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A Hierarchical Routing Method based on Fog Technology using the Grey system Theory in Internet of Things

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Abstract Considering the great growth of IoT networks and the need for highly reliable networks and also considering the manufacturing divides of IoT equipment which are highly limited by their memory, processing power and battery; we need a highly efficient routing for guaranteeing our network's high life span. So, this paper has suggested an efficient energy routing method based on the overlapping clustering method which is inspired from the Grey theory. The Overlap clustering method means that some Things collect data that must be sent to two or more Fog nodes for processing. In the suggested method the best node is selected as the cluster head based on factors such as remaining energy, distance, link expiration time, signal power for receiving data from things by the Fog nodes. In the next step the Fog node's data are sent in a hierarchical method using a symmetrical tree of processed data to the server. Thus, the main issue here is making using a proper routing method for data sending to the Cloud that doesn't just focus on energy, but also considers other factors such as delay and network life span. The simulation results show that the HR-IoT reduces the average end to end delay more than 17.2% and 23.1%, decreases the response time more than 20.1% and 25.78% and increase packet delivery rate more than 23.1% and 28.78% and lifetime more than 25.1% and 28.78% compared to EECRP and ERGID approaches.

Keywords Internet of Thing (IoT) . Hierarchical Routing . Overlap clustering . Fog computing . Cloud computing

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1 Introduction

The term Internet of Things was first used by Kevin Ashton in 1999 and ever since had an ascending development rate. In this technology Things are any device equipped with a sensor for trading data. The biggest advantage of Internet of Things is the ability of speaking to the Analog world around us (Machines, People, Animals, Plants and etc.) using digital languages and with all the benefits of such languages, this the importance of connection and data routing in Internet of Things is undeniable. Furthermore, using proper routing and selecting the best routes for fast data transfer optimizes such networks [1, 2]. One of the most common processing methods is sending data towards the cloud processing space which has many fans, but using cloud processing has many challenges such as long delays, therefore the need for other methods for fast data transfer such as Fog processing arises. In Fog processing instead of sending all the data to a cloud processing serves and waiting for a proper respond, we use a local processing unit. In truth the Fog processes are a distributed infrastructure in which data, calculation, storage and applications are scattered in a place in between the distributor and the cloud. On the other hand, nodes in the Internet of Electrical Things have limited power, so the worry of them running out of power while transferring data always exists. One method for reducing the power usage in the Internet of things while gathering data from the sensors is using routing methods based on clustering [3]. So, a method can be suggested that in addition to reducing the power usage in the networks can reduce the delay in data access, increase the networks life span and processing power. The general structure of the IoT is shown in Figure 1.

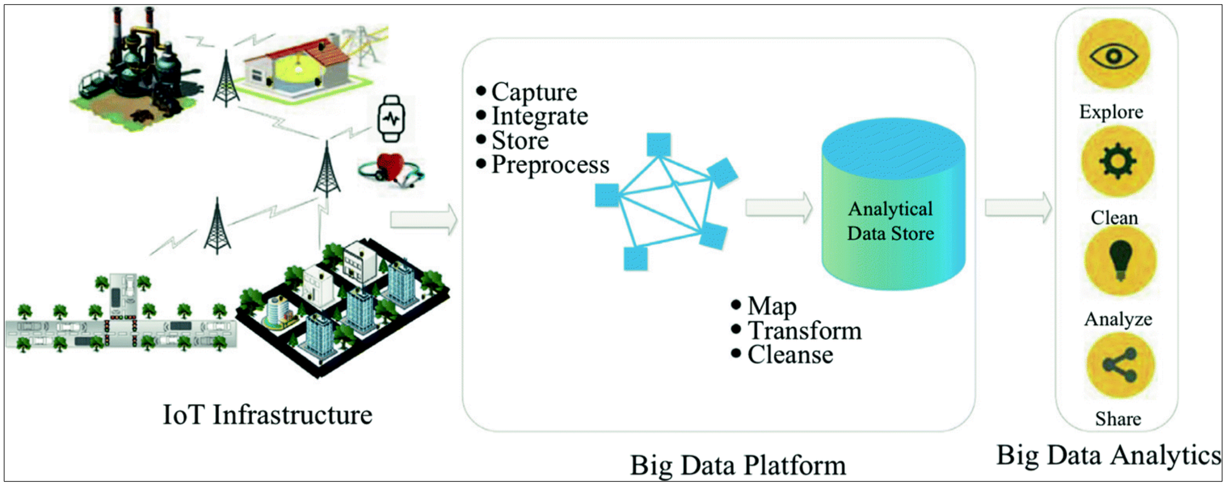

Fig. 1 Internet of Things structure

Considering the mentioned problems and an Overlap clustering method will be proposed facts in this paper. The proposed method of efficient routing in the Internet of Things for fast data transfer to the Fog nodes uses clustering, the cluster head is chosen using parameters and the Grey system theory; the node with the highest rank is chosen as the cluster head. The Grey system theory is a system used for solving multi-criteria decision-making problems. After selecting the cluster head, the data collected by this cluster head must be sent to the Fog. Since the Fog calculation reduces the delay and energy consumptions, this method is good for the Internet of Things especially in the fields of Health Care, Public Transfer and Smart Cities; thus, in the next phase of Fog calculation a Hierarchical tree is used for sending data to the server. The Fog processing method is helpful in the efficient realization of the IoT technology, because processes and data will be distributed in the nodes alongside the servers. Therefore, the

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traffic of the servers and networks are reduced in the Fog processing model, this in turn reduces the delay and energy consumption in the Fog nodes and serves and also increases the network's life span.

The rest of the paper is organized as follows: Section 2 explains the basic concepts around Gray Theory System. Section 3 presents related works. In Sect. 4 brings the proposed HR-IoT solution. The parameters used for assessing the performance are studied and simulation outcomes are deliberated in Section 5. Finally, the conclusion of this research is discussed in Section 6.

2 Basic concepts

This section explains the basic related concepts.

2.1 Grey System Theory

Grey System Theory is a multi-criteria decision-making system that uses the combination of deferent parameters for choosing the right option. In many cases the results will be favorable and satisfactory for the decision maker when they have been analyzed based on multiple criteria. Grey System Theory is just a multi-criteria decision-making technique with its own principles and rules. This system has an algorithm with certain steps. The Grey Relation Analysis technique is used for selecting the best option based on some criteria. This technique just like the TOPSIS and Vikor techniques starts with a decision matrix, but here alongside a difference between negative and positive criteria; there will be a difference between the most desirable values. Based on this there are three criteria categories in the Grey Decision Matrix:

- The bigger the better (Same as positive criteria in the TOPSIS and Vikor techniques)
- The smaller the better (Same as negative criteria in the TOPSIS and Vikor techniques)
- The closer to the desirable value the better (Is not considered in the TOPSIS and Vikor techniques)

The main idea of the Grey Relation Analysis as a Quantitative analysis method is based on the fact that the degree of closeness and correlation of the relationship between two different factors in a dynamic and developing process must be measured based on their curve similarity. The more similar the curves, the higher the relation between these series and vice versa. The Grey Relation Degree is used for measuring the amount of this similarity. In this step each option is analyzed based on this criterion.

In the following the overall steps of the Grey System Theory are expressed:

Step One: This step is known as creating the Grey Relation. For analyzing the performance of multiple units, if m shows the number of units and n the number of available parameters, then ith unit can be shown as $Y_i = \left(y_{i1}, y_{i2}, ..., y_{ij}, ..., y_{in}\right)$ in such a way that Y_i is the amount of parameter j for the unit of i. Y_i can be turned into a comparable sequence $X_i = \left(x_{i1}, x_{i2}, ..., x_{ij}, ..., x_{in}\right)$ using Equation (1) and Equation (2). In other words, these equations can normalize the parameters.

$$X_{ij} = \left(\frac{y_{ij} - Min\left\{y_{ij}, i = 1,2,...,m\right\}}{Max\left\{y_{ij}, i = 1,2,...,m\right\} - Min\left\{y_{ij}, i = 1,2,...,m\right\}}\right) \quad (1)$$

$$X_{ij} = \left(\frac{Max\left\{y_{ij}, i = 1,2,...,m\right\} - y_{ij}}{Max\left\{y_{ij}, i = 1,2,...,m\right\} - Min\left\{y_{ij}, i = 1,2,...,m\right\}}\right) \quad (2)$$

In Equation (1) and Equation (2), i and j are defined as follows:

$$i \in \left\{1,2,3,...,n\right\}, j \in \left\{1,2,3,...,m\right\} \quad (3)$$

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The Eq (1) equation is used for positive parameters; in this equation the bigger values of X_{ij} leads to better results. The Eq (2) equation is used for negative parameters; in this equation the smaller values of X_{ij} leads to better results. After using the mentioned equations to create the Grey Relations, all performance values, like when normalization is used, will be between zero and one. The closer X_{ij} is to one, will lead to a parameter with higher desirability. As a result, a comparative series in which all the options are equal to one is the best choice. The reference target series is a series in which all the performance values are equal to one. The Eq (4) equation shows the (X_0) reference series in which all the parameters are equal to one.

$$X_0 = \left(x_{i1}, x_{i2}, \ldots, x_{ji}, \ldots, x_{in}\right) = (1,1,\ldots,1,\ldots,1) \quad (4)$$

After this step the main goal is to find a value that is the closest to this reference series. For finding such value, first the Grey Coefficient must be calculated. The following describes the method for calculating this coefficient.

Step Two: In the second step the value of the Grey Relation must be calculated, this relation is also known as the Grey Relation Degree. Calculating this relation degree first needs the calculation of the Grey Relational Coefficient. The Grey Coefficient is used to show the closeness of X_{ij} to X_{0j}. The Eq (5) equation is used for calculating this coefficient.

$$\gamma\left(x_{0j}, x_{ij}\right) = \left(\frac{\Delta_{\min} + \varepsilon\Delta_{\max}}{\Delta_{ij} + \varepsilon\Delta_{\max}}\right) \quad (5)$$

In this equation, $\gamma\left(x_{0j}, x_{ij}\right)$ is the gray coefficient and its value is between x_{ji} and x_{oj}. In Equation (6-8), values of Δ_{ij}, $\Delta_{\min}$, and $\Delta_{\max}$ are defined as follow:

$$\Delta_{ij} = \left|X_{0j} - X_{ij}\right| \quad (6)$$

$$\Delta_{\min} = Min\left\{\Delta_{ij}, i = 1,2,\ldots,m; j = 1,2,\ldots,n\right\} \quad (7)$$

$$\Delta_{\max} = Max\left\{\Delta_{ij}, i = 1,2,\ldots,m; j = 1,2,\ldots,n\right\} \quad (8)$$

In this equation Δ_{ij} is used to determine the deference between x_{ij} and x_{oj}. $\Delta_{\min}$ shows the lowest values among all the parameters and $\Delta_{\max}$ shows the highest values among all the parameters. After calculating the Grey Relational Coefficient, the Grey Rank must be determined. This rank is determined as follows.

Step Three: The Grey Relational Coefficient has a value between zero and one, in a way that if the coefficient is one, then the two factors are the same and if the coefficient is equal to zero, then the two factors are independent of each other. After calculating this coefficient, the Grey Rank can be determined using the (9) equation and the results of this can be used in many different decision makings.

$$T\left(X_0, X_i\right) = \sum W_j * y\left(x_{0j}, x_{ij}\right) \quad (9)$$

Here $T\left(X_0, X_i\right)$ shows the Grey Rank between X_0 and X_i which in its turn shows the level of correlation between reference sequence and yardstick sequence. W_j, which shows the weight or importance, is a parameter determined by the decision maker or the structure of the problem. Furthermore, other structures like the AHP can be used to calculate this weight. Equation (10) is always right for all W_j.

$$\sum_{j=1}^{n} W_j = 1 \quad (10)$$

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In other words, based on this equation, the total of all the weights will always add up to one. The Grey Rank shows the similarities between reference sequence and yardstick sequence. The reference sequence shows the best possible perforce for each analyzed unit, which can be determined using the yardstick sequence. Based on this system and the explained criterion the best possible node is selected as the cluster head [4].

3 Related works

In this section we will analyze four groups of recent studies.

The LOADng-IoT Method: The LOADng method [5] is a reactionary routing protocol which is creating using route request and route answering messages for finding the best possible routes. The suggested LOADng-IoT is created from three components: Discovering Internet Route Process, Internet Route Cache system (IRC) and a New Error Code for RERR messages. So, whenever a node is trying to send a message and the route to the destination is unknown then a new route discovering process must start. The route discovering process is done using control messages inspired by the AODV. In the date message delivering process, the node must use the route created in the route discovering process to safely deliver its message to the correct destination. Thus, the node searches the collection of its routes by searching an entry point that is suitable for the destination. Therefore, the node most transfers the message to the next Hop in the entrance of the determined route. Based on the latest LOADng specifications, a node must always freshen the valid entry time of a route that it's using. An intermediate node that receives the data message must be transferred to the Hop in the route based on the available data in its own routing series. This process is repeated until the message reaches its final destination. Each node that receives the RREP-IoT must create an entry point in its own routing series with data based on the fact that the basis of the message has an internet connection. As RREP-IoT reaches its destination the node must immediately start sending the internet data messages.

Energy Transfer Algorithm based on RPL: In the next paper [6], a routing and energy transfer algorithm has been presented for designing a system based on RPL with reliable and low-cost energy for useful programs in the Internet of Things. RPL needs the data from inside the DODAG for routing network traffic. The Parent Node is determined inside the DODAG. The RPL protocol collects the data from inside the DODAG. DODAG uses control packages labeled DODAG Object Information (DIO) and also DODAG Information Solicitations (DIS) to transfer the data from within itself. The purpose of this study is to achieve an efficient energy in the system and for Internet of Things' useful programs, so that the nodes consume less energy and guarantee the network's life span. Furthermore, this algorithm increases the network's processing power. The simulation results show that each node can chose the optimal energy levels for transfer. Although these simulations were done for two nodes, the suggested system can work for more nodes. The limitation of our suggested model is that all considered factors are homogenous, but the nodes have a RF CC2420 transmitter. This suggested model might not work in networks with different nodes and different RF transmitters.

The NLEE Method: In paper [7], an efficient energy protocol has been proposed for improving energy productivity in the Internet of Things. The proposed algorithm makes decision to find the fewest number of uploads. The remaining energy in each node and the overall node numbers in the transfer route were used as the routing factors for improving the energy productivity with the help of expected countdowns. The transferred numeration controls the distributed requests for discovering routes. Furthermore, the route discovering process is done using remaining energies and step counting from the node routes. Moreover, the NLEE algorithm guarantees the belter usage of energy by the nodes. Also, the increase of routing setting delay leads to the shortest path in the network.

The EARS Method: In paper [8] an emergency aware mechanics called EARS is suggested, a mechanics that is truly a light and low consumption process for restoring lost packets and analyzing the path that is aware of the packet delivery emergency situation. This protocol uses the Pre-hearing feature and also recognized wireless channels for a mechanism called Implicit ACK. Furthermore, this protocol provides us with the ability to choose the compatible route based on link quality.

The MPCA Method: Paper [9] is designed in a way that fog calculation in mobile devises can use and run on fog devises for their heavier calculations. Using the best possible fog device to upload the data to is a serious time and energy consuming challenge. This paper has presented a Module Placement method by Classification and regression tree Algorithm (MPCA). This paper choses the best fog devises for the MPCA module. At first the mobile devises energy consumption is analyzed, if this amount is higher than the Wi-Fi energy consumption then the downloading process is reset. Authentication, Privacy, Honesty, Availability, Capacity, Speed and Cost are the MPCA's parameters for selecting the best Fog Device. Network resources on loading the analyzed module might have been used for optimizing the MPCA. This paper's results include energy consumption levels, response time and performance and they prove that this suggested method is better than other compared methods.

The P-SEP Protocol: Paper [10] has suggested a new method based on Fog computing. This method is known as the P-SEP protocol. The P-SEP is a modified stable protocol selected for elongating the stable period of Fog supported sensor networks by maintaining balanced energy consumption. P-SEP makes the new balanced distribution of cluster head selection policy possible and also makes the system's run times longer before the breakdown of the first node. P-SEP considers the Inconsistency of two node levels which include advanced nodes and normal nodes. In P-SEP advanced and normal nodes have the ability to turn into cluster heads.

The Improved P-SEP Protocol: Paper [11] has used the FEAR and FECR algorithms as Fog based algorithms to improve the P-SEP protocol. These algorithms introduce a method to find the optimized cluster heads in the network by considering the remaining energy in each node. Fog nodes send and receive data between the cloud space and network sensors. FEAR and FECR are two algorithms for sending data to the cloud space. FECR algorithm uses the PEGASIS algorithm to create a chain between the nodes and send data to the cloud space. The FEAR algorithm uses the Ant Colony Optimization (ACO) algorithm for routing. In this suggested algorithm the cluster heads send the collected data from the nodes of the other cluster to the closest Fog node. Then the Fog nodes merge these collected data and use on the mentioned algorithms to upload them to the cloud space. In this method energy is the only factor considered while selecting cluster heads.

The HFC Method: In the next paper [12], the HFC framework has been introduced as the internal connection framework combining cloud and fog for fast, efficient, and automated virtual network management. This framework uses factor-based method that provides the ability to interact with the Fog infrastructure for different cloud services. Stability, security, flexibility and supporting L2 and L3 are the most important advantages of this method.

SDN based Method: In the Computing calculation model of paper [13] each sensor data is transferred from the sensors to the cloud servers of the network. The sensor data are processed using the proper processes in the servers and then these activities are sent to the launchers by the servers. In this paper the scalability of classical IoT designs in mobile edge network calculation which manages the data flow in these mobile edge networks. In this

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protocol the base stations are connected to Fog nodes that calculate the local resources and send data using software-defined networking and based on the cell nucleus above the Fog nodes.

The WPA-SA Method: In paper [14] the most suitable IoT cluster head has been selected for optimizing the energy consumption in the Internet of Things technology, for routing from the introduced clustering and for making improvements in the network. This paper uses a combined meta-heuristic algorithm alongside the Whale Optimization Algorithm and Simulated Annealing. Factors such as number of live nodes, load balance, remaining energy and operation costs were used for selecting the optimized cluster head in the clusters of IoT networks. Afterwards the suggested method is compared with other methods using a few optimization algorithms such as Artificial Bee Colony algorithm, Genetic algorithm and Compatible Gravitational Search algorithm.

The MPR-LEACH Method: In the next paper [15] a new routing method was introduced by modifying the LEACH protocol. This method is actually an improvement on the PR-LEACH method with the adage of the factor of distance and is known as MPR-LEACH. This method reduces the energy consumption levels by reducing the connection between the cluster heads and the Sink. So this increases the sensor node life span in the IoT communication networks and this is achieved by threshold evaluation of each Cluster Head (CH), which the main factor for selecting each CH. This method only pays attention to the energy, and distance between cluster head and sink and doesn't consider other factors such as packet delivery rate and operational power of the IoT network.

The KTRP Method: In paper [16], a routing protocol has been suggested by considering low delay times and high reliability to replace the mixed link scenarios. In this method, first One-step delay model has been introduced for analyzing the possible delays in the Media Access Control (MAC) layer parameters. Then sending, preserving and performance strategies have been made for creating the main properties of the routing protocol. Respective processes and key approaches have been highlighted and two side protocols were created and their respective operation steps are described. Actually the Kernel tree routing protocol (KTRP) has been analyzed using deep learning theory of modeling. In the first step, a direct transmission algorithm has been established with a focus on neighbor nodes for reducing the overall steps. After creating the tree topology, the packets can be directly sent to the destination node from the list of one step neighbors. In the second step, for blocking reconnection requests, a new stabilizing algorithm has been designed considering the tree topology for saving in the protocol. In the third step, wired connection priority policy has been used for improving the link usage and the multi-step mechanism was considered for further reducing the delay times.

How to Use FSG: Devices with testable connections in the Internet of Things are made using unique IP designs and transferring their collective data to the IoT cloud. However, currently these devices, belonging to different technologies, use IoT gates to connect to the internet. Considering the high amount of IoT devices that connect to the internet, a need for establishing high number of IoT gates arises which is not economical. Therefore, study [17] has used the Fog Smart Gateway (FSG) as a method with very low cost. In this method as volumetric data are created by IoT divides, network routing becomes a problem. In this paper data collection has been done using edge processing in the IoT network and by the help of a variety of wireless technologies used by the FSGs.

The CCR Method: Internet of Things networks can be used for many useful applications in other industries such as supervising the infrastructures, civil, security and surveillance services and etc. However, collecting large data from these networks such as pictures and movies usually causes traffic congestion in the central hub. Paper [18] has presented the Content Centric Routing method that determines paths based on the

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available content, to solve this problem. Higher data congestion ratios can be reached by routing data correlated to intermediate relay nodes for processing, which in turn can lead to the reduction of the network's traffic. As a result, reducing the time delays is an important factor. Furthermore, extra collected data can be deleted after the data collection process, which reserves some energy that is usually wasted in wireless transmissions and increases the battery life by a finite amount. CCR is coordinated with the IETF RPL protocol and is run in the Contiki OS using the TelosB platform.

ERGID: The method introduced in this reference is based on delay. Their proposed mechanism is called Delay Repeat Method (DIM), which is based on delay estimation to solve the problem of ignoring valid paths. To ensure the performance of the proposed method, in real time for ErIoT, the DIM mechanism places the node according to the amount of delay in the candidate set. At the same time, the routing information table is periodically updated by neighboring communications. ERGID introduces a new strategy called Residual Energy Probability Choice (REPC) to balance network load for data transmission. A node with more residual energy is more likely to become a transport node [19].

EECRP: To improve network performance, an energy-efficient routing protocol called EECRP has been proposed for the IoT. This method introduces a new set of algorithms for cluster adaptation and rotation of the cluster head based on the centroid position evenly among all sensor nodes, as well as a new mechanism for reducing energy consumption for telecommunications. This technique of forming new distributed clusters that make it possible to self-organize local nodes, in particular, the residual energy of the nodes is calculated to calculate the position of the centroid in EECRP.

The advantages and disadvantages of all the previous methods are given in Table 1.

Table 1 Comparing related works.

Method and Year	Performance	Benefits	Disadvantages
LOADng 2019[5]	Choosing the most suitable internet node for sending messages	Memory reduction - Increasing packet delivery rate - Energy consumption reduction	Focusing on the paths available in memory and only choosing one path for each destination
NLEE 2016[7]	Efficient energy protocol for improving energy productivity in IoT	Delay improvement - Energy consumption reduction	Overloading because of counting all sent and control packets, number of steps and remaining energy
EARS 2017[8]	Mechanism aware of emergency situations, a low weight and low consumption process	Considering the link qualities for preventing the loss of packets and also improving the network's energy	Overloading for transferring implicit ACK and pre-hearing
MPCA 2020[9]	Inserting modules using the tree categorization and regression algorithm in chosen Fog divides for reducing energy consumption	Reducing energy consumption and response time	Not disclosing how the data is collected from things
P-SEP Protocol 2017[10]	Increasing the network's stability by considering the energy factor	improving clustering in the network and increasing the network's life span	-
	Using the energy factor is selecting the cluster head and transfer using Fog processing	Reducing energy consumption in the network - Increasing the number of active nodes in the	Not considering the method of performing processes in the Fogs and

Improved P-SEP Protocol 2018[11]		network (increasing the network life span)	also the method of merging the data which lead to the increase of delay in the network
HFC Method 2017[12]	Factor based method for merging the Cloud and Fog	Fast, efficient and automatic management of the network	Need for extra hardware for designing and considering the factors
SDN based Method 2017[13]	Data flow management using mobile edge networks with the help of Fog processing	Increasing the packet delivery rate and reducing network delay	Creating limitations by considering the station connections to the edge Fog nodes
MPR-LEACH 2018[15]	Adding the factors of energy and distance to the LEACH protocol	Reducing energy consumption - Reducing delay	Not considering the operational power and packet delivery rate as factors
KTPR 2020[16]	Improving tree routing for reducing delay	Increasing packet delivery rate and reducing end to end delay	Limitations because of considering wired connections
FSG 2017[17]	Collecting data with edge calculations and using Gates with smart FOGs	Reducing delay in the network	Lack of high trust
CCR 2016[18]	Route based technology for routing the data dependent on the relay nodes	Reducing network traffic- reducing network delay and reducing energy	Limited to the TelosB platform

4 The proposed HR-IoT solution

In this method instead of directly sending the data of things to the Cloud, which is known as Cloud Processing, we use Fog processing. Using Fog processing instead of Cloud processing has some advantages such as reducing traffic, low delay and scalability. The suggested method is presented based on the P-SEP protocol. The P-SEP protocol is introduced to increase the life span of Fog based networks [10]. In the suggested method the network structure is as such that each Fog node covers a certain area named the Fog node coverage area. In the network each area is equipped with sensor nodes that are responsible for collecting the data. The nodes must transfer the collected data to the cluster head. These cluster heads are responsible for receiving, collecting and merging data packets from the nodes. The cluster heads transfer the collected data to the Fog node, and then the Fog nodes send the data to the Cloud space. Fog nodes collect the cluster head and then merge the received data and finally are responsible for getting this data to the cloud servers. The suggested method is performed in two phases. The first phase pays attention to selecting the best possible cluster heads for transferring the collected data to the closest Fog node to reduce the time delay and consumed energy by the things. In the first phase of the proposed method, the things available in the network are clustered using a clustering method. Here the Overlapping method is used for clustering. The reason behind this choice is the fact that some things collect some data that must be sent to two or more different Fog nodes for processing, so the network structure uses this type of clustering. Each cluster has a leader titled the cluster head. This cluster head is chosen by factors such as noise rate, distance to fog node, number of steps, link expiration time and the thing's energy based on the system of the Grey theory. The proposed method does this in two phases according to Figure 2.

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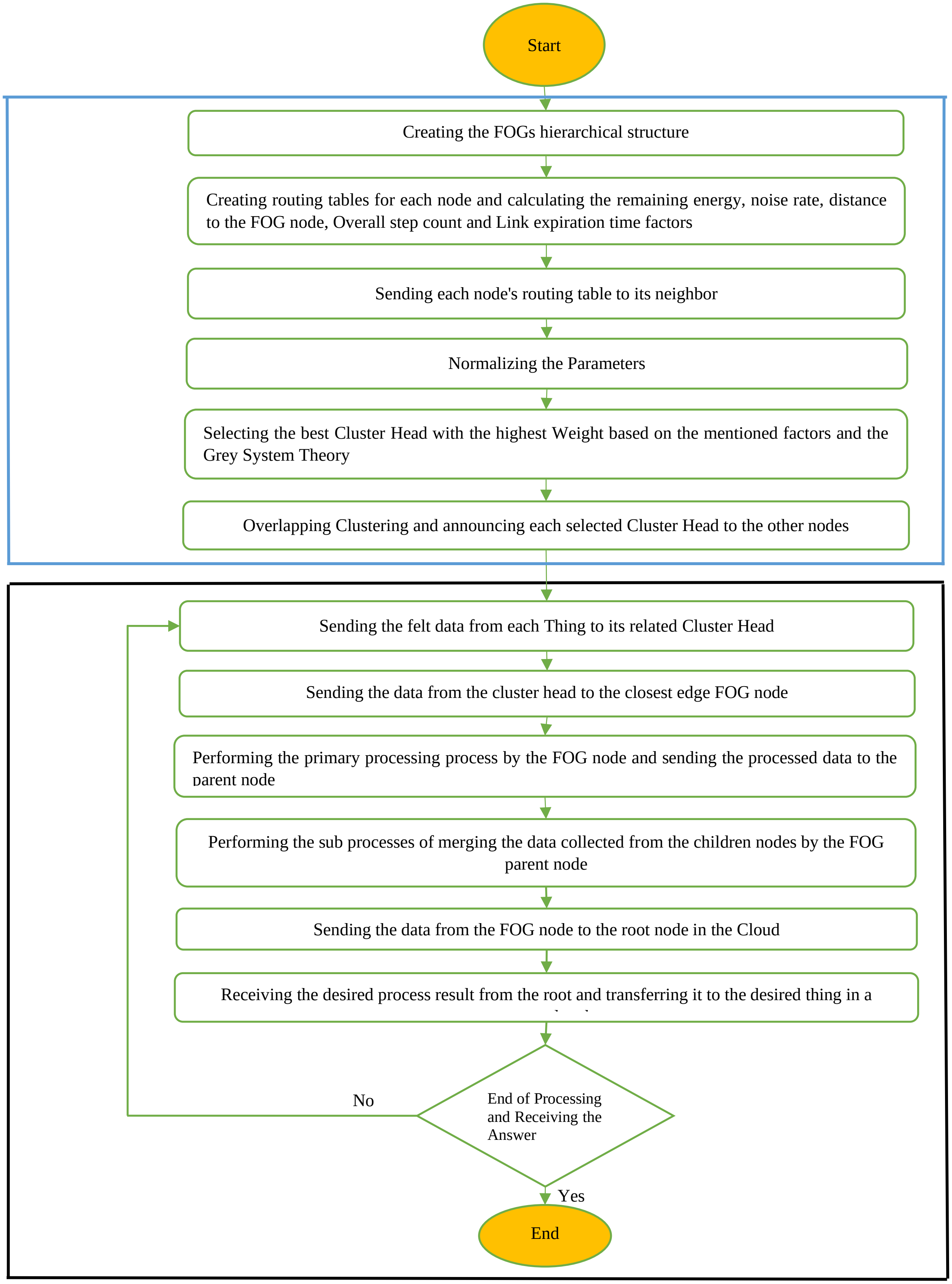

Fig. 2 Proposed Method Flowchart

4.1 Phase 1: Choose the best cluster head

The first phase is spent for selecting the best possible cluster head for transferring the collected data to the closest Fog node in order to reduce the delay and consumed energy by the subject using the Grey system Theory. In the first phase of the proposed method, the things available in the network are clustered using a clustering method. Here the Overlapping method is used for clustering. The reason behind this choice is the fact that some things collect some data that must be sent to two or more different Fog nodes for processing, so the network structure uses this type of clustering. Each cluster has a leader titled the cluster head. Other than the cluster head, all other nodes are a part of the cluster. Each cluster head is chosen based on the available nodes and the Grey system Theory and all the nodes that are a part of a cluster always communicate with their cluster head. They do not communicate with nodes from the other clusters. The nodes of one cluster never communicate directly with the cluster head of another cluster. Also, the cluster head of the cluster that contains the source node, receives the information from this node and transfers it to the cluster head in the cluster that contains the destination node so that cluster head could send this data to the actual destination node. This cluster head is chosen by factors such as noise rate, distance to fog node, number of steps, link expiration time and the thing's energy based on the system of the Grey theory.

Determining the Position of Each Thing to calculate its distance: One the unknown aspects of this research is efficient routing and selecting the best thing as the cluster head with the lowest possible distance for transferring the data felt by the sensors. The propose method in this paper is a routing method based on geographical location, so we assume that each object and node is equipped with a GPS for determining its location. Also, each device send's its location data with the route discovery message so each neighbor device can have their own neighbor's information for selecting the proper thing. The distance between two devices can be calculated using the Eq (11).

$$D = \sum Dist(i, j) \qquad \& \quad Dist = \sqrt{(X_1 - X_2)^2 + (Y_1 - Y_2)^2} \tag{11}$$

In the Eq (11) equation (x_1, y_1) is the geographical location of node (i), and (x_2, y_2) is the geographical location of its neighbor node (j).

Calculating the Energy of Each Thing (or Object): The other unknown aspect of this method is calculating the remaining energy in each thing present in the delivery route to the destination. The presented method uses the Hanselman energy consumption model. Equation (12) is used for calculating the remaining energy:

$$RES = E_P - E_c \tag{12}$$

In which E_P stands for node's primary energy and E_C is the consumed energy by the node. The Radio Energy Model presented in paper [14] is used for determining energy consumption values. In this model the energy related for transferring k bit of data from one transmitter node and one receiver node with the distance of d meters is calculated using Equation (13):

$$\begin{aligned} E_c &= E_{TX} + E_{RX} \\ E_{TX} &= E_{elec} * k + E_{amp} * k \\ E_{RX} &= E_{elec} * k \end{aligned} \tag{13}$$

In which, E_{TX} stands for the consumed energy by a node in exchange for transmitting data. Also, E_{RX} stands for the consumed energy by a node in exchange for receiving data. The needed energy

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for running the electronic parts is shows with E_{elec}, and the energy needed for boosting the signal with E_{amp}. The value of E_{amp} is dependeent on distance.

Link Expiration Time: Link expiration time is the time that a link remains stable and the longer this time, the more stable the link between two nodes. This time is dependent on node movement speed. The faster the nodes move, the more unstable the link between them will be. The link expiration time is determined using the Equation (14) equation based on the packets transferred between nodes:

$$LET(i,j) = \left(\frac{-(ab+cd)+\sqrt{(a^2+c^2)R^2-(ad-bc)^2}}{a^2+c^2} \right) \quad (14)$$

$$a = v_i * \cos\theta_i - v_j * \cos\theta_j$$

$$b = x_i - x_j$$

$$c = v_i * \sin\theta_i - v_j * \sin\theta_j$$

$$d = Y_i - Y_j$$

As we mentioned before, these nodes are aware of their locations by using GPS. In the above equation we have the i and j nodes with the coordinates of $(x_i$ و $y_i)$& $(x_j$ و $y_j)$ and movement speed s of v_i & v_j and also the movement angles of θ_i & θ_j.

The cluster head is chosen based on these parameters and also based on the Grey system Theory. These factors turn the cluster head into a rotating position and because of this a certain node is not always the cluster head. This rotating cluster head balances the energy consumption of all nodes; also considering the distance and step number values reduces the network's delay. After choosing the cluster head, the collected data must be sent to the Fog.

4.2 Phase 2: Send data to the server using hierarchical tree-based cloud computing

In the next phase, data are transferred to the servers using Fog Computing based on a hierarchical tree. This method reduces the energy consumption in the Fog nodes and servers in the IoT. The hierarchical structure of this proposed tree is similar to Figure 3.

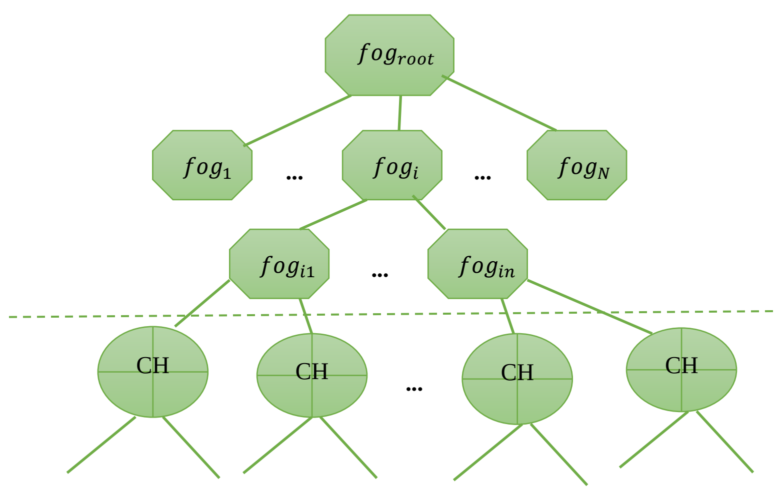

Fig. 3 The Hierarchical structure of the proposed method

In the structure of the proposed method, the Fog nodes are structured in a hierarchical tree with a balanced height. The Root node shows the available cloud servers, actually Root Fog nodes show the cluster servers. Each Fog nodes has a parent node. Each leafless node has one or more children Fog nodes. A Fog edge node is considered as a tree leaf which is in connection with the sensors and launchers. The process of the application run on the servers for managing the sensor data in the cloud computing model is based on the sequence of sub-processes. Each sub-process receives its input data from the previous sub-process and then sends its output data to the next sub-process. Similar sub-processes are installed on each Fog node and each level. In the next phase, the Fog nodes are categorized in the hierarchical tree with a

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balanced height. The Root Node is the cloud servers. Each node is connected with its parent and children nodes within the same network. Fog nodes in the lower layers are known as the Fog Edge nodes.

Devices that are within the Fog are known as "Node". Nodes can be placed in any place with a connection to the network: this could include the factory floor, above a power source, on a railroad track, in a car or oil rig. Any device with a connection to the network, computational power and storage capabilities can be a node. Industrial controllers, Switches, Routers and Surveillance cameras are some examples of this. Based on estimation the amount of data analyzed in the Internet of Things is close to the 40 percent of the overall amount. The reason behind this is simple: When the data collection location is close, Data analysis has a low delay.

- Data that cannot handle the delay are sent to the closes Fog node.
- Data that cannot handle seconds or minutes of delay can be sent as a group.
- Data that are not sensitive to time are sent to the cloud so that they would be used for history completion and big data analysis. This transfer can be done n the hierarchical tree created from the Fog node; in which the nodes from the last row are actually nodes that are really close to the objects and the objects can send their own data to them.

The fog_{i1-iN} process is performed on the Fog nodes of level i after collecting the sensor data. The i process is an edge process. The output data of the i edge process are sent to the i-1 location, and then the i-2 location and this process is repeated so that these data are sent to the Root node situated in the Cloud (the Root node is the server of a Root process). Actually, the Fog edge nodes are related to the sensor cluster heads. The sensor of each thing collects the data felt by that thing and then presents these data to its own cluster head. Then this cluster heads sent the sensor data to the Fog edge nodes. Each Fog edge node processes the sensor data and sends the processed data to the parent Fog node. This parent node receives its input data from the children nodes and processes them. Then this Fog node sends the processes data to its parent node.

So, in the end, the cloud space servers receive the processed data from the Fog nodes. These servers just process the Fog node data and then decide on the activities that need other actions. The servers send these activates to the Fog nodes. Fog nodes send these activates to their children and at the end the Fog edge nodes send these to their children launchers; this act reduces the server and network traffic in the Fog computing model. Fog computing model are useful for the efficient realization of technology, because the processes and data are distributed not only in the servers but in the fog nodes as well. Because of this, the server and network traffic are reduced in the Fog computing model.

5 Evaluating the Performance

This section analyzes QoS parameters and evaluates the qualitative performance in the form of numerical results to validate the performance of the proposed HR-IoT method [26-32]. To demonstrate a feasibility study, the performance analysis of HR-IoT has been divided into four parts:

1) Packet Delivery Rate,
2) Delay
3) Response time
4) Lifetime

5.1 Performance metrics

The proposed HR-IoT method has been simulated and its performance evaluated in Network Simulator version 2 (NS-2) running on Linux Ubuntu 18.04 LTS. The results were compared

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with both methods (EECRP [19] and ERGID [20-25]).

5.2 Simulation results

All four methods are evaluated according to Table 3 under three scenarios [33-39]. Table 9 displays the significant parameters used in the simulation. In this section, the performance of our proposed approach is evaluated using NS-2 on Linux Ubuntu 18.04 LTS as the simulation tool, and the results are discussed further. Table 2 displays the significant parameters used in the simulation.

Table 2 Parameters used.

Parameters	Value
Operating System	Linux Ubuntu
Network size	100m * 100m
Number of nodes	500
Transmitting energy	40 nJ/bit
Reception energy	40 nJ/bit
BS locations	Inside
MAC Protocol	802.11
Simulation time	1000 second
Packet size	64 bytes

Table 3 Parameters used for four scenarios.

Scenario #1		**Scenario #2**	
Rate of Transmission	20	Rate of Transmission	40
Topology	100m *100m	Topology	100m *100m
Time	1000	Time	1000
Scenario #3		**Scenario #4**	
Rate of Transmission	60	Rate of Transmission	80
Topology	100m *100m	300m X 300m	100m *100m
Time			1000

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Table 4-7 compares the performance of HR-IoT solution vs EECRP and ERGID methods in terms of PDR, delay, response time, lifetime

Table 4 PDR vs Nodes (Rate of Transmission=80)

Number of Node	PDR (%)		
	ERGID	EECRP	HR-IoT
50	72	78	86
100	75	80	89
150	77	81	90
200	78	83	92
250	80	84	93
300	82	86	94
350	83	87	95
400	85	88	96
450	86	90	97
500	87	92	98

Table 5 Delay vs Nodes (Rate of Transmission=80)

Number of Node	PDR (%)		
	ERGID	EECRP	HR-IoT
50	3900	3411	2678
100	3400	3212	2419
150	3189	3006	2290
200	2876	2867	2056
250	2654	2567	1856
300	2466	2390	1720
350	2216	2189	1420
400	2004	1945	1144
450	1897	1834	1067
500	1699	1690	956

Table 6 Response time vs Nodes (Rate of Transmission=80)

Number of Node	PDR (%)		
	ERGID	EECRP	HR-IoT
50	71	52	50
100	68	51	52
150	66	49	44
200	65	45	51
250	64	47	36
300	61	45	34
350	67	44	32
400	64	43	39
450	63	42	27
500	67	41	25

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Table 7 Lifetime vs Nodes (Rate of Transmission=80)

Number of Node	PDR (%)		
	ERGID	EECRP	HR-IoT
50	950	980	997
100	920	973	994
150	870	963	980
200	830	940	974
250	762	930	954
300	730	795	943
350	670	840	939
400	630	836	930
450	660	770	898
500	510	760	889

PDR: As shown in Figure 4, in all four scenarios A to D at different transfer rates, the proposed HR-IoT method has a higher PDR rate in all scenarios than the ERGID and EECRP methods. This is because, first, in the proposed HR-IoT method, data is collected from sensors in the Internet of Things by clusters that have a higher energy and expiration time, which allows all data to be transferred to FOG. And the data is not lost during sending, secondly when sending data from FOG to fog, in the proposed method, hierarchical tree-based cloud computing is used to send data to the server. This method causes the data to be sent by the node. Based on the tree structure, FOGs are sent to the root servers in the root and after processing, they are sent to the sent header so that the response is sent to the requesting device via the header. These steps in the proposed HR-IoT method make this method work better than the EECRP method in which only energy-based heading is selected because the EECRP method does not provide a way to send data from headers to servers. The HR-IoT method in the PDR criterion also performed much better than the ERGID method. This is because the ERGID method only selects high-energy paths for sending data, but the proposed method for sending data from the object to the server and receiving a response is useful measures. PDR rate in all four scenarios increases with the number of sensor nodes in the network because by increasing the number of nodes in the intended range, the node distance is closer to the head and less energy is used to send data and the number of packets They are much less lost.

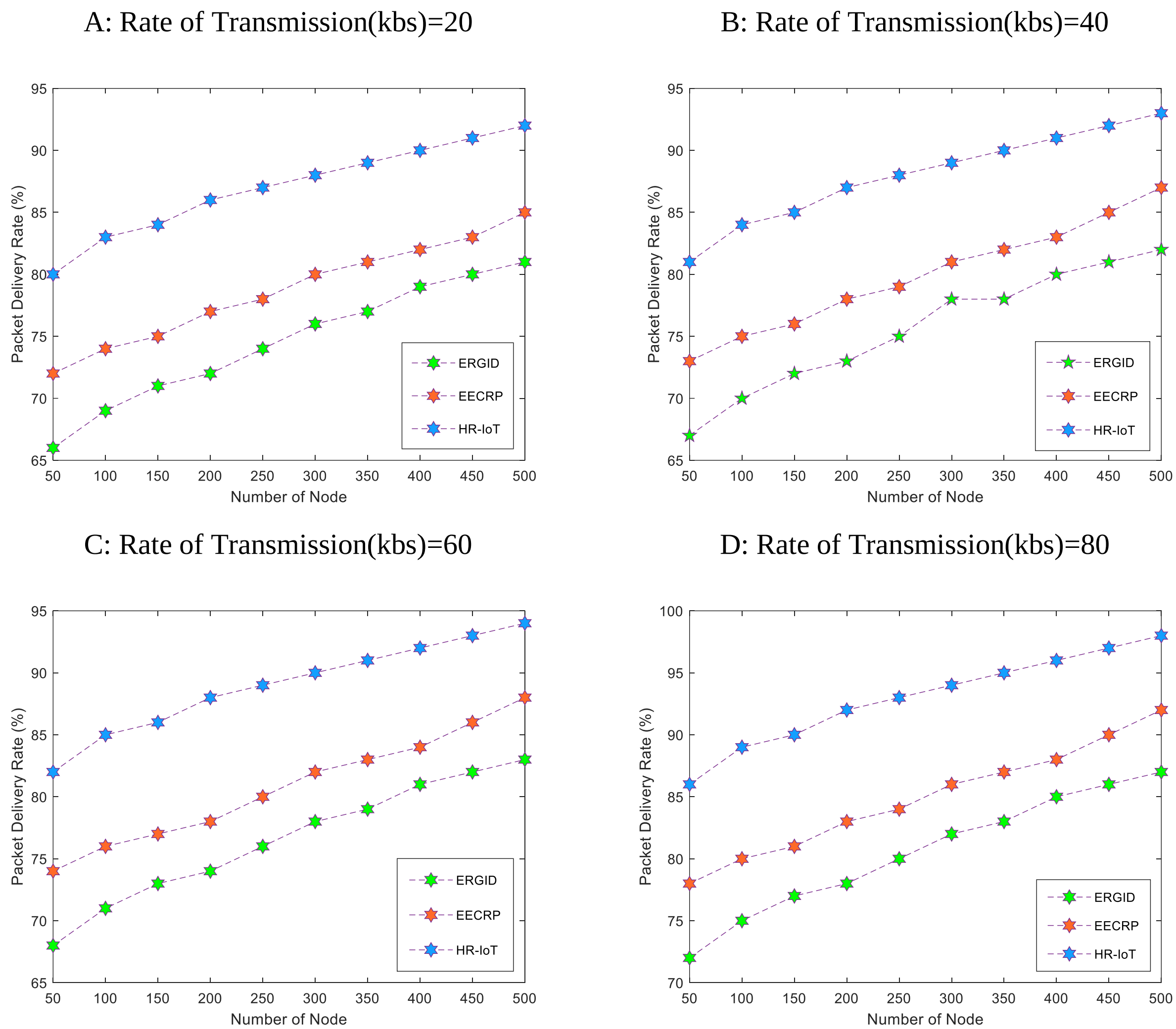


Fig. 4 PDR vs number of nodes.

Delay: In IoT technology, sending a quick request and receiving a quick response is very important, and this is much more critical for time-sensitive data. As shown in Figure 5 in different scenarios, the delay of the proposed HR-IoT method in all four scenarios is less than ERGID and EECRP methods. In the proposed HR-IoT method, various measures have been considered to reduce the delay. The first solution to reduce the delay in the proposed HR-IoT method is to use a header to send data to the FOG, which reduces the delay in sending data directly from objects to the FOG. The second approach in the proposed method is to select the header based on the distance and link expiration criteria, which allows data to be sent faster to the header near the object. The next solution is to use a hierarchical tree structure to send data from FOG to the root server. The main advantages of this method are the reduction of latency. Another reason for the reduced latency in the proposed HR-IoT method compared to the other two methods is that in this method the data that cannot tolerate the delay is sent to the nearest node in May and the data that can tolerate the delay can be sent by one node. To be sent together and aggregated. Therefore, time-sensitive responses are sent immediately. These factors make the proposed HR-IoT method much better than the ERGID and EECRP methods, which use only one or two criteria to reduce latency. In these cases, the delay is further reduced by increasing the number of sensor nodes in the network, which is due to the proximity of the nodes to the selected header and faster request and response.

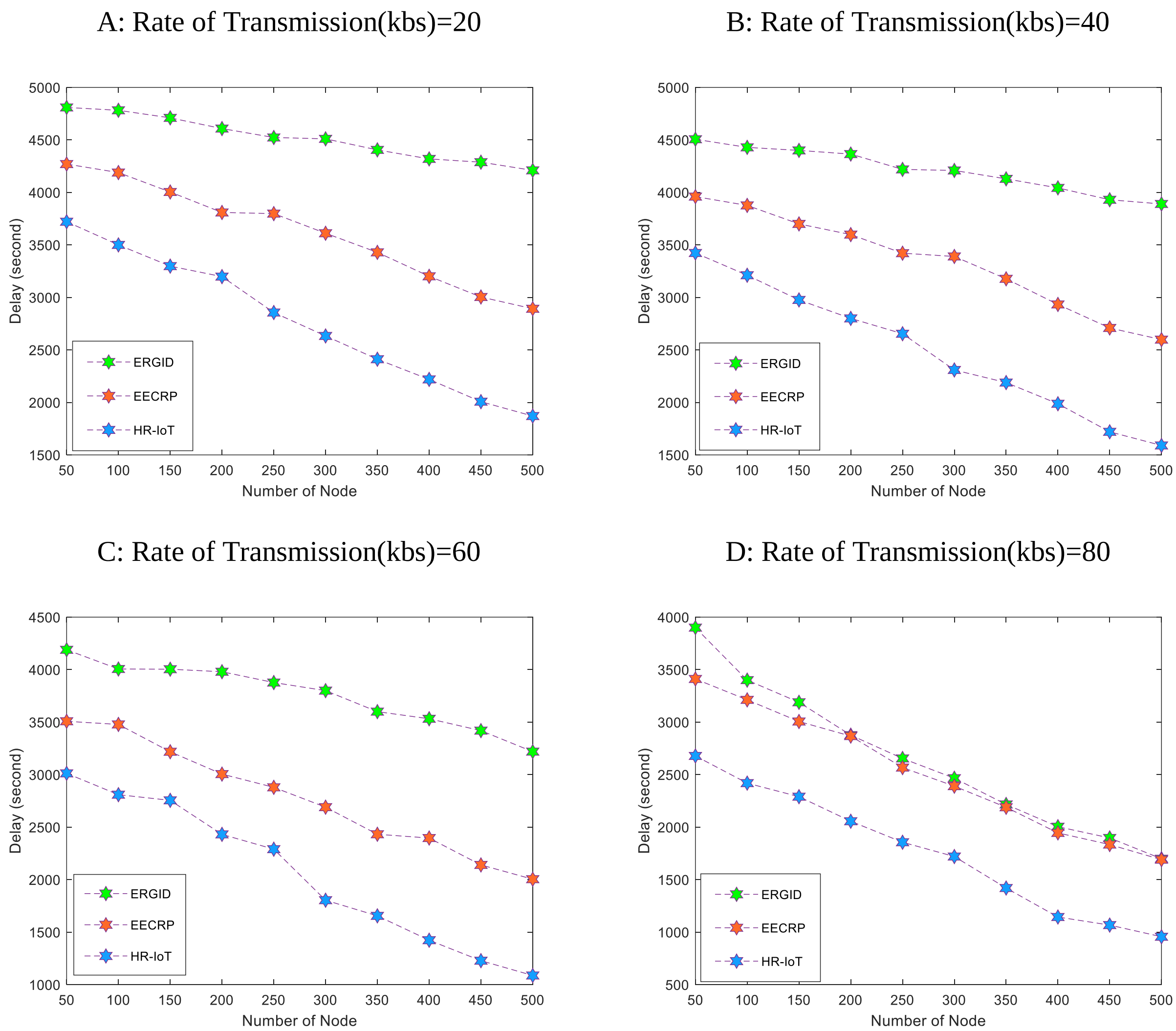


Fig. 5 Delay vs number of nodes.

Response time: Response time is the time from sending the request to starting receiving the first response. Like the delay criterion, the lower the criterion, the higher the efficiency of the method. The simulation results performed according to Figure 6 in four scenarios A-D show that the proposed HR-IoT method has less response time than ERGID and EECRP methods. Although in B-D scenarios this amount has slightly increased to 200 nodes in the network, but with increasing the number of nodes in the network this amount decreases. But the reason for the superiority of this method over the two methods ERGID and EECRP is that in the ERGID method to reduce the response time, only high-energy nodes in each path are selected, and in the EECRP method, only positive action to reduce the response time is selected. The energy was high and both methods did not differentiate between time sensitive data and normal data and did not explain how to send data to the server. But the proposed method takes into account both of these cases, and to reduce the response for devices that have a quick response request, their request is sent by Sarkhosheh to the nearest node in May, as well as to send a quick request and response from FOG to the server using the method A hierarchy is used that reduces this time. However, we also know that sending requests from objects to selected headers that have a high link expiration time and are a short distance from the objects is very effective in reducing this time.

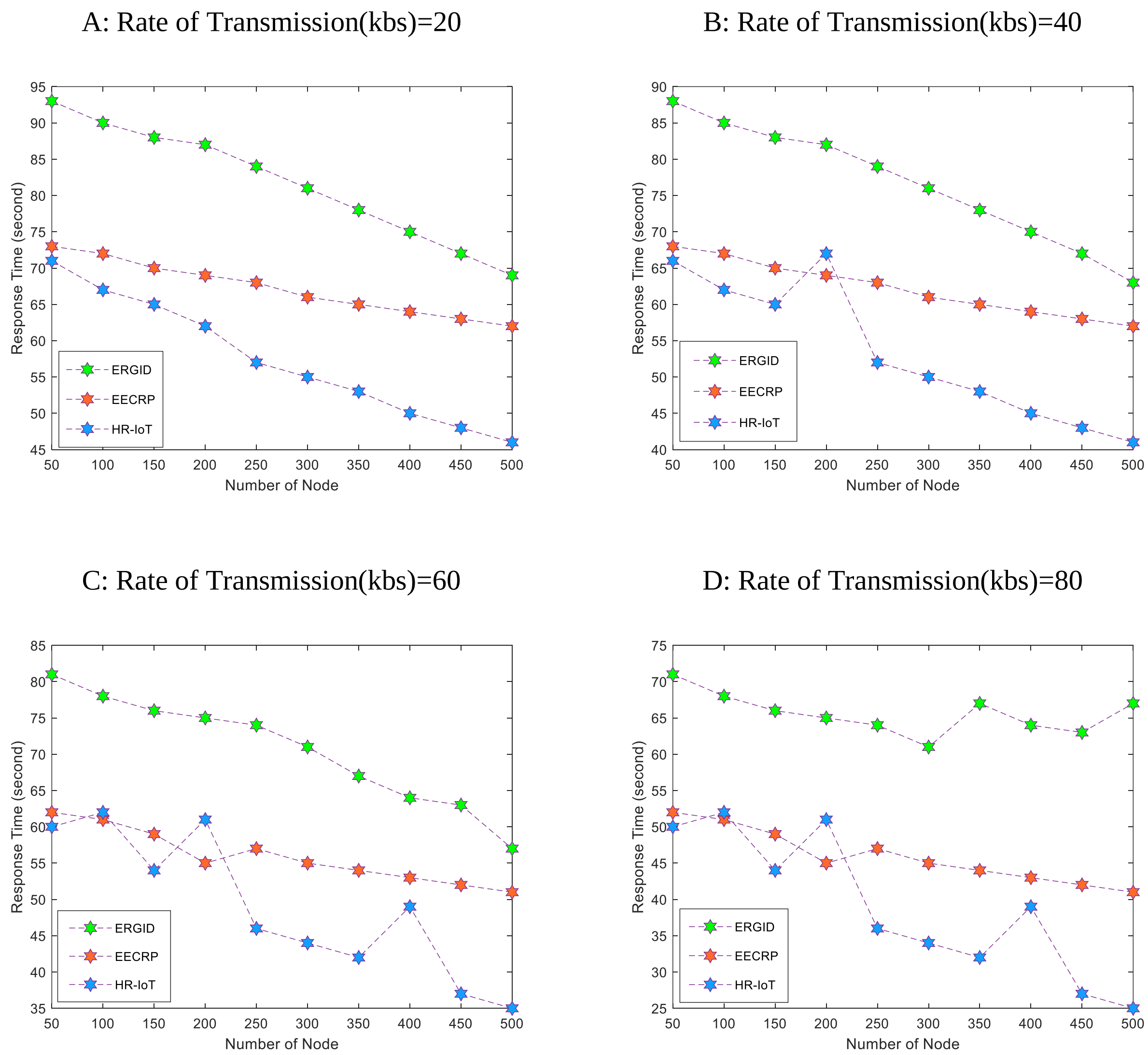
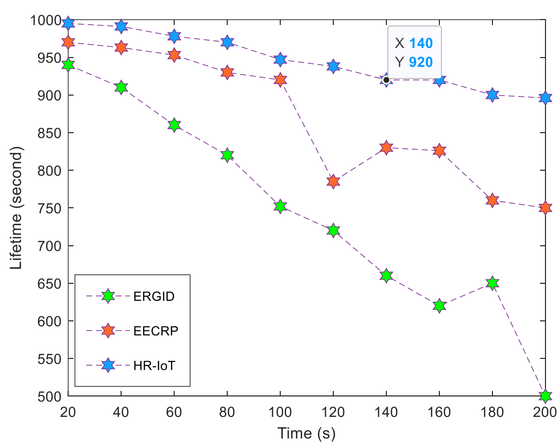


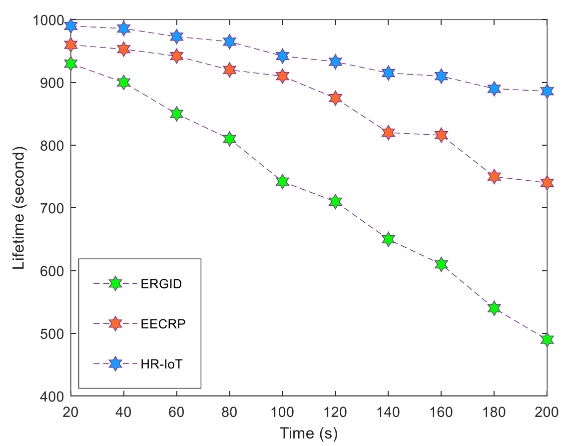
Fig. 6 Response time vs number of nodes.

Lifetime: Network life is the length of time that network nodes are alive and able to function. The simulation performed according to Figure 7 A-D shows that the proposed HR-IoT method has a longer lifetime than the ERGID and EECRP methods. The reason for this high standard in the proposed method is that the longevity of the network is directly related to the energy standard, and the less energy objects consume, the longer their lifetime increases. In the proposed method, in the step of sending data to the server, the data is sent from objects to clusters, which have high energy and have a shorter distance to the objects, which causes sending to these clusters and the rotation of selecting clusters among nodes. Consume less energy from objects, on the other hand, sending data to the server from clusters to FOGs and from them to the server in a hierarchical way reduces energy consumption. These factors have increased the network life in the proposed method compared to ERGID and EECRP methods.

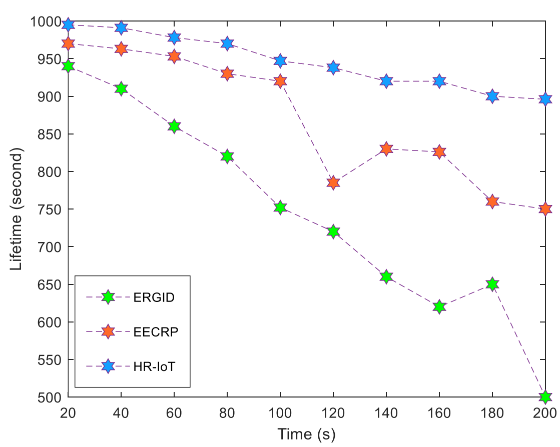
A: Rate of Transmission(kbs)=20



B: Rate of Transmission(kbs)=40



C: Rate of Transmission(kbs)=60



D: Rate of Transmission(kbs)=80

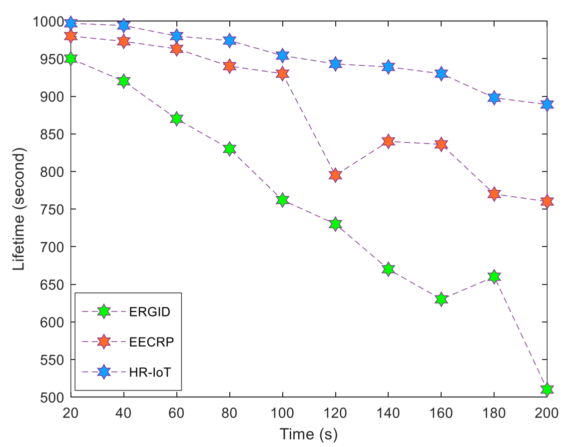


Fig. 7 Life time vs number of nodes.

6 Conclusion

The Internet of Things is a heterogeneous network which includes classical internet and limited device networks that are connected to each other using IP protocols. The reality is that the devices in IoT are very heterogeneous and many of them have limited resources and connecting to them creates a rather important challenge in the IoT. Then clustering is an important and effective method for transferring data with lower energy consumption. Since the cluster heads are responsible for collecting and sending data, then they must be selected in a way that they don't run out of energy while transferring their data. Also one node or certain factor must not be selected as the cluster head reputedly. In the first phase of this paper the cluster head is selected based on many factors and the help of the Grey System theory. In the second phase, cluster heads based on Fog computing were used for fast transfer of data. By using the Fog computing method, instead of sending all the data to the cloud servers for receiving a proper answer, we use a local processing unit to reduce the time delay.

Conflict of Interest

None.

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