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5G Network Data Migration Service Based on Edge Computing

Furong Li * and Duan Wang

School of International Education, Huanghuai University, Zhumadian 463000, China; wangduan@huanghuai.edu.cn
* Correspondence: lifurong@huanghuai.edu.cn

Abstract: With the development of mobile network technology, the continuous increase of mobile traffic has put forward higher requirements for quality of service (QoS) issues such as asymmetric transmission delay. The paper mainly studies the energy distribution problem on the migration data link from the terminal device to the edge node in the mobile edge network. Multiple data service packages are set up at each hop on the migration data link, and these data service packages compete with each other, and ultimately only one terminal provides and stores energy for this hop. The migration strategy of the data service package is affected by the edge node, and the edge node changes the migration strategy according to the migration strategy of the data service package. The paper is based on the formation of nodes between the data service packages of different nodes on the 5G network data link to jointly control the migration strategy, coordinate the migration strategy formulated, and better coordinate the migration strategy. In this competitive game model, the optimal migration strategy of nodes is found out according to the terminal equipment access requirements. Then according to the node stability rules, the composition of nodes when the nodes are stable is obtained, the migration strategy of stable nodes and the migration and spectrum strategies of operators are obtained, and the migration strategy of joint control provides energy for edge nodes.

Keywords: 5G communication; mobile network; data migration; edge computing; game model

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1. Introduction

5th Generation Mobile Communication Technology (5G) is a new Generation of broadband Mobile Communication Technology featuring high speed, low delay and large connection. It is a network infrastructure for the realization of man-machine and object interconnection. In the future, the main technological update of mobile communication technology will improve the efficiency of energy utilization while avoiding environmental damage. For asymmetric services, the amount of data information, service time, transfer time and other parameters entering the network at any time are randomly variable, so the corresponding performance analysis is quite challenging. It is relatively difficult to make a substantive breakthrough. However, asymmetric services can be more flexibly used in real life. In practical applications, there are often different information or different sites. Accordingly, under the same service strategy, the parameters set by the system need to meet the requirements of different sites, which requires asymmetric service strategy.

In reference [1], the author proposed a system LAVEA for edge computing, which can unload the computing tasks between the client and the edge node. It can also cooperate with the nearby edge node, and provide low latency video analysis near the user. The priority edge design is adopted to minimize the response time, and the variable placement schemes set for edge cooperation are compared. The client edge configuration is used to speed up the local or cloud client tasks. In reference [2], a general architecture and framework for the use of mobile devices for hybrid mobile edge computing is proposed. This is a new use case of edge computing, which is called hybrid mobile edge computing. In this technology, mobile devices can overcome their battery limitations and performance limitations by dynamically using the computing power provided by edge computing. It can improve performance and reduce energy consumption. It also provides a means to protect user privacy, sensitive data and computing [3]. In reference [4], the author describes the model of unloading system and proposes an innovative architecture of "MVR", which is helpful for computing unloading in mobile edge computing. MVR supports the use of virtual resources (VR) in edge computing to reduce the burden of resources, reduce the energy consumption of mobile devices and improve the performance of applications. In reference [5], the computing offload and MEC server framework are introduced, and then the existing algorithms are analyzed, compared and summarized according to the computing offload algorithm model and evaluation index. In reference [6], the integration of MEC and small cellular network (SCN) are studied. Firstly, the energy-saving unloading problem is studied to optimize the unloading energy of tasks and reduce the delay. In the application of cloud computing technology, businesses can be unloaded to remote cloud servers for processing through computing unloading technology so as to effectively solve the problem of large equipment load.

Currently, the high energy consumption in mobile networks mainly lies in two aspects: one is the data collection and data processing of terminal mobile network equipment, and the other is the generation, transmission and energy storage of energy required for data traffic transmission. Regarding how to reduce energy consumption, it is also an issue worthy of attention.

Mobile network devices are usually devices with weak computing power to reduce the size of the device. It is usually necessary to offload the tasks of various applications with a large number of computing resources to a computing system with sufficient computing resources, such as servers, cloud systems or data centers for processing; but this will inevitably lead to high latency and network congestion. Users' demand for high-speed mobile networks and the ever-increasing variety of services, such as AR/VR, high-definition video, autonomous driving and other new services, have led to a rapid increase in the amount of data in the business, which will inevitably affect the 5G communication system, leading to high The delay may even cause network congestion, affecting the normal use of users.

In the traditional network structure, the way to transfer computing tasks to the cloud has been difficult to meet the future business needs. This structure not only increases the amount of data transmission, but also causes great pressure to the core network, and introduces a large amount of data transmission delay, and reduces the quality of service. In order to solve the above problems, two technologies, MEC and D2D communication, are introduced into 5G network. Among them, D2D communication technology is a new technology under the control of the base station, which allows the user data to be transferred directly between terminals without passing through the network. It can effectively expand the cellular communication and reduce the load pressure of the base station.

For a long time, the standard IT service platform is a centralized cloud computing model architecture, which transfers resources through the network to the central cloud server center for data storage, processing and business processing. With the rapid growth of transmission traffic, the current centralized business processing will inevitably lead to excessive load pressure on central network data transmission [7]. Mobile Edge Computing (MEC) is a solution that can effectively alleviate the large amount of data transmitted in the network.This paper proposes that energy suppliers at different nodes form an alliance to jointly formulate strategies. The problem is modeled as a Stackel berg game, in which the participants are leaders (operators) and multiple followers (alliances composed of energy suppliers). In order to solve this game, the reverse analysis method is used to obtain the strategy of the alliance composed of energy suppliers, and the operators adjust their spectrum strategy and pricing strategy according to the strategy of the energy supplier alliance [8].

The main innovations of this paper are as follows:

(1) In this paper, the game between edge nodes and renewable energy suppliers is modeled as Stackel berg game.

(2) By forming an alliance, jointly formulate strategies, and calculate the spectrum strategy of stabilizing the alliance according to the alliance stability rules.
(3) According to the exponential access demand of the terminal, the resource allocation method on the retransmission link under multiple access requirements is obtained.

This paper takes 5G network as the basis, and in the case that the demand quantity of terminal equipment is distributed exponentially. Through the cooperative game relationship between data back haul links in 5G network, combined with Formation conditions and algorithm design of stable relay terminal of energy terminal, a data migration service strategy model is created.

The other structure of this paper is Section 2 introduces the related work. Section 3 discusses the system model of 5G access data back haul link. Section 4 is the relay terminal analysis and data migration service of 5 g network energy terminal. Section 5 is the simulation experiment, and Section 6 is the conclusion of the whole paper.

2. Related Work

At present, related scholars have carried out a series of studies on data migration service of 5G network.

Among them, LEACH (Low Energy Adaptive Clustering Hierarchy) algorithm is a self-adaptive Clustering topology algorithm. Its running process is periodic, and each cycle is divided into the stage of cluster establishment and the stage of stable data communication. LEACH algorithm can ensure that each node acts as the cluster head with equal probability, so that the nodes in the network consume energy in a relatively balanced way. However, when LEACH algorithm is used to complete the data migration of 5G network, the data in the same network living space is easy to be lost; Different from LEACH protocol, the improved LEACH-E protocol also takes into account the energy consumption of nodes in the process of selecting cluster heads. If the remaining energy of nodes is greater than the total average energy of the network, it can be selected as the cluster head, so as to make the energy consumption distribution more uniform, avoid premature death of nodes, and thus prolong the life of nodes. However, when the LEACH-E algorithm is applied to complete the data migration of 5G network, the acceptable amount of data is small; Stochastic Proximity embedding (SPE) algorithm can be used for data dimension reduction. It does not require a complete distance information matrix between sensor network nodes, and can obtain the precise coordinates of each node only by using the similarity between the data. However, when SPE algorithm is applied to the network data migration process, it is found that the life cycle of the initial node is short and it is difficult to maintain the stability of the network.

This study designed the 5G wireless data network migration strategy based on the index distribution of the terminal equipment, and obtained the optimal migration strategy, which extends the life cycle and adaptability of the 5G network.

2.1. Application of 5G Technology

The International Telecommunication Union has defined three technical scenarios for 5G Technology:

(1) Enhanced Mobile Broadband (EMBB) focuses on providing sufficient bandwidth resources and takes AR/VR, video and other services as the main body to achieve a service experience rate of up to 1 Gbps [9].
(2) Ultra Reliable & Low Latency Communication (URLLC), which mainly serves users with high reliability and delay requirements, is mainly used in networking of vehicles, UAV, industrial control and other scenarios [10].
(3) Mass Machine Type Communication (MMTC), aiming at providing high endurance and high reliability services, relying on the high connectivity of 5G technology, promotes the integration of smart home, smart city and other industries, and truly realizes the concept of "interconnection of all things" [11].

5G key technical indicators:

(1) In order to alleviate the explosive growth of the number of terminals, the number of serviceable devices per unit coverage area of 5G technology will be increased by 100 times compared with 4G technology.
(2) The transmission rate of 5G technology will increase by 10–100 times compared with 4G technology, and the peak rate and user experience rate can reach 10 Gbps and 1 Gbps respectively [12].
(3) The delay of 5G technology is 5–10 times lower than that of 4G, reaching the order of milliseconds. At the same time, the reliability should reach more than 99.999%.
(4) In terms of spectrum demand, the spectrum efficiency of 5G technology needs to be improved by 5–10 times.
(5) 5G's support for mobility will reach 500 km/h, which is very conducive to the implementation of 5G technology in the Internet of vehicles industry.

2.2. Edge Computing Concept

The concept of edge computing is inherited from the original ETSI definition of MEC (further extended to "Multi- Access Edge Computing" in November 2016). It is a generalization of the mode of MEC in specific scenarios, which refers to a network structure that provides it functions and cloud computing services at the network edge close to the data source to improve data processing and transmission capabilities. Gartner defines it as "a part of the distributed computing topology, in which data processing is located near the edge where people and things use or generate data." [13]. At present, the concept of edge computing is developing in two directions. One is to emphasize the edge of the Internet of things, which is mainly for data acquisition and real-time processing of Internet of things devices; the other is the edge of cloud services, which represents the micro cloud services extending from the centralized big cloud to the edge of the network. In short, edge computing brings computing and storage resources closer to the demand side, rather than relying solely on the central cloud that may be thousands of miles away. The core advantage is that it can provide faster processing and storage capacity [14]. In addition, some similar concepts have been gradually put forward:

(1) Mobile Cloud Computing (MCC) combines the advantages of mobile computing and cloud computing. Cloud computing focuses on building large Internet-based infrastructure and platforms, such as Amazon EC2 and Microsoft Azure, and manages a large number of high-performance CPU, memory, switches and other hardware resources. It integrates the resources of multiple data centers and coordinates the differences between underlying devices through virtualization technology. When the mobile computing component is introduced, MCC infrastructure can support the on-demand allocation of resources such as server, data analysis, storage and computing under the mobile environment network, and provides a survival opportunity for third-party business providers to flexibly deploy and develop innovative applications to a certain extent. However, it still follows the centralized server erection method, which is far away from terminal equipment users. It is prone to network delay or connection interruption in task intensive application scenarios [15].
(2) Micro cloud, also known as Cloudlet or small cloud, is a network model that provides cluster computing power and access services closer to the demand. Logically, it belongs to the link between mobile devices and remote cloud. It is a computing and storage service provided based on trust mechanism so as to share the load for remote cloud services. At present, due to the limitation of equipment hardware performance, most of the research on micro cloud still stays in the laboratory, lacking the universality of effective promotion [16].
(3) The concept of Fog computing shows a highly virtualized cloud computing expansion platform, which aims to solve the problems of tight capacity and excessive delay of backhaul links in WLAN. Compared with edge computing, the network hierarchy of fog computing architecture is stronger, and often shows the peer-to-peer interconnection state between multiple nodes [17].

2.3. Data Migration

The establishment of data migration is the basis and key of edge computing tasks. According to the data migration status, it can be divided into static data migration and dynamic data migration. The former is also called fixed data migration, that is, the task data or data volume requiring data migration is fixed and does not change in real time with the change of users or resources. On the contrary, Dynamic data migration means that the content and size of data migration will be changed in real time due to changes in external conditions during data migration [18]. The more common data migration models are divided by data migration methods, including binary metadata migration, partial data migration and probability/random data migration.

(1) Binary metadata migration is the most basic and earliest data migration model. Its "binary" means that the computing tasks to be processed are either executed locally or all data are processed at the edge server. It is usually replaced by the symbols "0" and "1", so it is also called "0–1". In the binary metadata migration model, each task can be regarded as an independent and indivisible data unit, which can be described by a ternary array $A_i = \{D_i, C_i, T_i\}$, where D_i represents the data size of the task to be executed, C_i represents the amount of computing resources required to complete the task (usually expressed in the number of CPU cycles), and T_i represents the maximum time limit to complete the task.

(2) The partial data migration model indicates that the total computing task to be processed can be subdivided into multiple sub task modules. Each sub task module can not only be executed locally, but also carry out data migration, that is, any part can be selected for processing [19]. Generally, there is a certain order/dependency between these sub task modules. For example, the input of a certain molecular task module must be the output of another sub task module. Thanks to the development of code decomposition and parallel processing technology, this model is gradually used by people with more reasonable resource utilization and more efficient data migration efficiency.

(3) Probabilistic/random data migration combines the characteristics of binary metadata migration and partial data migration model to a certain extent, which means that in the process of task data migration. Users decide that some task units adopt local processing mode or were handed over to server nodes according to a certain probability. Compared with binary metadata migration and partial data migration, this data migration method has high requirements for the scene [20].

3. System Model of 5G Access Data Back Haul Link

At present, there are chain topology, ring topology, star topology and tree topology. The chain topology has high fault tolerance. When a node cannot be connected, it can also be connected to other nodes. It has good scalability and is extremely suitable for scenarios with a large number of nodes and frequent access to or removal from the network. It can be seen that the chain topology is very consistent with the characteristics of the Internet of vehicles. Based on this, this paper selects the chain topology to deploy the MVN architecture. The MVN architecture adopts the chain topology, which is mainly composed of four parts: BS (Base Station), MECP (Multi-Access Edge Computing Point), gNB (5G Micro Base Station) and terminal [21]. BS is the root node of MVN tree topology, which gathers local information by connecting MECP and promotes MVN network to comprehensively manage traffic from a global perspective; MECP will process the collected delay sensitive information in time to shorten the delay; gNB can communicate with MECP for up to two hops and transmit the collected information of adjacent terminals; in order to realize the mobile coverage test of the target, static Test Points (TP) are set up at several representative locations on the target road section to test whether the connectivity and coverage of MVN network meet the requirements.

Based on the 5G network data back haul link model shown in Figure 1.

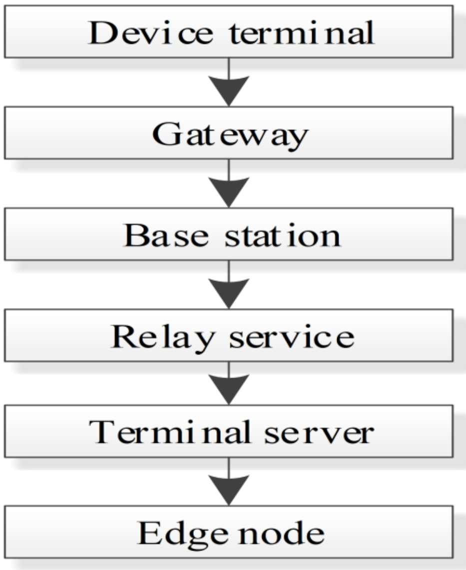

Figure 1. System model of the back haul link.

In the 5G network shown in Figure 1, the terminal device transmits data to the edge node through a back haul link. There are more than one relay node on the back haul link, and on each relay node, there are more than one energy terminal to provide energy for the relay node through competition. The network base station, depending on the energy, obtains the service packet from the terminal device and provides the spectrum to the 5G access network [22].

3.1. Edge Calculation Analysis

From the basic definition of edge of computing technology, margin calculation is close to the object or the network edge end of the data source, network, computing, storage, application of core competence of the combination of distributed open platform, came to the edge of intelligence services and meet the demand of industrial digital key, including agile connection, real-time business, data optimization, application of intelligent, security and privacy protection, Thus, the corresponding edge calculation model is generated, and the structure of the model is shown in Figure 2.

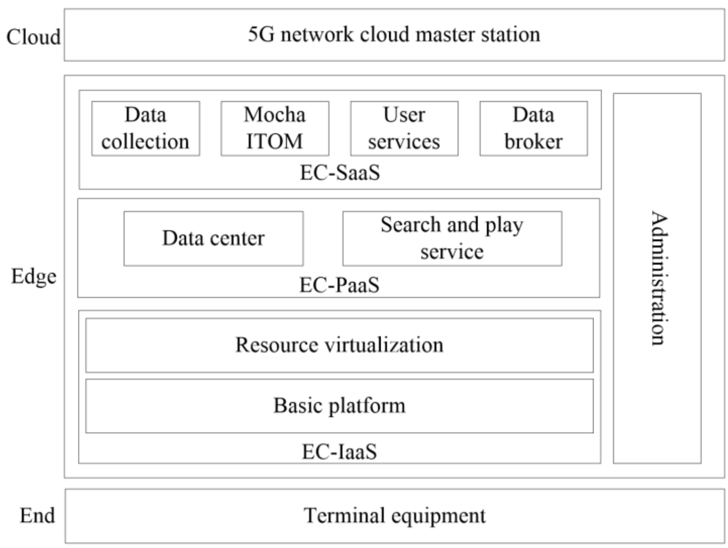

Figure 2. Structure diagram of edge calculation model.

As shown in Figure 2, in the 5G network environment, the edge computing model is a three-level structure of "cloud, edge and end". The "cloud" refers to the primary site platform in the cloud, where a variety of micro-services are deployed. Edge computing gateway refers to the deployment of multiple micro applications on the edge of the network close to terminal devices or data sources and edge computing nodes providing edge intelligence services, so as to realize the monitoring, collection and perception of basic data such as 5G network operating environment and device status. In addition, in the edge computing model, the data center is an important part of the edge computing node, and it is the data collection, processing, transmission, calculation and other processes closely related to the network data transmission business. A perfect data interaction mechanism is designed to make the data better serve the edge computing and improve the operating efficiency.

Edge computing technology is close to the information source in terms of geographical location. When the user sends a request, the network can respond to the user's request quickly, which greatly reduces the response delay, and makes the data transmission network and the core network in the network avoid network congestion. Mobile edge computing technology can also be used to obtain the real-time information of each major network base station ID, user network data, user request and other information, the network links can be effectively perceptual adaptive, for users to deploy location applications at the edge of the network, so as to improve the quality of service for network users.

3.2. Channel Model of 5G Access Back Haul Link

At the beginning of each transmission gap, the base station broadcasts a beacon on the back haul link, and the terminal device will start transmission after receiving this beacon. Because the base station needs to obtain the data packet p from the terminal device, the higher the data packet p, the fewer devices that want to access the network. Conversely, when the p of the data packet obtained from the terminal device decreases, it will lead to higher access demand. It is assumed here that the number of connected demand $Q(p)$ is an exponential demand function.

$$Q(p) = ae^{-i\phi} \tag{1}$$

Because the number of terminal devices connected to the network cannot be determined, a represents a random variable. In the 5G data access stage, each terminal device connected to the terminal device occupies a bandwidth of B to transmit small data packets. The base station provides spectrum according to the access demand of terminal equipment. The amount of spectrum provided by the base station during 5G data access, and the base station must pay the data packet w to the energy terminal that provides energy. Suppose that at the node $i(i \in \{1, 2, \ldots, n\})$, the data volume of one unit of energy produced by the energy terminal is c_i, and the data volume of other energy terminals at the same node is $\bar{c}_{\mathrm{i}}$. In order to reduce the p of data packets obtained from the terminal equipment, the base station always selects the energy terminal with the lowest profit and loss as the only energy terminal, so $c_i \leq \bar{c}_t$. The value of the data volume difference $(c_i - \bar{c})$ indicates the intensity of competition for energy terminals at the same node. The smaller the value, the more intense the competition [23]. It can be seen as an incomplete information game, because the energy terminals at the same node do not share their own profit and loss strategies or other information.

The 5G access backhaul link is a random-access channel. This article describes the channel through a standard time slot Aloha (SA) method. At this time, the throughput of the channel is $S = Ge^{(-\sigma)}$, where G is the number of data packets transmitted in each average time slot, and the terminal device in the transmission phase sends a randomly selected preamble sequence to the base station on the 5G backhaul link. If multiple terminal devices transmit different preamble sequences to the base station in the same time slot, there will be no conflicts on the channel. x_s represents the number of available preamble sequences, the bandwidth of AS time slot is B_s, and the data transmission time on the channel is t_a [9]. Therefore, in the access process, the total number of RA time slots is $\frac{\omega\tau}{t_r B}$, so at this time $G = \frac{Q(p)t_d b_s}{\omega t \alpha_s}$. In each phase of 5G access, the average number of successfully connected terminal devices is $T(\omega, p) = Q(p)e^{\frac{Q(p)\varpi}{\varpi}}$, where $\overline{\varpi} = -\frac{t_o B_s}{|\alpha_i|}$.

According to the Friesian transmission equation, it only describes the law that the electromagnetic wave follows in the transmission process, and has nothing to do with the characteristics of the transmitter and receiver, and the power of the first antenna can be ignored. Therefore, the equation for path loss in dB is:

$$L(h) = 3.25 + 20\log_{10}(f) + 10\gamma\log_{10}(h) + A \times h \tag{2}$$

In Formula (2), h is the transmission distance on the link, f is the carrier frequency, A is the attenuation coefficient, and γ is the path loss index, which depends on the geographic environment during transmission. Meanwhile, in this transmission equation, the unit of signal power is MHz, and the unit of transmission distance is km. Let P_i be the transmission power at relay node i, and h_i the distance of each node [24]. Therefore, according to the transmission loss $L(h_i)$ and Shannon's theorem, the formula can be obtained.

$$R = \varepsilon \ln(1 + \frac{L(h_i)P_i}{h_N \varepsilon}) \to P_j = \frac{(e^{\frac{k}{z}} - 1)n_d \varepsilon}{L(h_i)} \tag{3}$$

In Formula (3), ε is the transmission bandwidth, R is the data transmission rate on the back haul link, and P_i represents the transmission power at relay node i.

Let $\phi(\varepsilon) = \frac{(e^{\frac{k}{\varepsilon}} - 1)n_d \varepsilon}{R}$, the conversion formula between energy and demand data volume can be obtained.

$$E_x = \frac{S}{R}p_i = Ge^{-\sigma}\frac{\phi(\varepsilon)}{L(h_i)} \tag{4}$$

Each unit of traffic transmitted at the rate R consumes energy $\frac{\phi(\varepsilon)}{L(h_r)}$.

3.3. Description of 5G Access Data Back Haul Link Resource Allocation Problem and Game Modeling

The conversion formula between energy and data volume, let w_i represent the profit and loss obtained by the base station on the 5G back haul link when the energy terminal $i, i = \{1, 2 \ldots, n\}$ produces one unit of energy, and c_i represents the data volume of one unit of energy produced by the energy terminal i [25].Therefore, the migration data of energy terminal i is:

$$\prod_j = (w_i - c_i)E_j = (w_i - c_j)D(\omega, p)\frac{\phi(\varepsilon)}{L(h_i)} \tag{5}$$

In Formula (3), $D(\omega, p) = Ge^{-\sigma}$, where $G = \frac{Q(p)t_d B_s}{\omega t x_l}$. Because the data packet obtained by the base station from the terminal device on the 5G backhaul link is p, the migration data of the base station can be obtained as:

$$\prod_f = p - \sum_{''}^{i=1} w_i E_i = p - D(\omega, p)\sum_{i=1} \mu \frac{\phi(\varepsilon)}{L(h_r)} \tag{6}$$

At each relay node, the energy terminal that wins the non-cooperative game will be allowed to freely form a relay terminal. The process of forming the relay end. This model can describe a cooperative game. The participants are the energy terminals on the 5G back haul link. The energy terminals that compete at each node on the back haul link choose who to form the relay end. Develop profit and loss strategies to enable yourself to obtain more migration data [26].

Assuming that there are n hops on the back haul link, the energy terminal at these n hops can form m relay ends. The terminal relay end structure is represented by $B = \{B_1, \ldots, B_{-\infty}\}$, and the output profit and loss strategy set of the relay end is $\{W_{B_1}, W_{B_2}, \cdots, W_{B_-}\}$, then the relay end structure needs to meet the conditions:

(1) The elements in the set do not overlap, which means that different relay terminals cannot have the same terminal, and the same terminal cannot join two relay terminals at the same time.
(2) The union of all elements in the set should be a complete set, that is, the energy terminals of all nodes should be included in the relay end structure, even if the energy terminals remain independent.

The condition is expressed as a formula:

$$W_{B_j} \cup_{j-1}^{m} B_j = N, h \neq k\ ,\ B_h \cap B_k \neq \phi \tag{7}$$

In Formula (8), W_{B_j} represents the data packet obtained by the relay terminal B_j from the base station, C_{B_j} is the total data volume of the relay terminal B_j, and the sum of the data volume of the relay terminal is the total energy terminal data volume without other additional data volume. W is the total data packet obtained by all terminal relays from the base station, namely $W = W_{B_1} + W_{B_2} + \cdots + W_{\delta_b}$.

The migration function of the relay terminal is:

$$\prod B_j = (W_{B_j} - C_{B_j})E_{B_j} = (W_{B_j} - C_{B_j})[D(\omega, W)\sum \frac{\phi(\varepsilon)}{L(h_i)} : i \in B_j] \tag{8}$$

The migration function of the 5G access network base station is:

$$\prod f = [p - \sum_{m}^{j=0}(W_B)]E = (p - W)[D(\omega, p)\sum \frac{\phi(\varepsilon)}{L(h_j)} : i \in n] \tag{9}$$

4. Relay Terminal Analysis and Data Migration Service of 5G Network Energy Terminal

In this section, we first studies the conditions under which the energy terminal relay terminal can achieve the maximum data exchange peak, then gives the definition of a stable relay terminal, studies how the energy terminal forms a stable relay terminal, and gives the composition of the stable relay terminal And the algorithm to form a stable relay terminal. Based on this, the largest migration service of the power terminal relay is explored.

4.1. Nash Stability Definition of the Energy Terminal Relay End

First, give the definition of Nash stable relay terminal:

Definition 1. *When each energy terminal in the relay terminal cannot transmit the current relay terminal to obtain a larger data exchange peak value, the relay terminal is Nash stable. That is,* $\left\{W_{B_1}^*, W_{B_2}^*, \cdots, W_{B_m}^*\right\}$ *is the strategy of the energy terminal relay end. For any relay end*$B_j \in B$, *when the condition* $\prod_{B_j}(W_{B_,}^*) \geq \prod_{B_,}(W_{s_j})$ *is satisfied, the relay end is Nash stable.*

However, combined with the definition of Nash stable relay terminal, it is unstable for all terminals to form a large relay terminal. It can be seen from Theorem 1 that the migration data of each relay terminal and the total migration data of the energy terminal decrease as the number m of relay terminals formed increases. Therefore, when all terminals form a large relay terminal, the migration data is the highest, and when all energy terminals remain independent, the migration data is the lowest. Theorem 2 proves that each relay terminal obtains the same migration data, and the migration data of the relay terminal has nothing to do with the real composition of the relay terminal, but is only related to the number of terminals composed of the terminal and the terminal access demand function.

4.2. Formation Conditions and Algorithm Design of Stable Relay Terminal of Energy Terminal

Each energy terminal will get more benefits than the original uncooperative state. According to the result of this game, the wireless base station can work out the optimal data return service profit and loss and the expected value of the data volume provided to the end user. This section studies the formation process of the terminal relay. In the process of forming a relay terminal, each energy terminal is free and can freely form a relay terminal with other terminals or choose to remain independent.

Given the relay end structure for the distribution of the migration data of the relay end, under the Nash stability concept, a non-independent energy terminal transmits back to the current relay end. If the relay end is transmitted, it can obtain more migration data. Assuming that the feasible transmission of the energy terminal is to transmit the current relay terminal to remain independent or to transmit the current relay terminal to join other relay terminals, it also means that the relay terminal it joins can obtain more migration data when it joins.

Let the relay end migration data of the relay end structure with m relay ends be $\prod(m)$.

$$\prod(m) = \frac{(\lambda + \gamma C)D(\omega, p^*)}{1 - \hbar m} \sum \frac{\phi(\varepsilon)}{L(h_i)} : i \in B_m \tag{10}$$

Under the concept of Nash stability, if a terminal in a relay can obtain more migration data by transmitting the current relay, it will transmit the current relay. $|B_j|$ represents the number of energy terminals in the relay terminal B_j, and $U(m) = \frac{\prod(m)}{\prod(m+1)}$ represents the migration data of the relay terminal structure with m relay terminals and the terminal transmits the migration data of the relay terminal structure independent of the relay terminal. Without loss of generality, let $\left|B_1\right| \leq \cdots \leq B_{N|}$, and for a given relay terminal structure, the energy terminal has only two states: independent and non-independent.

For a given relay terminal structure $B = \{B_1, \cdots, B_m\}$, it is Nash stable if and only if the following conditions are true:

(1) $U(m-1) \leq |B_2| + 1$, it is proved that there are independent energy terminals in the relay end structure,

(2) $U(m) \geq \left|B_{n|}\right|$, it is proved that there are non-independent energy terminals in the relay terminal structure.

If $U(m) = \frac{\prod(m)}{\prod(m+1)}$ represents the ratio of migration data before and after transmission by members in the relay. It measures the desire of the terminal to transmit the current relay to join other relays, and the transmission relay to remain independent or maintain the current state.

According to the proof of Theorem 3, for a given relay end structure of m relay ends, $U(m-1)$ measures the tendency of independent terminals to remain independent, and $U(m)$ measures the non-independent energy terminals not transmitting the current tendency of the relay end to remain independent. Therefore, the value of $U(m)$ determines the stability of the relay terminal. The smaller the value, the independent terminal is more likely to remain independent, and the non-independent terminal is more likely to transmit the relay terminal to become independent. In the following, $U(m)$ represents the stability factor. In order to test whether the structure of the relay end is Nash stable, it is necessary to understand the behavior of the stability factor $U(m)$. Based on the above theorem, some properties of $U(m)$ can be derived.

Under the exponential access demand $Q(p)$ of terminal equipment, the stability factor $U(m)$ should satisfy: ΣΣ ∈ ∈=ΠΠ=.

$$U(m) = \frac{\prod(m)}{\prod(m+1)} = \frac{1 - \gamma(m+1)}{1 + hm} \sum [L(h_i) : i \in B_m] \sum [L(h_i) : i \in B_{m+1}] \tag{11}$$

Further, we can acquire $\frac{\partial U(m)}{\partial m} = \frac{(1-\gamma)\beta}{(1-\gamma m)^2}\frac{D(\omega,p_m^*)}{D(\omega,p_{m+1}^*)}\frac{\sum[L(h_i):i\in B_m]}{\sum[L(h_i):i\in B_{m+1}]}$, where $p_k^* = \frac{(1-\gamma)k+\lambda+C}{(1-\gamma)(1-\gamma k)}$ represents the profit and loss of a single terminal when the relay end structure with k relay ends is stable.

Proof. The expression of $U(m)$ in Formula (21) is derived from the definition of Formula (20) and $U(m)$. Let $k = \frac{1-\gamma(m+1)}{1-\hbar m}$, $\varphi = \frac{D(\omega,p_m^*)}{D(\omega,p_{n+1}^*)}$, so that

$$\frac{\partial U(m)}{\partial m} = \varphi\frac{\partial\kappa}{\partial m} + K\frac{\partial\phi}{\partial m} \tag{12}$$

It can be obtained $\frac{\partial\kappa}{\partial m} = -\frac{\gamma^2}{(1-\gamma m)^2}$, $\frac{\partial\varphi}{\partial m} = \frac{\lambda\gamma}{(1-\gamma)(1-\gamma(m+1))}$ by derivation.

According to Formula (12), and $p_{m+1}^* = \frac{\lambda(1-\gamma)(m+1)+\lambda+C}{(1-\gamma)(1-\gamma(m+1))}$, $\frac{\partial K}{\partial m}$, $\frac{\partial\varphi}{\partial m}$ is substituted into Formula (12), we can get:

$$\frac{\partial U(m)}{\partial m} = \frac{\varphi(1-\gamma)\gamma}{(1-\gamma m)^2} \tag{13}$$

In Formula (13), it can be seen that $U(m)$ is only related to the sign of γ with the increase or decrease of m, which is related to the curvature of the demand function $\psi(p) = 1+\gamma$. When $\gamma > 0$ is $\psi(\mathrm{p}) < 1$, $U(m)$ increases as m increases, which means that the terminal is more likely to form a relay end. When $\gamma < 0$, $U(m)$ decreases as m increases, which means that the terminal tends to remain independent. The relationship between the curvature of the demand function and the transfer rate along with the transfer rate can be used to explain the stability effect of the demand curvature on the structure of the relay end. The pass-through rate is the ratio of the reduction in the overall profit and loss caused by the reduction in a single profit and loss. The mathematical expression of the transfer rate is $\frac{dp}{dW}$, the function $\frac{dp}{dW} = \frac{1}{2-\Psi(p)}$ is required to solution curvature. Therefore, in $\Psi(p) < 1$, the transfer rate is less than 100%, in $\Psi(p) = 1$, it is equal to 100%, and in $\Psi(p) > 1$, it is greater than 100%.

When $Q(p)$ is an exponential demand function, when $\lambda > 0, \gamma = 0$. Therefore, the $\lambda = \frac{1}{b}, \Psi(p) = 1$ transfer rate is equal to 100%, and $U(m) = e \approx 2.73$.

Given the relay end structure $B = \{B_1, \cdots, B_m\}$, where $|B_1| = 1, |B_2| = \cdots = |B_\rho| = 2$, $B_{(n)(n)}$ are denoted as $B_{(n)(n)} = \{B_1, \cdots, B_m\}$, where $|B_1 models \cdots = |B_m| = 2$. Without loss of generality, $|B_1| \leq \cdots \leq B_m|$ is let. $\overline{B}$ represents an independent structure, such as: $|\overline{B}| = 1$, that is, there is only one energy terminal in each relay terminal, and B^* is a large relay terminal, that is, all energy terminals of $|B^*| = m$ are in the same relay terminal. □

According to the above research on the stable relay terminal of the energy terminal, the distributed iterative algorithm design for the energy terminal to form the Nash stable relay terminal is now given. The specific algorithm flow is shown in Figure 3.

Step 1: Assume that the relay terminal structure $B = \{B_1, \cdots, B_{e\gamma}\}$ is formed through its own actions at the energy terminal.

Step 2: B_1 to B_m in turn, $U(m) = \frac{\prod(m)}{\prod(m+1)}$ is calculated.

Step 3: If the number of energy terminals on the relay end is 1, then it will remain independent during $U(m-1) \leq B_2|+1$. Otherwise, it will deviate from the current relay and join other relays.

Step 4: If the number of energy terminals in the relay end is greater than 1, then it will stay in the current relay end during $U(m-1) \leq B_2|+1$. Otherwise, it deviates from the current relay and joins other relays or becomes independent.

Step 5: Return to the second step to traverse the entire relay end structure $B = \{B_1, \cdots, B_{n\infty}\}$.

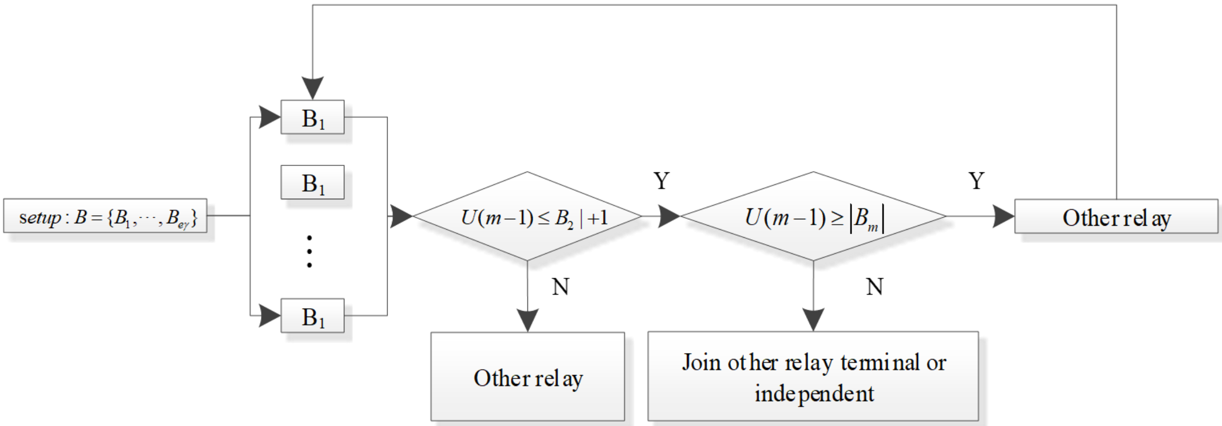

Figure 3. The distributed iterative algorithm of the Nash stable relay terminal structure formed by the energy terminal in the 5G access back haul link.

4.3. Maximum Migration Service Analysis

For the relay terminal structure $B = \{B_1, \cdots, B_m\}$, according to the condition function of the base station in Formula (7), the data migration of the base station is affected by two factors: the data packet p obtained from the terminal device and the energy supply profit and loss of all energy terminals on the back haul link. At the same time, for the terminal relay end, the strategy with the greatest profit should also be selected. When the relay end can obtain the maximum migration data, the first derivative of Formula (10) needs to meet the conditions:

$$\frac{\partial \prod_{ik}}{\partial W_{i_k}} = [D^*(\omega, W) + (W_{R,j} - C_{B_j}) \sum \frac{\phi(\varepsilon)}{L(h_l)} : i \in B_j] = 0 \tag{14}$$

Because the value of $\sum \frac{\phi(\varepsilon)}{L(h_l)} : i \in B_j$ is not 0, Formula (14) can be converted to:

$$W_{B,} - C_{B_j} = \frac{-D^+(\omega, W)}{\partial D^+(\omega, W)} \tag{15}$$

Because $W = \sum_{h}^{j-1} W_{B_J}$ so there is $\frac{\partial Q^*(\omega,W)}{\partial W_{kj}} = \frac{dQ^*(\omega,W)}{dW}$, Formula (15) can be converted to:

$$W_{B_j} - C_{B_j} = \frac{-Q^*(\omega, W)}{dQ^*(\omega, W)} \tag{16}$$

That is $W_{B_1} - C_{B_1} = W_{B_2} - C_{B_2} = \cdots = W_{B_2} - C_{B_2}$, it can be seen that in order to obtain the maximum benefit for the energy terminal, when the amount of data transmitted by all nodes on the back haul link is the same, regardless of whether the data amount is the same, all the relay terminals obtain the same migration data. When the relay end structure $B = \{B_1, \cdots, B_m\}$ and the relay end pricing strategy $\{W_R, W_{B,}, \cdots, W_{B_k}\}$ are known, the base station will obtain data packets from the terminal equipment according to the maximum data migration. In order for the base station to obtain the maximum migration data, the first derivative of the profit and loss p in Formula (13) needs to meet the following conditions:

$$\frac{dL_y}{dp} = [D(\omega, p) + (p - W)D'(\omega, p)] \sum [\frac{\phi(\varepsilon)}{L(h_j)} : i \in n] = 0 \tag{17}$$

In Formula (17), $\frac{D(\omega,p)}{D'(\omega,p)} + \mu^* - W = 0$. Demand $Q(p)$ can get the best profit and loss $p^* = W + \frac{1}{b}$. In the same way, in order for the energy terminal to obtain the maximum migration data, the optimal (p^*, D^*) of the base station at this time depends on the overall energy gains and losses of all energy terminals.

Because the number of terminal accesses is $Q(p)$, the elasticity of profit and loss is $\eta(p) = -\frac{pD'(\omega,p)}{D(\omega,p)}$, where $D'(\omega,p) = \frac{dD(\omega,p)}{dp}$. Suppose that let $\eta(p) = \frac{p}{(\lambda+\gamma)}$, where λ and γ are constants, and $\lambda \geq 0, \gamma \leq 1$. Because $Q(p)$ is the access demand function, the above profit and loss elasticity formula needs to satisfy $\lambda + \gamma p > 0$, and $\psi(p) = \frac{D(\omega,p)D'(\omega,p)}{(D'(\omega,p))^2}$ is a constant, which represents the curvature of the demand function.

In order to ensure that there is an equilibrium solution for the base station's profit and loss, the condition $\psi(p) \leq 2$, namely $\gamma \leq 1$, is required. $\prod_{(m)}$ represents the migration data of the relay terminal with m energy terminals.

For a given relay terminal structure and energy terminal energy loss, the base station must maximize its own migration data. Therefore, the profit and loss of the maximum migration data can be obtained as $p^* = \frac{\lambda+W}{1+\gamma}$. The profit and loss p^* is substituted when the base station obtains the optimal migration data into the relay end migration data function, we can obtain:

$$\begin{aligned} \frac{d\prod_{B_j}}{dW_{B_j}} &= [D(\omega,p^*) + (W_{B,i} - C_{B_j})D'(\omega,p^+) \\ &= [(1-\gamma m)W - \lambda m - C][\sum \frac{\phi(\varepsilon)}{L(h)} : i \in B] \end{aligned} \quad (18)$$

It can be noted in Formula (18) that if there is $(1-\gamma m) \leq 0$, the migration data of the relay end B_j strictly increases with the increase of W_{B_j}. Therefore, the higher the profit and loss p is set at this time, the higher the migration data of the relay end, which does not conform to the actual situation, and this situation is not considered. When $(1-\gamma m) > 0$, according to Formula (15), the migration data of relay B_j has a peak value obtained at $W^* = \frac{\lambda m + C}{1-\psi m}$:

$$W^*{}_{B_n} - C_{B_n} = \cdots = W^*{}_{B_n} - C_{B_n} = \frac{\lambda + rC}{1 - rm} \quad (19)$$

W^* is substituted into the maximum migration data, the profit and loss are P^*, we can get:

$$P^* = \frac{\lambda(1-\gamma)m + \lambda + C}{(1-\gamma)(1-\gamma m)} \quad (20)$$

W^*, and P^* are substituted into the relay terminal migration data function and the base station migration data function respectively, we can get $\prod^*_{B_j} = \frac{(\lambda+\gamma C)}{1-\hbar m} D(\omega,p^*)[\sum \frac{\phi(\varepsilon)}{L(h)} \cdot i \in B_j]$, $\prod^*_f = \frac{\lambda+\gamma C}{(1-\gamma)(1-\gamma m)} D(\omega,p^*)[\sum \frac{\phi(\varepsilon)}{L(h)} : i \in n]$, $B_j \in B$. It is inferred:

$$\frac{\partial W^*}{\partial m} \geq 0, \frac{\partial p^*}{\partial m} \geq 0, \frac{\partial \prod(m)}{\partial m} \leq 0, \frac{\partial D(\omega,p^*)}{\partial m} \leq 0, \frac{\partial m \prod(m)}{\partial m} \leq 0 \quad (21)$$

Assuming $1-\gamma m \geq 0$, if $1-\gamma m \geq 0$, there will be no relationship between the energy terminal and the relay terminal, that is, if there is no migration data, the energy terminal will not form a relay terminal.

When the energy terminal forms the relay terminal according to the optimal profit and loss strategy, the relay terminal is not necessarily stable, so it is necessary to study how the energy terminal forms a Nash stable relay terminal.

5. Simulation Experiment

5.1. Simulation Environment Settings

In order to evaluate the algorithm in this paper and compare the performance indicators of existing algorithms, a variety of simulation evaluation methods in the paper is proposed. In the simulation area of 100 m × 100 m, 100 nodes are randomly thrown around the base station node located in the central area, and the migration data 5G network is constructed as shown in Figure 4.

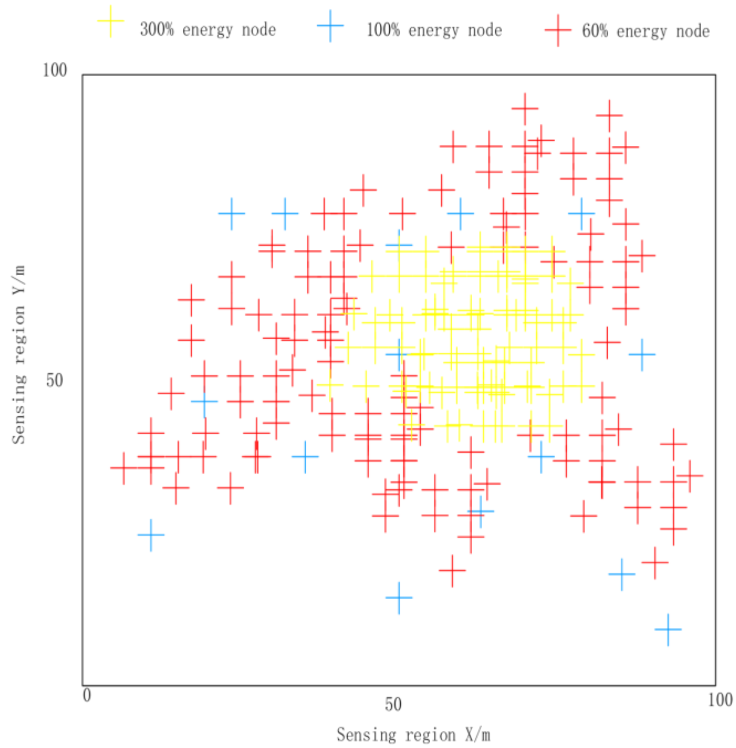

Figure 4. Distribution of 5G data nodes.

In Figure 4, 60% of the data is deployed for ordinary nodes twice the E0 level 1 node; 20% of the data is deployed for 1/2E0 migration data nodes, and the remaining nodes are second-level nodes with normal data levels.

In this paper, edge computing is adopted to cluster disordered network nodes into clusters. By adopting the first clustering measure, it is helpful to determine the minimum distance between the cluster head node and the base station, and reduce the network energy consumption. The final clustering result adopts the Tyson polygon as shown in Figure 5.

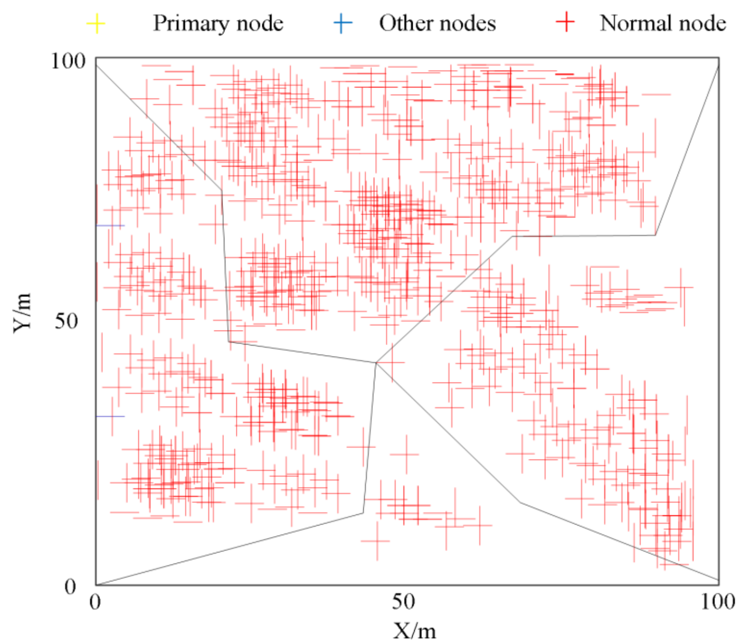

Figure 5. Edge clustering algorithm results.

In the test of simulating the effect of edge computing, the initial experimental parameters determine the performance of the entire experimental results. The specific parameters are shown in Table 1.

Table 1. Simulation parameters.

Parameter	Value
Network range	(100^2)
Number of nodes	100
Receiving energy consumption	$E_{p_1} = 50$ nJ/bit
Transmission energy consumption	$E_{chv} = 50$ nJ/bit
Data packet bytes	4000 bits
Transmission power	$10\ \text{pJ}/(\text{bit} \cdot \text{m}^2)$
Transmission power	$0.0013\ \text{pJ}/(\text{bit} \cdot \text{m}^4)$

Because the unreasonable data distribution and consumption agreement accelerates the process of node death, the more data the node stores, it means that it can bring the greatest benefits of network survival, which directly reflects the survival value of the agreement.

The hardware environment of this experiment is Intel Core i7-10700M processor with the main frequency of 4.80 GHz. The performance of this scheme is simulated and analyzed by Matlab 2016a simulation platform. The simulation edge computing network scenario includes 1 edge base station and 12 user equipment. Each user is randomly distributed in the $[200\text{m}, 200\text{m}]$. For parameter setting, consider that the working frequency of the local CPU of the equipment is 1G cycles/s, the maximum transmission power is 0.8 W; the transmission bandwidth between the equipment and the base station is 15 MHz; the noise power and unloading transmission channel gain are $\sigma^2 = 2 \times 10^{-13}$ and $h_i = 127 + 30 \times \log d$ respectively, and d is the transmission distance. It is assumed that the maximum computing capacity of the edge is 35G cycles/s. The equipment idle power is 0.01 W, the task data size is 0.42 MB and the task processing density is 297.62 cycles/bit. For the cache content data setting, the maximum capacity of edge cache assistance is 120 MB.

The paper comprehensively compares the Leach protocol and its improved Leach-E and SPE algorithms. In order to fully analyze the characteristics of the algorithm, the evaluation is mainly based on the following.

5.2. The Remaining Data Balance Ratio

The remaining data balance ratio is expressed as the ratio of the remaining data of the node to the total data of all nodes. Because the initial data priority is different, the loss of the data loss value of each node is different at different positions. The edge calculation proposed in this paper is 1000. In the second iteration, the number of dead nodes is 4, and the remaining data balance ratio of most nodes exceeds 50%. The balance comparison with other algorithms is shown in Figure 6.

In Figure 6, the edge computing proposed in this article has a significant effect on solving the data balance problem in 5G wireless sensor networks.

5.3. Node Death Cycle

In the 5G wireless sensor network, due to the large difference in migration data, the traditional LEACH algorithm based on the probability of disadvantages highlights the serious situation that the node death occurs first; the improved LEACH-E algorithm makes up for this deficiency, but The problem of cluster head selection does not essentially solve the congenital defects in the algorithm process; the SPE algorithm itself uses two nodes with different initial data, and designs different cluster head election thresholds, making the advanced node become the cluster head. The probability is further improved, increasing the death time of the first node; however, this method does not consider the negative impact of the distance between the cluster head node and the base station, which promotes the death probability of the node in a certain period of time. Great, it did not get the proper lifting effect. The simulation results are shown in Figure 7.

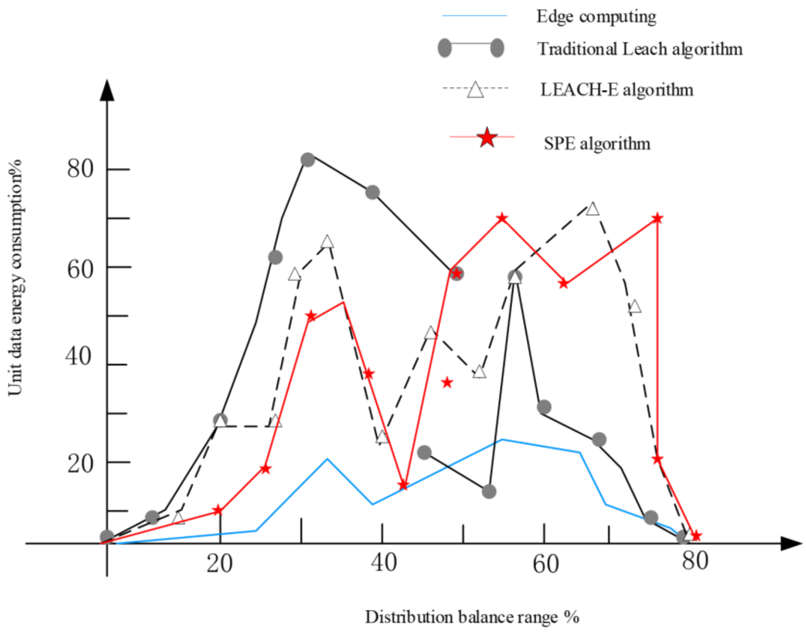

Figure 6. Comparison of residual data balance effect.

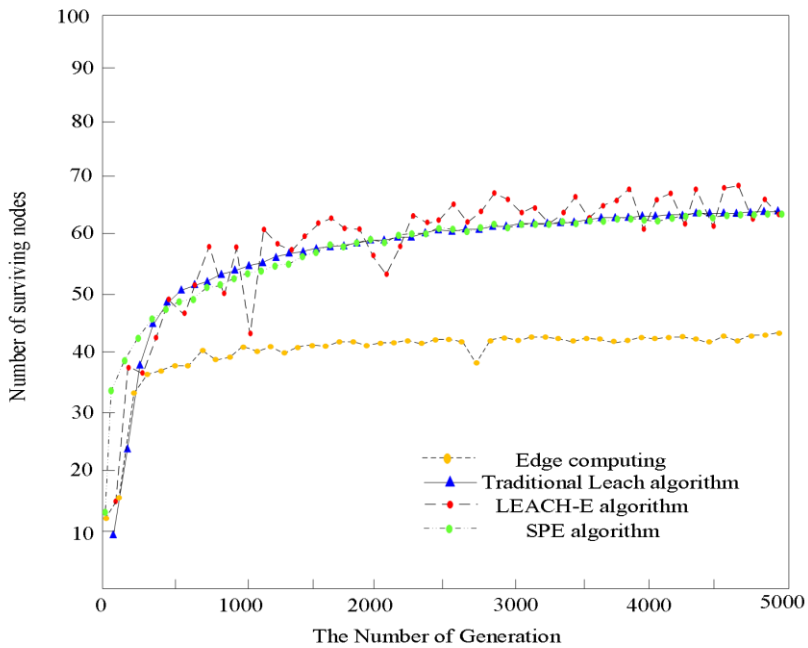

Figure 7. Network life cycle.

Figure 7 compares the initial node death algebra, 50% node death algebra, and all node death algebras of various algorithms, as shown in Table 2.

Table 2. Comparison of network life cycle data of various algorithms.

Algorithm	Initial Node Death	1/2 Node Dead	All Nodes Die
Edge computing	362	834	2635
Traditional Leach algorithm	432	1044	2638
LEACH-E algorithm	657	1744	2753
SPE algorithm	964	2621	3932

Compared with LEACH algorithm, LEACH-E algorithm, and SPE algorithm, the initial node death cycle in this article has increased by 226.30%, 223.15%, and 146.73%, respectively. Compared with the life cycle, it has increased by 70.1%, 32.3%, and 119.3%, respectively. %, so the experimental data shows that this article has profound significance and influence in improving the network life cycle.

5.4. Number of Data Packets Received by the Base Station

The more data the base station receives, the longer the survival time of the network. In a complex environment, the amount of information monitored by the network will increase, which directly reflects the effectiveness of the algorithm in this paper, as shown in Figure 8.

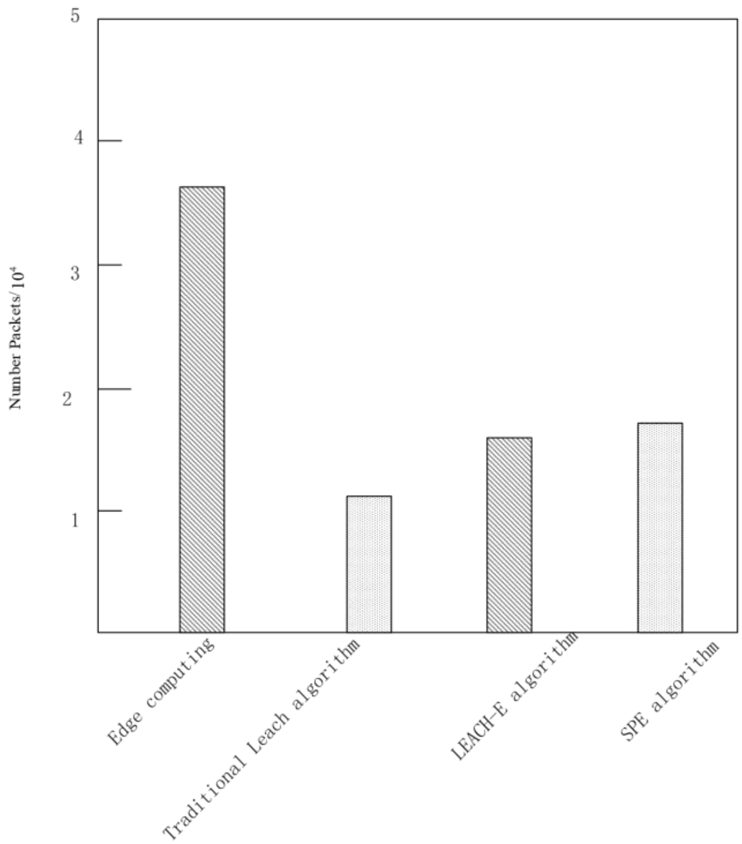

Figure 8. Base station receives data value.

The data in this article is about 36,679, which are LEACH algorithm, LEACH-E algorithm, and SPE algorithm increased by 65%, 49% and 47%.

5.5. Average Node Remaining Data

The average node remaining data is the ratio between the total data of the current node and the number of surviving nodes. The higher the average node remaining data means the higher the survival value of the network and the greater the use value of the network. The result is shown in Figure 9.

The fitness function is established by combining the residual energy of the network node and the distance from the node to the base station, making full use of the relationship between the node energy and location in the process of information transmission, selecting the three nodes with the strongest adaptability in each cluster, iteratively selecting the cluster head node that can best reflect the current cluster structure, and completing the cluster transmission of sensor information. Finally, a variety of evaluation criteria are used to simulate the real network environment. The experimental results show that the model has a good network life cycle and has better adaptability than the traditional isomorphic and heterogeneous network models; in addition, although the proposed algorithm improves the life cycle of heterogeneous WSNs networks, it does not consider the delay and jitter in the process of information transmission.

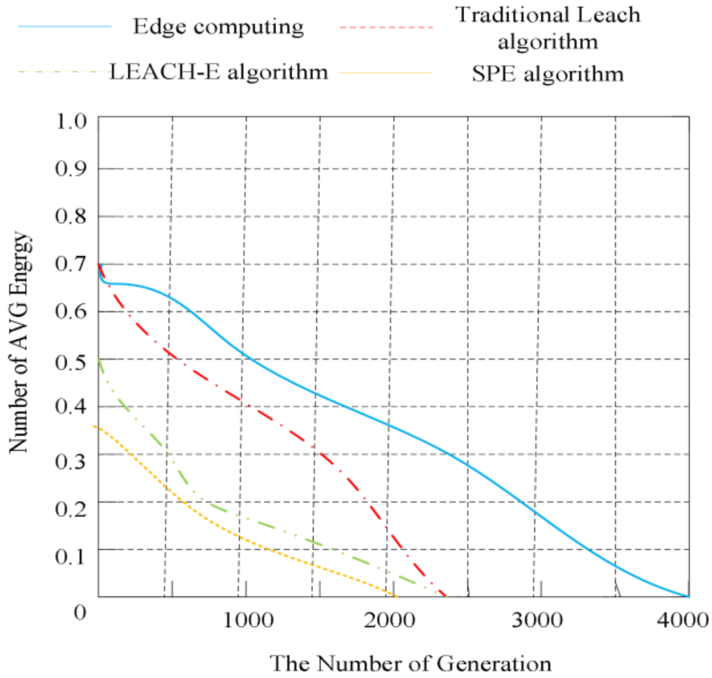

Figure 9. Number of received information groups.

Compared with the other three algorithms, the algorithm proposed in this paper has the smallest slope, which means that the data loss is slower in the same network living space, which is about 33% higher than the traditional LEACH algorithm and LEACH-E algorithm, and is better than the SPE algorithm an increase of nearly 50%.

6. Conclusions

This study designs a 5G wireless data network migration strategy based on edge computing, which not only improves the life cycle of the 5G network, but also improves the utilization rate of the remaining data in the network. The experiment shows that the model has a good network life cycle and better adaptability than the traditional network model. However, although this method improves the life cycle of 5G network, it does not consider the problem of time delay and jitter in the process of information transmission. Therefore, in the following research, this method will be optimized from these two aspects.

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