ambiguity-Aware Social Recommendations", IEEE Transactions on Network Science and Engineering, doi: 10.1109/TNSE.2021.3049262.
[49] K. Yu, L. Tan, L. Lin, X. Cheng, Z. Yi and T. Sato, "Deep-Learning-Empowered Breast Cancer Auxiliary Diagnosis for 5GB Remote E-Health," IEEE Wireless Communications, vol. 28, no. 3, pp. 54-61, June 2021, doi: 10.1109/MWC.001.2000374.
[50] K. Yu, L. Tan, S. Mumtaz, S. Al-Rubaye, A. Al-Dulaimi, A. K. Bashir, F. A. Khan, "Securing Critical Infrastructures: Deep Learning-based Threat Detection in the IIoT", IEEE Communications Magazine, 2021.