Research Article

Optimizing Quality of Service of Clustering Protocols in Large-Scale Wireless Sensor Networks with Mobile Data Collector and Machine Learning

Rahma Gantassi¹, **Bechir Ben Gouissem¹**, **Omar Cheikhrouhou²**, **Salim El Khediri^{3,4}**, and **Salem Hasnaoui¹**

¹Communication System Laboratory Sys'Com (ENIT), University of Tunis El Manar (UTM), Tunis, Tunisia

²College of Computers and Information Technology, Taif University, Taif 21944, Saudi Arabia

³Department of Information Technology, College of Computer, Qassim University, Buraydah, Saudi Arabia

⁴Department of Computer Sciences, Faculty of Sciences, University of Gafsa, Gafsa, Tunisia

Correspondence should be addressed to Rahma Gantassi; rahmagantassii@gmail.com

Received 30 January 2021; Revised 22 February 2021; Accepted 4 March 2021; Published 15 March 2021

Academic Editor: Shafiq Muhammad

Copyright © 2021 Rahma Gantassi et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

The rise of large-scale wireless sensor networks (LSWSNs), containing thousands of sensor nodes (SNs) that spread over large geographic areas, necessitates new Quality of Service (QoS) efficient data collection techniques. Data collection and transmission in LSWSNs are considered the most challenging issues. This study presents a new hybrid protocol called MDC-K that is a combination of the K-means machine learning clustering algorithm and mobile data collector (MDC) to improve the QoS criteria of clustering protocols for LSWSNs. It is based on a new routing model using the clustering approach for LSWSNs. These protocols have the capability to adopt methods that are appropriate for clustering and routing with the best value of QoS criteria. Specifically, the proposed protocol called MDC-K uses machine learning K-means clustering algorithm to reduce energy consumption in cluster head (CH) election phase and to improve the election of CH. In addition, a mobile data collector (MDC) is used as an intermediate between the CH and the base station (BS) to further enhance the QoS criteria of WSN, to minimize time delays during data collection, and to improve the transmission phase of clustering protocol. The obtained simulation results demonstrate that MDC-K improves the energy consumption and QoS metrics compared to LEACH, LEACH-K, MDC maximum residual energy leach, and TEEN protocols.

1. Introduction

Over the past few years, wireless technology has continued to grow through technological developments in various fields related to the microelectronics field. Simultaneously to WSN, new fields have emerged and challenges have been taken up to meet the needs of people and the demands of various application areas such as the environment, industry, and culture. These new applications have motivated researchers to sought solutions to achieve application requirements. Indeed, in spite of the outstanding achievements in this area, many problems still remain to be

solved. For instance, some new protocols for the WSN have been proposed in order to handle media access control, routing protocols, data aggregation, and so on. Many research efforts have been carried out on sensor network energy consumption minimization, but only a few have focused on improving clustering protocol based on Quality of Service (QoS) criteria. As a result, clustering protocols have become the key target for sensor optimization studies.

The adoption of machine learning, such as the K-means algorithm, with the LEACH protocol [1] during cluster head (CH) election yields significant gains in network lifetime, throughput, CH number, latency, and power consumption

[1]. Nevertheless, multihop routing adopted by LEACH-K [1] can influence energy consumption, throughput, reliability, and latency time. Therefore, it is very important to address the problem of poor stability and latency that save energy and all QoS essentially in terms of throughput. On the other hand, mobile data collector (MDC) is used as an intermediate between the CH and the Base Station (BS) to further improve the QoS criteria of WSN, to minimize time delays during data collection, and to extend the lifespan of the network in WSN. Therefore, this study proposed a new protocol, which is a combination of the LEACH-K approach and MDC, to improve the QoS of clustering protocols. Specifically, the purpose of the proposed protocol is to prolong the lifetime of the network and enhance its QoS criteria. As a result, an enhancement of the clustering protocol is proposed, which relies on network division in clusters before the election of the CH according to the machine learning K-means algorithm. An efficient mobile data collection system is advocated as well based on data aggregation that operates as clusters on the basis of the WSN that efficiently uses mobile nodes for data collection. Specifically, the contribution of this document is as follows:

- (i) We have proposed a new routing protocol called MDC-K. The proposed algorithm first applies the machine learning K-means algorithm to split the network into K clusters. After that, it determines the CH of each cluster which will be the closest node to the centroid of each K-means cluster. Assign each CH to the sensor node (SN) having the minimum distance to the CH. The CH can broadcast data to MDC when MDC visits the nearest CH. MDC completes its collection and finally delivers the data to the BS. The MDC uses the location of each CH to calculate the distance between it and all the CHs and moves to the CH having the minimum distance.
- (ii) We compared the proposed protocol with existing solutions and proved its performance.

The remainder of the paper is arranged as follows. Following a brief introduction to the study proposed in Section 1, some related works are outlined in Section 2. Next, in Section 3, the proposed approach is explained. Section 4 gives several simulation scenarios with simulation parameters and evaluates the performance of the proposed approach. Section 5 summarizes the main contribution of this work and gives the perspectives.

2. Literature Study

Several studies have been conducted to develop MDC in clustering protocols [2–15] where they have focused on the maximization of WSN's lifespan, while other studies have been conducted in order to assess the impact of the K-means algorithm on the clustering performances in WSNs [1, 16–20]. Particularly, some studies have integrated MDC into clustering protocol, whereas others have applied the machine learning K-means algorithm in the clustering protocol. The objective of this section is to review and summarize the recent studies on both K-means and MDC

approaches in routing protocols. Some studies used MDC in clustering protocol; others used MDC in Large-Scale Wireless Sensor Networks (LSWSNs), whereas the rest of the studies used MDC in WSN in general. Table 1 summarizes some literature works.

Besides, many studies used the machine learning K-means clustering algorithm in WSN. In particular, the majority used the K-means algorithm in clustering protocol. The K-means approach can make the cluster of nodes close to the centroid, which decreases the energy consumption and increases the throughput. Furthermore, the integration of MDC into the routing protocol can reduce the data collection times and extends network life in WSNs. Moreover, clustering protocols contain two phases, namely, the CH election phase and the data transmission phase. As previously discussed, some studies have integrated the MDC in clustering protocol, whereas others have applied the machine learning K-means algorithm in clustering protocol. To the best of our knowledge, this work presents the first attempt to combine both MDC and K-means algorithm to reduce the energy consumption in clustering protocol.

3. The MC-K Proposed Protocol

To the best of our knowledge, no study has used the combination of K-means and MDC in clustering protocol, which is the aim of this study. Specifically, the K-means algorithm was integrated into the election step and MDC in the transmission step of the clustering protocol in order to improve the QoS metrics.

During data collection, the MDC follows a greedy approach, each time selects the nearest CH, and moves to it to collect its data. Afterward, the MDC sends all collected data to the BS. Our proposed protocol contains two phases, the initialization phase and the transmission phase.

3.1. Initialization Phase. This phase starts with the application of the K-means algorithm [21, 22] to the WSN. Then, the SNs are divided into K groups.

The output of the K-means algorithm is k centroids. The BS selects the SN with the minimum distance to these centroids to be the CH. After CH assignment, an advertisement message containing the CH identifier is broadcast. Once receiving this message, SNs send a request message containing their coordinates to the CH to join the cluster. Each CH chooses its member nodes that are closest to it. Specifically, the CHs select the nodes belonging to their K-means cluster. Then, the BS knows the coordinates of the CHs. Suppose that the SNs denoted by n_i are divided into k clusters $\{C_1, C_2, C_3, C_4, C, \dots, C_k\}$. Assume c_k to be the centroid of the cluster C_k . Therefore,

$$C_1 \cup C_2 \cup \dots \cup C_k = \sum_{i=1}^N n_i, \quad (1)$$

where N is the total number of nodes in the network.

The goal of K-means is to reduce the overall Euclidean distance between the CH and all the members of the cluster.

TABLE 1: Comparative study of the literature.

Study	Approach	Advantages	Challenges
[2]	The authors proposed distance energy evaluated (DEE) approach: (i) Introducing the stratified network topology arrangement that provides resiliency in multihop communication data to the base station	The simulation shows that protocol behavior is significantly enhanced for reliability, lifetime, and energy savings	(i) In this approach, the authors did not focus on the QoS improvement
[3]	The author approved the steering convention based mainly on the multichannel plan MDC at the lower station: (i) This allocates channel to MDCs instead of the single channel	(i) This protocol demonstrates meaningful changes from LEACH and a single application-specific network protocol for WSNs. (ii) The conventions for using sensor hub vitality and improving system lifetime and efficient information assembly due to less use of vitality in the middle of information transmission	(i) Despite the good finding of this study, it did not improve QoS performance
[4]	MEACBM protocol addresses heterogeneous clustering taking into account 3 SNs levels of multihop for intercluster communication and connectivity of SNs throughout the network area	Simulation results indicate the performance of MEACBM protocols compared to other contemporaneous routing protocols based on clusters regarding network lifetime, stability, throughput, channels, and dead nodes	(i) MEACBM protocol improves QoS performance
[5]	The proposed approach used MDC minimum distance leach which is based on the multihop communication between BS, SNs, and MDC	The MDC minimum distance leach approach outperforms the hybrid multihop LEACH approach regarding energy consumption and greatly improves lifetime	(i) Despite the good finding of this study, it did not improve QoS performance
[6]	The authors proposed analytic methods to compute node power consumption and identify the optimum node clusters to be used multihop and single-hop models	This approach can model large-scale networks (10,000 nodes and more) and test various network scenarios in little time. (i) For multihop, it demonstrated that the increase of clusters does not always reduce the energy consumption of the nodes owing to the DREQ problem flooding. (ii) For single hop, sensor nodes would have to spend a significant quantity of energy to send to the mobile access point when the number of clusters is lower in LSWSNs	(i) In this approach, the authors did not focus on the QoS improvement
[7]	The authors used the multilevel MDC method to assess the lifespan of the network in an open and dense agricultural area. Specifically, this study provided an effective method for extending the lifespan based on automaton learning at WSN.	(i) Experimental results showed a significant improvement in network lifetime extension compared to previous methodologies	(i) This approach did not ameliorate the QoS
[8]	The authors proposed MDC maximum residual energy protocol: (i) The authors presented a comparative study between MDC maximum residual energy routing protocol and LEACH multihop hybrid routing protocol	(i) Simulation results showed significantly better performance of the proposed maximum residual energy MDC protocol than the LEACH multihop hybrid routing protocol regarding the lifetime of the network	(i) The simulation parameters were very limited as in [14]. Except in [14], the MDC moves toward the nodes with the minimum distance appearing at the MDC, while in [8], MDC moves toward the nodes with maximum energy.
[9]	In the proposed approach: (i) The network is divided into equal clusters. (ii) In particular, [9] has integrated the fine-tuning of the node transmission range and the adjustment of the MDC speed	(i) Simulation findings showed significant reductions in the energy consumption of the CH	(i) In this approach, the authors did not focus on the QoS improvement. (ii) This approach did not ameliorate the QoS
[10]	In the proposed approach [10], the MDC begins its data collection journey from the data sink by getting a signal of the CH beacon, then collects the data directly at the CH, and conducts the data to the BS	(i) With this method, the lifetime of the sensors can be extended because the method is reactive	(i) In [10], the authors however did not make any simulation to validate the proposed approach

TABLE 1: Continued.

Study	Approach	Advantages	Challenges
[11]	In [11], MDC can interrogate one by one the sensors located nearby upon receipt of the acknowledgment; a sensor loads the data directly into the MDC and does not transmit the data back to another SN	(i) This approach has the potential to significantly extend the network lifetime relative to the schematic with a static data collector and greatly reduce the length of displacement relative to the coverage line protocol	(i) This approach did not ameliorate the QoS
[12, 13]	The authors focused on the design of an LWSN-based MDC, in which the mobile node tours each SN within the network, collects the data from the SNs, and transports the collected data to the BS [12, 13]	(i) For the multihop approach, researchers in [12] decrease the network distance while utilizing several well nodes. Thus, the problem of hot spots is prevented and the number of hops can also be reduced, resulting in a reduction of energy consumption	(i) This approach did not ameliorate the QoS
[14]	(i) The authors proposed, analyzed, and validated the MDC using the LEACH protocol in an environmental application	(i) This protocol shows considerable progress in the energy consumption of the sensor nodes. (ii) This protocol improves the life of the network	The simulation parameters were very limited (i) The maximal number of the used SNs was only 40 and the simulation area was equal to 1 Km ²
[15]	To avoid the premature death of sensors and avoid the problem of hot spots, a dynamic clustering approach is proposed in [15]. Furthermore, the technique of ant colony optimization (ACO) is used for the efficient selection of the mobile sinks path.	(i) The results of the simulation demonstrate that the CH election strategy based on the COA-based MDC greatly improves the WSN's lifespan. (ii) ACO was compared to current GA, PSO, and LEACH	(i) This approach did not ameliorate the QoS
[16]	(i) The author applied the K-means approach in WS	(i) The number of clusters is increasing. (ii) WSN's energy consumption is reduced	(i) The limitation to this approach is that a minimum number of parameters are used. For example, during the simulation phase, the authors focused only on 2 clusters with 10 nodes. (ii) This approach did not ameliorate the QoS.
[1]	In [1], the K-means algorithm was applied in LEACH protocol prior to the election of CH to reduce energy consumption and enhance the Quality of Service criteria	(i) The results showed that the proposed protocol decreased power consumption and latency and improved network stability, lifetime, and throughput. (ii) The mechanisms of aggregation and LEACH-K deteriorate the QoS leading to reduced stability and latency Based on this analysis, an aggregation process based on the K-means algorithm is provided and a verification function is appended to the K-means algorithm for dynamically adjusting the system to obtain stable system operation and transmitting information while minimizing the system's energy consumption	(i) This approach did not ameliorate the QoS (ii) This approach did not apply the MDC (iii) This approach had not been tested in LWSNs
[17]	The authors analyzed the routing protocol and started from the point of view of cluster routing in order to investigate the classical ACH protocol and evaluate its advantages and drawbacks		(i) This approach did not ameliorate the QoS (ii) This approach did not apply the MDC (iii) This approach had not been tested in LWSNs
[18]	The authors analyzed the performance of KM and FCM and investigated which of them is best suited to build balanced clusters, allowing researchers to choose the right algorithm to improve network lifetime	Simulation results show that FCM is more superior to KM by producing balanced clusters with the random distribution manner for SN	(i) This approach did not ameliorate the QoS (ii) This approach did not apply the MDC (iii) This approach had not been tested in LWSNs
[19, 20]	The authors of [19, 20] proposed two hybrid clustering algorithms, K-means particle swarm optimization (KPSO) and K-means genetic algorithms (KGAs), which show improvements compared to traditional LEACH in energy saving	The results showed that the proposed protocol reduced energy consumption	(i) This approach did not ameliorate the QoS (ii) This approach did not apply the MDC

It reduces the sum of the distances between SNs and the cluster centroid as shown in Figure 1.

The BS decides the nodes to be CH, based on two conditions: the closer node from the centroid and the total number of CHs should not be greater than the probability value.

$$P(t) = \frac{K}{N - K}. \quad (2)$$

So, if the energy of the nodes differs, the probability $P_i(t)$ relates to the remaining energy at each node. This probability will therefore be equal to

$$P_i(t) = \frac{E_i(t)}{E_{total}(t)} K, \quad (3)$$

where $E_i(t)$ is the residual energy relating to each node n_i . This probability favours the nodes with more energy resource to become CHs. $E_{total}(t)$ is the total energy available in the network.

3.2. Data Transmission Phase. The MDC moves toward the nearest CH and collects its data. MDC maintains a set of already visited CHs and then goes to the nearest CH from the remaining CHs until it collects all data from all CHs. Afterward, it sends all the data to the BS. Afterward, it sends all the data to the BS. Figure 2 explains the flowchart of data transmission from CH to MDC.

4. Simulation Results and Analysis

In order to evaluate the performance of the proposed approach, it is compared with various existing protocols based on QoS criteria such as throughput and energy consumption in the WSN. The simulation of the proposed approach is done using MATLAB and various parameters and factors are taken into consideration while performing the simulation to enhance the network performance. In order to obtain these results, the value of K was set to 10 (10 is the optimal value of k for the best QoS criteria values according to [1]). Table 2 describes the simulation parameters common to all scenarios.

In these simulation scenarios, we compared the MDC-K protocol with LEACH, LEACH-K, TEEN, and MDC maximum residual energy protocol based on residual energy, throughput, and latency time of network in 10000 rounds. One hundred nodes have been chosen to test the performance of the MDC-K protocol. Figure 2 compares the residual energy of MDC-K against LEACH, LEACH-K, TEEN, and MDC maximum residual energy.

As indicated in the above figures, the proposed solution improves the network lifetime with higher performances. It improves the SN residual energy as well and numerical results show that the proposed method is able to decrease the SN energy consumption, which will result in more network lifetime. Figure 3 presents the residual energy and the throughput variations (when $K=10$) of the proposed approach compared to LEACH, LEACH-K, TEEN, and MDC maximum residual energy leach. The graphs illustrated in Figure 3 depict that, by the integration of

FIGURE 1: Initialization phase of the MDC-K.

FIGURE 2: Data transmission from CH to MDC.

an unsupervised algorithm which is the K-means before the CH election and MDC in data transmission phase, total residual energy and throughput increase. The sensor network can be coated with an acceptable amount of energy (more than 0,027mj) in comparison to 0 of LEACH, 0 of TEEN, 0 of LEACH-K, and 0 of MDC maximum residual energy leach during 10000 rounds. Specifically, the MDC moves to its nearest CH to reduce energy consumption and consequently increases the residual energy.

As indicated in the above figures, the proposed solution improves the network lifetime with higher performances as the throughput is increased. Figure 4 presents the throughput variations (when $K = 10$) of the proposed approach compared

TABLE 2: Simulation parameters.

Settings	Values
Initial energy	Eelec = 0.5 J/node
Electronic dissipation energy (sending; receiving)	Eelec = 50 nJ/bit
Data aggregation energy	EDA = 5 nJ/bit/m ²
Transmit amplifier if $dtoBS \leq d_0$	Efs = 10pJ/bit/m ²
Transmit amplifier if $dtoBS \geq d_0$	Emp = 0.0013pJ/bit/m ⁴
Number of nodes	100nodes
LEACH routing percentage	0.05 (percentage of cluster head 5%)
Simulation area	(100 * 100)m

FIGURE 3: Comparison of residual energy between LEACH, LEACH-K, MDCEACH-K, TEEN, and MDC maximum residual energy leach protocols.

to LEACH, LEACH-K, TEEN, and MDC maximum residual energy leach. The graphs illustrated in Figure 4 depict that, by the integration of an unsupervised algorithm which is the K-means before the CH election and MDC in data transmission phase, throughput increases.

Specifically, SNs can be coated with an acceptable amount of energy (more than 0,027J) in comparison with 0 for LEACH, 0 for TEEN, 0 for LEACH-K, and 0 for MDC maximum residual energy leach during 10000 rounds) and can provide a considerable throughput (more than 37865 packets in comparison to 12009 for LEACH, 12001 for TEEN, 23300 for LEACH-K, and 17864 for MDC maximum residual energy leach during 10000 rounds). The simulation results are summarized in Table 3.

As shown in Table 3, the use of K-Means improved the election of the CH, whereas the use of MDC improved the routing. The effectiveness of the MDC-K protocol in LSWSNs was also tested. Specifically, we have evaluated the QoS criteria values in different area sizes. The latency time also falls down from 194,865 (ms) in LEACH, 153,74 (ms) in TEEN, 96,1602 (ms) in LEACH-K, and 51,551 in MDC maximum residual energy leach to 47,33 (ms) in MDC-K. Figure 5 presents a comparison between MDC-K, LEACH-

FIGURE 4: Comparison of throughput between LEACH, LEACH-K, MDCEACH-K, TEEN, and MDC maximum residual energy leach protocols.

K, TEEN, MDC maximum residual energy leach, and LEACH protocol in terms of stability, latency time, residual energy, and throughput in different area sizes.

Figure 5 showed that when the area size increases, the residual energy, throughput, and stability decreased slightly which means that the benefits of our protocol remain almost stable with a large area. For instance, the latency time also increases from 47,33 (ms) in area size (100, 100) to 50,505 (m) in area size (1000, 1000). The throughput decreases down from 37865 (packet) in area size (100, 100) to 37601 (packet) in area size (1000, 1000). According to its results, we conclude that our MDC-K is the best solution for LSWSNs. The stability decreases down from 2567 (rounds) in area size (100, 100) to 2407 (rounds) in area size (1000, 1000).

We have also tested the effect of the speed of MDC on QoS criteria. Figure 6 summarizes the simulation results of MDC-K with K-means by varying the speed of MDC.

We have also tested the effect of the speed of MDC on QoS criteria. Figure 6 summarizes the simulation results of MDC-K with K-means by varying the speed of MDC.

As shown in Figure 6, when the speed of MDC increases, the residual energy, throughput, and stability increases. This can

TABLE 3: Comparison of the network lifetime (residual energy), the stability, throughput, latency time, and number of CHs between the LEACH, TENN, LEACH-K, and MDC-K of 10000 rounds.

	LEACH	TEEN	LEACH-K	MDC maximum residual energy leach	MDC-K
Throughput (packet)	12009	12001	30017	23300	37865
Residuals energy (mJ)	0	0	0	0	$\geq 0,027$
Latency time (ms)	194,86	153,74	96,160	51,551	47,33
Stability (rounds)	799	1078	1399	1913	2567

(a)

(b)

FIGURE 5: Comparison between MDC-K, LEACH-K, TEEN, MDC maximum residual energy leach, and LEACH protocol in terms of stability, latency time, residual energy, and throughput in different area sizes.

show the importance of MDC in routing protocols. In order to evaluate the effect of the density of nodes on the improvement of the QoS. We have simulated MDC-K with a different number of nodes. Figure 7 presents the results of the simulation.

Results showed that the variation of density of nodes keeps the same benefit and improvement with residual energy, stability, throughput, and latency time. As shown in Figure 7, when the number of nodes increases, the latency

slightly increases, but it is still less than the latency of LEACH and LEACH-K protocols.

5. Discussion

To evaluate the efficiency of the proposed protocol in enhancing QoS of clustering protocol, Table 4 compares this protocol with similar protocols reported in the literature.

FIGURE 6: Comparison of the network lifetime (residual energy), the stability, the throughput, latency time of MDC-K with various MDC velocities during 10000 rounds.

FIGURE 7: Comparison of the network lifetime (residual energy), stability, throughput, and latency time of MDC-K with a various number of nodes.

As shown in Table 4, several protocols were proposed for enhancing the LEACH protocol. For instance, the LEACH-K protocol is proposed for improving all the metrics of QoS. MDC-K approach also improved residual energy, latency, stability, and throughput. However, LEACH-K was not useful for LWSNs. The MDC-K protocol is better than

MDC minimum distance LEACH, MDC maximum residual energy leach, and DV-MDC because it improves all the QoS criteria. For example, MDC-K has 37865 (packet) throughput value more than 23300 (packet) in MDC maximum residual energy leach, 23422 (packet) in MDC maximum residual energy leach, and 714 (packet) in DV-

TABLE 4: Comparison of the network lifetime, stability, throughput, and latency time between MDC-K and similar protocols reported in the literature.

	Type of network	Energy efficiency	Stability	CH election	Throughput	Network lifetime	Latency time
LEACH-K [1]	Homogeneous WSN	Higher than LEACH and TEEN	More stable than TEEN and LEACH	Based on initial and residual energy	More than TEEN, LEACH, MDC minimum distance leach, and MDC maximum residual energy leach	Higher than TEEN and LEACH	Lesser than LEACH and TEEN
MDC-K (this paper)	Homogeneous WSN	Higher than TEEN, LEACH, LEACH-K, MDC minimum distance leach, MDC maximum residual energy leach, energy-efficient cluster head LEACH, DV-MDC, and MEACBM	More stable than TEEN, LEACH, LEACH-K, MDC minimum distance leach, and MDC maximum residual energy leach	Based on residual energy	Higher than TEEN, LEACH, LEACH-K, MDC minimum distance leach, MDC maximum residual energy leach, energy-efficient cluster head LEACH, MEACBM, and DV-MDC	Higher than TEEN, LEACH, LEACH-K, MDC minimum distance leach, MDC maximum residual energy leach, energy-efficient cluster head LEACH, and DV-MDC	Lesser than TEEN, LEACH, LEACH-K, MDC minimum distance leach, MDC maximum residual energy leach, MEACBM, and energy-efficient cluster head LEACH
MDC minimum distance leach [5]	Homogeneous WSN	Higher than TEEN, LEACH, and LEACH-K	More stable than LEACH, TEEN, and LEACH-K	Based on initial and residual energy	More than TEEN and LEACH	Higher than TEEN, LEACH, and LEACH-K	Lesser than TEEN, LEACH, and LEACH-K
MDC maximum residual energy leach [8]	Homogeneous WSN	Higher than TEEN, LEACH, and LEACH-K	More stable than LEACH, TEEN, and LEACH-K	Based on initial and residual energy	More than TEEN and LEACH	Higher than TEEN, LEACH, and LEACH-K	Lesser than TEEN, LEACH, LEACH-K, and MDC minimum distance leach
DV-MDC [23]	Homogeneous WSN	Higher than TEEN, LEACH, LEACH-K, MDC minimum distance leach, MDC maximum residual energy leach, and energy-efficient cluster head LEACH	More stable than LEACH, TEEN, MDC minimum distance leach, MDC maximum residual energy leach, and energy-efficient cluster head LEACH	Based on initial and residual energy	More than TEEN, LEACH, energy-efficient cluster head LEACH, MDC minimum distance leach, and MDC maximum residual energy leach	Higher than TEEN, LEACH, LEACH-K, MDC minimum distance leach, MDC maximum residual energy leach, and energy-efficient cluster head LEACH	Lesser than LEACH, LEACH-K, MDC minimum distance leach, MDC maximum residual energy leach, and energy-efficient cluster head LEACH
Energy-efficient cluster head LEACH [14]	Homogeneous WSN	Higher than TEEN, LEACH, LEACH-K, MDC minimum distance leach, and MDC maximum residual energy leach	More stable than LEACH, TEEN, MDC minimum distance leach, MDC maximum residual energy leach, and energy-efficient cluster head LEACH	Based on initial and residual energy	More than LEACH and TEEN	Higher than TEEN, LEACH, LEACH-K, MDC minimum distance leach, and MDC	Lesser than TEEN and LEACH

TABLE 4: Continued.

	Type of network	Energy efficiency	Stability	CH election	Throughput	Network lifetime	Latency time
MDC/PEQ [28]	Homogeneous WSN	Higher than TEEN, LEACH, and LEACH-K	More stable than LEACH and TEEN	Based on residual energy	More than TEEN, LEACH, energy-efficient cluster head LEACH, MDC minimum distance leach, and MDC maximum residual energy leach	Higher than TEEN, LEACH, and LEACH-K	Lesser than TEEN and LEACH, LEACH-K, and energy-efficient cluster head LEACH
MEACBM [14]	Homogeneous WSN	Higher than TEEN, LEACH, energy-efficient cluster head LEACH, MDC minimum distance leach, MDC maximum residual energy leach, and LEACH-K	More stable than TEEN, LEACH, energy-efficient cluster head LEACH, MDC minimum distance leach, and MDC maximum residual energy leach	Based on residual energy	More than TEEN, LEACH, energy-efficient cluster head LEACH, MDC minimum distance leach, and MDC maximum residual energy leach	Higher than TEEN, LEACH, MDC minimum distance leach, MDC maximum residual energy leach, and LEACH-K	Lesser than TEEN, LEACH, LEACH-K, and energy-efficient cluster head LEACH
DEE [2]	Homogeneous WSN	Higher than LEACH, optimum LEACH, TEEN, MDC minimum distance leach	More stable than LEACH, optimum LEACH, TEEN, and MDC minimum distance leach	Based on residual energy and distance to base station	More than LEACH, optimum LEACH, TEEN, and MDC minimum distance leach	Higher than LEACH, optimum LEACH, TEEN, and MDC minimum distance leach	Lesser than LEACH, optimum LEACH, TEEN, and MW-LEACH

MDC. The combination of the K-means and MDC approach improves all the QoS criteria of the LEACH-K protocol.

6. Conclusion

In this paper, we have proposed a new hybrid protocol called MDC-K, which is a combination of LEACH-K approach and MDC. Specifically, this protocol uses the K-means algorithm to reduce energy consumption in the CH election phase. In addition, MDC is used as an intermediate between the CH and the BS to further enhance the QoS criteria of WSN, to minimize time delays during data collection, and to extend the lifetime of the network in WSN. The obtained simulation results demonstrate that MDC-K has a considerable impact on energy consumption and QoS metrics. Particularly, this protocol achieves a significant improvement in terms of energy consumption, residual energy, throughput, latency time, and stability gains better than LEACH, TEEN, LEACH-K, and maximum residual energy LEACH protocols. Moreover, the simulation results show that MDC-K is more suited for LSWSNs as it maintains a good performance in energy consumption and all studied QoS criteria for the large supervised area.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

Dr. Omar Cheikhrouhou acknowledges Taif University for supporting this study through Taif University Researchers Supporting Project no. TURSP-2020/55, Taif University, Taif, Saudi Arabia.

References

- [1] R. Gantassi, B. Ben Gouissem, and J. Ben Othmen, "Routing protocol LEACH-K using K-means algorithm in wireless sensor network," in *Springer Nature Switzerland AG 2020 L*, Barolli, Ed., pp. 299–309, WAINA 2020, AISC, Caserta, Italy, 2020.
- [2] S. E. Khediri, N. Nasri, R. U. Khan, and A. Kachouri, "An improved energy efficient clustering protocol for increasing the life time of wireless sensor networks," *Wireless Personal Communications*, vol. 116, no. 1, pp. 539–558, 2020.
- [3] M. Tech and S. Bhatnagar, "Energy preserve using LEACH protocol in wireless sensor networks," *International Journal of Scientific Research & Engineering Trends*, vol. 5, no. 6, 2019.
- [4] A. S. Toor and A. K. Jain, "Energy aware cluster based multi-hop energy efficient routing protocol using multiple mobile nodes (MEACBM) in wireless sensor networks," *AEU-*

- International Journal of Electronics and Communications*, vol. 102, pp. 41–53, 2019.
- [5] R. Vishnuvarthan, R. Sakthivel, V. Bhanumathi, and K. Muralitharan, “Energy-efficient data collection in strip-based wireless sensor networks with optimal speed mobile data collectors,” *Computer Networks*, vol. 156, pp. 33–40, 2019.
 - [6] K. Li and M. Ang, “Optimizing energy consumption for big data collection in large-scale wireless sensor networks with mobile collectors,” *IEEE Systems Journal*, vol. 12, no. 1, 2018.
 - [7] M. Kamarei, A. Patooghy, M. Z. Shahsavari, and M. Javad Salehi, “Lifetime expansion in WSNs using mobile data collector: a learning automata approach,” *Journal of King Saud University-Computer and Information Sciences*, vol. 32, no. 1, pp. 65–72, 2020.
 - [8] M. Arshad, Y. A. Mohamed, and A. S. Farhan, “Energy efficient cluster based routing scheme for mobile wireless sensor networks,” in *Proceedings of the 5th International Conference on Intelligent and Advanced Systems (ICIAS)*, Kuala Lumpur, Malaysia, June 2014.
 - [9] S. K. Singh, P. Kumar, and J. P. Singh, “A survey on successors of leach protocol,” *IEEE Access*, vol. 5, pp. 4298–4328, 2017.
 - [10] B. Mrinal Kanti Deb and D. Sudeshna, “Data gathering mechanism of mobile data collector in wireless sensor network,” in *Proceedings of the 2016 International Conference on Internet of Things and Applications (IOTA)*, Maharashtra Institute of Technology, Pune, India, January 2016.
 - [11] M. Sajid, K. Khan, U. Qasim, Z. a. Khan, S. Tariq, and N. Javaid, “A new linear cluster handling (LCH) technique toward’s energy efficiency in linear WSNs,” in *2015 IEEE 29th International Conference on Advanced Information Networking and Applications*, vol. 7, pp. 389–393, Gwangju, Korea, March 2015.
 - [12] I. Jawhar, N. Mohamed, J. Al-Jaroodi, and S. Zhang, “A framework for using unmanned aerial vehicles for data collection in linear wireless sensor networks,” *Journal of Intelligent & Robotic Systems*, vol. 74, no. 1-2, pp. 437–453, 2013.
 - [13] I. Jawhar, M. Ammar, S. Zhang, J. Wu, and N. Mohamed, “Ferry-based linear wireless sensor networks,” in *Proceedings of the GLOBECOM-IEEE Global Communications Conference*, pp. 304–309, Atlanta, GA, USA, October 2013.
 - [14] M. Arshad, N. Armi, N. Kamel, and N. M. SaadM, “Mobile data collector based routing protocol for wireless sensor networks,” *Scientific Research and Essays*, vol. 6, no. 29, pp. 6162–6175, 2011.
 - [15] M. Krishnan, S. Yun, and M. J. Yoon, “Dynamic clustering approach with ACO-based mobile sink for data collection in WSNs,” *The Journal of Mobile Communication, Computation and Information*, vol. 25, pp. 4859–4871, 2018.
 - [16] G. Devi, “The K-means clustering used in wireless sensor network,” *International Journal on Computer Science and Engineering (IJCSE) ISSN*, vol. 8, no. 4, pp. 975–3397, 2016.
 - [17] E. Rabiata, B. Nourab, and C. Adnenec, “Improvements in LEACH based on K-means and Gauss algorithms,” in *Proceedings of the International Conference on Advanced Wireless, Information, and Communication Technologies AWICT*, Tunis, Tunisia, October 2015.
 - [18] S. Randhawa and S. Jain Computer, “Performance analysis of LEACH with machine learning algorithms in wireless sensor network,” *International Journal of Computer Applications*, vol. 147, no. 2, pp. 975–8887, 2016.
 - [19] Y. Feng, S. Zhao, and H. Liu, “Analysis of network coverage optimization based on feedback K-means clustering and artificial fish swarm algorithm,” *IEEE Access Date of Current Version*, vol. 8, pp. 42864–42876, 2020.
 - [20] S. ElKhediria, W. Fakheth, T. Moulahid, R. N. Khand, A. Thajjaouie, and K. Abdennaceur, “Improved node localization using K-means clustering for wireless sensor networks,” *Computer Science Review*, vol. 37, Article ID 100284, 2020.
 - [21] B. Zhu, E. Bedeer, Ha H. Nguyen, R. Barton, and H. Jerome, “Improved soft-K-means clustering algorithm for balancing energy consumption in wireless sensor networks,” *IEEE Internet of Things Journal*, vol. 8, no. 6, pp. 4868–4881, 2020.
 - [22] A. A.-H. Hassan, W. Md Shah, M. F. I. Othman, and H. A. H. Hassan, “Evaluate the performance of K-means and the fuzzy C-Means algorithms to formation balanced clusters in wireless sensor networks,” *International Journal of Electrical & Computer Engineering*, vol. 10, no. 2, pp. 2088–8708, 2020.
 - [23] D. Kim, R. N. Uma, B. H. Abay, W. Wu, W. Wang, and A. O. Tokuta, “Minimum latency multiple data MULE trajectory planning in wireless sensor networks,” *IEEE Transactions on Mobile Computing*, vol. 13, no. 4, pp. 838–851, 2014.