An Enhanced Algorithm for Selecting Cluster Heads in Wireless Sensor Networks

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Abstract: *The Centralized Energy Efficient Distance (CEED) algorithm is significantly modified in this article with the introduction of the Modified CEED cluster head selection algorithm (MODCEED). By dividing the workload among them, MOD-CEED actually balances the energy usage across all sensor nodes. More specifically, using the LEACH algorithm's energy dissipation model, we determine the ideal number of cluster heads for the network. The residual energy of the sensor node and the distance between the sensor node and the base station are also taken into account in the introduction of an effective cluster head selection technique. Using the MATLAB simulator version 8.5, our suggested approach is assessed in terms of network longevity. According to the simulation's findings, MOD-CEED effectively extends the network lifetime. Additionally, it has proven to be superior to LEACH-DT and CEED, two other pertinent algorithms.*

Keywords: *Cluster head selection, residual energy, optimal number of cluster heads.*

I. Introduction

The creation of sensors, which are compact, inexpensive, smart, and multi-functional devices, is a result of recent advancements in the field of wireless communication technologies [1–4]. These sensors are able to sense, communicate, and carry out activities [5–8]. By detecting various physical phenomena like pressure, temperature, or humidity, sensor nodes can also monitor and regulate surroundings [9–12]. These sensor nodes are put together to form a wireless sensor network (WSN). WSNs are a brand-new, potent technology that is now being employed in a wide range of industries, including robotics, environmental monitoring, tracking forest fires, healthcare monitoring, and military sensing. These applications actually require high performance networks to function. In contrast to wired networks, wireless networks experience numerous resource limitations, such as constrained communication bandwidth and distance [13–15]. Researchers have put out a variety of routing methods in recent years with the goal of managing the finite resources in sensor networks. In a hierarchical-based routing protocol, wireless sensor nodes are grouped into clusters, and a particular sensor node is then selected as a cluster head. This cluster head is then in charge of gathering data from its cluster members and beginning to transmit the data to the base station or to cluster heads closer to the base station[1] [2][16–18]. The cluster head typically consumes more energy than the nodes that are not the cluster head.

The Low Energy Adaptive Clustering Hieraechy (LEACH), as indicated in [18], is regarded as one of the popular and established hierarchical routing methods. According to the LEACH protocol, wireless sensor nodes are grouped into clusters, with one sensor node acting as the cluster head and the others as member nodes. LEACH's operation is separated into numerous rounds, each of which consists of two phases known as the setup phase and the steady-state phase. The clusters are created during the setup phase, and during the steady-state phase, each sensor node transmits its unique sensed data to the cluster head, which then transmits to the base station. To balance the energy consumption across all sensor nodes, the authors in [19] proposed the Distance Based Thresholds (LEACH-DT) method. Based on the separation between the sensor node and the base station, LEACH-DT suggests a distributed cluster head selection process. The residual energy of the sensor nodes, however, is not taken into account while selecting the cluster heads using LEACH-DT.

The authors of [20] suggested a routing algorithm based on Centralized Energy Efficient Distance (CEED) to increase the network lifetime over LEACH-DT. Using the energy lost during the cluster head selection, cluster formation, and steady-state phases as a starting point, CEED determines the ideal number of cluster heads. In addition, CEED presents a distributed cluster head selection algorithm based on the residual energy of the sensor node as well as the separation between the sensor nodes and the base station. Sadly, the CEED algorithm raises the likelihood that no clustering will emerge in most rounds by decreasing the likelihood of sensor nodes becoming cluster heads.

Additionally, CEED does not rely on the assumption that sensor nodes should relay their sensed data to the base station singly in the absence of clustering. Because of this, CEED has demonstrated in its studies an exceptional improvement in the network lifetime.

In this paper, we suggest a more effective cluster head selection algorithm to address the issues found in earlier publications (i.e., LEACH-DT and CEED algorithms). Modified CEED is the name of this algorithm (MOD-CEED).

Following is how this article is structured in its entirety. Section II provides an explanation of our suggested algorithm. Section III presents the simulation findings and contrasts them with earlier related techniques. The article is concluded in Section IV.

II. The Proposed Algorithm

Literature reviews [6, 7].

II-A Network Assumptions

- N sensor nodes make up the WSN, along with one base station. A square field with area A= M M [m2] has evenly spaced sensor nodes.
- There are no heterogeneous sensor nodes. In other words, they all have the same processing speed, memory size, battery life, and range of communication.
- The Base Station is placed outside of the sensing region and has unlimited resources (i.e., power and storage capacity).
- During the designated transmission window, sensor nodes always have data to communicate.
- The Base Station as well as the sensor nodes are immobile (i.e., not mobile).
- Sensor nodes are GPS-enabled and thus aware of their location.

II-B Radio Energy and Channel Propagation Models

The primary source of energy lost in a wireless sensor network is often wireless transmission, and this source greatly relies on the separation of transmitter and receiver. The radio energy model utilised in [16–17] was used in our research. In this radio paradigm, the transmitter uses energy to operate the power amplifier and electronics circuits, while the receiver uses energy to operate the electronics circuits. A decaying power law function of the separation between the transmitter and the receiver can be used to represent the electromagnetic wave propagation in a wireless channel. Depending on how far apart the transmitter and receiver were from one another, the Friss free-space and multipath fading channel propagation models were employed for our simulation studies. The Friss free-space propagation model is employed if this distance, when compared to another distance, is smaller than a specific cross-over distance (do) (d2 power loss). The multipath fading propagation model is utilised in all other cases (d4 power loss). As a result, the following is the amount of energy required by the radio model to send an L-bit message over a distance d:

$$E_{Tx}(L,d) = E_{Tx-elec}(L) + E_{Tx-amp}(L,d) \qquad (1)$$

$E_{Tx-elec}$ (L) is the amount of energy used by the transmitter circuit to send an L-bit message. E_{Tx-amp} (L, d) is the amount of energy that the transmitter expends to amplify the signal. In light of this, (1) can be rewritten as follows:

$$E_{Tx}(L,d) = \begin{cases} LE_{elec} + L\varepsilon_{fs}d^2 & d < d_0 \\ LE_{elec} + L\varepsilon_{mp}d^4 & d \geq d_0 \end{cases} \qquad (2)$$

where E_{elec} is the energy lost when the transmitter and receiver's electronic circuits are in operation. For the Friss free-space and multipath fading channel propagation models, fs and mp are the radio amplifier energy parameters, respectively. The energy required by the radio model, on the other hand, to receive an L-bit message across a distance d is calculated as follows:

$$E_{Rx}(L) = E_{Rx-elec}(L) = LE_{elec} \qquad (3)$$

where$E_{Rx-elec}$ (L) is the amount of energy used by the receiver circuit to decode an L-bit message.

II-C Optimum Number of Clusters

In a wireless sensor network, the quantity of cluster heads is regarded as a key variable that, in essence, affects both the total amount of energy consumed and the network's lifespan. When there aren't enough clusters, the sensing data from the cluster members frequently needs to be transmitted over very long distances to the cluster head, which increases energy usage. A lower level of local data aggregation occurs when there are too many clusters since the cluster heads receive sensing data from fewer members. In this scenario, N sensor nodes are assumed to be evenly dispersed throughout a M by M region. K clusters are arranged throughout the network area.

As a result, each cluster has N/K nodes on average. One cluster head and (N/K-1) non-cluster head nodes make up each cluster. Each cluster head node in our suggested approach broadcasts an advertisement message with a length of L bits to a distance of $\sqrt{0.5}$ M as soon as the cluster heads are selected (half the length of the network). Due to the assumption that the advertisement message will be sent to a distance below the cross-over distance and that the Friss free-space propagation model (d^2 attenuation) will be utilised, there will be a reduction in energy usage. It's interesting to note that the ideal number of clusters may be expressed as in (4).

$$K_{OPT} = M\sqrt{\frac{2\sqrt{3}}{27}}\sqrt{\frac{(2L+L_{DATA})N\varepsilon_{fs}}{L\,(E_{elec}+NE_{elec}+\varepsilon_{fs}0.5\,M^2)+L_{DATA}\,(E_{elec}+\varepsilon_{mp}d_{toBS}^4)}} \tag{4}$$

$$T\,(s_i) = \begin{cases} \dfrac{P_{OPT}(s_i)}{1-P_{OPT}(s_i)\left\{r \bmod \left[\frac{1}{P_{OPT}(s_i)}\right]\right\}}\dfrac{E_{CUR}(s_i)}{E_{AVG}}\dfrac{d_{AVG-toBS}}{d_{toBS}(s_i)} & : if\ s_i \in G \\ 0 & : \quad otherwise \end{cases} \tag{5}$$

III. Simulation Results

Three distinct definitions of the network lifetime—First Node to Die (FND), Half Node to Die (HND), and Last Node to Die—have been utilised to assess the effectiveness of our suggested approach (LND). Figure 1 illustrates how the number of alive nodes has been analysed in connection to rounds while taking into account both our suggested technique and LEADH-DT, a CEED-relevant algorithm. We ran the simulation 20 times before taking the average of those runs.
The number of alive nodes did, however, tend to decline as the number of rounds grew across all algorithms, which was to be expected given that each sensor must use energy to relay its sensed data at each round.

Additionally, from the perspective of network longevity, we can see that our suggested algorithm performs better.
In contrast to LEACH-DT and CEED, where its values are at rounds 247 and 269, respectively, the FND metric for MOD-CEED is at round 392 in Figure 2. For LEACH-DT and CEED, respectively, this led to improvements of 59% and 46%. While the HND measure for LEACH-DT and CEED has values at rounds 480 and 707, respectively, it is at round 1001 for MOD-CEED. Surprisingly, this results in improvements of 109% for LEACH-DT and 42% for CEED, respectively.
Last but not least, the FND metric for MOD-CEED is at round 3518 whereas its values for LEACH-DT and CEED are at rounds 854 and 3490, respectively. This led to remarkable gains for LEACH-DT of 316% and a modest improvement for CEED of 1%.

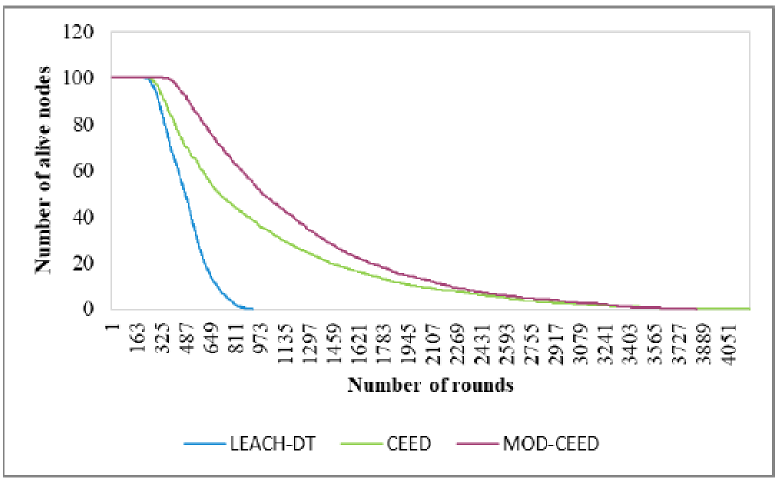

Figure 1. Number of alive nodes versus number of rounds considering LEACH-DT, CEED and MOD-CEED algorithms

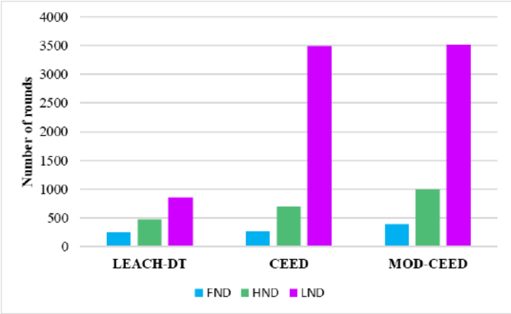

Figure 2. Results of FND, HND, and LND considering LEACH-DT, CEED and MOD-CEED algorithms.

IV. Conclusion

In this study, we propose MOD-CEED, a new cluster head selection algorithm for wireless sensor networks that is a modification of CEED. The favourable effect of determining the ideal number of cluster heads on CEED performance serves as a summary of the main finding of our proposed algorithm. It's interesting that it's calculated using the energy lost at all stages of communication. Another key discovery of our proposed algorithm is the effective integration of the residual energy of the sensor nodes and the distance between the sensor nodes and Base Station into the cluster head selection technique, which intriguingly results in balancing the energy consumption amongst all sensor nodes and extending the network lifetime. The simulation results demonstrated the suggested algorithm's superior performance over LEACH-DT and CEED.

References

[1] A. Khalifeh, K. A. Darabkh, and A. Kamel, “Performance Evaluation of Voice-Controlled Online Systems,” Proceedings of the 9th IEEE/ Multi-conference on Systems, Signals, and Devices (SSD’12), Chemnitz, Germany, pp. 1-6, March 2012.

[2] Khalid A. Darabkh, Abeer M. Awad, and Ala’ F. Khalifeh, “Efficient PFD-Based Networking and Buffering Models for Improving Video Quality over Congested Links,” Wireless Personal Communications, vol. 79, no. 1, pp. 293-320,November 2014.

[3] K. A. Darabkh and R. S. Aygun, "Performance Evaluation of Sequential Decoding System for UDP-Based Systems for Wireless Multimedia Networks", Proceedings of 2006 International Conference on Wireless Networks (ICWN'06), Las Vegas, Nevada, pp. 365-371, June 2006.

[4] K. A. Darabkh and R. Aygun, “Improving UDP Performance Using Intermediate QoD-aware Hop System for Wired/Wireless Multimedia Communication Systems,” International Journal of Network Management, vol. 21, no. 5, pp. 432–454, September 2011.

[5] Ala F. Khalifeh, Abdel-Karim Al-Tamimi, and Khalid A. Darabkh, “Perceptual Evaluation of Audio Quality Under Lossy Networks,” Proceedings of 2017 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET 2017), Chennai, India, March 2017.

[6] K. A. Darabkh and W.D. Pan, "Stationary Queue-Size Distribution for Variable Complexity Sequential Decoders with Large Timeout," Proceedings of the 44th ACM Southeast Conference, Melbourne, Florida, pp. 331-336, March 2006.

[7] Mu'awiah M. Hlayel, Ali M. Hayajneh, Mamoun F. Al-Mistarihi, Mohammad Shurman, and Khalid A. Darabkh, “Closed-form Expression of Bit Error Rate in Dual-Hop Dual-Branch Mixed Relaying Cooperative Networks with Best-Path Selection over Rayleigh Fading Channels,” Proceedings of the 2014 IEEE International Multi-Conference on Systems, Signals & Devices, Conference on Communication & Signal Processing, Castelldefels-Barcelona, Spain, pp. 1-4, February 2014.

[8] K. A. Darabkh, A. Khalifeh, M. Naser, and E. Al-Qaralleh, “New Arriving Process for Convolutional Codes with Adaptive Behavior,” Proceedings of the 9th IEEE Multi-conference on Systems, Signals, and Devices (SSD’12), Chemnitz, Germany, pp. 1-6, March 2012.

[9] K. A. Darabkh and B. Abu-Jaradeh, “Bounded Fano Decoders over Intermediate Hops Excluding Packet Retransmission,” Proceedings of IEEE 24th International Conference on Advanced Information Networking and Applications (AINA 2010), Perth, Australia, pp. 299-303, April 2010.

[10] Mohammed Hawa, Khalid A. Darabkh, Raed Al-Zubi, and Ghazi Al-Sukkar, “A Self-Learning MAC Protocol for Energy Harvesting and Spectrum Access in Cognitive Radio Sensor Networks,” Journal of Sensors, vol. 2016, Article ID 9604526, pp. 1-18 pages, March 2016.

[11] Raed Al-Zubi, Marwan Krunz, Ghazi Al-Sukkar, Mohammed Hawa, and Khalid A. Darabkh, “Packet Recycling and Delayed ACK for Improving the Performance of TCP over MANETs,” Wireless Personal Communications, vol. 75, no. 1, pp. 943-963, March 2014.

[12] Mohammed Hawa, Khalid A. Darabkh, Loay D. Khalaf, and Jamal S. Rahhal, “Dynamic Resource Allocation Using Load Estimation in Distributed Cognitive Radio Systems,” AEÜ - International Journal of Electronics and Communications, vol. 69, no. 12, pp. 1833–1846, December 2015.

[13] M. Shurman, M. Al-Mistarihi, and K. Darabkh, “Merging Dynamic Address Autoconfiguration and Security Key Protocols in Mobile Ad Hoc Networks,” Proceedings of 36th IEEE International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO 2013), Opatija, Croatia, pp. 441-445, May 2013.

[14] Khalid A. Darabkh and Mohammad Z. El-Yabroudi, “A Reliable Relaying Protocol in Wireless Sensor Networks,” Proceedings of 2017 IEEE European Conference on Electrical Engineering & Computer Science, Bern, Switzerland, November 2017.

[15] Khan, S., & Gupta, C. (2014). An optimization techniques used for economic load dispatch. Int J Adv Technol Eng Res (IJATER), 4(4).

[16] A. Hridaya and C. Gupta, “Hybrid Optimization Technique Used for Economic Operation of Microgrid System,” *Academia.Edu*, vol. 5, no. 5, pp. 5–10, 2015, [Online]. Available: http://www.academia.edu/download/43298136/Aditya_pape_1.pdf.

[17] A. Dwivedi and Y. Pahariya, “Design and Analysis of Hybrid Multilevel Inverter for Asymmetrical Input Voltages,” *J. Electr. Eng. Technol.*, no. 0123456789, 2021, doi: 10.1007/s42835-021-00814-5.

[18] Khalid A. Darabkh, Wala’a S. Al-Rawashdeh, Mohammed Hawa, and Ramzi Saifan, “MT-CHR: A Modified Thresholdbased Cluster Head Replacement Protocol for Wireless Sensor Networks,” Computers and Electrical Engineering, https://doi.org/10.1016/j.compeleceng.2018.01.032, 2018.

[19] S. H. Kang and T. Nguyen, “Distance based thresholds for cluster head selection in wireless sensor networks,” IEEE Communications Letters, vol. 16, no. 9, pp. 1396–1399, September 2012.

[20] R. D. Gawade and S. L. Nalbalwar, “A centralized energy efficient distance based routing protocol for wireless sensor networks,” Hindawi Publishing Corporation Journal of Sensors, 2016.