Enhancing QoS and residual energy by using of Grid-size clustering, K-means, and TSP algorithms with MDC in LEACH protocol

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ABSTRACT Some recent researches have shown that the energy consumption problem caused by data collection in a wireless sensor network (WSN) based on a static data collector is a main threat to the network lifetime. However, with the progress of the mobile terminal technology, the implementation of mobile data collectors (MDCs) has become more popular in large-scale WSNs, but it remains a big problem to improve the Quality of Service (QoS) criteria and minimize the energy consumption at the same time. However, most existing systems based on MDCs do not successfully strike a balance between routing energy consumption and QoS. In addition, most WSN protocols fail to maintain their impact when the network topology changes. Thus, for a dynamic WSN, it is important to support an intelligent MDC to continue data propagation despite the inevitable changes in the WSN topology. Considering all the above challenges, we propose a new intelligent MDC based on the traveling salesman problem (TSP) to determine the optimal path traveled by the MDC for energy efficiency and latency. Specifically, our proposed Mobile Data Collectors-Traveling Salesman Problem-Low Energy Adaptive Clustering Hierarchy-K-Means (MDC-TSP-LEACH-K) protocol uses K-Means and Grid clustering algorithm to decrease energy consumption in the cluster head (CH) election phase. Additionally, MDC is utilized as an intermediate between CH and the sink to further enhance the QoS of WSNs, to reduce delays while collecting data, and improve the transmission phase of the LEACH protocol.

INDEX TERMS Energy consumption, large-scale wireless sensor networks, optimal path, QoS.

I. INTRODUCTION

MOST recently, studies have demonstrated that introducing mobile data collectors (MDCs) can significantly enhance the performance of wireless sensor networks (WSNs). But there are important design issues, such as how to determine the location of the nodes, the number of sensor nodes (SNs), and the design of an optimal MDC path. Therefore, new WSN protocols have been proposed to deal with media access control, routing protocols, data aggregation, etc. Although much research has focused on reducing the energy consumption of routing protocols, only a few have addressed other quality of service (QoS) criteria, such as node throughput and latency. Therefore, in this paper, we propose a routing protocol that considers energy consumption, throughput, latency, and stability of nodes in terms of QoS. In WSNs, clustering has been considered as an important data mining technique to solve problems such as data aggregation, network lifetime, load balancing, energy consumption, stability, and scalability [1]. For many advantages, aggregation is recommended in WSN [2], [3] data operation. In addition, clustering is an important element of network organization, which has an impact on network efficiency anyway. The process of clustering divides a WSN into groups called "clusters", each cluster has an elected leader among the SNs who is called "cluster head" (CH). All data flows are transferred by the WSNs and aggregated...
by their CHs into a cluster. After that, data streams are transmitted by the CHs to the base station (BS). Transmitting data continuously in a wireless network using multi-hop communication to reach the BS consumes the energy at the nodes, and therefore, reduces the network lifetime. Clustering algorithms in WSNs consist of rounds. The clustering algorithms of WSNs are executed in rounds. The rounds involve cluster creation, CH election, and data transmission [4]. WSN clustering algorithms running data streams are divided into two main steps, the clustering phase, and the data transmission phase. Using the grid clustering algorithm [5], each cluster is formed according to the size of each grid in WSN. In particular, this method fixes the size and location of clusters. In addition, other Machine Learning clustering algorithms have been proposed in the research literature, such as the K-Means algorithm. The latter divides the dataset into K clusters using the mean Euclidean distance, which allows for the optimization of intra-cluster similarity [1], [6].

Our research focuses on combining the MDC with the traveling salesman problem (TSP) during the transmission phase of our protocol, which is implemented by a company in the USA in order to find a solution to the path problem by utilizing linear programming. The TSP is a specific case of the vehicle touring problem. However, the problem of how to select the best travel route and not to miss each landscape has become a problem that needs to be considered in recent years. This current example exactly mirrors problems common in mathematics-TSP problem, in which a businessman visits $n$ city and then goes back to the starting city, with the assumption that a city can be visited only once to determine the fastest [6], [7].

This study proposes a new protocol called Mobile Data Collectors-Traveling Salesman Problem-Low Energy Adaptive Clustering Hierarchy-K-Means (MDC-TSP-LEACH-K), which is a combination of the LEACH protocol and the TSP-based MDC approach. It uses K-Means and Grid clustering algorithms to decrease the energy consumption of the CH election phase and to improve the CH election and a new intelligent MDC based on the TSP to determine the optimal MDC path for an efficient latency. More precisely, the contribution of this paper is as follows:

1) This work proposes a new routing protocol called MDC-TSP-LEACH-K. The proposed algorithm first applies the Grid algorithm to divide the network into equal size regions, then the K-Means algorithm is applied to each grid cluster to determine the CH. Assigned each CH to the SN having the minimum distance to the centroid of each grid cluster. The CH can broadcast data to MDC when MDC visits its lineup. MDC completes its collection and finally delivers the data to the BS.

2) This work integrates TSP to the proposed solution to determine the MDC optimal path.

3) This work compares the proposed protocol to existing solutions and proves its higher performance.

The remaining of this paper is organized as below. Literature review on clustering protocol using the K-Means algorithm, Grid algorithm, and TSP in MDC are provided in section II. An explanation of the proposed clustering protocol is provided in section III. The analysis and simulation results are presented in section IV. Finally, conclusions are provided in Section V.

II. RELATED WORK

Many studies have been conducted to evaluate the effect of K-Means on the LEACH protocol performance in WSN [1], [8]–[13]. Other studies, apply the Grid-sizes clustering on LEACH to enhance the WSNs performances as in [5], [8], [14], [15]. Several other studies have been carried out to develop MDC routing protocols [16]–[20] in which they have concentrated on increasing the lifetime of the WSN. Some research studies implement the MDC in the LEACH protocol, while others apply the K-Means and Grid-sizes Clustering in the LEACH protocol. Other studies, on the other hand, apply the TSP algorithm, on LEACH to enhance the WSNs performances as in [21]–[26]. Table I summarizes some literature works.

As noted above, some works integrate the Grid, and K-Means algorithm into the LEACH protocol, while others implement the TSP algorithm in this protocol. Note that both Grid and K-Means algorithms have similar philosophies but are used separately, as stand-alone algorithms, to reduce energy consumption in LEACH. However, only a few works integrate both algorithms (Grid, K-Means) to improve the QoS of the LEACH protocol. To our knowledge, no work has combined the K-Means, Grid and TSP algorithms in the MDC of the LEACH protocol. This work aims to integrate the K-means and Grid algorithms in a clustering setup phase where the TSP approach is used in the transmission phase of the LEACH protocol to improve QoS measurements. In the following section, our MDC-TSP-LEACH-K clustering algorithm will be discussed.

III. PROPOSED APPROACH

A. MDC-TSP-LEACH-K

Our proposed protocol MDC-TSP-LEACH-K is an extension of the basic principle of LEACH [4], [31] and convergence of wireless mobile communication technologies and enhanced sensor technology. This work uses the K-Means and Grid algorithm to improve the LEACH protocol before CHs election and the MDC as an interface between the CHs and the BS. The whole WSN area is divided into a logical grid of a defined size (i.e. 4x4 grid, as shown in Fig. 1). Every grid is a rectangle (with $d$ units on each side) of size $(d \times d)$. Therefore, the size of the grid is determined according to the nominal radio range ($R$). For a large value of $R$, the grid includes a large number of nodes. Once the grid is configured and all nodes are placed, the K-Means algorithm is applied for each cluster in the grid to reduce the intra-cluster communication distance and to provide the centroid coordinates. The choice of the CH is made accord-
In this paper, researchers implemented the Grid and K-Means algorithm in LEACH.

This approach is based on a shutdown timer. This is calculated based on the residual energy levels of each node in the network. The global energy of the given cluster, comprising the rest of the nodes and the CH, is kept during the process.

This paper proposes an adaptive network multi-mode LEACH protocol to address the QoS and energy efficiency requirements of the IoT/M2M communication system. The protocol provides an adaptive grid partitioning, considering three different transmission modes: node-to-gateway (CNG), node-to-base station (CN-BS), and node-to-cluster head (CH) and CH-to-base station (BS), with residual energy and inter-node distance taken into account for the CH selection.

Grid-based clustering algorithms are used in routing protocol.

The result was improved in terms of energy efficiency, reducing cost and increasing network reliability.

The proposed routing protocol decreased energy consumption and latency time, and increased network stability time, network lifetime, and throughput.

Cluster-grid protocols are employed to optimize the distribution of CH to reduce the cluster area.

The limitation of the study is that the proposed solution does not use an intelligent MDC.

This approach did not use the MDC and TSP algorithm in the transmission phase and tested in LS-WSNs.

This work is weak because it uses only a very limited number of parameters. The simulation phase, for example, focused on only two clusters of 10 nodes. This approach did not use the MDC and TSP algorithm in the transmission phase. It did not improve the QoS of the network.

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In this paper, researchers implemented and discussed the K-Means and MDC in LEACH.

This paper developed a JayaX approach with local search module based CH selection (JayaX-LSM-CS) and a cluster formation method and adopted an ant colony optimization (ACO) based algorithm for efficient data collection.

The authors propose, analyze and test the LEACH routing protocol-based MDC that is predicated on a multi-hop routing strategy.

The authors report a comparison between the MDC’s maximum residual energy routing protocol and LEACH multi-hop hybrid routing protocol. Reference [18] reports that the MDC moves to the nodes with the maximum energy.

This approach provides a significant reduction in SNs, energy consumption, improved network lifetime, and improved data collection compared to the LEACH protocol.

The authors propose Multi-hop Simulated Annealing-LEACH (MiSA-LEACH) protocol based on intra-cluster multi-hop communication. The selection of intermediate nodes in the multi-hop protocol is done using Simulated Annealing algorithm on TSP.

There is an additional column for summaries:

| Reference | Summary |
|-----------|---------|
| [16]      | In this paper, researchers implemented and discussed the K-Means and MDC in LEACH. This routing protocol reduces energy consumption and latency, and increases network stability time, network lifetime and throughput. QoS optimization for LEACH in LWSN with MDC and K-Means. From the experimental results, proposed framework (PF) is found to significantly improve the WSN lifetime. The limitation of the study is that the proposed solution does not use an intelligent MDC. |
| [30]      | This approach did not use the MDC and was TSP algorithm in the transmission phase and tested in LS-WSNs. This approach did not use the intelligent MDC and TSP algorithm in the transmission phase and was tested in LS-WSNs. This approach did not use the intelligent MDC and TSP algorithm in the transmission phase and tested in LS-WSNs and ameliorate the QoS. |
| [17]      | The authors report a comparison between the MDC’s maximum residual energy routing protocol and LEACH multi-hop hybrid routing protocol. Reference [18] reports that the MDC moves to the nodes with the maximum energy. The results of the simulation demonstrate the better performance of the “MDC Maximum Residual Energy” protocol compared to the LEACH protocol in terms of energy consumption of the SNs. These results also show a significant increase in network lifetime. In addition, the proposed scheme can be applied to LWSN. This method extends the life of the sensors since it is a reactive rather than proactive method. |
| [18]      | In this paper, the MDC starts its data collection at the data BS by capturing the signal from the CH beacon, then collecting CH data, and finally conducting the data to the BS. The MDC maximum residual energy method focuses on multi-hop communication among SNs, the MDC, and the sink. This approach is of nature to reduce the energy consumption of the network nodes. In addition, this approach can be implemented in a network covering large regions. Simulation results demonstrate that the proposed protocol outperforms the LEACH protocol in terms of sensor node power consumption and network lifetime. |
| [19]      | Authors develop a new strategy for data collection in LS-WSN by using mobility in the network. In this paper, the problem of single-hop data collection (SHD) concentrates on reducing the time of each round of data collection. Typically, the round follows the path of the TSP. When MDC is traveling in the SHDG, it can query neighboring SNs to gather data. When a sensor receives the polling message, it simply downloads the data to the MDC in a single hop from one sensor to another. Authors propose Multi-hop Simulated Annealing-LEACH (MiSA-LEACH) protocol based on intra-cluster multi-hop communication. The selection of intermediate nodes in the multi-hop protocol is done using Simulated Annealing algorithm on TSP. The simulation results of this approach show the optimization of MiSA-LEACH on the number of packets received by the BS or the CH and the number of dead or alive nodes of the LEACH and Multi-Hop Advance Heterogeneity-aware Energy Efficient (MA-HEE) protocols. The simulation results show that MA-LEACH surpasses LEACH with a fuzzy descriptor in network lifetime and energy consumption. |
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| [26]      | This approach did not ameliorate the QoS and did not use the MDC in the transmission phase. This approach did not ameliorate the QoS and did not use the MDC in the transmission phase. This approach did not ameliorate the QoS and did not use the MDC in the transmission phase. |

Routing protocols with TSP

| Reference | Summary |
|-----------|---------|
| [21]      | Authors develop a new strategy for data collection in LS-WSN by using mobility in the network. In this paper, the problem of single-hop data collection (SHD) concentrates on reducing the time of each round of data collection. Typically, the round follows the path of the TSP. When MDC is traveling in the SHDG, it can query neighboring SNs to gather data. When a sensor receives the polling message, it simply downloads the data to the MDC in a single hop from one sensor to another. Authors propose Multi-hop Simulated Annealing-LEACH (MiSA-LEACH) protocol based on intra-cluster multi-hop communication. The selection of intermediate nodes in the multi-hop protocol is done using Simulated Annealing algorithm on TSP. The simulation results of this approach show the optimization of MiSA-LEACH on the number of packets received by the BS or the CH and the number of dead or alive nodes of the LEACH and Multi-Hop Advance Heterogeneity-aware Energy Efficient (MA-HEE) protocols. The simulation results show that MA-LEACH surpasses LEACH with a fuzzy descriptor in network lifetime and energy consumption. |
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| [25]      | In this paper, the authors studied the LEACH routing protocol and its performance and proposed a new protocol, MA-LEACH. First, the mobile aggregator is introduced which represents the overhead of the CH. Furthermore, by using particle swarm optimization trajectory optimization is performed. Therefore, to determine the optimal trajectory that a mobile... |
| [26]      | This approach did not ameliorate the QoS and did not use the MDC in the transmission phase. This approach did not ameliorate the QoS and did not use the MDC in the transmission phase. This approach did not ameliorate the QoS and did not use the MDC in the transmission phase. |
aggregator could travel to visit each CH in the network, the authors fit the TSP problem to their protocol. In the proposed protocol of this article, in PERLDA sensors do not send their data directly to CH for aggregation; rather each sensor sends its data to the nearest neighbor sensor. It receives data and aggregates it with its data. Then it sends the new information to another neighbor SN that is in line with CH. Therefore, data aggregation in PERLDA does not perform only in one sensor, rather it local data aggregation network. PERLDA protocol saves a lot of energy by selecting the shortest route for data transmission by TSP.

In the PERLDA protocol, to avoid data interference, the TDMA technique is used within each cluster. In fact, the combination of TDMA and the traveling salesman problem is quite unique. Each CHs energy is verified by the Neuro-Fuzzy network. Any CH possessing the lowest energy is detected, and the duration for which the CH can continue to do its job with the least energy is also estimated. This approach did not ameliorate the QoS and did not use the MDC in the transmission phase and was tested in LS-WSNs.

[26] In this paper, the authors proposed an anchor point with a clustering (APAC) algorithm in WSNs. It implemented TSP to find the shortest route. The results showed that the latency is reduced compared to the only point substitution method. This approach did not ameliorate the QoS and did not use the MDC in the transmission phase.

The proposed scheme uses a Grid-cluster-based WSN. One of the SNs is selected as the CH of each Grid cluster, which TSP provides a dynamic trajectory to MDC. Since the CH are located almost very close to the centroid, the MDC moves on an almost linear trajectory starting from the first centroid of the first grid-cluster to the last grid column. Then it moves to the nearest centroid of the grid-cluster until the whole grid-cluster. Finally, it transmits all the data to the sink. The process of the MDC-TSP-LEACH-K Problems algorithm is shown in Fig. 2:

![FIGURE 2. The process of the MDC-TSP-LEACH-K.](image-url)

The MDC-TSP-LEACH-K process has the following advantages:
1) Less energy consumption.
2) Less Overheads
3) Less latency times.
4) More Robustness
5) Stability
6) Balancing of areas between groups
7) Scalability

The process of the MDC-TSP-LEACH-K is shown in Fig. 3:

![FIGURE 3. The process of the MDC-TSP-LEACH-K.](image-url)
B. MDC-TSP-LEACH-K ENERGY MODEL

MDC-TSP-LEACH-K is an improvement of the LEACH-K protocol [1]. LEACH-K adapts the energy model of LEACH [4], as shown in Fig4.

If the distance is less than a threshold D, the free space model ($d^2$ power loss) is used; otherwise, the multi path model ($d^4$ power loss) is used. Or, for short distance transmission, such as intra-cluster communication, the energy consumed by a transmitting amplifier is proportional to $d^2$ and for long distance transmission, such as inter-cluster communication, the energy consumption is proportional to $d^4$. D is a threshold transmission distance where:

$$D = \sqrt{\frac{\epsilon_{fs}}{\epsilon_{Amp}}}$$

Thus, if the transmitter sends a message of $b$ bits to the receiver until $d$ distance, the required energy to transmit $b$ bits of data is modeled by (3):

$$E_{Transmitting} = (\epsilon_{ele}b) + \epsilon_{Amp}bd^2$$

Where:
- Each SN is static and homogeneous.
- $B$ is the number of transmitted bits.
- $\epsilon_{fs}$ is the power loss of free space.
- $\epsilon_{Amp}$ is the power multi path models.
- $d$ is the distance between CH and MDC.
- $E_{ele}$ is The parameter $E_{ele}$ is the per bit energy dissipations for transmission and reception.

The required energy to get $B$ bits of data is modeled by (4):

$$E_{Receiving}(B) = E_{ele}B$$

where :
- $E_{ele}$ is the energy required to operate electronic circuitry of receiver.

Energy consumed during a data collection cycle is calculated in (5).

$$E_{Round} = E_{Transmitting} + E_{Receiving}$$

IV. SIMULATION RESULTS AND ANALYSIS

To evaluate the performance of the proposed approach, it is compared to various existing protocols that are based on QoS criteria such as throughput and energy consumption in the operate of CH as an aggregator. It aggregates the data received from its nodes and sends it to the BS via the MDC. The simulation of the proposed approach is done by using MATLAB simulators. We chose MATLAB due to the facility of its interface and the availability of the necessary functions programmed in advance such as the K-Means and grid functions. Furthermore, the implementation of our mathematical model is very easy on MATLAB because the MATLAB language is a matrix language allowing the most natural expression of computational mathematics.

Various parameters and factors are taken into consideration while performing the simulation to enhance the network performance. Our simulation is divided into two scenarios. In the first scenario, we have evaluated MDC-TSP-LEACH-K with hierarchical WSNs routing protocols such as LEACH-K, which is one of the proposed enhanced versions of LEACH. In particular, in this scenario, the position of the BS is outside the area (0, 1.25). In the second step, we have evaluated the simulation results of our proposed protocol MDC-TSP-LEACH-K with different protocols including threshold-sensitive energy-efficient sensor network (TEEN), LEACH, LEACH-K, LEACH-C, LEACH-G-K, Improved-LEACH, Stable-Improved-LEACH, MhSa-LEACH, MDC maximum residual energy leach and, MDC-K protocols, which used K-means, MDC, TSP or Grid function in LEACH for LS-WSNs. In particular, in this scenario, we have increased the size of the area from 100*100 to 1000*1000. Table 2 describes the simulation parameters to all scenarios.
TABLE 2. Simulation Parameters

| Settings                                      | Values                  |
|----------------------------------------------|-------------------------|
| Electronic dissipation energy (sending, receiving) | $E_{elec} = 50$ nJ/bit  |
| Energy for data aggregation                  | $E_{DATA} = 5$ nJ/bit/m² |
| Transmit Amplifier if $d_{toBS} \leq d_0$    | $\epsilon_{f} = 10$ pJ/bit/m² |
| Transmit Amplifier if $d_{toBS} \geq d_0$    | $\epsilon_{Amp} = 0.0013$ pJ/bit/m² |
| Position of BS                               | (0, 125)                |
| Initial power                                | 0.5 J/node              |
| Node distribution                            | Static                  |
| Simulation period                            | 10000 rounds            |
| Simulation Area                              | 100 m² to 1500 m²       |

1) First scenario
In these simulation scenarios, the SNs have 0.5 J battery energy. We evaluate the following parameters in the TENN, LEACH, LEACH-K, LEACH-C, LEACH-G-K, Improved-LEACH, Stable-Improved-LEACH, MhSa-LEACH, MDC maximum residual energy leach, MDC-K protocols, and our proposed protocol MDC-TSP-LEACH-K. In this section, we discuss the considered test scenario and the adopted performance metrics. We present the results of simulation scenarios. These results are analyzed to make a tradeoff between residual energy, throughput (packets received by the BS), and latency as a function of $K$ variation over 10000 rounds.

One hundred nodes were chosen to test the performance of their improvement method against the MDC-TSP-LEACH-K protocol. Fig. 5 shows the throughput in each round of LEACH, TENN, LEACH-K, LEACH-C, Improved-LEACH, Stable-Improved-LEACH, MhSa-LEACH, MDC maximum residual energy leach, MDC-K protocols, and the proposed protocol MDC-TSP-LEACH-K.

Fig. 5 illustrates the throughput variations of the proposed MDC-TSP-LEACH-K protocol compared to the TENN, LEACH, LEACH-K, LEACH-C, LEACH-G-K, Improved-LEACH, Stable-Improved-LEACH, MhSa-LEACH, MDC maximum residual energy leach and, MDC-K protocols. The curves of Fig. 5 point out that integrating MDC by using the TSP algorithm increases throughput significantly. We noticed that the throughput value of MDC-TSP-LEACH-K in round 10000 is equal to 18910 packet/round compared to 18300 packet/round for MDC-K protocol, 18110 packet/round of LEACH-K protocol, 16271 packet/round of MDC maximum distance leach protocol, 16020 packet/round for MhSa-LEACH protocol, 15111 packet/round of LEACH-G-K, 12046 packet/round of Stable-Improved-LEACH protocol, 11199 packet/round of Improved-LEACH protocol, 8747 packet/round of LEACH-C, 8012 packet/round of the TENN protocol, and 8001 packet/round of LEACH protocol.

The proposed protocol increases the throughput value by minimizing the distance between SB and CH with the K-Means algorithm and reducing the latency time by using TSP in MDC. Fig. 5 shows that the number of packets received by the sink for LEACH is very less than other protocols. The comparison of MDC-LEACH-K-TSP and MDC-K showed that MDC-LEACH-K-TSP is better than MDC-K from 2500 rounds. At 2500 rounds, the number of packets received by the sink starts to deviate significantly from the previous round. Moreover, MDC-TSP-LEACH-K protocol can play a vital role to enhance reliability. Fig. 6 presents a comparison between the MDC-TSP approach TENN, LEACH, LEACH-K, LEACH-C, LEACH-G-K, Improved-LEACH, Stable-Improved-LEACH, MhSa-LEACH, MDC maximum residual energy leach, and MDC-K protocols in terms of lifetime.

FIGURE 5. Simulation throughput results of TENN, LEACH, LEACH-K, LEACH-C, LEACH-G-K, Improved-LEACH, Stable-Improved-LEACH, MhSa-LEACH, MDC maximum residual energy leach, MDC-K, and MDC-TSP-LEACH-K protocols.

FIGURE 6. Simulation lifetime results of LEACH, TENN, LEACH-K, LEACH-C, Improved-LEACH, Stable-Improved-LEACH, MDC maximum distance leach, MDC-K, MhSa-LEACH, LEACH-G-K protocols, and MDC-TSP-LEACH-K.

As indicated in the above figures, our proposed
solution of MDC-TSP-LEACH-K improves the network lifetime with higher performances compared to LEACH, TENN, LEACH-K, LEACH-C, Improved-LEACH, Stable-Improved-LEACH, MDC maximum distance leach, LEACH-G-K but it is less stable than MDC-K and MhSa-LEACH protocols. It improves the sensor node’s residual energy as well. Numerical results show that the proposed method is able to decrease the sensor node’s energy consumption. Fig. 7 presents the stability of the proposed approach compared to LEACH, TENN, LEACH-K, LEACH-C, Improved-LEACH, Stable-Improved-LEACH, MDC maximum distance leach, LEACH-G-K but it is less stable than MDC-K and MhSa-LEACH protocols.

The stability slightly increases from 207 (rounds) in Improved-LEACH to 499 (rounds) in LEACH to 584 (rounds) in LEACH-C to 603 (rounds) in Stable-Improved-LEACH to 747 (rounds) in TENN to 1329 (rounds) in LEACH-K to 1399 (rounds) in Improved-LEACH to 1917 (rounds) in MDC maximum distance leach to 1992 (rounds) in MDC-TSP-LEACH-K to 2000 (rounds) in MhSa-LEACH to 2008 (rounds) to MDC-K. We notice that our protocol is less stable than MhSa-LEACH and MDC-K protocols. Fig. 8 presents a comparison between LEACH, TENN, LEACH-K, LEACH-C, Improved-LEACH, Stable-Improved-LEACH, and MDC maximum distance leach protocols in terms of latency time.

As shown in Fig. 8, when we used our approach, the latency time also increases to 35.16 (ms) from MDC-TSP-LEACH-K protocol compared to 232.07 (ms) in LEACH protocol, 174.08 (ms) from LEACH-C protocol, 151.002 (ms) from TENN protocol, 137.56 (ms) from Stable-Improved-LEACH protocol, 117.67 (ms) from MhSa-LEACH protocol, 92.07 (ms) from LEACH-K protocol and 84.1 (ms) from LEACH-G-K protocol, 61.27 (ms) from MDC maximum distance leach, 50.001 (ms) from MDC-K. Based on the experimental results, we conclude that our MDC-TSP-LEACH-K protocol is the best solution to reduce the latency time compared to the LEACH protocol and their improvement.

2) Second scenario
Since LS-WSNs are very developed nowadays, in the second scenario, the effectiveness of our proposed protocol TSP-LEACH-K in LS-WSNs is also tested. Specifically, we have evaluated the QoS criteria values in different area sizes. Fig. 9 presents a comparison between MDC-TSP-LEACH-K LEACH, LEACH, TENN, LEACH-K, LEACH-C, Improved-LEACH, Stable-Improved-LEACH, MDC maximum distance leach, MDC-K, MhSa-LEACH, and LEACH-G-K protocols in terms of stability, latency time, lifetime, and throughput in different area sizes.
LEACH-K also improved the lifetime, latency, stability, and posed to improve all QoS metrics. In addition, MDC-TSP-LEACH-K, LEACH-K, and MDC-K protocols are proposed to improve the LEACH protocol. For example, protocols in the literature.

It is shown in Fig. 9 that when the area size increased, the lifetime, throughput, and stability decreased slightly, which indicates that the benefits of our protocol stay almost stable with a large area. For example, the latency also increases from 35.16 (ms) in an area size (100, 100) to 38.98 (ms) in an area size (1500, 1500). The throughput decreases from 18910 (packets/ rounds) in a (100, 100) size area to 18667 (packets/ rounds) in a (1500, 1500) size area. The stability decreases from 7321 (rounds) in a (100, 100) size area to 6933 (rounds) in a (1500, 1500) size area. According to its results, we conclude that our MDC-TSP-LEACH-K is the better solution for LS-WSNs.

To assess the effectiveness of our MDC-TSP-LEACH-K protocol in improving the reliability of the routing protocol, Table 3 provides a comparison of our protocol and some similar protocols in the literature.

As illustrated in Table 3, several protocols have been proposed to improve the LEACH protocol. For example, LEACH-G-K, LEACH-K, and MDC-K protocols are proposed to improve all QoS metrics. In addition, MDC-TSP-LEACH-K also improved the lifetime, latency, stability, and throughput. However, LEACH-G-K and LEACH-K was not useful for LS-WSNs. Our protocol is better than LEACH-G-K, MDC-K, MDC maximum residual energy leach, and Stable-Improved-LEACH because it improves all QoS criteria for LWSNs. The combination of K-Means, Grid, TSP, and MDC approaches improves all QoS criteria of LEACH, LEACH-G-K, and LEACH-K protocols LS-WSNs.

In our approach, we have chosen the SN where its position is close to the centroid i.e. the center of each grid cluster and therefore the distance between the CH and the SNs is very small and therefore the CH does not consume a lot of energy and therefore the communication between the CH and the SNs is very reliable. Otherwise all CHs will be moved on the same trajectory of all K-Means cluster which facilitates the movement of MDC also via TSP the MDC will be chosen the CH closest to their position, so less movement and less energy consumption is required and the risk of falling the CH battery failure is low and subsequently we can say that our approach is very reliable.

To assess the effectiveness of our MDC-TSP-LEACH-K protocol in improving the reliability of the routing protocol, table 4 provides a comparison of our protocol and some similar protocols in the literature.

V. CONCLUSION

In this paper, a new hybrid protocol called MDC-TSP-LEACH-K, which is a combination of LEACH-G-K, TSP, and MDC approach, had been proposed to improve LEACH protocol aggregation. To be more precise, MDC-TSP-LEACH-K used the grid, and K-Means algorithms to minmize the energy consumption during the CH election phase. Furthermore, MDC was used as the intermediary between CH and sink in order to improve the QoS criteria of LS-WSNs again, reduce the latency during data collection, and prolong the network lifetime in the LS-WSNs. Our simulation results showed that MDC-TSP-LEACH-K had a significant impact on QoS metrics, and energy consumption. Specifically, this protocol provided considerable enhancement in terms of residual energy, throughput, latency, and stability gains more than LEACH, TENN, LEACH-K, LEACH-C, Improved-LEACH, Stable-Improved-LEACH, MDC maximum distance leach, LEACH-G-K but it is less stable than MDC-K and MhSa-LEACH protocols.

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| Protocols          | Communication Scheme | Lifetime | Stability | CH Selection | Latency Time | Complexity | Load Balancing | Type of Network | Scalability | Energy Dissipation |
|-------------------|----------------------|----------|-----------|--------------|--------------|------------|----------------|-----------------|-------------|------------------|
| LEACH [4]         | Single-hop           | Low      | Poor      | Random       | High         | Low        | No             | Homogeneous     | Poor        | Less than all the amelioration of LEACH |
| TENN [32]         | Single-hop           | Low      | Poor      | Random       | High         | Low        | No             | Homogeneous     | Poor        | High than LEACH  |
| LEACH-C [33]      | Multi-hop            | Low      | Poor      | Random       | High         | Low        | No             | Homogeneous     | Poor        | High than LEACH  |
| LEACH-K [1]       | Multi-hop            | Low      | High      | Random       | less         | High       | No             | Homogeneous     | High        | High than \( \text{LEACH, LEACH-C, TEEN, Improvement-LEACH, and Stable-Improved-LEACH} \) |
| LEACH-G-K [5]     | Multi-hop            | High     | High      | Choose the node near the centroid of the cluster | Poor         | High       | No             | Homogeneous     | High        | High than \( \text{LEACH, LEACH-C, TEEN, Improvement-LEACH, Stable-Improved-LEACH, and LEACH-K} \) |
| Improved-LEACH [34] | Multi-hop            | High     | Poor      | According to the residual energy | High         | Low        | No             | Homogeneous     | High        | High than \( \text{LEACH, LEACH-C, and TEEN} \) |
| Stable-Improved-LEACH [35] | Multi-hop         | High     | Medium    | According to the residual energy | High         | Medium     | No             | Homogeneous     | High        | High than \( \text{LEACH, LEACH-C, TEEN, Improvement-LEACH, Stable-Improved-LEACH, and LEACH-K} \) |
| MhSa-LEACH [23]   | Multi-hop            | Medium   | High      | Choose node that has the highest energy and near BS | High         | High       | No             | Homogeneous     | High        | High than \( \text{LEACH, LEACH-C, TEEN, Improvement-LEACH, LEACH-K, and Stable-Improved-LEACH} \) |
| MA-LEACH [24]     | Multi-hop            | Medium   | High      | Random       | High         | Medium     | No             | Homogeneous     | High        | High than \( \text{LEACH, TEEN, and Fuzzy LEACH} \) |
| Fuzzy LEACH [25]  | Multi-hop            | Medium   | Medium    | Random       | High         | Medium     | No             | Homogeneous     | High        | High than \( \text{LEACH and TEEN} \) |
| MDC maximum distance leach [36] | Multi-hop       | High     | Medium    | Choose the node near the BS | less         | Medium     | No             | Homogeneous     | High        | High than \( \text{LEACH, LEACH-C, TEEN, Improvement-LEACH, LEACH-K, Stable-Improved-LEACH, MhSa-LEACH, and LEACH} \) |

(To be Continued)
| Algorithm       | Hop Model | Hop Efficiency | Hop Energy Efficiency | Node Selection Method | Energy Efficiency |Homogeneity | Hop Efficiency |
|-----------------|-----------|----------------|-----------------------|-----------------------|------------------|------------|----------------|
| MDC-K           | Multi-hop | High           | High                  | Choose the node near the centroid of the cluster | Poor             | No         | Homogeneous    |
| MAHEE           | Multi-hop | Medium         | Poor                  | According to remaining energy, location of the node | High             | YES        | Homogeneous    |
| SEP             | Multi-hop | High           | High                  | Choose node that has the highest energy | High             | No         | Heterogeneous  |
| MDC-TSP-LEACH   | Multi-hop | High           | High                  | Choose the node near the centroid of the cluster | Poor             | No         | Homogeneous    |

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Contributions Already Provided

In this paper, a novel CH selection protocol has been proposed based on the firefly algorithm (FA) and hesitant fuzzy. It utilizes three SN parameters in order to calculate the score of each node and find the best CHs.

 validations Already Done

The assessment of the performance included various factors related to the energy efficiency and the lifetime and not the reliability of the system.

This paper proposes a novel extended LEACH-based algorithm to improve WSN performance in terms of reliability, energy efficiency, and lifetime. This algorithm, EM-LEACH, firstly takes on new rules for CH selection and the calculation of round time based on the remaining energy. On the other hand, EM-LEACH improves the communication model from a single hop to a multi-hop between CHs and the sink using two operational processes: leveling and generic multi-hop routing.

The evaluation of performance focused on various aspects related to the network’s reliability, energy efficiency and lifetime.

Our paper proposed a new clustering algorithm based on extended LEACH to improve the performance of WSN in terms of QoS, and lifetime. First, our protocol, MDC-TSP-LEACH-K, supports new rules for CH selection and clustering using Grid and KMeans function.

MDC-TSP-LEACH-K

As a result, an simulation of the proposed scheme is performed in MATLAB simulator. By using various performance parameters, a comparison is made between the proposed scheme and the existing protocols to measure its efficiency in order to provide more reliability and extend the lifetime for the low power consumption protocols.

TABLE 4. The comparison analysis of reliability for cluster head election and clustering of our protocol and some clustering protocols in the literature

| Research / Year | Contributions Already Provided | Validations Already Done |
|-----------------|-------------------------------|--------------------------|
| [38] / 2022    | A clustered routing scheme for heterogeneous network (CRSH) has been proposed in this paper to carry out the clustering of SNs and network data aggregation. | The comparison analysis of reliability for cluster head election and clustering of our protocol and some clustering protocols in the literature. |
| [39] / 2022    | In this paper, a novel CH selection protocol has been proposed based on the firefly algorithm (FA) and hesitant fuzzy. It utilizes three SN parameters in order to calculate the score of each node and find the best CHs. | The assessment of the performance included various factors related to the energy efficiency and the lifetime and not the reliability of the system. |
| [40] / 2018    | This paper proposes a novel extended LEACH-based algorithm to improve WSN performance in terms of reliability, energy efficiency, and lifetime. This algorithm, EM-LEACH, firstly takes on new rules for CH selection and the calculation of round time based on the remaining energy. On the other hand, EM-LEACH improves the communication model from a single hop to a multi-hop between CHs and the sink using two operational processes: leveling and generic multi-hop routing. | The evaluation of performance focused on various aspects related to the network’s reliability, energy efficiency and lifetime. |

MDC-TSP-LEACH-K

Our paper proposed a new clustering algorithm based on extended LEACH to improve the performance of WSN in terms of QoS, and lifetime. First, our protocol, MDC-TSP-LEACH-K, supports new rules for CH selection and clustering using Grid and KMeans function.

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