

Lecture Notes in Networks and Systems 371

Pandian Vasant

Ivan Zelinka

Gerhard-Wilhelm Weber *Editors*

Intelligent Computing & Optimization

Proceedings of the 4th International
Conference on Intelligent Computing
and Optimization 2021 (ICO2021)

 Springer

Contents

Sustainable Artificial Intelligence Applications

Low-Light Image Enhancement with Artificial Bee Colony Method	3
Anan Banharnsakun	
Optimal State-Feedback Controller Design for Tractor Active Suspension System via Lévy-Flight Intensified Current Search Algorithm	14
Thitipong Niyomsat, Wattanawong Romsai, Auttarat Nawikavatan, and Deacha Puangdownreong	
The Artificial Intelligence Platform with the Use of DNN to Detect Flames: A Case of Acoustic Extinguisher	24
Stefan Ivanov and Stanko Stankov	
Adaptive Harmony Search for Cost Optimization of Reinforced Concrete Columns	35
Aylin Ece Kayabekir, Sinan Melih Nigdeli, and Gebrail Bekdaş	
Efficient Traffic Signs Recognition Based on CNN Model for Self-Driving Cars	45
Said Gadri and Nour ElHouda Adouane	
Optimisation and Prediction of Glucose Production from Oil Palm Trunk via Simultaneous Enzymatic Hydrolysis	55
Chan Mieow Kee, Wang Chan Chin, Tee Hoe Chun, and Nurul Adela Bukhari	
Synthetic Data Augmentation of Cycling Sport Training Datasets	65
Iztok Fister, Grega Vrbančič, Vili Podgorelec, and Iztok Fister Jr.	
Hybrid Pooling Based Convolutional Neural Network for Multi-class Classification of MR Brain Tumor Images	75
Gazi Jannatul Ferdous, Khaleda Akhter Sathi, and Md. Azad Hossain	

Importance of Fuzzy Logic in Traffic and Transportation Engineering	87
Aditya Singh	
A Fuzzy Based Clustering Approach to Prolong the Network Lifetime in Wireless Sensor Networks	97
Enaam A. Al-Hussain and Ghaida A. Al-Suhail	
Visual Expression Analysis from Face Images Using Morphological Processing	108
Md. Habibur Rahman, Israt Jahan, and Yeasmin Ara Akter	
Detection of Invertebrate Virus Carriers Using Deep Learning Networks to Prevent Emerging Pandemic-Prone Disease in Tropical Regions	120
Daeniel Song Tze Hai, J. Joshua Thomas, Justina Anantha Jothi, and Rasslenda-Rass Rasalingam	
Classification and Detection of Plant Leaf Diseases Using Various Deep Learning Techniques and Convolutional Neural Network	132
Partha P. Mazumder, Monuar Hossain, and Md Hasnat Riaz	
Deep Learning and Machine Learning Applications	
Distributed Self-triggered Optimization for Multi-agent Systems	145
Komal Mehmood and Maryam Mehmood	
Automatic Categorization of News Articles and Headlines Using Multi-layer Perceptron	155
Fatima Jahara, Omar Sharif, and Mohammed Moshiul Hoque	
Using Machine Learning Techniques for Estimating the Electrical Power of a New-Style of Savonius Rotor: A Comparative Study	167
Youssef Kassem, Hüseyin Çamur, Gokhan Burge, Adivhaho Frene Netshimbupfe, Elhamam A. M. Sharfi, Binnur Demir, and Ahmed Muayad Rashid Al-Ani	
Tree-Like Branching Network for Multi-class Classification	175
Mengqi Xue, Jie Song, Li Sun, and Mingli Song	
Multi-resolution Dense Residual Networks with High-Modularization for Monocular Depth Estimation	185
Din Yuen Chan, Chien-I Chang, Pei Hung Wu, and Chung Ching Chiang	
A Decentralized Federated Learning Paradigm for Semantic Segmentation of Geospatial Data	196
Yash Khasgiwala, Dion Trevor Castellino, and Sujata Deshmukh	

Development of Contact Angle Prediction for Cellulosic Membrane . . .	207
Ahmad Azharuddin Azhari bin Mohd Amiruddin, Mieow Kee Chan, and Sokchoo Ng	
Feature Engineering Based Credit Card Fraud Detection for Risk Minimization in E-Commerce	217
Md. Moinul Islam, Rony Chowdhury Ripan, Saralya Roy, and Fazle Rahat	
DCNN-LSTM Based Audio Classification Combining Multiple Feature Engineering and Data Augmentation Techniques	227
Md. Moinul Islam, Monjurul Haque, Saiful Islam, Md. Zesun Ahmed Mia, and S. M. A. Mohaiminur Rahman	
Sentiment Analysis: Developing an Efficient Model Based on Machine Learning and Deep Learning Approaches	237
Said Gadri, Safia Chabira, Sara Ould Mehieddine, and Khadidja Herizi	
Improved Face Detection System	248
Ratna Chakma, Juel Sikder, and Utpol Kanti Das	
Paddy Price Prediction in the South-Western Region of Bangladesh . . .	258
Juliet Polok Sarkar, M. Raihan, Avijit Biswas, Khandkar Asif Hossain, Keya Sarder, Nilanjana Majumder, Suriya Sultana, and Kajal Sana	
Paddy Disease Prediction Using Convolutional Neural Network	268
Khandkar Asif Hossain, M. Raihan, Avijit Biswas, Juliet Polok Sarkar, Suriya Sultana, Kajal Sana, Keya Sarder, and Nilanjana Majumder	
Android Malware Detection System: A Machine Learning and Deep Learning Based Multilayered Approach	277
Md Shariar Hossain and Md Hasnat Riaz	
IOTs, Big Data, Block Chain and Health Care	
Blockchain as a Secure and Reliable Technology in Business and Communication Systems	291
Vedran Juričić, Danijel Kučak, and Goran Đambić	
iMedMS: An IoT Based Intelligent Medication Monitoring System for Elderly Healthcare	302
Khalid Ibn Zinnah Apu, Mohammed Moshiul Hoque, and Iqbal H. Sarker	
Internet Banking and Bank Investment Decision: Mediating Role of Customer Satisfaction and Employee Satisfaction	314
Jean Baptiste Bernard Pea-Assounga and Mengyun Wu	

Inductions of Usernames' Strengths in Reducing Invasions on Social Networking Sites (SNSs)	331
Md. Mahmudur Rahman, Shahadat Hossain, Mimun Barid, and Md. Manzurul Hasan	
Tomato Leaf Disease Recognition Using Depthwise Separable Convolution	341
Syed Md. Minhaz Hossain, Khaleque Md. Aashiq Kamal, Anik Sen, and Kaushik Deb	
End-to-End Scene Text Recognition System for Devanagari and Bengali Text	352
Prithwish Sen, Anindita Das, and Nilkanta Sahu	
A Deep Convolutional Neural Network Based Classification Approach for Sleep Scoring of NFLE Patients	360
Sarker Safat Mahmud, Md. Rakibul Islam Prince, Md. Shamim, and Sarker Shahriar Mahmud	
Remote Fraud and Leakage Detection System Based on LPWAN System for Flow Notification and Advanced Visualization in the Cloud	370
Dario Protulipac, Goran Djambic, and Leo Mršić	
An Analysis of AUGMECON2 Method on Social Distance-Based Layout Problems	381
Şeyda Şimşek, Eren Özceylan, and Neşe Yalçın	
An Intelligent Information System and Application for the Diagnosis and Analysis of COVID-19	391
Atif Mehmood, Ahed Abugabah, Ahmad A. L. Smadi, and Reyad Alkhawaldeh	
Hand Gesture Recognition Based Human Computer Interaction to Control Multiple Applications	397
Sanzida Islam, Abdul Matin, and Hafsa Binte Kibria	
Towards Energy Savings in Cluster-Based Routing for Wireless Sensor Networks	407
Enaam A. Al-Hussain and Ghaida A. Al-Suhail	
Utilization of Self-organizing Maps for Map Depiction of Multipath Clusters	417
Jonnell Alejandrino, Emmanuel Trinidad, Ronnie Concepcion II, Edwin Sybingco, Maria Gemel Palconit, Lawrence Materum, and Elmer Dadios	

Big Data for Smart Cities and Smart Villages: A Review	427
Tajnim Jahan, Sumayea Benta Hasan, Nuren Nafisa, Afsana Akther Chowdhury, Raihan Uddin, and Mohammad Shamsul Arefin	
A Compact Radix-Trie: A Character-Cell Compressed Trie Data-Structure for Word-Lookup System	440
Rahat Yeasin Emon and Sharmistha Chanda Tista	
Digital Twins and Blockchain: Empowering the Supply Chain	450
Jose Eduardo Aguilar-Ramirez, Jose Antonio Marmolejo-Saucedo, and Roman Rodriguez-Aguilar	
Detection of Malaria Disease Using Image Processing and Machine Learning	457
Md. Maruf Hasan, Sabiha Islam, Ashim Dey, Annesha Das, and Sharmistha Chanda Tista	
Fake News Detection of COVID-19 Using Machine Learning Techniques	467
Promila Ghosh, M. Raihan, Md. Mehedi Hassan, Laboni Akter, Sadika Zaman, and Md. Abdul Awal	
Sustainable Modelling, Computing and Optimization	
1D HEC-RAS Modeling Using DEM Extracted River Geometry - A Case of Purna River; Navsari City; Gujarat, India	479
Azazkhan Ibrahimkhan Pathan, P. G. Agnihotri, D. Kalyan, Daryosh Frozan, Muqadar Salihi, Shabir Ahmad Zareer, D. P. Patel, M. Arshad, and S. Joseph	
A Scatter Search Algorithm for the Uncapacitated Facility Location Problem	488
Telmo Matos	
An Effective Dual-RAMP Algorithm for the Capacitated Facility Location Problem	495
Telmo Matos	
Comparative Study of Blood Flow Through Normal, Stenosis Affected and Bypass Grafted Artery Using Computational Fluid Dynamics	503
Anirban Banik, Tarun Kanti Bandyopadhyay, and Vladimir Panchenko	
Transportation Based Approach for Solving the Generalized Assignment Problem	513
Elias Munapo	

Generalized Optimization: A First Step Towards Category Theoretic Learning Theory	525
Dan Shiebler	
Analysis of Non-linear Structural Systems via Hybrid Algorithms	536
Sinan Melih Nigdeli, Gebrail Bekdaş, Melda Yücel, Aylin Ece Kayabekir, and Yusuf Cengiz Toklu	
Ising Model Formulation for Job-Shop Scheduling Problems Based on Colored Timed Petri Nets	546
Kohei Kaneshima and Morikazu Nakamura	
Imbalanced Sample Generation and Evaluation for Power System Transient Stability Using CTGAN	555
Gengshi Han, Shunyu Liu, Kaixuan Chen, Na Yu, Zunlei Feng, and Mingli Song	
Efficient DC Algorithm for the Index-Tracking Problem	566
F. Hooshmand and S. A. MirHassani	
Modelling External Debt Using VECM and GARCH Models	577
Naledi Blessing Mokoena, Johannes Tshepiso Tsoku, and Martin Chanza	
Optimization of Truss Structures with Sizing of Bars by Using Hybrid Algorithms	592
Melda Yücel, Gebrail Bekdaş, and Sinan Melih Nigdeli	
Information Extraction from Receipts Using Spectral Graph Convolutional Network	602
Bui Thanh Hung	
An Improved Shuffled Frog Leaping Algorithm with Rotating and Position Sequencing in 2-Dimension Shapes for Discrete Optimization	613
Kanchana Daoden	
Lean Procurement in an ERP Cloud Base	623
Adrian Chin-Hernandez, Jose Antonio Marmolejo-Saucedo, and Jania Saucedo-Martinez	
An Approximate Solution Proposal to the Vehicle Routing Problem Through Simulation-Optimization Approach	634
Jose Antonio Marmolejo-Saucedo and Armando Calderon Osornio	
Hybrid Connectionist Models to Investigate the Effects on Petrophysical Variables for Permeability Prediction	647
Mohammad Islam Miah and Mohammed Adnan Noor Abir	

Sustainable Environmental, Social and Economics Development

Application of Combined SWOT and AHP Analysis to Assess the Reality and Select the Priority Factors for Social and Economic Development (a Case Study for Soc Trang City)	659
Dang Trung Thanh and Nguyen Huynh Anh Tuyet	
Design and Analysis of Water Distribution Network Using Epanet 2.0 and Loop 4.0 – A Case Study of Narangi Village	671
Usman Mohseni, Azazkhan I. Pathan, P. G. Agnihotri, Nilesh Patidar, Shabir Ahmad Zareer, D. Kalyan, V. Saran, Dhruvesh Patel, and Cristina Prieto	
Effect of Climate Change on Sea Level Rise with Special Reference to Indian Coastline	685
Dummu Kalyan, Azazkhan Ibrahimkhan Pathan, P. G. Agnihotri, Mohammad Yasin Azimi, Daryosh Frozan, Joseph Sebastian, Usman Mohseni, Dhruvesh Patel, and Cristina Prieto	
Design and Analysis of Water Distribution Network Using Watergems – A Case Study of Narangi Village	695
Usman Mohseni, Azazkhan I. Pathan, P. G. Agnihotri, Nilesh Patidar, Shabir Ahmad Zareer, V. Saran, and Vaishali Rana	
Weight of Factors Affecting Sustainable Urban Agriculture Development (Case Study in Thu Dau Mot Smart City)	707
Trung Thanh Dang, Quang Minh Vo, and Thanh Vu Pham	
Factors Behind the World Crime Index: Some Parametric Observations Using DBSCAN and Linear Regression	718
Shahadat Hossain, Md. Manzurul Hasan, Md. Mahmudur Rahman, and Mimun Barid	
Object Detection in Foggy Weather Conditions	728
Prithwish Sen, Anindita Das, and Nilkanta Sahu	
Analysis and Evaluation of TripAdvisor Data: A Case of Pokhara, Nepal	738
Tan Wenan, Deepanjali Shrestha, Bijay Gaudel, Neesha Rajkarnikar, and Seung Ryul Jeong	
Simulation of the Heat and Mass Transfer Occurring During Convective Drying of Mango Slices	751
Ripa Muhury, Ferdusee Akter, and Ujjwal Kumar Deb	
A Literature Review on the MPPT Techniques Applied in Wind Energy Harvesting System	762
Tigilu Mitiku and Mukhdeep Singh Manshahia	

Developing a System to Analyze Comments of Social Media and Identify Friends Category	773
Tasfia Hyder, Rezaul Karim, and Mohammad Shamsul Arefin	
Comparison of Watershed Delineation and Drainage Network Using ASTER and CARTOSAT DEM of Surat City, Gujarat	788
Arbaaz A. Shaikh, Azazkhan I. Pathan, Sahita I. Waikhom, and Praveen Rathod	
Numerical Investigation of Natural Convection Combined with Surface Radiation in a Divided Cavity Containing Air and Water	801
Zouhair Charqui, Lahcen El Moutaouakil, Mohammed Boukendil, Rachid Hidki, and Zaki Zrikem	
Key Factors in the Successful Integration of the Circular Economy Approach in the Industry of Non-durable Goods: A Literature Review	812
Marcos Jacinto-Cruz, Román Rodríguez-Aguilar, and Jose-Antonio Marmolejo-Saucedo	
Profile of the Business Science Professional for the Industry 4.0	820
Antonia Paola Salgado-Reyes and Roman Rodríguez-Aguilar	
Rainfall-Runoff Simulation and Storm Water Management Model for SVNIT Campus Using EPA SWMM 5.1	832
Nitin Singh Kachhawa, Prasit Girish Agnihotri, and Azazkhan Ibrahimkhan Pathan	
Emerging Smart Technology Applications	
Evaluation and Customized Support of Dynamic Query Form Through Web Search	845
B. Bazeer Ahamed and Murugan Krishnamurthy	
Enhancing Student Learning Productivity with Gamification-Based E-learning Platform: Empirical Study and Best Practices	857
Danijel Kučak, Adriana Biuk, and Leo Mršić	
Development of Distributed Data Acquisition System	867
Bertram Losper, Vipin Balyan, and B. Groenewald	
Images Within Images? A Multi-image Paradigm with Novel Key-Value Graph Oriented Steganography	879
Subhrangshu Adhikary	
Application of Queuing Theory to Analyse an ATM Queuing System	888
Kolentino N. Mpeta and Otsile R. Selaotswe	

A Novel Prevention Technique Using Deep Analysis Intruder Tracing with a Bottom-Up Approach Against Flood Attacks in VoIP Systems	893
Sheeba Armoogum and Nawaz Mohamudally	
Data Mining for Software Engineering: A Survey	905
Maisha Maimuna, Nafiza Rahman, Razu Ahmed, and Mohammad Shamsul Arefin	
Simulation of Load Absorption and Deflection of Helical Suspension Spring: A Case of Finite Element Method	917
Rajib Karmaker, Shipan Chandra Deb Nath, and Ujjwal Kumar Deb	
Prediction of Glucose Concentration Hydrolysed from Oil Palm Trunks Using a PLSR-Based Model	927
Wan Sieng Yeo, Mieow Kee Chan, and Nurul Adela Bukhari	
Ontology of Lithography-Based Processes in Additive Manufacturing with Focus on Ceramic Materials	938
Marc Gmeiner, Wilfried Lepuschitz, Munir Merdan, and Maximilian Lackner	
Natural Convection and Surface Radiation in an Inclined Square Cavity with Two Heat-Generating Blocks	948
Rachid Hidki, Lahcen El Moutaouakil, Mohammed Boukendil, Zouhair Charqui, and Abdelhalim Abdelbaki	
Improving the Route Selection for Geographic Routing Using Fuzzy-Logic in VANET	958
Israa A. Aljabry and Ghaida A. Al-Suhail	
Trends and Techniques of Biomedical Text Mining: A Review	968
Maliha Rashida, Fariha Iffath, Rezaul Karim, and Mohammad Shamsul Arefin	
Electric Vehicles as Distributed Micro Generation Using Smart Grid for Decision Making: Brief Literature Review	981
Julieta Sanchez-García, Román Rodríguez-Aguilar, and Jose Antonio Marmolejo-Saucedo	
A Secured Network Layer and Information Security for Financial Institutions: A Case Study	992
Md Rahat Ibne Sattar, Shrabonti Mitra, Sadia Sultana, Umme Salma Pushpa, Dhruva Bhattacharjee, Abhijit Pathak, and Mayeen Uddin Khandaker	
Author Index	1003



Towards Energy Savings in Cluster-Based Routing for Wireless Sensor Networks

Enaam A. Al-Hussain^(✉) and Ghaida A. Al-Suhail

Department of Computer Engineering, University of Basrah, Basrah, Iraq
enaam.mansor@uobasrah.edu.iq

Abstract. Wireless Sensor Networks (WSNs) are mainly composed of a number of Sensor Nodes (SNs) that gather data from their physical surroundings and transmit it to the Base Station (BS). These sensors, however, have several limitations, including limited memory, limited computational capability, relatively limited processing capacity, and most crucially limited battery power. Upon these restricted resources, clustering techniques are mainly utilized to reduce the energy consumption of WSNs and consequently enhance their performance. The Low Energy Adaptive Clustering Hierarchy (LEACH) protocol serves as a good benchmark for clustering techniques in WSNs. Despite LEACH retains energy from sensor nodes, its energy efficiency is still considerably compromised due to unpredictable and faster power draining. Therefore, the goal of this paper focuses on how the LEACH protocol may be used effectively in the field of environmental monitoring systems to address issues about energy consumption, efficiency, stability, and throughput in a realistic simulation environment. The realistic performance analysis and parameter tuning were carried out utilizing the OMNET++/Castalia Simulator to serve as a baseline for future developments.

Keywords: WSNs · LEACH · Clustering · Energy efficiency · OMNET · Castalia

1 Introduction

Recently, Wireless sensor networks (WSNs) have been regarded as a significant research area due to their critical involvement in a variety of applications. Wireless sensor nodes collect data, analyze it for optimization, and then send it to the sink via a network of intermediary nodes. The network of these nodes as a whole constitutes the wireless sensor network, which is capable of organizing data and transmitting it to the requester (sink) [1]. Meanwhile, energy efficiency is still a critical problem in the design of WSN's routing protocol according to resource constraints and the non-rechargeability of resources for sensor nodes [2, 3].

Notably, clustering approach is widely used approach for managing the topology of WSNs, since it may significantly enhance the network's performance. It can make nodes in groups according to predefined criteria such as ensuring QoS, optimizing resource requirements, and balancing network load. A leader node which manages each cluster is called Cluster Head (CH). This node is responsible for data collection from

cluster members (CMs) and transmitting it to the Base Station. Clustering techniques eliminate the need for resource-constrained nodes to transfer data directly to gateways (sinks), which results in energy depletion, inefficient resource utilization, and interference.

Numerous studies on energy efficiency and data collection for cluster-based routing algorithms have been conducted [4–7]. The most of these strategies consist of two phases: (i) Setup phase and (ii) Steady-State phase. The first phase involves the selection and formation of CHs, as well as the assignment of a TDMA schedule to member nodes by the CH [8]. Meanwhile, the former phase is responsible for transmitting the identifiable data to their CHs via a specified TDMA slot allocated by the setup phase's CH. Then, the CHs collect the data from CMs and transfer it to the Base Station.

Several LEACH, PEGASIS, TEEN, APTEEN, and HEED protocols [9–12] are devoted as the primary hierarchical routing protocols in WSN. Each has numerous variants that are adapted to certain applications.

Typically, the Sensor Nodes (SNs) consume a great deal of energy during data transmission rather than data processing. As a result, it is critical to minimize redundant sensed data transmission to the BS through the efficient deployment of Cluster Heads (CHs) in a network. Hence, it is important to evaluate the routing protocol in major aspects and scenarios to guarantee the real-world design of WSNs and ensure optimal environment simulation for further improvement utilizing a variety of optimization methods.

In this paper, the LEACH protocol is evaluated as a good benchmark for a single-hop clustering algorithms. Numerous scenarios are presented to evaluate the overall energy efficiency and throughput. Moreover, in order to find the typical values for each scenario, several parameters are considered, including the optimal CHs percentage, packets received by the Sink (BS) located in various locations under various node density and data rates. Extensive simulation demonstrates that once the node density of the same area size increases, the network's energy consumption decreases, resulting in extending the network lifetime of a WSN. Additionally, it is observed that when the CH percentage is optimal, the energy consumption of a network is minimal. However, when the CH percentage of a network exceeds an optimal value, energy consumption increases, significantly reducing the network's lifetime.

The rest of this paper will be structured as follows. Firstly, the literature review is addressed in Sect. 2. In Sect. 3 the LEACH protocol is described in detail. Meanwhile, in Sect. 4 the network model is discussed. Section 5 displays and discusses the simulation results. Finally, in Sect. 6, the conclusion has been drawn.

2 Related Works

“The Low Energy Adaptive Clustering Hierarchy (LEACH) protocol [13] is one of the most well-known protocols. It makes use of energy consumption by employing adaptive clustering via its advantage as a good benchmark for clustering routing protocols in WSNs and MANETs. Within LEACH, the nodes in the network field are clustered and established. Each cluster has a single leader node identified as the cluster head (CH), and this node is selected at random manner. Moreover, while the LEACH protocol retains

energy from sensor nodes, its energy efficiency is likely impacted by random and fast energy dissipation, which is increased by the cluster's unequal distribution of nodes and the time restriction imposed by the TDMA MAC Protocol [13–15].

In LEACH protocol, the CHs are randomly assigned to operate as relay nodes for data transmission; afterward, the cluster heads shift roles with regular nodes to spend a uniform amount of energy in all nodes. The suggested hybrid approach extends the lifetime of nodes while decreasing the energy consumption of the transmission. Numerous research have recently examined the routing and energy consumption challenges related to LEACH protocol by modifying the mathematics models to increase overall performance using a variety of efficient ways [16, 17]. Meanwhile, intelligent algorithms [18–22] are also used as a viable strategy for lowering the energy consumption of WSNs and extending the network's lifetime. Furthermore, other researchers have stressed the critical role of Fuzzy Logic System (FLS) in the decision-making process for CH efficiency in WSNs [23]. All these studies emphasize on the predefined protocol with specific parameters that affect the efficiency of the optimized LEACH protocol's routing. Such parameters include the sensor node's life time, the total number of packets received, the latency of the transmission, and the scalability of the number of sensor nodes.

Nevertheless, most works evaluated their proposed protocols in a virtual environment without examining the effect of the original protocol's parameters on the network's efficiency. Thus it is critical to evaluate the routing protocol in major aspects and scenarios using realistic simulation environments such as Castalia and OMNET++ Simulator. This technique ensures that WSNs are designed in the actual world environment and provides a realistic implementation for further development of the LEACH protocol and its versions (LEACH-C, M-LEACH,...etc.) using various optimization techniques.

3 Low Energy Adaptive Clustering Hierarchy Protocol

LEACH is a pioneering WSN clustering routing protocol. LEACH Protocol's major purpose is to enhance energy efficiency by random CH selection. LEACH is operated in rounds that consist of two phases: Set-Up Phase and Steady-State Phase. Clusters are constructed and a cluster head (CH) is elected for each cluster during the setup phase. Meanwhile, during the steady phase, the data is detected, aggregated, compressed, and transmitted to the base station.

- i. **Set-Up Phase:** The Set-Up step involves the selection and construction of CHs, as well as the assignment of a TDMA schedule to member nodes.
 1. **Cluster Head Selection:** Each node assists in the process of CH selection by randomly creating a value between (0 and 1). If the random number generated by the SN is smaller than the threshold value $T(n)$, the node becomes CH, else it considers as CM and waits for ADV messages to join the nearby CH. Equation 1 is used to find the value of $T(n)$.

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

Where: P is the percentage of the CHs, which is used at the beginning of each round (starting at time t), such that expected the number of CHs nodes for this round is K.

$$P = K/N \quad (2)$$

2. **Cluster Formation:** Once the CHs are elected, they broadcast ADV messages to the rest of the sensors using CSMA MAC protocol. Non-CHs must maintain their receivers throughout the Set-Up phase to hear all CHs' ADV messages. After this phase is complete, each sensor determines which cluster it belongs to based on the RSSI value. Meanwhile, each sensor node (SN) transmits JOIN-REQ messages to its corresponding CH using CSMA.
3. **Schedule Creation:** Each CH node generates a TDMA schedule based on the number of JOINT-REQ messages received. The schedule is broadcast back to the cluster's nodes to inform them when they can transmit.
- ii. **Steady-State Phase:** The steady-state or transmission phase is where environmental reports are communicated from the network field. During this phase, each sensor node transmits its data to the CH during its assigned time slot (intra-cluster communication), meanwhile, each CH aggregated the data from the corresponding CMs and sent it to the BS (inter-cluster communication).

The key advantages and limitations of the LEACH protocol can be summarized as follow (Table 1):

4 Network Model

The following criteria are considered when describing the network model based on the proposed protocol:

1. Sensor Nodes are uniformly distributed across a $M \times M$ interesting area, and throughout the process, all nodes and the BS remain stationary (non-mobile).
2. Each sensor node is capable of sensing, aggregating, and transmitting data to and from the base station (BS) and other sensors (i.e., acts as a sink node).
3. The network's nodes are non rechargeable and have homogeneous initial energy.
4. To ensure optimal performance, the Sink Node (BS) is positioned in the network field's center. Quite frequently, the assumption is made that the communication links between the nodes are symmetrical. As a result, when it comes to packet transmission, any two nodes' data rate and energy consumption are symmetrical.
5. The nodes operate in power control mode, with the output power determined by the receiving distance between them.

Table 1. Advantages and Limitations of LEACH protocol.

Advantages	Limitations
<ul style="list-style-type: none"> ■ The clustering technique used by the LEACH protocol results in decreased communication between the sensor network and the BS, extending the network's lifetime 	<ul style="list-style-type: none"> ■ Expansion of the network may result in a trade-off between the energy distances of a CH and a BS
<ul style="list-style-type: none"> ■ CH utilizes a data aggregation technique to reduce associated data on a local level, resulting in a significant reduction in energy consumption 	<ul style="list-style-type: none"> ■ Due to the random number principle, nodes do not resurrect to become CHs, which further reduces their energy efficiency
<ul style="list-style-type: none"> ■ Each sensor node has a reasonable chance of becoming the CH and subsequently a member node. This maximizes the lifetime of the network 	<ul style="list-style-type: none"> ■ No consideration is made of heterogeneity in terms of energy computational capabilities and link reliability
<ul style="list-style-type: none"> ■ By utilizing TDMA Scheduling, intra-cluster collisions are avoided, extending the battery life of sensor nodes 	<ul style="list-style-type: none"> ■ The TDMA approach imposes constraints on each frame's time slot

5 Simulation Results and Performance Analysis

This section discusses the LEACH's performance evaluation. The LEACH protocol is examined when a network of 100 sensor nodes is uniformly distributed over a $100 \times 100 \text{ m}^2$ area. The BS is positioned in the sensor field's center. All nodes should have initial energy of 3 J. Moreover, we used around the time of 20 s in our scenarios with a maximum simulation time equal to 300 s. The size of all data messages is the same and the slot time is utilized to 0.5 in all simulation situations. The total overview of simulation parameters is shown in Table 2.

Table 2. Simulation parameters.

Parameters	Value	Parameters	Value
Network size	$100 \times 100 \text{ m}^2$	Initial energy	3 J
No. of nodes	100	Simulation time	300 s
No. of clusters	5	Round time	20 s
Location of BS	$50 \times 50 \text{ m}$		
Node distribution	Uniform	Packet header size	25 Bytes
BS mobility	Off	Data packet size	2000 Bytes
Energy model	Battery	Bandwidth	1 Mbps
Application ID	Throughput test		

5.1 Performance Evaluation of LEACH Protocol

In this section, numerous factors are considered when evaluating Low Energy Adaptive Clustering, including the number of nodes, the CH percentage, and the area size. The LEACH protocol's performance is quantified in term of the total energy consumed by sensor nodes during each round for data processing and communication. Also, reliability is another metric evaluated by the total number of received data packets.

Experimental Case I

Figures 1 and 2 depict the effect of node density (number of nodes per m^2) and area size on energy consumption. Where (50, 100, 200) sensor nodes are uniformly distributed across $100 \times 100 m^2$ and $200 \times 200 m^2$ areas, respectively. Each node has initial energy of 3J, with a CH percentage of 5%. If the CH percentage remains constant but the network's node density increases, this results in an increase in the number of CHs in the network proportional to the network's node density. The energy consumption of nodes is minimal at CH = 5% of $100 \times 100 m^2$ area networks with 100 nodes (5 CHs selected), and minimal at 200 nodes (10 CHs selected) of $200 \times 200 m^2$ network. This is because as the coverage area increases, the node consumes more energy transmitting the sensed information to the sink with the fewest CHs possible.

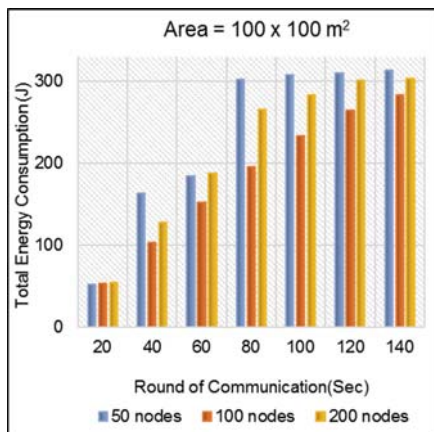


Fig. 1. Total energy consumption

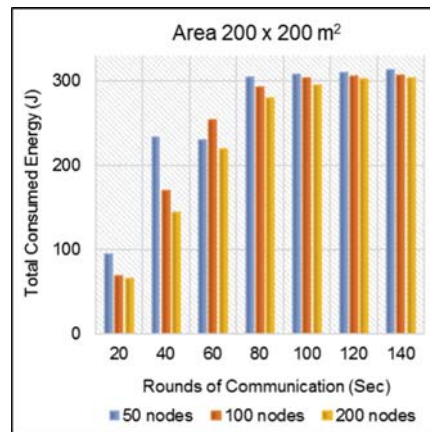


Fig. 2. Total energy consumption

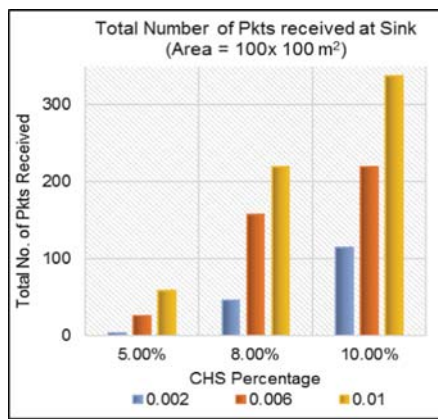
In Fig. 1, it is shown that when the CH percentage is optimal, the energy consumption of a network becomes minimal. However, when the CH percentage of a network exceeds an optimal value, energy consumption increases, significantly reducing the network's lifetime. So that it's important to choose the optimal value of the CHs percentage to avoid extra power consumption from the sensor nodes.

Experimental Case II

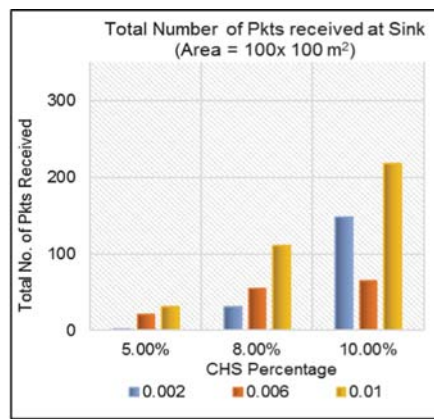
Figures 3 (a–d) illustrate the effect of node density (number of sensor nodes per m^2), area size, and packet rates expressed as a percentage of CHs on the total number of packets received at the sink. The network is configured as in Table 3:

Table 3. Network Configuration.

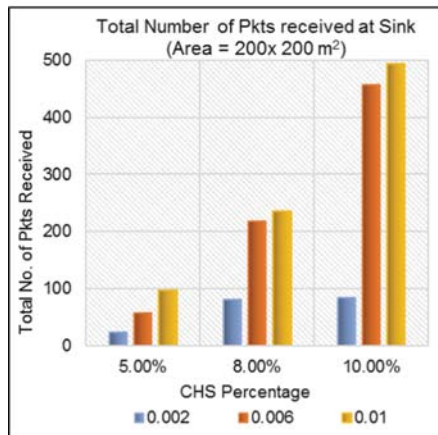
Area (m ²)	Node density	No. of nodes	CH percentage	Packet rate
100 × 100	0.002	20	5%, 8%, 10%	1, 3
	0.006	60		
	0.01	100		
200 × 200	0.002	80	5%, 8%, 10%	1, 3
	0.006	240		
	0.01	400		



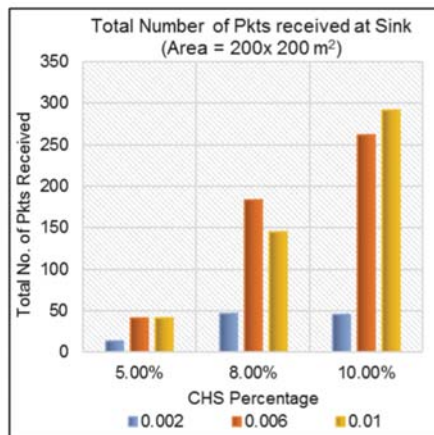
(a) packet rate = 1 packet/sec/node.



(b) packet rate = 3 packet/sec/node.



(c) packet rate = 1 packet/sec/node.



(d) packet rate = 3 packet/sec/node.

Fig. 3. (a–d): The effect of node density, area size, and the packet rates with CHs percentage on the total number of packets received at the sink

In Figs. 3 (a–d), the obtained results illustrate that increasing the packet rate results in a decrease in the network's packet reception rate, this occurs due to increased CH congestion. Increased packet rate enables source sensor nodes to relay the sensed data more quickly to their CHs during their assigned time slot. CH is now receiving more packets from its associated sensor nodes than it is broadcasting to a sink as a result of this increase in the packet rate. In effect, the Congestion arises in the WSN as a result of this condition. Thereby, the sensor buffer begins to overflow, increasing packet loss and lowering the rate at which packets are received in the WSN.

6 Conclusions and Discussion

The Low Energy Adaptive Clustering Hierarchy (LEACH) is evaluated with many considerations, including node density, CH percentage, packet rates, and Area size.

As seen from the findings, the CH percentage remains constant but the network's node density increases. This results in an increase in the number of CHs in the network proportional to the network's node number. Moreover, when the CH percentage is optimal, the energy consumption of a network is minimal. However, when the CH percentage of a network exceeds an optimal value, energy consumption increases, significantly reducing the network's lifetime. So that it's important to choose the optimal value of the CHs percentage to avoid extra power consumption from the sensor nodes. The energy consumption of nodes is minimal at CH = 5% of $100 \times 100 \text{ m}^2$ area networks with 100 nodes (5 CHs selected), and minimal at 200 nodes (10 CHs selected) of $200 \times 200 \text{ m}^2$ network. This is because as the coverage area increases, the node consumes more energy transmitting the sensed information to the sink with the fewest CHs possible. As the number of CHs increases, the amount of energy consumed is reduced proportionately.

In addition, the obtained results also illustrate that increasing the packet rate can cause in a decrease in the network's packet reception rate due to the increase in CH congestion. Note that once packet rate is increased this would enable source sensor nodes relay the sensed data more quickly to their CHs during their assigned time slot. CH is now receiving more packets from its associated sensor nodes than it is broadcasting to a sink, then this may increase the packet rate. As a result, Congestion arises in the WSN and the sensor buffer begins to overflow. This means that packet loss becomes high and a significant reduction happens in the resultant packet rate during packets delivery in the WSN.

For future work, fuzzy logic systems and intelligent algorithms such as FPA, GWO, ACO, and ABC algorithms can be utilized to improve the routing strategy in the LEACH protocol. Additionally, multi-hop routing techniques can be also considered for optimal monitoring system design.

References

1. Priyadarshi, R., Gupta, B., Anurag, A.: Deployment techniques in wireless sensor networks: a survey, classification, challenges, and future research issues. *J. Supercomput.* **76**(9), 7333–7373 (2020). <https://doi.org/10.1007/s11227-020-03166-5>
2. Bandur, Đ, Jakšić, B., Bandur, M., Jović, S.: An analysis of energy efficiency in Wireless Sensor Networks (WSNs) applied in smart agriculture. *Comput. Electron. Agric.* **156**, 500–507 (2019)
3. Kalidoss, T., Rajasekaran, L., Kanagasabai, K., Sannasi, G., Kannan, A.: QoS aware trust based routing algorithm for wireless sensor networks. *Wireless Pers. Commun.* **110**(4), 1637–1658 (2019). <https://doi.org/10.1007/s11277-019-06788-y>
4. Ketshabetswe, L.K., Zungeru, A.M., Mangwala, M., Chuma, J.M., Sigweni, B.: *Heliyon* **5**, e01591 (2019)
5. Mann, P.S., Singh, S.: Energy-efficient hierarchical routing for wireless sensor networks: a swarm intelligence approach. *Wireless Pers. Commun.* **92**(2), 785–805 (2016). <https://doi.org/10.1007/s11277-016-3577-1>
6. Fanian, F., Rafsanjani, M.K.: Cluster-based routing protocols in wireless sensor networks: a survey based on methodology. *J. Netw. Comput. Appl.* **142**, 111–142 (2019)
7. Singh, H., Bala, M., Bamber, S.S.: Taxonomy of routing protocols in wireless sensor networks: a survey. *Int. J. Emerg. Technol.* **11**, 63–83 (2020)
8. Rostami, A.S., Badkoobe, M., Mohanna, F., Keshavarz, H., Hosseinabadi, A.A.R., Sangaiah, A.K.: Survey on clustering in heterogeneous and homogeneous wireless sensor networks. *J. Supercomput.* **74**, 277–323 (2018)
9. Al-Shaikh, A., Khattab, H., Al-Sharaeh, S.: Performance comparison of LEACH and LEACH-C protocols in wireless sensor networks. *J. ICT Res. Appl.* **12**, 219–236 (2018)
10. Khedr, A.M., Aziz, A., Osamy, W.: Successors of PEGASIS protocol: a comprehensive survey. *Comput. Sci. Rev.* **39**, 100368 (2021)
11. Asqui, O.P., Marrone, L.A., Chaw, E.E.: Evaluation of TEEN and APTEEN hybrid routing protocols for wireless sensor network using NS-3. In: Rocha, Á., Ferrás, C., Montenegro Marin, C.E., Medina García, V.H. (eds.) *ICITS 2020. AISC*, vol. 1137, pp. 589–598. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-40690-5_56
12. Ullah, Z.: A survey on Hybrid, Energy Efficient and Distributed (HEED) based energy efficient clustering protocols for wireless sensor networks. *Wirel. Pers. Commun.* **112**(4), 2685–2713 (2020). <https://doi.org/10.1007/s11277-020-07170-z>
13. Kwon, O.S., Jung, K.D., Lee, J.Y.: WSN protocol based on leach protocol using fuzzy. *Int. J. Appl. Eng. Res.* **12**, 10013–10018 (2017)
14. Lee, J.S., Teng, C.L.: An enhanced hierarchical clustering approach for mobile sensor networks using fuzzy inference systems. *IEEE Internet Things J.* **4**, 1095–1103 (2017)
15. Amutha, J., Sharma, S., Sharma, S.K.: Strategies based on various aspects of clustering in wireless sensor networks using classical, optimization and machine learning techniques: Review, taxonomy, research findings, challenges and future directions. *Comput. Sci. Rev.* **40**, 100376 (2021)
16. Basavaraj, G.N., Jaidhar, C.D.: H-LEACH protocol with modified cluster head selection for WSN. In: *International Conference on Smart Technologies for Smart Nation (SmartTech-Con)*, pp. 30–33. IEEE (2017)
17. Cui, Z., Cao, Y., Cai, X., Cai, J., Chen, J.: Optimal LEACH protocol with modified bat algorithm for big data sensing systems in Internet of Things. *J. Parallel Distrib. Comput.* **132**, 217–229 (2019)

18. Devika, G., Ramesh, D., Karegowda, A.G.: Swarm intelligence-based energy-efficient clustering algorithms for WSN: overview of algorithms, Analysis, and Applications. In: Swarm Intelligence Optimization, pp. 207–261 (2020)
19. Tamtalini, M.A., El Alaoui, A.E.B., El Fergougui, A.: ESLC-WSN: a novel energy efficient security aware localization and clustering in wireless sensor networks. In: 1st International Conference on Innovative Research in Applied Science, Engineering and Technology (IRASET), pp. 1–6. IEEE (2020)
20. Sharma, N., Gupta, V.: Meta-heuristic based optimization of WSNs energy and lifetime-a survey. In: 10th International Conference on Cloud Computing, Data Science & Engineering (Confluence), pp. 369–374. IEEE (2020)
21. Yuvaraj, D., Sivaram, M., Mohamed Uvaze Ahamed, A., Nageswari, S.: An efficient Lion optimization based cluster formation and energy management in WSN Based IoT. In: Vasant, P., Zelinka, I., Weber, G.-W. (eds.) ICO 2019. AISC, vol. 1072, pp. 591–607. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-33585-4_58
22. Mitiku, T., Manshahia, M.S.: Fuzzy logic controller for modeling of wind energy harvesting system for remote areas. In: Vasant, P., Zelinka, I., Weber, G.-W. (eds.) ICO 2019. AISC, vol. 1072, pp. 31–44. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-33585-4_4
23. Al-Husain, E., Al-Suhail, G.: E-FLEACH: an improved fuzzy based clustering protocol for wireless sensor network. Iraqi J. Electr. Electron. Eng. **17**, 190–197 (2021)