ITC 1/52
Information Technology and Control
Vol. 52 / No. 1 / 2023
pp. 140-154
DOI 10.5755/j01.itc.52.1.32199

Maximization of WSN Based IoT Systems Lifetime by Minimized Intra-cluster Transmission Distance Clustering Protocol

Received 2022/09/01 | Accepted after revision 2022/12/20

https://doi.org/10.5755/j01.itc.52.1.32199

HOW TO CITE: Krishnan, N., Raja, K., Divakaran, S. (2023). Maximization of WSN Based IoT Systems Lifetime by Minimized Intra-cluster Transmission Distance Clustering Protocol. *Information Technology and Control*, 52(1), 140-154. https://doi.org/10.5755/j01.itc.52.1.32199

Maximization of WSN Based IoT Systems Lifetime by Minimized Intra-cluster Transmission Distance Clustering Protocol

Nallarasu Krishnan
Department of Computer Science and Engineering, Tagore Engineering College, Chennai, Tamil Nadu, India; e-mail: nallarasu@gmail.com

Kathiroli Raja
Department of Computer Technology, Madras Institute of Technology (MIT) Campus, Anna University, Chennai, India; e-mail: kathirolig@gmail.com

Sheela Divakaran
Department of Electronics and Communication Engineering, Saveetha School of Engineering, SIMATS, Chennai, India; e-mail: sheelad.sce@saveetha.com

Corresponding author: nallarasu@gmail.com

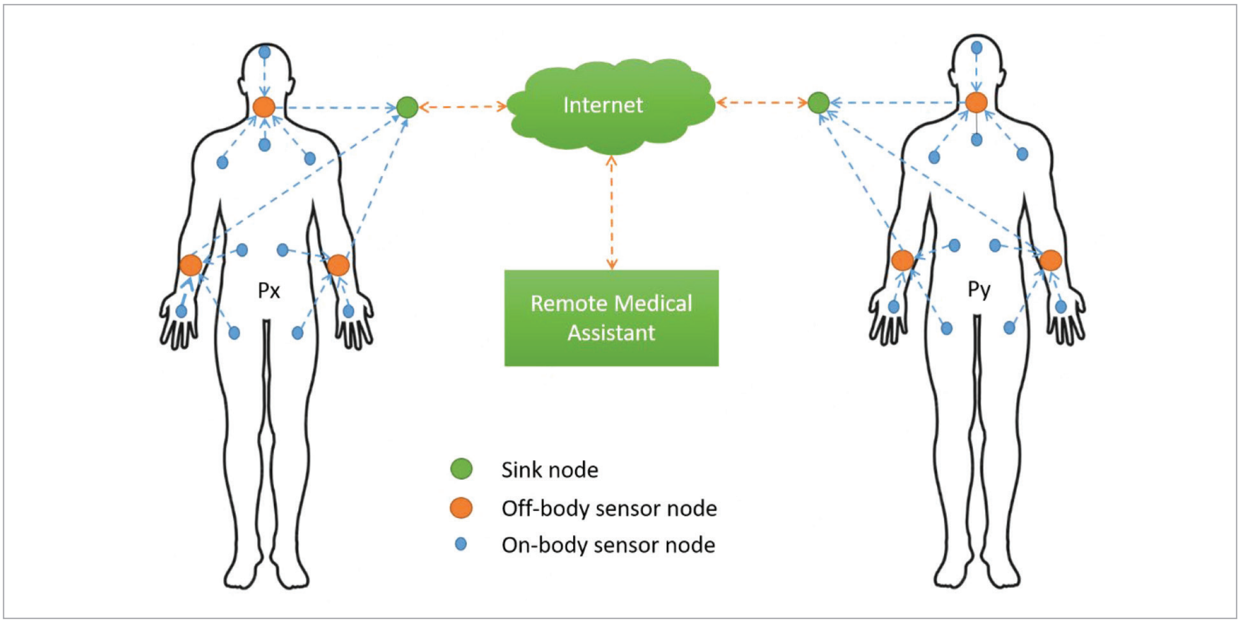
Internet of Things (IoT) enabled by Wireless Sensor Network (WSN) is the principal idea behind target tracking, environment survelance, and patients monitoring systems in which human attentions are very crucial for round the clock. Since the sensor nodes that constitute the IoT is power constrained, it is suffering energy related problems which further badly affect the lifetime of the core sensor network. A well-knows topology management and routing scheme called Clustering is widely used for WSNs in maximizing the network lifetime due to its intrinsic characteristics. Clustering solves the energy constrained issues of WSN by providing a local infrastructure like arrangement to manage the network and resources in suitable manner. Various clustering approaches have been proposed so far by scientific community to address energy issues of WSN. But these existing approaches fail to provide required clustering output to improve lifetime by balancing the energy consumption in efficient manner. In this work, we propose a Minimized Intra-cluster Transmission Distance Clustering Protocol (MITDCP) to improve lifetime of WSN by innovatively clustering and intelligently placing the Base Station (BS). Innovative clustering involves a FCM (Fuzzy C Means) with Cluster Balancing algorithm to create balanced clusters. Then the proposed work makes use of back off timer weighted with residual energy to select and rotate Cluster Head (CH). Simulations show that our proposed work has achieved significant improvement in lifetime of WSN beneath the IoT systems when compared with Improved Energy-Efficient Clustering Protocol (IEECP).

KEYWORDS: IoT, Sensor nodes, Wireless Sensor Network, Lifetime improvement, Fuzzy C Means, Clustering, Energy balancing, Intra-cluster distance.

1. Introduction

WSN is a crucial backbone technology used in a variety of fields. It encourages and supports development of new technologies that simplify and protect human life. A wireless sensor network (WSN) which itself is a low cost network lowers the cost of the new upcoming and trending technologies, hence providing a much needed big push to such futuristic wonders. Smart sensor node networks with internet connectivity broadens the boundary of WSN applications [18]. As it could be used to gather and send data, wireless sensor networks (WSNs) are a key component of internet based application like IoT. A WSN based IoT application for patient monitoring is shown in Figure 1. Vital measurements from both patients Px and Py are collected through the underlying sensors that can be on-body or off-body installations. Off-body sensors communicate with a sink node in the outside environment of the patients, thus constituting a WSN. The gathered vital information about patients are sent to a remote medical assistant, which could be doctors or medical professionals, through the Internet for real time monitoring. So, the lifetime of sensor network is very essential in any IoT approach in which frequent replacing and replenishing of energy to the installed sensors is not possible.

Figure 1
WSN enabled IoT in Patient Monitoring



WSNs serve as the IoT eyes and ears, bridging the gap separating physical and virtual worlds. They are usually made up of tiny and limited resource sensor nodes deployed in large numbers. WSN consists such huge number of sensor nodes serve as the underlying layer of the recent IoT domain, which has been used in wide range of applications that require to meet unique demands and characteristics. WSN, a low-cost legacy technology, has been used in a variety of industries, including control systems, monitoring cum surveillance systems, and smart travel systems, and it provides large-scale of sensed data that can be processed for further decision making [23]. As a result, no major paradigm shift is required by merging IoT and WSN applications. The advantages of WSN-based IoT include ease of and low cost implementation. WSN can also operate as independent technology in tough or hostile environments where human intervention is impossible [27]. On the other hand, WSNs too have flaws that must be rectified.

The main hurdle in WSN is the network lifespan problem. However, because sensors are often mainly battery powered, expected to function for a long duration, and because replacing sensor nodes and battery is infeasible and expensive once they have been installed, energy efficiency is a top priority requirement always in WSNs [9]. Indeed, past research has shown that data transmission consumes a significant amount of energy, and transmission performance is largely determined by the routing plan. As a result, an energy-efficient routing protocol that incorporates clustering must be developed in order to save energy and extend the network's lifetime [22, 25]. Nowadays rechargeable sensor nodes are suggested to overcome resource depletion. But that too will not be adequate to sustain the continuous operation as the energy obtained from the environment is not sufficient [30].

Various clustering methods have been presented to enhance the lifetime of WSNs by designing energy-efficient WSNs. By minimizing long-distance communication [5], the clustering protocol, in which nodes are separated into small groups, is an effective strategy for achieving energy efficiency and thereby extending lifetime of WSN [3]. Each cluster has a header node called Cluster Head (CH) which has greater responsibilities than cluster member nodes (MNs). In practice, each MN sends the sensed data to its CH, which subsequently sends it to BS through one-hop or next hop based multi-hop transmission. Clustering protocol is thought to be an apt technique for nodes in WSNs to save energy, because clustering structure plays a major role on improving network lifetime due to balanced and efficient node energy usage [13, 14, 17, 24]. Moreover, the clustering structure in WSN has further advantages such as topology management, resource management, data aggregation and routing etc. As a result, the efficiency of the clustering technique has a significant impact on continued and efficient functioning of WSN [26]. However, if such crucial clustering is not performed carefully and correctly, it will impact WSN's intended objective and lifetime gravely [6].

There are two challenges in clustering: balanced cluster creation, and creating sufficient number of clusters. To address the importance of clustering, this study proposes MITDCP to maximize the lifetime of WSN. Intra-cluster distance needs to be minimized as CH is consumed more by communication within than inter-cluster [11]. This energy efficient clustering protocol consists of two parts: First one is to achieve balanced clustering structure to reduce intra-cluster transmission distance which is to reduce communication cost in terms of energy. And, second part is to answer the negative impact on network lifetime due to inefficient energy consumption among sensor nodes in the cluster. It is stated in [15] that clustering efficiency is as important as energy efficiency.

To find the ideal number of clusters, a new mathematical equation is provided based on constant value obtained from the analysis and simulation of multi-hop energy consumption model [10]. In order to construct balanced clusters, FCM with cluster balancing technique addresses the challenges of clustering is developed. Finally, an efficient way to select CH and rotate it in subsequent phases is suggested. It combines the back-off timer mechanism with residual energy and distance to forward cluster head. In simple terms, selection and rotation of CH is achieved through an eligibility (fitness) function 'F'. It is suggested to achieve energy balancing across cluster members.

2. Related Works

An AODV based static routing technique known as Dynamic Cluster-Based Static Routing Protocol (DCBSRP) to improve the network lifetime has been used by Adil et al. [1], in which cluster heads are selected dynamically for certain time period. After the expiry of the time period, cluster nodes are freed from the current clusters to initiate fresh clustering formation and to make them available for CH election. A new CH is selected based on highest number of RREP messages it received. The present CH does not participate in the CH election process and act as normal node for five successive cycle of the protocol. This DCBSRP protocol ensures involvement of all nodes throughout the network in balancing the load among them.

Zhu et al. [31] has proposed Clustering by Fast Search and Find of Density peaks (CFSFDP) protocol to balance energy utilization among sensor nodes by IS-k-means algorithm. The algorithm uses a fitness function defined by KDE for optimal selection of initial cluster centers. It achieves balanced cluster by reassigning member nodes of high density clusters at the cluster boundary to smaller clusters. This reallocation of border nodes is done based on the nodes' membership probability. The authors also have used a multi-cluster heads technique in which more than one CH for a cluster is selected to achieve more energy balancing among clusters.

Xu et al. [28] have introduced a routing protocol called Energy-efficient Region Source Routing (ER-SR) to prolong the WSN lifetime. In this work, the authors have made ER-SR as a distributed protocol which dynamically selects high residual energy nodes as next hop node in source routing. Such source routing nodes are responsible for computing the forwarding path for other normal nodes. It tries to achieve energy balanced WSN by ensuring all nodes in the network take part in routing process, and by employing ant colony optimization to find global optimal forwarding path. The authors have used a criteria in the form of effective distance to further optimize ant colony algorithm before it is used to compute the routing path.

An energy hole mitigation strategy called Virtual Force based Energy-hole Mitigation (VFEM) is proposed by Sha et al. [21] to improve network lifetime by prolonging the appearance of energy hole in the network. It tries to postpone energy hole by reducing redundant data and avoiding blind sensing area creation. The authors use natural virtual forces such as gravity and repulsion as a means to deploy the sensor nodes uniformly in the region. And further they divide the network into concentric circles to better manage the energy utilization of nodes in whole network. In each concentric circles the nodes' placement is optimized by virtual force. Further, the approach has tried to achieve energy balancing by selecting optimal data forwarding area which enables reduction in overhead for routing.

Gulec et al. [8] has proposed a distributed algorithm known as Connected Dominating Set construction with Solar Energy Harvesting Algorithm (CDSSEHA) that uses harvesting nodes of solar energy to maximize the network lifetime by constructing CDS. There are two types of nodes in this algorithm: Harvester nodes, and normal nodes. Harvesters are selected by considering node type, remaining energy, and the number of harvesters as neighbors. These harvesters use CDS to harvest energy from solar. Every harvester nodes become dominator depending on its capacity of energy harvesting. Nodes that receive harvest state message from neighboring harvester becomes ordinary node. Present harvester nodes do not participate in the next rounds of harvester election to balance the energy among harvesters in the network.

Collotta et al. [4] presented Fuzzy Logic Controllers (FLC) algorithm that dynamically modifies the transmission power and sleeping time with the help of two fuzzy logic controllers. The authors have identified as these two parameters gravely affecting the energy consumption of sensor nodes. Sleeping time is adjusted by first controller by computing remaining energy and ratio of throughput to handled workload. It can be found here that transmission power is adjusted with respect to available battery power and quality of link.

An Enhanced Clustering Hierarchy (ECH) protocol is proposed by El Alami et al. [7]. The protocol uses sleeping and waking methodology to control the ideal and active cycle of nodes so as to balancing the energy consumption among nodes. The authors have pointed out that only waking nodes are necessary to take part in data transmission phase to reduce energy consumption. Moreover, since some nodes are sleeping while others in waking state, it considerably reduces redundant data. As noted by authors, reducing such redundancy from overlapping and neighboring nodes also contribute to energy saving.

Pang et al. [16] have presented Path-based path Equalization (PEABR) algorithm, which is a data collection strategy that involves multiple mobile nodes as sink nodes. Further it uses manually deployed higher energy nodes as CH. Such CH nodes are placed at the cluster center identified by the dynamic clustering algorithm used in the proposed system. It mainly adopts path planning of mobile nodes and routing strategy to address the energy constraints of the network. The authors have tried to manage multiple mobile sinks in data collection task from cluster heads. It divides the area under monitoring into several parts based on which number of mobile sink is decided. The mobile sinks traverses to CHs in a pre-determined optimal path to collect data from them. PEABR scheme has tried to reduce energy consumption by reducing and equalizing the path length of mobile nodes in such a way that it addresses the energy limitations.

Improved Energy-Efficient Clustering Protocol (IEECP) has been proposed by Hassan et al. [10] to prolong the network lifetime of IoT based on WSN. It employs two algorithms: M-FCM to create balanced clusters, and CHSRA for optimally selecting and rotating CHs. The authors have used a permittivity value to decide optimal number of clusters required to utilize energy efficiently in the network. Further, they have introduced a fitness function for doing CHSRA efficiently. The fitness function is based on back-off timer and remaining energy of nodes. A dynamic threshold provided through the fitness function is considered as a means for achieving balanced consumption of energy among clusters. The protocol tried to meets its objective of extending lifetime of network by yielding quality clusters and their effective management.

Kalidoss et al. [12] has proposed QoS aware Energy Efficient Routing Protocol (QEERP) to achieve energy efficient cum secured routing for energy restricted WSN. Security for routing is met by key based authenticating mechanism that provides various scores for various levels of trust. For reducing energy consumption while performing routing, it uses the usual clustering approach.

Selvi et al. [20] has proposed Energy Aware Trust based Secure Routing Algorithm (EATSRA) in which energy related concerns of WSNs where recharging or replenishing of energy is not possible. Here, the optimization of energy spending in the network is achieved from security perspective by avoiding malignant interruptions. The logic behind this approach is energy efficiency in the WSN can be improved by reducing unnecessary communications taking place among the sensor nodes.

Xunli et al. [29] has proposed Low Energy Consumption and Data Redundancy (LECDR) approach to reduce energy spending of sensor nodes by eliminating redundant data in densely deployed WSN where sensor nodes supposed to involve in handling large chunk of repeating data. They achieve their intended task by categorizing sensor nodes as active and non-active nodes, and then clustering the categorized sensor nodes.

Sampradeepraj et al. [19] has proposed an approach called as Minimum Connected Dominating Set (MCDS) to achieve better energy management for resource constrained WSN. They achieve it by suggesting a multicasting function that ensures efficient exchange of data between closed groups of sensor nodes. The idea behind this MCDS is creating virtual group with few nodes performing the forwarding function to the multicast group.

AL Zubi et al. [2] has proposed Event Reporting Protocol based on Distributed Data Aggregation (ERP-DDA) framework for achieving energy efficiency through an optimal event tracking model for WSN. The logic behind this technique is to restrict more than one nodes from informing about the same event. It means that, while other nodes can track the event, only one node is entitled for reporting about the event with an aim to preserve the energy of other nodes. This technique combines the advantages of clustering with suitable event reporting management for effective energy utilization.

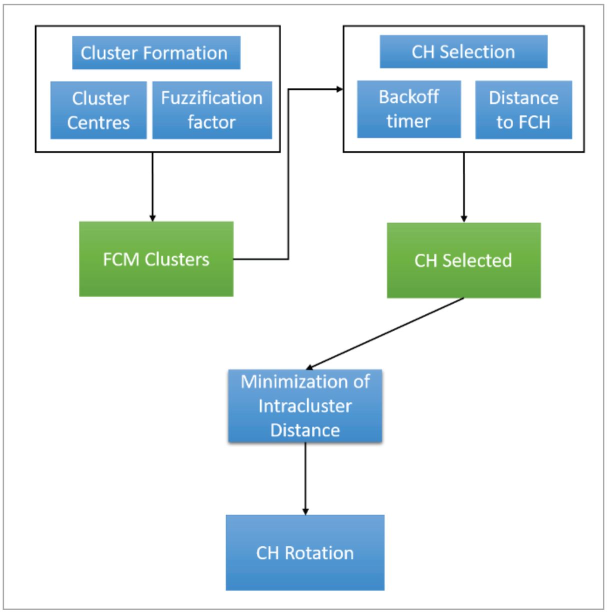
3. Proposed Work

The proposed work mainly concentrates on further reducing the intra-cluster distance of FCM clusters than existing technique discussed in [10], by adopting an innovative intra-cluster distance reduction technique. It is one of the promising way to improve the lifetime of WSN based IoT systems. The proposed model consists of four modules namely, Cluster formation, CH selection, Minimizing intra-cluster distance, and CH rotation. The proposed MITDCP framework is shown in Figure 2.

3.1. Cluster formation

Cluster formation is done first to produce unbalanced clusters with the help of FCM, which is a centroid based clustering algorithm. Those clusters of sensor

Figure 2
Framework of MITDCP



nodes formed by FCM clustering, which is governed by the objective function J_{ob} given in Equation (1).

$$J_{ob} = \sum_{j=1}^{K} \sum_{i=1}^{N} \mu_{ij} \left\|(x_i - p_j)\right\|^m, \quad (1)$$

where $||(x_i - p_j)||$ is Euclidean distance between i^{th} node and j^{th} cluster centroid, 'K' is number of intended clusters, and N is number of sensor nodes. There are two important parameters in the objective function. They are fuzzification factor 'm', and membership probability μ_{ij}. The fuzzification factor determines the cohesion between the members of a cluster, whereas membership probability decides to which cluster a node belongs. In fact, membership matrix is nothing but the probability values for nodes to take part in each cluster. So, a node is assigned to a cluster for which it has highest membership probability. With this logic, the clusters are formed first by simply assigning sensor nodes to the respective clusters based on the membership probability.

3.2. CH Selection

Input to this module is FCM clusters obtained from the previous one. In cluster of sensor nodes there must be at least one CH while the remaining nodes acts as CMs. The CH is selected based on selection objective function, which is defined as the ratio between residual energy E_{res} and distance to forward cluster head D_{fch}. As every CMs of a cluster contend for becoming CH, there must be a contention resolving mechanism to select one suitable CH form the contending members. The contention resolving mechanism used here is called as back-off timer. Back-off timer is calculated as inverse of the selection objective function. Selection objective function attain maximum value when it has more residual energy and shorter distance to either FCH or BS. Such maximum value of the objective function is very desirable since it contributes to the energy efficient performance of the WSN. When inverse of such maximum value is taken, it always provide a small resultant value. It means that, a node which is more suitable to become CH always has shorter waiting time to become CH when compared with other member nodes. FCH distance is an additional parameter used to select suitable CM as a CH in each round. So, A CM node that has less both back-off timer is preferably made as a CH for the current round of protocol operation.

3.3. Minimizing Intra-cluster Distance

When FCM clusters are formed, they have uneven clusters members as there is no restricting factor for cluster size. In this stage, number of members per cluster is defined. So, each cluster has even cluster members. If there are 'N' number of nodes, and 'K' number of clusters, then members per cluster is N / K. In case any left out nodes exit, they are assigned to nearby clusters. Due to this left out nodes assignment, some clusters have few additional members than the average N / K value. Cluster balancing is not just ensuring the C_{th} amount of nodes taking place in a cluster. If it is done with a cognizant approach, it provides two benefits such as reduced intra-cluster distance along with balanced clusters in a single move.

Minimization of intra-cluster distance (ICD) is very important as it is leading to reduced overall energy consumption. As the energy consumption by sensor nodes got reduced, the lifetime of WSN enabled IoT system improves, which is the ultimate aim of this proposed work. In existing system [10], there is no such minimization technique applied to reduce ICD as far as possible. But, in MITDCP, it is achieved by partially restructuring the clusters without affecting or modifying existing CH. The logic behind partial restructuring is, moving border nodes of clusters to nearby clusters after careful examining of distance to centers of current and next best clusters. The innovation behind this technique is, even though ICD of some individual clusters increases, the overall ICD when all clusters are considered is reduced. Such reductions in ICD naturally provides improved lifetime of IoT systems supported by WSN.

3.4. CH Rotation

Since the roles of a CH is to coordinate the CMs and to involve in data aggregation and forwarding, it quickly depletes its energy than other CMs. So letting a particular node to play the CH role continuously leads to expiry of the node. To avoid such adverse situation, the role of CH is rotated among the CMs of the cluster after each round of the protocol. In the proposed model, CH rotation is done after the module of minimizing intra-cluster distance. In the start of every round, except the first one, a CH role is rotated to another member node of the cluster with the help of the same CH selection procedure. A CM which played the CH role recently has large back-off timer thus overloading of a CM with CH role is avoided. The objective function ensures that the cluster head role is rotated with the help of back-off timer, in such a way that each CM node has its own chance to become as a CH once in every N / K rounds.

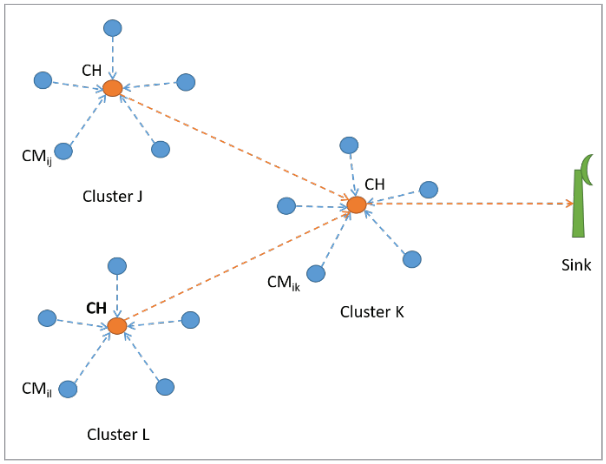
4. Models and Algorithms

4.1. Network Model

Network model depicts how various components of the network interact with each other to accomplish the objective of the network. Figure 3 represents the network model of the proposed intra-cluster distance reduction protocol named as MITDCP. The deployed sensors are grouped into clusters with each cluster having a cluster head and N / K members. CMs communicate only with respective CHs by single hop manner, whereas the CHs alone communicate with sink either by single or multi-hop manner.

After each round of the protocol operation, CHs are changed. So, the node that going to act as CH computes afresh the forwarding path for reaching to the sink. The role of CH is rotated within the cluster itself, so the old CH has to handover member details

Figure 3
Network Model of MITDCP



such as member IDs, and allotted slot to the newly selected CH. All of the CMs are supposed to transmit their data to the respective CHs in the respective time slots allotted to them. The base station or sink node receives the data forwarded from all the attached clusters through the cluster heads that transmit aggregated data in time-driven approach. Clustering is mainly used here as a topology management technique for the WSN environment, since it extremely contributes for the balancing of energy consumption throughout in the network.

4.2. Communication Model

The communication model of radio transmitter and receiver preferred for the proposed work is used to compute the energy consumption of sensor nodes irrespective of whether they are cluster member or cluster head. The communication model is based on the distance between transmitting and receiving node. Depending on the distance threshold (d_o) either multipath or free space models can be used. Hence, when a message 'g' bit is sent for the distance (d), the energy utilized by the transmitter ET can be written as in Equation (2).

$$ET(g,d) = \begin{cases} E_{el} * g + E_{da} * g + \epsilon_{fs} * g * d^2, & d < d_o \\ E_{el} * g + E_{da} * g + \epsilon_{mp} * g * d^4, & d \geq d_o \end{cases} \quad (2)$$

if the transmitting node is CH. Oterwise, as given in Equation 3.

$$ET(g,d) = \begin{cases} E_{el} * g + \epsilon_{fs} * g * d^2, \ d < d_o \\ E_{el} * g + \epsilon_{mp} * g * d^4, \ d \geq d_o \end{cases} \quad (3)$$

if the transmitting node is cluster member. It is because nodes do not do data aggregation when they act as member.

In the above equations, where $d_o = \sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}}$ is the threshold distance between transmitting and receiving node; ϵ_{fs} and ϵ_{mp} are power needed to transmit in free-space and multipath communication models measured as joules/bit/meter; E_{el} is power spent in electronic circuitry; E_{da} is power spent on data aggregation; The energy utilized by the receiver, whether it is cluster member or CH can be written as,

$$ER(g,d) = E_{el} * g.$$

The energy spent on receiving and transmitting g bits is measured in joules. The equation shows that while receiving the g bits, the power is spent only on electronic circuitry. The power spent on idle listening of channels by nodes is denoted as E_{lis}. So power spent on channel listening is,

$$EL = t * E_{lis}$$

Since EL is a constant value, it is neglected for the simplicity of the communication model.

4.3. Algorithms of MITDCP

Algorithm 1: FCM Cluster Formation

Input: N, C, R, C_{Th}, m, ε, μ

Output: FCM Clusters

```
C random points as initial cluster centers
for i = 1:1:R , do
    calculate C new cluster centers;
    calculate new membership metrics;
    find distance from node to new cluster centers;
    update membership metrics m;
    calculate tolerance value T by Equation (1);
    if |T (i) – T (i–1)| < ε, then
            break;
    else
            T (i-1) = T (i)
    end if
end for
```

In Algorithm 1, the inputs are identified as the number of sensor nodes, clusters, rounds are represented respectively by 'N', 'C', and 'R'. The cluster size threshold 'C_{Th}', fuzzification parameter 'm', the convergence parameter 'ε', and membership metrics 'μ' are other important input parameters. Output of the algorithm is set of FCM clusters 'C_{FCM}'. The FCM cluster formation algorithm initially chooses the centroid points in a random manner. The members associated with each clusters are defined by the respective membership metric. With the newly added members, new centroid of each cluster is calculated. Thus, a parallel update is done in the membership metric based on the new centroid points. This process continues until either the convergence of termination threshold or the predefined number of execution rounds of the algorithm is reached. Finally The FCM clusters are formed as a set of nodes with the help of this algorithm of module 1.

FCM clusters obtained from the Algorithm 1 acts as an important input to the succeeding Algorithm 2. Another required input here is d_o the crossover distance. It is used in d_{fch} computation process by assisting a CH to decide

Algorithm 2: CH Selection and Rotation

Input: FCM clusters

Output: Suitable Cluster head – SCH and CH rotation

```
# CH selected in round 1, rotated from round 2 in C_b
for q = 1 to C_FCM, do
    for r = 1 to cluster_size[q], do
        calculate E_res and D_fch;
        calculate objective function = E_res / D_fch
        back-off timer = 1 / objective function;
    end for
    initiate back-off timer;
    if(back-off timer = 0) then
        send Join message for members;
    else
        stop back-off timer;
        if(join message received) then
            join as member;
        end if
    end if
    selected CH updates members;
    selected CH informs other CH;
```

18. **end for** # CH selection ends
19. go to Algorithm 3 if R = 1;
20. go to step 24 if R = 1;
21. **for** p = 2 to R, do # cluster rotation starts
22. **for** q = 1 to C_b, do
23. **for** r = 1 to cluster_size[q], do
24. compute d_{FCH};
25. compute E_{con};
26. $E_{res} = E_{res} - E_{con}$;
27. **end for**
28. **end for**
29. go to step 4 to rotate cluster head;
30. **end for**

between with BS and forward cluster head for forwarding the data. If the distance between a CH and BS is greater than the distance threshold, a forward cluster head FCH is needed to reach the BS. Generally, the output of this stage is a suitable cluster head is assigned to all clusters. By precisely speaking, this algorithm perform two different tasks on two different clustering structures: first one is CH selection performed on unbalanced FCM clusters, and the second one is CH rotation done on balanced FCM. During first round, the algorithm performs CH selection, then proceeds to cluster balancing. And in successive rounds, it simply performs the CH rotation by using the same CH selection method. Since both CH selection and rotation tasks uses the same back-off timer method this algorithm is shared by modules 2 and 4.

Algorithm 3: Minimization of ICD

Input: Cluster centers

Output: Minimized ICD and Balanced clusters $\{C_b\}$

Executed once after initial selection of SCH in round 1

1. **for** (i: 1: C_{FCM}), do
2. sort cluster[] in descending order of cluster size;
3. store ids of sorted cluster in ids[];
4. store size of sorted clusters in size[];
5. **end for**
6. **for** j = 1 to C_{FCM} do
7. largest = ids[j];
8. **if** size[largest] > C_{Th}, then
9. k = size[largest] - C_{Th};
10. **end if**
11. **if** k > 0, then
12. **for** every members in cluster[largest]
13. find distance to cluster center;
14. sort cluster[largest] in descending order;
15. **end for**
16. **for** first k excess nodes in cluster[largest]
17. find distance to other cluster centers;
18. assign first k nodes to nearest cluster;
19. **end for**
20. **end if**
21. **end for** # return to step 21 of Algorithm 2

Existing system discussed in [10] achieves cluster balancing by sequentially adding nearby nodes based on Euclidean distance to final cluster centroids of FCM clustering. It starts from centroid 1 and simply adds first C_{th} number of nodes to it, and proceeds similarly to build other clusters in balanced manner. This approach produces clusters with larger ICD, as it is not concerned about the ICD at all. Another notable drawback of the existing protocol is it completely restructures the FCM clusters which is considered unnecessary and leads to extra overhead. Contradicting to this existing approach, the Algorithm 3 of module 2 of proposed approach builds ICD conscious balanced clusters without disturbing the FCM clusters much.

The idea is to move out border nodes, which have large Euclidean distances with respect to CH of the currently attached cluster, to their respective next nearest clusters to meet reduced ICD. To do this, FCM clusters are sorted based on cluster size first to identify bigger clusters. Clusters that have more member nodes than Cth are bigger clusters. Then, those excess border nodes of larger clusters are simply attached with next nearest clusters. This process continues until all the clusters are balanced. If there are left out nodes, they are just added to nearby clusters without worrying about C_{th}. Once the algorithm finishes its task, the execution flow is then transferred to data transfer phase, and then to CH rotation module. The switch over between these two is carried out until live nodes exist.

5. Results and Discussion

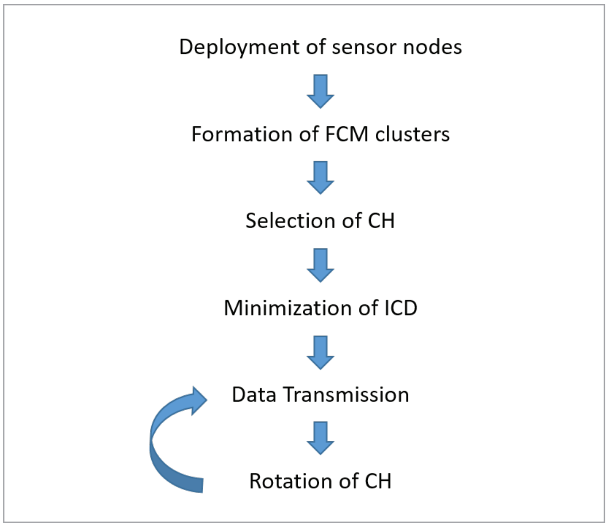
The proposed framework has been implemented in Matlab with the selected simulation parameters given in Table 1. There is always a dynamic nature in clustering algorithms. Due to this intrinsic nature, to ascertain the performance of the MITDCP algorithm, it was executed in five runs with each run having 5000 rounds. While executing the algorithm, various performance parameters such as ICD of individual clusters, overall ICD, First Node Dead, Half Node Dead (HND), Last Node dead (LND), and cluster size are recorded and analyzed. FND is the main parameter used to measure lifetime of the WSN based IoT systems. This lifetime is a crucial requirement of a WSN based IoT systems in which recharging and replenishing of energy for the sensor nodes are not possible. For example, sensors that are implanted within the body of the patients in a Body Area Network (BAN) is not rechargeable.

Table 1
Simulation Parameters

Parameters	Values
Number of clusters	5
Number of Sensor Nodes	100
Deployment area	200 x 200 m
Cluster size threshold	20
Node Energy	1Joule
Fuzzification factor	2
Convergence factor	0.01

Simulation process of the proposed method is shown in the Figure 4. First, the nodes are deployed randomly by generating random coordinates with the help of 'randi' function of Matlab. The deployed nodes are then clustered by FCM algorithm after randomly choosing initial cluster centers among the coordinates of the sensor nodes. Generally, the FCM algorithm produces unbalanced clusters. For the entire run of protocol, the FCM clustering is done only once. A run is nothing but predetermined times of rounds the protocol is executed. Then, a CH is selected for each clusters. The selection is made locally within the clusters to avoid unnecessary energy consumption during setup phase. Once clusters with CHs are ready, now it the time for minimizing the intra-cluster distance which is done by carefully handling the border nodes, and making all clusters as balanced ones.

Figure 4
Simulation process



Next following step is data transmission of steady state phase with each round is considered to be having six frames. After the data transmission, both and CHs and CMs updates their residual energy which is then combined with distance to forward CH or base station to rotate the CH role locally within the balanced clusters. It means that a new CH is selected for each round of data transmission. This steady state phase continues until live nodes are existing. balancing in the WSN based IoT systems. When the proposed protocol MITDCP is considered, the smallest cluster size achieved among the five runs is 17 and the largest cluster size reached is 23, which are better in cluster size variations than the existing protocol IEECP, which is the recent work than discussed in [22, 23] to envisage improving lifetime of IoT systems assisted by WSN. Outstanding performance of IEECP approach among the existing ones is credited to its strategy for building quality and balanced clusters. As long as the variations in sizes of clusters are small in WSN based IoT systems, it provides improved overall performance for those systems in terms of energy consumptions.

Table 2

Cluster Formations before and after cluster balancing of MITDCP

	Before CB (C_{FCM})	After CB (C_b)
Cluster Sizes	**C1 C2 C3 C4 C5**	**C1 C2 C3 C4 C5**
Run 1	24 20 20 18 18	20 20 20 20 20
Run 2	18 21 17 21 23	20 20 20 20 20
Run 3	17 21 21 23 18	20 20 20 20 20
Run 4	22 19 18 23 18	20 20 20 20 20
Run 5	21 17 18 22 22	20 20 20 20 20

Table 2 shows cluster formations of five clusters of the proposed MITDCP when before and after the cluster balancing is done. They are obtained from five different runs of the proposed protocol. Before the cluster balancing, the FCM clusters have unequal cluster sizes. The cluster sizes resulted from the FCM clustering process has vast variations between them. The smallest cluster size falls as low as 17, and largest cluster size rises to as high as 23. This greater variations affect the much needed energy balancing in the WSN based IoT systems. After the cluster balancing approach, all clusters become balanced ones by having same number of member nodes as 20. As long as the variations in sizes of clusters are small in WSN based IoT systems, it provides improved overall performance for those systems in terms of energy consumptions.

ICD of individual clusters of the existing system in Meters is shown in Table 3. From the table it is evident that the ICD of 5^{th} clusters are large when compared with other clusters due to the sequential processing of the clusters form 1 to five. That is, cluster 1 is built first with closest nodes and then the algorithm proceeds successive clusters to build. It means that the cluster that is built at last is having only nodes that are left out by other clusters, and those nodes are naturally far from the current CH.

ICD of Individual clusters of the proposed MITDCP has been shown in Table 4. It can be seen from the

Table 3

ICD of Individual clusters in Existing System IEECP in $\times 10^2$ meters

Run	IEECP				
	ICD1	ICD2	ICD3	ICD4	ICD5
Run 1	6.866873	6.910614	5.442709	6.034011	11.00789
Run 2	5.391015	8.483233	6.618894	6.995071	14.90461
Run 3	5.929934	4.556754	6.526335	6.623895	16.69920
Run 4	5.812077	8.595426	6.351555	7.069980	10.79440
Run 5	5.463666	6.064150	5.462811	6.531052	14.89047

Table 4

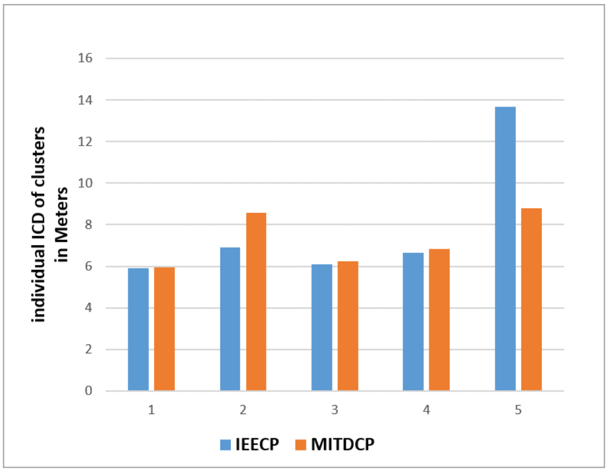
ICD of Individual clusters in $\times 10^2$ MITDCP in meters

Run	MITDCP				
	ICD1	ICD2	ICD3	ICD4	ICD5
Run 1	6.950313	10.94697	5.442709	6.061915	7.113728
Run 2	5.391015	9.157046	6.681479	6.995071	9.870845
Run 3	6.053657	4.770981	6.780817	7.207475	9.358624
Run 4	5.812077	11.65808	6.504199	7.069980	8.453710
Run 5	5.475231	6.294879	5.868748	6.887702	9.153831

table that the ICD has been spread almost uniformly throughout all the clusters. This property is achieved due to how the algorithm process the clusters. In the proposed algorithm, the largest clusters are processed first, and then it proceeds to smaller clusters. To facilitate this, first the clusters are sorted in descending order. Then the excess border nodes from each clusters are moved to corresponding next nearest clusters. Instead of building clusters by adding nearby clusters as in the existing system, here the algorithm builds cluster based on the membership probabilities. From Tables 3-4 it is evident that the ICD of individual clusters are influenced by the flow of the algorithm. Average of Individual ICD values in 10ˆ2 meters unit obtained for the five clusters from five runs of protocols is shown in Figure 5.

Figure 5

Average Individual ICD of IEECP and MITDCP



It proves that the algorithms used in cluster formation and minimizing ICD modules largely influence the distribution of nodes to various clusters, and their respective ICD being evenly achieved more or less in all clusters. Lifetime of a WSN based IoT systems are denoted by First Node Dead parameter, which is measured in terms of the number of round of the protocol execution. It is nothing but the node that depletes its energy very first among the deployed nodes and becoming as a dead node. Once a node becomes as a dead one, the sensing activity around it stops and affects the network objective being carried out. Thus, when the FND event occurs, the network performnce in the direction of achieving the objective starts to reduce.

This condition is equivalently reflected at the sink node side with reference to the quality and quantity of data received. During each round of protocol operation nodes send and receive data that leading to gradual depletion of energy, Hence, at a certain round of protocol operation FND occurs. This number of round is further advanced or improved by effectively reducing the communication cost in terms of energy consumed. This warrants that cluster members should be as close as possible to their respective CH in order to achieve the reduced transmission distance.

Comparison of FND parameter of both existing and proposed systems for five runs of protocol execution is shown in Figure 6. To get the FND data, the proposed MITDCP is associated with benchmark LEACH protocol of WSN. It is evident from the graph that MITDCP has increased the number of rounds for the FND when compared with the existing IEECP protocol. Precisely speaking, MITDCP has improved the lifetime of WSN based IoT systems by 35 rounds in an average which is nothing but 7.16% increase in lifetime than the existing protocol under examination here. This improvement is the outcome of the same amount of reductions achieved in overall ICD as depicted in Figure 5.

To further demonstrate the performance of the proposed work, another scenario is created in which 500 nodes are deployed in 1000 x 1000 size of region. Overall ICD of five clusters is obtained from average of individual ICDs. The overall ICD data of the two scenarios are summarized and provided in Table 5. From the

Figure 6

FND comparison of IEECP and MITDCP

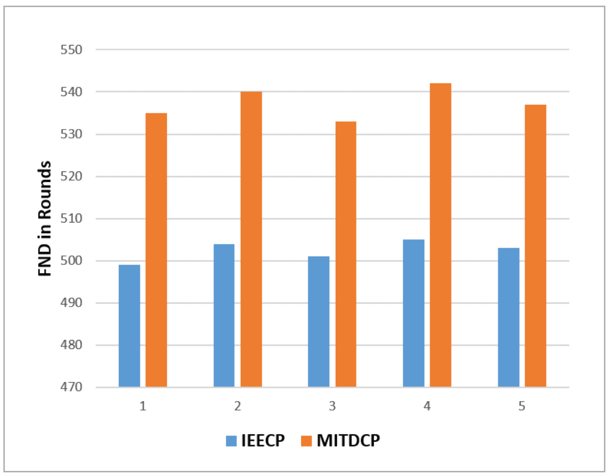
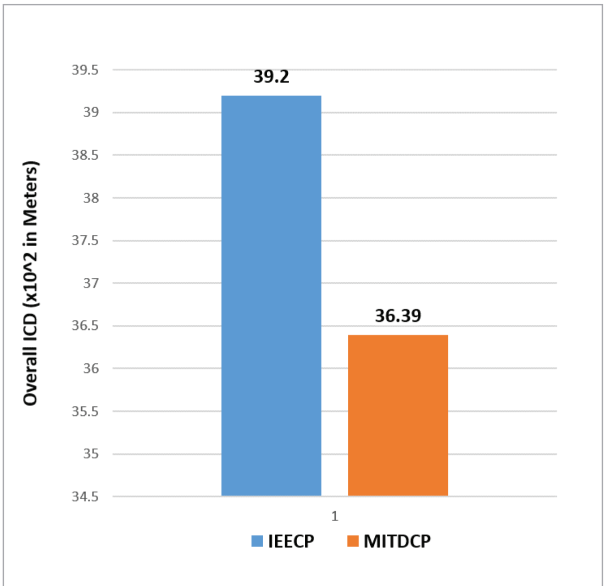


Table 5
Overall ICD in two scenarios

Number of Nodes	Overall ICD	
	IEECP	MITDCP
100	39.2 x 10^2	36.39 x 10^2
500	1.15 x 10^5	1.01 x 10^5

data, it can be observed that the proposed work excel in both 100 and 500 nodes deployment scenarios.
Figure 7 shows the comparison of overall ICD between the existing IEECP and the proposed MITDCP models. The overall distance which is measured in Meters, is computed here as the total sum of five individual ICDs of the five clusters, and the individual ICDs are obtained by taking the average of those ICDs of five runs of both of the algorithms. From the graph it can be seen that the overall ICD obtained from MITDCP is reduced than the existing system. It means that the overall energy consumptions of WSN based IoT systems are decreased by 7.16% due to the proportionate fall in gross intra cluster transmission distance of WSN.

Figure 7
Overall ICD between IEECP and MITDCP



6. Conclusion

Along with the balanced clusters and efficient re-arrangement of border nodes of those clusters, the proposed MITDCP model achieves the minimized intra-cluster distance to reduce communication cost, which further leads to improving the network lifetime of WSN enabled IoT systems. The cluster head is selected and rotated in successive rounds to reduce the rate of energy depletion of CH nodes. Thus, effective energy saving within the clusters is achieved through three-pronged approach involving cluster balancing, CH rotating, and Minimizing ICD. The existing model IEECP had used only two-pronged approach in which there is no ICD minimizing approach. Due to incorporation of this missing approach, the proposed model enables high energy efficiency in the IoT systems than the existing one. In the implementation of MITDCP, improvement of the lifetime of WSN supported IoT is achieved by innovatively reducing the gross ICD of clusters uniquely built by the Fuzzy C Means with Cluster Balancing algorithm (FCM-CB). The CH selection based on back-off timer weighted with residual energy, and distance to forward CH approach has also contributed to energy efficient performance of the proposed method. Experimental results have shown that the proposed model improves the overall lifetime of WSN based IoT systems by 7.16%. As a future work, wireless recharging technique can be combined with MITDCP to examine the feasibility of achieving further improvement in energy efficient functioning of those IoT systems. Wireless charging is an upcoming energy harvesting approach, which is considered useful in recharging the batteries of sensor nodes through radio frequency. Combining the wireless recharging idea and minimized intra-cluster distance approach is expected to perform well than when they are used in standalone manner.

References

1. Adil, M., Khan, R., Ali, J., Roh, B- H., Ta, Q. T. H., Almaiah, M. A. An Energy Proficient Load Balancing Routing Scheme for Wireless Sensor Networks to Maximize Their Lifespan in an Operational Environment. IEEE Access, 2020, 8, 163209-163224. https://doi.org/10.1109/ACCESS.2020.3020310

2. AL-Zubi, R. T., Alawad, M. Q., Kreishan, A. A., Darabkh, K. A. ERP-DDA: Event Reporting Protocol Based on Distributed Data Aggregation for Wireless Sensor Networks. Information Technology and Control, 2021, 50(3), 470-484. https://doi.org/10.5755/j01.itc.50.3.27932
3. Bouyer, A., Hatamlou, A., Masdari, M. A New Approach for Decreasing Energy in Wireless Sensor Networks with Hybrid LEACH Protocol and Fuzzy C-means Algorithm. International Journal of Communication Networks and Distributed Systems, 2015, 14(4), 400-412. https://doi.org/10.1504/IJCNDS.2015.069675
4. Collotta, M., Ferrero, R., Rebaudengo, M. A Fuzzy Approach for Reducing Power Consumption in Wireless Sensor Networks: A Testbed With IEEE 802.15.4 and WirelessHART. IEEE Access, 2019, 7, 64866-64877. https://doi.org/10.1109/ACCESS.2019.2917783
5. Dehghani, S., Barekatain, B, Pourzaferani, M. An Enhanced Energy Aware Cluster-Based Routing Algorithm in Wireless Sensor Networks. Wireless Personal Communications, 2018, 98(1), 1605-1635. https://doi.org/10.1007/s11277-017-4937-1
6. El Alami, H., Najid, A. CFFL: Cluster Formation Using Fuzzy Logic for Wireless Sensor Networks. In Proceedings of IEEE/ACS 12th International Conference on Computer Systems and Applications (AICCSA), 2015, 1-6. https://doi.org/10.1109/AICCSA.2015.7507248
7. El Alami, H., Najid, A., ECH: An Enhanced Clustering Hierarchy Approach to Maximize Lifetime of Wireless Sensor Networks. IEEE Access, 2019, 7, 107142-107153. https://doi.org/10.1109/ACCESS.2019.2933052
8. Gulec, O., Haytaoglu, E., Tokat, S. A Novel Distributed CDS Algorithm for Extending Lifetime of WSNs with Solar Energy Harvester Nodes for Smart Agriculture Applications. IEEE Access, 2020, 8, 58859-58873. https://doi.org/10.1109/ACCESS.2020.2983112
9. Gupta, H. P., Rao, S. V., Yadav, A. K., Dutta, T. Geographic Routing in Clustered Wireless Sensor Networks Among Obstacles. IEEE Sensors, 2015, 15(5), 2984-2992. https://doi.org/10.1109/JSEN.2014.2385734
10. Hassan, A. A. H., Shah, W. M., Habeb, A. H. H., Othman, M. F. I., Al-Mhiqani, M. N. An Improved Energy-Efficient Clustering Protocol to Prolong the Lifetime of the WSN-Based IoT. IEEE Access, 2020, 8, 200500-200517. https://doi.org/10.1109/ACCESS.2020.3035624
11. Jain, A. Traffic Aware Channel Access Algorithm for Cluster Based Wireless Sensor Networks. Wireless Personal Communications, 2017, 96(1), 1595-1612. https://doi.org/10.1007/s11277-017-4258-4
12. Kalidoss, T., Rajasekaran, L., Kanagasabai, K. QoS Aware Trust Based Routing Algorithm for Wireless Sensor Networks. Wireless Personal Communications, 2020, 110, 1637-1658. https://doi.org/10.1007/s11277-019-06788-y
13. Kong, L., Xiang, Q., Liu, X., Liu, X. Y., Gao, X., Chen, G., Wu, M. Y., ICP: Instantaneous Clustering Protocol for Wireless Sensor Networks. Computer Networks, 2016, 101, 144-157. https://doi.org/10.1016/j.comnet.2015.12.021
14. Muthurajkumar, S., Ganapathy, S., Vijayalakshmi, M. An Intelligent Secured and Energy Efficient Routing Algorithm for MANETs. Wireless Personal Communications, 2017, 96, 1753-1769. https://doi.org/10.1007/s11277-017-4266-4
15. Ni, Q., Pan, Q., Du, H., Cao, C., Zhai, Y. A Novel Cluster Head Selection Algorithm Based on Fuzzy Clustering and Particle Swarm Optimization. IEEE/ACM Transactions on Computational Biology and Bioinformatics, 2017, 14(1), 76-84. https://doi.org/10.1109/TCBB.2015.2446475
16. Pang, A., Chao, F., Zhou, H., Zhang, J. The Method of Data Collection Based on Multiple Mobile Nodes for Wireless Sensor Network. IEEE Access, 2020, 8, 14704-14713. https://doi.org/10.1109/ACCESS.2020.2966652
17. Pradeep, S., Muthurajkumar, S., Ganapathy, S. A Matrix Translation and Elliptic Curve Based Cryptosystem for Secured Data Communications in WSNs. Wireless Personal Communications, 2021, 119, 489-508. https://doi.org/10.1007/s11277-021-08221-9
18. Reddy, V., Gayathri, P. Integration of Internet of Things with Wireless Sensor Network. International Journal of Electrical and Computer Engineering, 2019, 9(1), 439-444. https://doi.org/10.11591/ijece.v9i1.pp439-444
19. Sampradeepraj, T., Raja, S. P. On Improving Reliability in Multicast Routing Protocol for Wireless Sensor Network. Information Technology and Control, 2020, 49(1), 260-274. https://doi.org/10.5755/j01.itc.49.2.24111
20. Selvi, M., Thangaramya, K. and Ganapathy, S. An Energy Aware Trust Based Secure Routing Algorithm for Effective Communication in Wireless Sensor Networks. Wireless Personal Communications, 2019, 105, 1475-1490. https://doi.org/10.1007/s11277-019-06155-x
21. Sha, C., Ren, C., Malekian, R., Wu, M., Huang, H., Ye, N., A Type of Virtual Force-Based Energy-Hole Mitigation Strategy for Sensor Networks. IEEE Sensors Journal, 2020, 20(2), 1105-1119. https://doi.org/10.1109/JSEN.2019.2945595
22. Shah, S. B., Chen, Z., Yin, F., Khan, I. U., Ahmad, N. Energy and Interoperable Aware Routing for Throughput

Optimization in Clustered IoT-wireless Sensor Networks. Future Generation Computer Systems, 2018, 81, 372-381. https://doi.org/10.1016/j.future.2017.09.043

23. Shen, J., Wang, A., Wang, C., Hung, P. C. K., Lai, C. F., An Efficient Centroid-based Routing Protocol for Energy Management in WSN-assisted IoT. IEEE Access, 2017, 5, 18469-18479. https://doi.org/10.1109/ACCESS.2017.2749606

24. Sheta, A., Solaiman, B. Evolving a Hybrid K-means Clustering Algorithm for Wireless Sensor Network Using PSO and Gas. International Journal of Computer Science Issues, 2015, 12(1), 23-32. doi: https://www.ijcsi.org/papers/IJCSI-12-1-1-23-32.pdf.

25. Su, S., Zhao, S. An Optimal Clustering Mechanism Based on Fuzzy-C Means for Wireless Sensor Networks. Sustainable Computing: Informatics and Systems, 2018, 18, 127-134. https://doi.org/10.1016/j.suscom.2017.08.001

26. Tinker M. S., Chinara, S. Energy Conservation Clustering in Wireless Sensor Networks for Increased Life Time. In Proceedings of 2nd International Conference Advanced Computing and Communication Technology, 2015, 7-10. https://doi.org/10.1109/ICACCE.2015.103

27. Wang, Q., Guo, S., Hu, J., Yang, Y. Spectral Partitioning and Fuzzy C-means Based Clustering Algorithm for Big Data Wireless Sensor Networks. EURASIP Journal on Wireless Communications and Networking, 2018, 2018(1), 1-11. https://doi.org/10.1186/s13638-018-1067-8

28. Xu, C., Xiong, Z., Zhao, G., Yu, S. An Energy-Efficient Region Source Routing Protocol for Lifetime Maximization in WSN. IEEE Access, 2019, 7, 135277-135289. https://doi.org/10.1109/ACCESS.2019.2942321

29. Xunli, F., Wei, W., Marcin, W., Ye L., Low Energy Consumption and Data Redundancy Approach of Wireless Sensor Networks with Bigdata. Information Technology and Control, 2018, 47(3), 406-418. https://doi.org/10.5755/j01.itc.47.3.20565

30. Ye, F., Zhou, X., Ren, Z., Yang, S. Energy Allocation for Stochastic Event Detection in Rechargeable Sensor Networks. Information Technology and Control, 2022, 51(2), 283-293. https://doi.org/10.5755/j01.itc.51.2.29941

31. Zhu, B., Bedeer, E., Nguyen, H. H., Barton, R., Henry, J., Improved Soft-k-Means Clustering Algorithm for Balancing Energy Consumption in Wireless Sensor Networks. IEEE Internet of Things Journal, 2021, 8(6), 4868-4881. https://doi.org/10.1109/JIOT.2020.3031272