Journal of
Data Acquisition and Processing
ISSN: 1004-9037
https://sjcjycl.cn/
DOI: 10.5281/zenodo.7639150

MINIMUM POWER CONSUMPTION ROUTING USING HIERARCHICAL FUZZY LOGIC CLUSTERING FOR INTERNET OF THINGS

K. Pradeepa

PG and Research Department of Computer Science, Cauvery College for Women (Autonomous), Affiliated to Bharathidasan University, Tiruchirappalli, Tamil Nadu- 620018, India, Email: pradeepa.cs@cauverycollege.ac.in

Dr. M. Parveen

PG and Research Department of Computer Science, Cauvery College for Women (Autonomous), Affiliated to Bharathidasan University, Tiruchirappalli, Tamil Nadu- 620018, India, Email: parveen.it@cauverycollege.ac.in

Corresponding author: K. Pradeepa

ABSTRACT:

The Internet of Things (IoT) is a very famous network because of its many applications. IoT network has an integration of large-scale IoT devices that generate data. These IoT devices have a very low level of interaction because they are very low power computational processors. These devices construct records and transmit the records to the base station via intermediate devices. The base station gathers and integrates the data and sends it to the administrator for further processing. The data attains the base station using various routing algorithms with the goal of low power consumption. When discussing low power IoT devices, power efficiency is an important performance measurement when creating a routing algorithm. This paper proposes a Minimum Power Consumption Routing (MPCR) algorithm using Hierarchical Fuzzy Logic Clustering (HFLC) algorithm for IoT networks. Since it aggregates data inside the cluster head and reduces the amount of data transmitted to the base station, the MPCR with HFLC algorithm has a lesser energy utilization for the cluster. This paper explains cluster formation and cluster-head selection, and a simulation has been conducted. Additionally, the proposed algorithm is evaluated with the previous algorithms using multiple metrics including throughput, packet delivery ratio, and power usage of the network. The experimental findings demonstrate that the proposed MPCR with the HFLC algorithm provides high throughput and packet delivery ratio and reduces power usage more efficiently than other existing algorithms.

Keywords: Clustering, Routing, Energy consumption, hierarchical clustering and fuzzy logic

I INTRODUCTION:

A wide variety of applications for the Internet of Things (IoT) are currently being found in a number of sectors, including smart homes, smart cities, medical services, industrial automation, disaster management, agriculture, etc. The IoT network generally uses IoT devices that are wirelessly linked together to accomplish a specific smart activity [1]. The IoT network differs from the traditional wireless sensor network (WSN) in that its devices connect to the internet on a dynamic basis and work together with other similar devices to complete tasks [2]. Like the classical WSN network, IoT devices typically periodically send the gathered event data to the base station (BS). The base station then sends the attained data to the administrator.

IoT utility devices typically contain transceivers, batteries, and microprocessors to perform key functions [3].

The IoT network has several uses because to this characteristic, including tracking, remote access, and automated. The IoT network has numerous applications and is more famous in nearly all technology fields. For example, industrial process monitoring, health care monitoring, battlefield monitoring, border field monitoring, smart city traffic monitoring are important applications [4]. The application, which includes the Smart Grid, Smart Traffic Management, Smart Hospital, Smart Home, Industry 4.0, and more, is further utilised for remote access and automating. A few usages of IoT systems include IIoT, system for water control, surveillance, and leak prevention, disaster detection system, smart farming to increase productivity, smart traffic monitoring and smart health monitoring. The major need to attain all applications is to gather and send data. Data transfer from any IoT device could be completed up to a specific distance because of its poor communicating skills. To send data from the IoT device to the base station, the other intermediate device must cooperate. The IoT device acts as both a source device and a relay device. The data should arrive at the base station having lower delay; higher dependability by utilizing fewer powers is the incentive for suggesting any routing algorithm [5]. For the majority of battery-powered uses, such as IoT devices, we place more emphasis on power expenditure.

To deal with issues of this nature, this paper proposes a Minimum Power Consumption Routing (MPCR) algorithm using the Hierarchical Fuzzy Logic Clustering (HFLC) algorithm for IoT networks that will be more energy efficient. Using the MPCR algorithm, through combining the data in the cluster head, lowering the communication costs, and conserving battery energy, we may reduce the amount of data transmitted to the base station. The network overheads for maintaining the best route are further reduced by the MPCR algorithm. Cluster creation implements based on Hierarchical clustering. By often merging multiple lesser clusters into a bigger one or dividing a bigger cluster into lesser ones, hierarchical clustering creates a hierarchy of clusters. Cluster head formation implements based on the Fuzzy Logic technique. One of the machine learning methods that can be applied in uncertain applications is fuzzy logic. Because the competency is dependent on overlapping parameters including power, the number of devices, the distance between devices and base stations, etcetera, the construction of clusters in IoT might not be acceptable if it is using predefined rules. Consequently, using fuzzy logic to solve the uncertainties in selecting the cluster head is suitable.

The remainder of the paper has been planned out: In section 2, the associated cluster-based routing work has been investigated. In section 3, the Minimum Power Consumption Routing (MPCR) algorithm using the Hierarchical Fuzzy Logic Clustering (HFLC) algorithm implemented in this task has been comprehensive. Section 4 contains an assessment of the suggested work and the findings, along with the necessary comparison study. Finally, in section 5 of this paper, we came to a conclusion.

II RELATED WORK:

A multi-layer cluster-based energy-aware routing algorithm for Low-Power and Lossy Networks was provided by Sankar et al. [1], which divided the network area into rings of equal length. The intra-ring clustering technique separates a ring into exactly equal clusters, and inter-cluster routing determines the best optimal path for transferring data. The outcome is an increase of 18 to 22% and 5 to 8%, correspondingly, in the network lifespan and ratio of packet delivery.

Sujanthi et al. [2] establish a Secure Deep Learning (SecDL) method for dynamical cluster-based WSN-IoT systems to bring energy competency to higher level protection. The network is designed as Bi-Concentric Hexagons with Mobile Sink method to increase energy competence. To guarantee QoS as well as other energy competence, dynamic clusters are built inside the Bi-Hex system, as well as the perfect cluster heads are selected by Quality Prediction Phenomenon (QP2). Each cluster permits data aggregating, which is controlled by a Two-way Data Reducing and Eliminating mechanism. To achieve higher security for integrated data, a One Time-PRESENT (OT-PRESENT) cryptography technique is used.

After that, the ciphertext is sent to the mobile base station by best path to guarantee higher-stage QoS. For the best path chosen, a Crossover based Fitted Deep Neural Network (Co-FitDNN) is provided. This task further focused on IoT-user protection because IoT users could use the sensory data. The idea of data mining was applied in this work to verify the IoT users. An Apriori-based Strong Multi-factor Validation technique that maps the ideal authentication feature set for all users is used to verify all IoT users. In this method, the SecDL technique attains energy efficiency, QoS and security.

Reactive, anchor-based routing system was developed by Aranzazu-Suescun et al. [3] using dynamic clustering and minimal flooding. Event-based and dynamic clustering techniques were presented by the authors. These enhancement outcomes in decreased power expenditure also a high number of packets process effectively through the base station. The IoT infrastructure provides data collected by the mobile base station to the end users.

Maheswar et al. [4] presented a cluster-based Backpressure routing (CBPR) method that has been presented that goal to extend the life span of the network and improve the transfer of data dependability utilizing the power load-balancing method. The CBPR technique selects the cluster head with the greatest level of power for each cluster of the sensing device. The CBPR routing technique additionally employs the Backpressure scheduling machine for data packet queuing and for the route selection, allowing it to select the next-hop sensor device utilising the queue length value of the sensor devices, as well as a more powerful data integration algorithm to checkmate avert the flow of redundant data packets in the network.

Clustering was used in the routing protocol offered by Jilong Li et al [5]. The author's primary goal in developing this protocol is to evenly distribute the load across the sensing devices in order to increase lifespan of the network and reduce end-to-end delay.

Clustering procedures were offered in a new type by Muhammad Asad et al. [6]. The whole system is divided into two sections; the initial section used the centralised method, and the next section used the diffused method. The location of the base station is constant and would be in the middle of two segments of the system because the author assumes that neither heterogeneous nor homogeneous types of sensors present in the system.

For WSN-Assisted IoT, Raj Kumar et al. [7] introduced a routing protocol based on clustering. There are essentially 3 phases in this routing technique; the first phase involves creating the transmission zone in the network. The zone cluster would be established in the second step, and the zone head will be selected using the energy and position in the final stage.

Depending on the situation, the broadcast between the zone head and the base station would either be single-hop or multi-hop.

For IoT enabled WSN, Sathya et al. [8] introduced a modified fuzzy-based clustering technique. In this procedure, a fuzzy multi-criteria most efficient method is employed to choose the cluster head. Remaining energy, quality of services (QoS), and sensor device location are included in the cluster head criteria.

For IoT enabled WSNs, Arshad et al. [9] suggested a multi-tier routing system. This procedure builds many clusters with randomly selected cluster heads. The cluster head uses an intermediate cluster head to transfer the data to the base station. As a result, it finally functions as a multi-hop routing mechanism.

For large IoT networks, S. M. Amini et al. [10] presented the Two-Level Distributed Clustering (TLDC) protocol. In this, the primary and secondary cluster heads are the two individuals selected. Data from sensor devices is transmitted by any cluster head, increasing the network's dependability.

The routing protocol was presented by Xinxin Du et al. [11] utilizing the idea of compression. This protocol's main idea is to reduce data duplication and only send the unique data to the sink. It is further used to forecast the data produced by the sensor network.

The Scalable and Energy Efficient Routing Mechanism (SEEP), developed by Anurag Shukla et al. [12], is a multi-hop cluster-based routing protocol which divides the network into several zones. Several clusters, referred to as sub-zones, make up each zone. Near the base station, there are other clusters. Like the relay and cluster heads, the sensor devices might be chosen. Any sensor devices that use relays or cluster heads to transfer data to the base station do so in a multi-hop fashion.

III MINIMUM POWER CONSUMPTION ROUTING (MPCR) ALGORITHM USING HIERARCHICAL FUZZY LOGIC CLUSTERING (HFLC) ALGORITHM

If any source IoT device wants to transfer data, the routing algorithm for the IoT network allows it to transmit the data to the base station if the distance between the source IoT device and the base station is one hop. If not, the source IoT device transfers the data to its neighbour, who then relays it to the base station through further intermediate relay devices. The way data is transferred from any source IoT device to the base station serves as the foundation for several routing algorithms. Due to its advantages over the low power IoT network, the cluster-based routing algorithm is renowned among all sorts of routing algorithms.

The benefits of cluster-based routing algorithms are because of the base station’s decreased number of data packets. But, due to the widespread adoption of IoT devices into networks, the base station collects the similar kind of data that increases network overhead and unquestionably has no relevance for making decisions. When using the cluster-based routing algorithm, the cluster head collects data from the cluster members, integrates it, and then transmits just one integrated data packet to the base station, greatly reducing the amount of data packets that base station must collect and eventually guiding to a power-efficient network.

Scientists and academics are interested in clustering in IoT networks due to its advantages for building a power-efficient network. The cluster head is picked during the clustering process, and other members are given data on the cluster head. This is Type-1 for cluster formation, where the members who want to be the cluster element can ask the cluster head to join the cluster. One cluster head would be picked after the cluster has been built; this is Type-2 for constructing the cluster.

This work proposed a Minimum Power Consumption Routing (MPCR) algorithm using Hierarchical Fuzzy Logic Clustering (HFLC) algorithm for IoT network has been proposed. This HFLC algorithm forms clusters using Type-2. Cluster formation executes based on Hierarchical clustering. By often merging multiple lesser clusters into a bigger one or dividing a bigger cluster into lesser ones, hierarchical clustering creates a hierarchy of clusters. Cluster head selection executes based on the Fuzzy Logic technique. One of the computational intelligence methods that can be used in uses with uncertainty is fuzzy logic. Algorithm 1 explained the proposed Minimum Power Consumption Routing (MPCR) algorithm.

Algorithm 1: Minimum Power Consumption Routing (MPCR)

Input	**:**	Admin, Base Station (BS), IoT Devices (IoTDs) with initial battery power, Packet Aggregation Threshold (PAT)
Output	**:**	Minimum power consumption
Step 1	**:**	Admin creates the IoT Network using IoT devices and base station
Step 2	**:**	Admin clusters IoT Network based on Hierarchical Fuzzy Logic Clustering (HFLC) algorithm // **Algorithm 2**
Step 3	**:**	For each cluster head CH from IoTDs
Step 4	**:**	DR = BS discovers all available routes between CH to the BS using intermediate cluster heads
Step 5	**:**	SR = Sorts DR from the shortest route to the longest route
Step 6	**:**	BS inform its SR to each CH
Step 7	**:**	CH keeps its SR to its Routes List
Step 8	**:**	End For
Step 9	**:**	Source IoT device SI sense, and construct a packet P
Step 10	**:**	Transmit P to its cluster head CH
Step 11	**:**	Set AP is equal to empty
Step 12	**:**	If the number of the received packet is not equal to PAT, Then
Step 13	**:**	AP = AP + P
Step 14	**:**	Send acknowledgement message to SI
Step 15	**:**	Else

Step 16 : AP = AP + P

Step 17 : Select SR from its Routes List

Step 18 : Find next cluster head NCH from SR

Step 19 : Transmit AP to NCH

Step 20 : If NCH is not equal to BS

Step 21 : Repeat Step 17 to Step 19

Step 22 : Else

Step 23 : Forward AP to admin

Step 24 : End If

Step 25 : End If

Step 26 : Admin received AP from BS

Step 27 : Extract each packet P from AP

First, the admin constructs the IoT network using IoT devices and base station (Step 1). Then the admin cluster the IoT network for routing purposes using the HFLC algorithm (Step 2). The base station then discovers all available routes between each cluster head using intermediate cluster heads (Step 4). It then sorts all the routes for each cluster head from the short route to the long route (Step 5). Followed by it informs each cluster head with its sorted route details (Step 6). Then, each cluster head stores its sorted route details to its Routes List (Step 7).

If an IoT device (cluster member) senses anything, it constructs a packet (Step 9). Followed by it transmits this packet to its cluster head (Step 10). Now cluster head aggregates all received packets until the number of the received packet is equal to the packet aggregation threshold (Step 11 - 14). If the number of received packets equals the packet aggregation threshold, it will transfer aggregated packets to the next device (cluster head or base station) in its shortest route (Step 19). If the next device is a cluster head, it repeats the above step (Step 21). But next device is the base station; it forwards the aggregated packet to the admin (Step 23). After received aggregated packet, the admin extracts each packet from the aggregated packet (Step 27). In case of any failure from any shortest route, all cluster heads take the next shortest route from their route list. This algorithm's key benefits are less battery use and successful packet delivery. The suggested MPCR algorithm's flow diagram is shown in Figure 1.

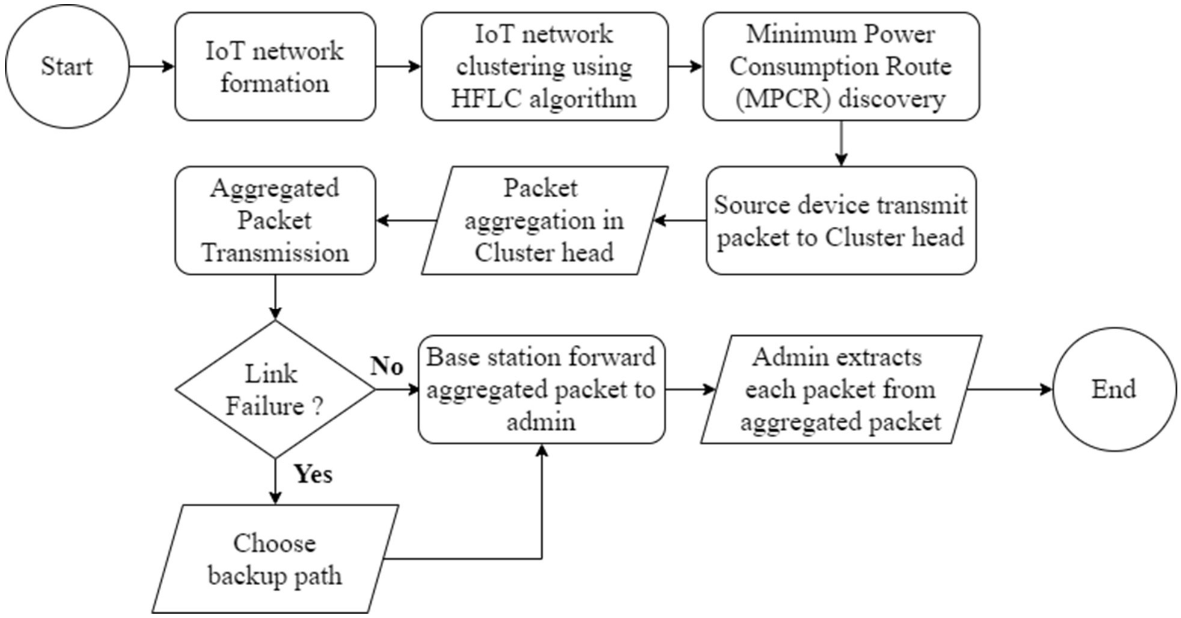

Figure 1: The MPCR algorithm flow diagram

3.1 Hierarchical Fuzzy Logic Clustering (HFLC) algorithm:

The main significant aim of the MPCR algorithm is to improve the life span of the IoT network. Therefore this work suggests a Hierarchical Fuzzy Logic Clustering (HFLC) algorithm to generate minimum power consumption routing, leading to lengthening the lifespan of the network. In the HFLC algorithm, cluster formation executes based on Hierarchical clustering. The unsupervised clustering algorithm known as the hierarchical clustering builds clusters with main hierarchy from top to bottom. For instance, our hard drive's folders and data are already set up in a hierarchy. The algorithm then groups the similar objects into clusters. The endpoint is a collection of clusters, each of which is distinct from the others but contains objects that are usually equal to one another. By often merging multiple lesser clusters into a bigger one or dividing a bigger cluster into lesser ones, hierarchical clustering creates a hierarchy of clusters. There are two categories for this clustering technique: 1) Agglomerative hierarchical clustering 2) Divisive hierarchical clustering. Agglomerative hierarchical clustering is a "bottom-up" clustering approach.

Conversely, Divisive Hierarchical Clustering is a “top-down” clustering approach. Therefore, the proposed HFLC algorithm is a “top-down” clustering approach. Figure 2 shows HFLC algorithm cluster formation.

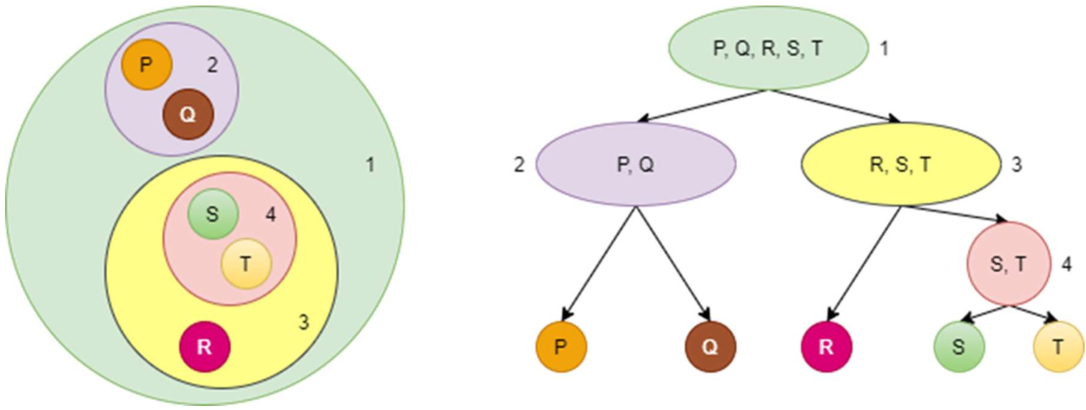

Figure 2: HFLC algorithm cluster formation

In the HFLC algorithm, the admin allocates all IoT devices to a single cluster (mentioned as 1 in Figure 2) and then splits the cluster into two least equivalent clusters (mentioned as 2 and 3 in Figure 2). Finally, the administrator divides each cluster iteratively until there is one cluster for each IoT device (mentioned as 4 in Figure 2).

In addition, in the HFLC algorithm, cluster head selection executes based on the Fuzzy Logic technique. One of the computational intelligence methods that can be used in uses with uncertainty is fuzzy logic. Three fuzzy parameters, that is the present level of power of the IoT device, the distance between the IoT device and base station, distance between cluster members and the IoT device, are utilized for efficient cluster head selection. The following levels are used for each fuzzy parameter,

- **IoT device present energy** – Less, medium less, medium, high medium and highly
- **Distance between IoT device and base station** – Closer, medium closer, medium, medium distant and distant
- **Distance between IoT device and cluster members** – Closer, medium closer, medium, medium distant and distant

The distance between the IoT device (ID) to the base station (BS) (or to cluster member) is determined based on the Euclidean distance. Eq. (1) has a formula for calculating distance.

$$\text{Distance(ID, BS)} = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \quad (1)$$

For choosing the best cluster head in this work, nine levels have been utilized: very much weak, weak, less weak, less medium, medium, high medium, less strong, strong; using fuzzy logic, Table 1 displays the IF-THEN rules used in the HFLC algorithm.

Table 1: Fuzzy Logic-based IF-THEN rules for cluster head selection

IoT device current energy	Distance between IoT device to the base station	Distance between IoT device to each cluster members	Fuzzy Logic Result (FLR)
Less	Distant	Distant	Very Much Weak

Less	Distant	Distant	Weak
Less	Distant	Distant	Less Weak
Less	Distant	Distant	Less Medium
Less	Distant	Distant	Medium
Medium Less	Medium Distant	Medium Distant	Weak
Medium Less	Medium Distant	Medium Distant	Less Weak
Medium Less	Medium Distant	Medium Distant	Less Medium
Medium Less	Medium Distant	Medium Distant	Medium
Highly Medium	Medium Closer	Medium	Less Medium
Highly Medium	Medium Closer	Medium	Medium
Highly Medium	Medium Closer	Medium	Less Medium
Highly Medium	Medium Closer	Medium	Medium
Highly Medium	Medium Closer	Medium	Highly Medium
Highly	Closer	Closer	Medium
Highly	Closer	Closer	Highly Medium
Highly	Closer	Closer	Less Strong
Highly	Closer	Closer	Strong
Highly	Closer	Closer	Very Much Strong

From the above table, if a fuzzy logic result of an IoT device in a cluster is very much strong, it will be chosen as the cluster head. Algorithm 2 explained the HFLC algorithm.

Algorithm 2: Hierarchical Fuzzy Logic Clustering (HFLC) algorithm

Input : IoT Devices, Base station (BS)

Output : Clusters with Cluster Head (CH)

Step 1 : Assign all of the IoT devices to a single cluster

Step 2 : Partition the cluster into two least similar clusters

Step 3 : CL[] = Admin proceeds partition recursively on each cluster until there is one cluster for each IoT device

Step 4 : For each cluster C from CL

Step 5 : For each Member M from C

Step 6 : CE = Get current energy of M

Step 7 : DB = Compute the distance between M to BS

Step 8 : DM = Compute the distance between M to other members

Step 9 : FLR = Apply Fuzzy Logic-based IF-THEN rules for CE, DB and DM // **Table 1**

Step 10 : If FLR is Very Much Strong Then

Step 11 : CH = M // Cluster Head of Cluster C is M

Step 12 : Break

Step 13 : End If

Step 14 : End For

Step 15 : End For

IV Results and Discussion:

The experimental findings and analysis of the MPCR using the HFLC algorithm on the IoT network are presented in this section. This simulation assumes that there are still a large number of IoT devices dispersed evenly and randomly throughout the forest. These IoT devices keep an eye on heat, moisture, brightness, rainfall, pollution, and wind speed. Readings from these devices are then transmitted via the base station to the admin. The MPCR and the HFLC algorithm was evaluated using Java. The results from the simulation of the MPCR with HFLC algorithm alongside three already-in-use routing techniques, such as InFRA [4], DRINA [4], and CBPR [4], under different node density conditions are presented in this section. There are comparisons made between the throughput, ratio of packet delivery and power usage of routing methods for the MPCR using the HFLC algorithm and the other listed techniques. The following critical analysis of the results is also carried out in this section;

4.1 Throughput:

The total number of data packets which an algorithm could effectively send to the base station during a specific amount of time is referred to as throughput. Table 2 demonstrates the throughput difference for MPCR with the HFLC algorithm, CBPR, DRINA, and InFRA at various network device densities.

Table 2: Throughput Comparison

Number of IoT devices	InFRA	DRINA	CBPR	MPCR with HFLC
50	72	81	93	104
100	74	86	108	113
150	79	96	115	121
200	88	112	132	139

Figure 3 demonstrates that for all network densities of device scenarios, the MPCR with HFLC algorithm beats the InFRA, DRINA, and CBPR in the area of throughput. Since only the best paths are often used when routing packets towards the base station by MPCR with HFLC algorithm. The MPCR using the HFLC algorithm is stated to have selected the route with the greatest residual power, lowest power consumption rate, and closest proximity to the base station; as a result, it exhibits link solidity and reduces packet drop during transmission of data. Furthermore, the proposed MPCR with HFLC algorithm benefits from the Fuzzy Logic cluster head selection to dynamically discover the most excellent cluster head utilized for aggregated packet transmission. All of the above taken into consideration by MPCR with the HFLC algorithm resulted in a better throughput effectiveness when compared to its competitors.

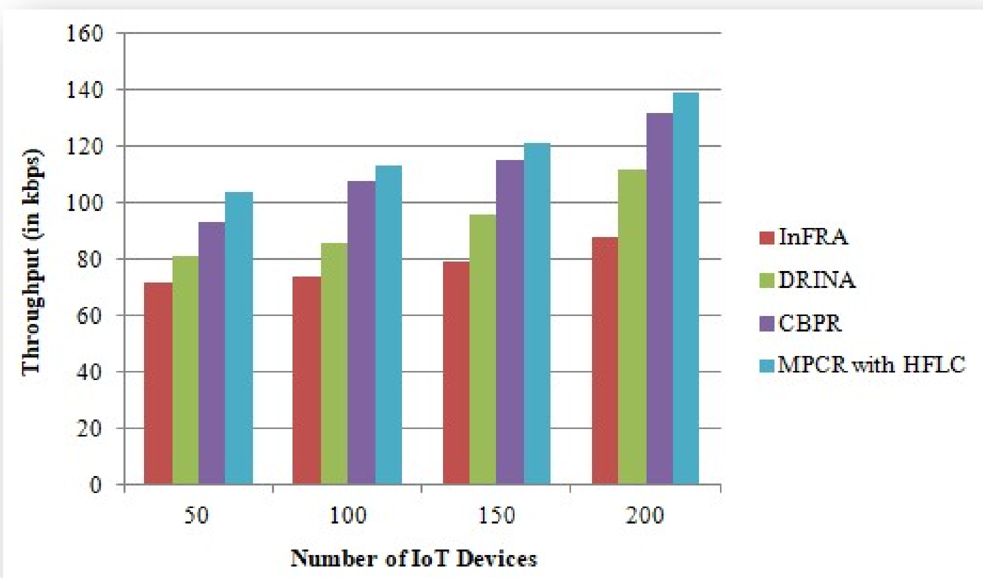

Figure 3: Throughput with the number of IoT devices in the IoT network

4.2 Packet Delivery Ratio (PDR):

The ratio of packets received at the base station over the duration of the simulation period to the total number of packets transmitted from the source IoT device is known as the packet delivery ratio. The optimum aggregation and effective routing are indicated by a high PDR. There are multiple route options between the source and destination devices as the number of devices in the network grows, along with the number of intermediate devices in the routing path.

The MPCR with HFLC algorithm takes advantage of this multi-path factor to boost efficiency by selecting intermediate cluster heads with greater remaining energy to construct the perfect forwarding routes with lesser opportunities of a link failure in the system, guiding to competent transfer and a greater packet delivery ratio. Additionally, the MPCR with HFLC algorithm prioritizes the packets based on the IoT device queue length condition, giving preference to the devices with a shorter queue length to minimize congestion in the IoT network and decrease waiting times, thus raising the PDR score. In addition, compared to InFRA, DRINA, and CBPR routings, MPCR with HFLC algorithm makes effective use of data aggregation that eliminates redundant data by combining all connected event data into a single meaningful data unit. Table 3 compares packet delivery ratios.

Table 3: Comparison of Packet Delivery Ratios

Number of IoT devices	InFRA	DRINA	CBPR	MPCR with HFLC
50	38	46	64	76
100	39	49	66	79
150	40	60	72	81
200	44	63	76	84

Figure 4 demonstrates the PDR performances of the assessed systems, indicating that each scheme's value raises as the number of devices rises.

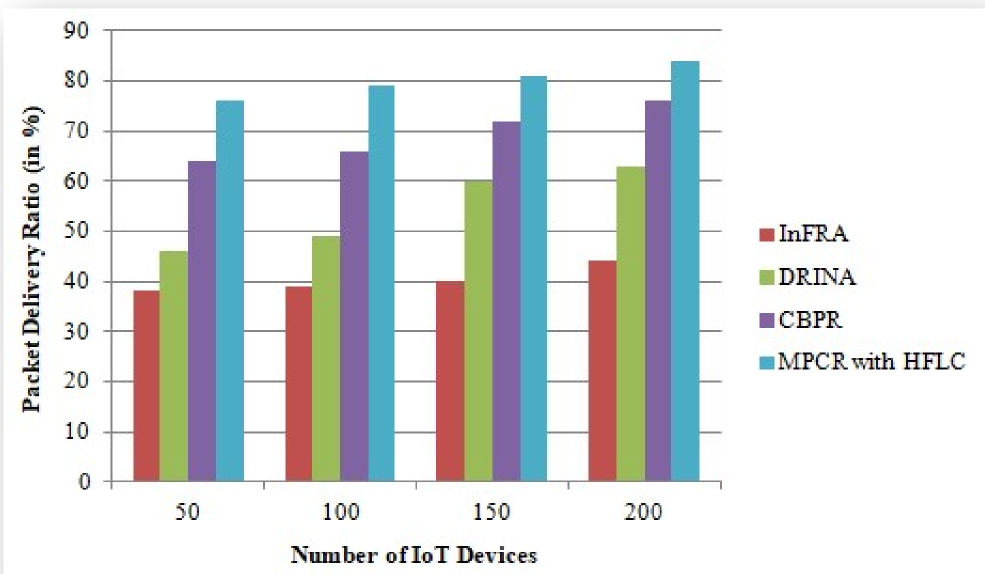

Figure 4: Packet delivery ratio with the number of devices in the IoT network

4.3 Energy Consumption:

The amount of energy required to transmit a unit of data from a source IoT device to a base station in an IoT system is referred to as energy consumption. As shown in Table 4 and Figure 5, the power usage effectiveness of the MPCR with HFLC algorithm has been assessed utilizing varied network device densities and compared with the InFRA, DRINA, and CBPR routing systems.

Table 4: Energy Consumption Comparison

Number of IoT devices	InFRA	DRINA	CBPR	MPCR with HFLC
50	0.59	0.38	0.23	0.19
100	0.46	0.34	0.17	0.15
150	0.43	0.31	0.14	0.12
200	0.37	0.29	0.13	0.1

The MPCR with HFLC algorithm forever selects the shortest route for decrease energy consumption. Furthermore, it chooses the best cluster head with high residual energy, closer to the base station and closer to all cluster members. Thus, it leads to reduce energy consumption. Followed by, it used packet aggregation technique. Therefore, it also leads to reduce unnecessary energy consumption. In addition, this algorithm also has a backup path. In case of any link failure, this algorithm automatically chooses another shortest route. This way saves a lot of energy. Therefore, compared with other existing algorithms proposed, MPCR with the HFLC algorithm reduce energy consumption efficiently.

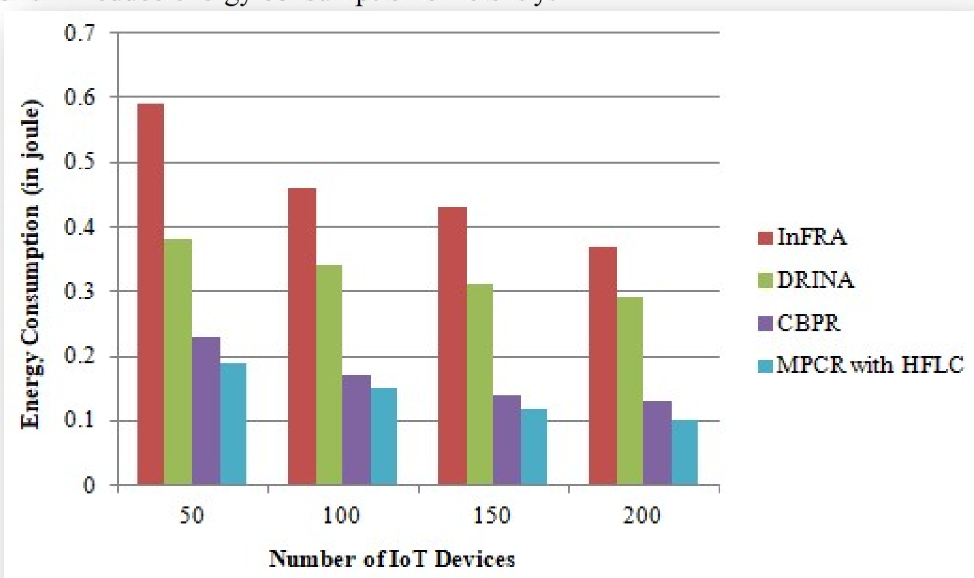

Figure 5: Energy consumption with the number of IoT devices in the IoT network

V Conclusion:

For an IoT-enabled WSN network, this paper proposed the Minimum Power Consumption Routing (MPCR) algorithm using the Hierarchical Fuzzy Logic Clustering (HFLC) algorithm. The MPCR with HFLC algorithm is the most power-efficient algorithm since it aggregates data within the cluster head and uses less data transmissions to the base station, resulting in a cluster's lowest power usage. The cluster construction in this research is carried out using hierarchical clustering, the cluster-head selection is carried out using fuzzy logic, and simulation has been carried out. Additionally, based on several parameters, including throughput, packet delivery ratio, and network energy usage, the proposed algorithm is compared with the existing algorithms. The experimental findings showed that the MPCR with HFLC algorithm decreases energy consumption more effectively than other existing algorithms while offering good throughput and packet delivery ratio. To reduce energy usage, we intend to expand this work using more than one base station in the future.

References:

[1] Sankar, S., & Srinivasan, P. (2018). Multi-layer cluster-based energy-aware routing protocol for the internet of things. Cybern. Inf. Technol, 18(3), 75-92.

[2] Sujanthi, S., & Kalyani, S. N. (2020). SecDL: QoS-aware secure deep learning approach for dynamic cluster-based routing in WSN assisted IoT. Wireless Personal Communications, 114(3), 2135-2169.

[3] Aranzazu-Suescun, C., & Cardei, M. (2019). Anchor-based routing protocol with dynamic clustering for Internet of Things WSNs. EURASIP Journal on Wireless Communications and Networking, 2019(1), 1-12.

[4] Maheswar, R., Jayarajan, P., Sampathkumar, A., Kanagachidambaresan, G. R., Hindia, M. N., Tilwari, V., ... & Amiri, I. S. (2021). CBPR: A cluster-based backpressure routing for the internet of things. Wireless Personal Communications, 1-19.

[5] Li, J., Silva, B. N., Diyan, M., Cao, Z., & Han, K. (2018). A clustering-based routing algorithm in IoT aware Wireless Mesh Networks. Sustainable cities and society, 40, 657-666.

[6] Asad, M., Aslam, M., Nianmin, Y., Ayoub, N., Qureshi, K. I., & Munir, E. U. (2019). IoT enabled adaptive clustering-based energy-efficient routing protocol for wireless sensor networks. International Journal of Ad Hoc and Ubiquitous Computing, 32(2), 133-145.

[7] Kumar, N. P. R., & Gnanadhas, J. B. (2020). Cluster Centroid-Based Energy Efficient Routing Protocol for WSN-Assisted IoT. Advances in Science, Technology and Engineering Systems Journal, 5(4), 296-313.

[8] Preeth, S. S. L., Dhanalakshmi, R., Kumar, R., & Shakeel, P. M. (2018). An adaptive fuzzy rule-based energy-efficient clustering and immune-inspired routing protocol for WSN-assisted IoT system. Journal of Ambient Intelligence and Humanized Computing, 1-13.

[9] Arshad, M., Almufarreh, A., Jilani, M. T., & Siddiqu, F. A. (2020). A three-tier cluster-based routing protocol for mobile wireless sensor networks. Indian Journal of Science and Technology, 13(33), 3409-3424.

[10] Amini, S. M., & Karimi, A. (2020). Two-level distributed clustering routing algorithm based on unequal clusters for large-scale Internet of Things networks. The Journal of Supercomputing, 76(3), 2158-2190.

[11] Du, X., Zhou, Z., Zhang, Y., & Rahman, T. (2020). Energy-efficient sensory data gathering based on compressed sensing in IoT networks. Journal of Cloud Computing, 9(1), 1-16.

[12] Shukla, A., & Tripathi, S. (2020). A multi-tier based clustering framework for scalable and energy-efficient WSN-assisted IoT network. Wireless Networks, 1-23.