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Design of algorithmic power reduction in 5G network using optimum network engineering tools

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Abstract
The innovation of the fifth-generation mobile communication (5G) network infrastructure is gradually accelerating, and the evolution of green and energy-saving communication networks Whether sustainable development. To study 5G network energy consumption management and control technology and explore the distributed clean energy system, Applying energy storage system and demand response in 5G network energy consumption management and control to achieve energy saving and emission reduction is of great significance. From the base station, the perspectives of models, algorithms, and technical routes for energy management and control research, based on 5G base stations equipped with energy harvesting devices, introduced and analyzed the current research status of 5G network energy consumption and related technologies of 5G network energy consumption management and control. The joint power flow optimization control of the information network and the power network and its technological innovation and application prospect, to pass the 5G network energy consumption management and control The coordinated application of technologies reduces the operating costs of 5G network operators and grid operators and provides ideas for the construction of green 5G networks.

Keywords: 5G network, energy consumption, distributed energy storage, demand response, collaborative energy consumption management and control

1. Introduction
In the context of the Energy Internet, the pressure to reduce emissions promotes electric energy. The structure of the green communication network is reformed. Energy Internet can be understood as a comprehensive combination of information technology and intelligent management technology, many distributed energy harvesting devices, distributed energy storage devices, and various types of negative. The new power network constituted by the Load is interconnected with each energy node to an energy peer-to-peer exchange and sharing network that realizes two-way energy flow. The fifth-generation mobile communication (5th generation mobile communication, 5G) network has a new type of infrastructure construction (simplified the most fundamental communication infrastructure in the "new infrastructure") is the other foundation, construction of facilities provides important network support, which is the realization of the energy. The key Technology, as the commercialization of 5G technology becomes more and more mature mobile communication. The number of credits increases exponentially [1], Base station (BS) density and energy. The corresponding increase in energy consumption and the increasing problem of mobile network energy consumption, how to build energy-saving and green 5G networks, reducing the operating costs of 5G network operators, and other issues need to be resolved urgently.

1.1 How to apply existing technologies to the construction and energy supply of 5G networks
China, integrate social resources and help green 5G network development and energy interaction. The network construction is worthy of attention from scholars from all walks of life. 5G network operators are dynamic large-scale capabilities of grid operators; Consumers use their load adjustability to cooperate with energy storage, distributed Technologies such as clean energy access can be used as the interactive Load of the grid. Grid optimizes power consumption and provides services such as demand response for the grid By integrating energy storage technology And getting economic benefits. Literature [2-3] proposes a green wireless communication Concept, applying distributed power generation to 5G network

power supply, reducing power, reducing power cost, and carbon emissions. However, the intermittent nature of distributed clean energy output.

This article discusses issues related to 5G network energy consumption at home and abroad from multiple perspectives. Research status and results of the topic are sorted out and summarized for follow-up development. More in-depth research provides references and references. Especially explored 5G communication network-power network joint optimization, and 5G communication network and How does the power network carry out energy exchange and realize the interaction between supply and demand And the combination of 5G communication network and power network under the background of energy. Concept, applying distributed power generation to 5G network power supply, reducing power

Liu Youbo *et al*. Key technologies and prospects for 5G network energy consumption management and control in the context of the energy Internet Meet the user's demand for network bandwidth, delay, and energy consumption. To solve For this problem, a 5G network came into being [6]. 5G technology is the latest generation Cellular mobile communication technology. The performance goal of 5G is high data rate, Reduce delays, save energy, reduce costs, increase system capacity and increase Scale equipment connection. 5G network operators are facing large 5G base stations

At the same time as the construction investment cost, it also has to face huge power consumption. High electricity bills. Taking China Unicom as an example, the electricity bill in 2018 was 13 billion yuan, while the pre-tax profit for 2018 was 12.1 billion yuan [7]. According to the data in the literature [8], information and communication technology in terms of emissions. The industry has caused 2%~3% of global carbon dioxide emissions, which is about1/4 of global car carbon dioxide emissions. 5G network achieves green Wireless network will reduce carbon dioxide emissions. In the 5G network energy consumption, the energy consumption of base station equipment accounts for 80% of the total energy consumption. Therefore, reducing the energy consumption of base stations in the development of green wireless communication.

1.2 Base station energy consumption model

The base station is the public mobile communication base station, the mobile device access mutual Networked interface device. The base station is broadly divided into the macro base station (macro base station, MBS) and small base station (small base station, SBS) 2 types, and small base stations can be divided into micro base stations according to the size of the coverage area Station, pico base station and flying base station [10]. The classification of 5G base stations is shown in Figure 1. Show. Driven by the exponential growth of wireless data traffic, Network quality, signal coverage, and guarantee in the designated planning area Service quality, the number of small base stations is increasing [11]. Although the small base station function Compared with the power consumption of macro base stations, the power consumption is very low, but due to the huge number, its total power consumption may be greater than the power consumption of the macro base station. Various base station signal coverage Networks, also known as a cellular networks, can provide time and space without changing Line communication [12].

1.2.1 Component model

The base station is the core equipment of the mobile communication network.

The main energy-consuming equipment of the letter network. The power consumption of the base station comes from different groups such as Components, including power amplifier, signal processing unit, antenna, and cooling [2]. Literature [13-14] split the energy consumption model based on actual hardware and architecture: digital baseband power consumption PBB, radio frequency (analogue) circuit power consumption PRF, power Amplifier power consumption PRA, and power consumption including power system and cooling part.

The specific formulas for these parts of Powerhead are as follows:

$$Ptotal = PBB + PRF + PRA + Poverhead \quad (1)$$

PBB is expressed as a digital baseband power consumption model in the literature [5] as:

$$PBB = PCPU + P\,OFDM + Pfilter + PFD + PFEC \quad (2)$$

Where: PCPU is idle mode power consumption; POFDM is orthogonal frequency division multiplexing (Orthogonal frequency division multiplexing, OFDM).

The power consumption of the process; Pfilter is the power consumption of the filtering; PFD is the frequency domain processing power Power consumption; PFEC is the power consumption of the forward error correction process. According to the literature [15], all variables in equation (2) depend on the weather Number of lines and bandwidth. In addition, only PFD and PFEC are flow-dependent. The power consumption model is divided into two parts, namely the power amplifier and other circuits Power consumption, the circuit loss is divided into static power consumption and dynamic power consumption, static Power consumption is mainly used for the circuit operation of the system, and dynamic power consumption is mainly used for Information processing of all nodes. The specific formula is as follows:

$$Ptotal,\ n = \kappa Ptrans,\ n + Pstatic + \xi \sum k = 1\ Kn\ Rn,\ k \quad (3)$$

$$Ptrans = \tau Pt \quad (4)$$

$$Ptotal = \sum n = 1\ N\ Ptotal,\ n \quad (5)$$

Where: Ptotal, n is the total power of base station n; Ptrans, n is the power of base station n

Rate amplifier power; Pstatic is static power consumption; Rn,k is dynamic power consumption;

Kn is the number of dynamic power nodes to be processed by base station n; N is the base Total number of stations; Pt is the transmit power of the power amplifier; τ is the peak average power. Rate ratio, its value is determined by the base station type and modulation mode; κ is the base station's. Power amplification factor; ξ is the power consumption per unit transmission bit rate.

1.2.2 Linear model

Literature [7] selects a certain manufacturer's 5G base station and uses the 5G base station The energy consumption test method and the wireless utilization rate service loading method, through the actual The international test obtains the

5G base station wireless utilization and Relational data of 5G base station energy consumption, fitted by linear regression algorithm To the 5G base station energy consumption model. 5G base station energy consumption can be used well Power model to approximate, in which the total energy consumption of the active transmitting base station The power consumption is affine/linear with its business load, and the corresponding slope is determined by the power Amplifier efficiency is determined [3]. This linear model has been widely used in research. Widely used, especially in research considering base station sleep strategy, Literature [7] selects a certain manufacturer's 5G base station and uses the 5G base station. The energy consumption test method and the wireless utilization rate service loading method, through the actual For example, in the literature [1, 3, 8-9], the specific formula is as follows:

PBS = {Pactive = Pfix + ηt Pt Base station activity mode
Psleep Base station sleep mode

In the formula: PBS is the base station power; Pactive is the base station active mode power;

Pfix is the fixed power; ηt is the efficiency of load-related power consumption; Psleep is the base: The station's power in sleep mode.

For small base stations, most of the power is consumed in the power amplifier.

The rate of the macro base station is different, and the load-dependent power amplifier is no longer. The main power consumption components [2]. Its transmission power Pt varies with the business increase in Load is only a small increase, such as when the business load goes from 80% When it is increased to 100%, the power of the small cell only increases by 0.07 W. therefore, It can be assumed that the power consumption of the macro base station increases with the increase of the service load, and the small base station notation power consumption has nothing to do with Load [10], PBS is a constant.

1.2.3 Heterogeneous Network (HetNet) Model

To meet the increasing communication demand, the types and specifications of base stations. Modes are also increasing, and HetNet is thus formed. HetNet solved The problem of mobile network coverage and capacity [1]. The difference in the urban environment In the deployment of the base station, the article [15] considers more access to the edge calculation HetNet (MEC-H) architecture, when the small cell is at the physical layer and radio frequency In the split mode, since the baseband processing takes place in the macro base station, its power consumption mode Type does not include the corresponding baseband power consumption PBB; on the contrary, the corresponding PBB is When added to the macro base station, the power consumption of the macro base station is shown in equation [7].

PBS = (P MBS BS + ∑i ∈ ζ PBB,i MECH architecture P MBS BS HetNet architecture

Where: P MBS

BS is the power consumption of the macro base station; PBB, i is the baseband power of the small base station i

Consumption; ζ is the physical layer and radio frequency separation mode including small base stations gather.

1.3 Significance of 5G network energy consumption control

In the context of the energy Internet, 5G networks are popular, compared with 5G networks. Mobile communication (4th generation mobile communication, 4G) network energy consumption is higher in the fourth generation. On the one hand, the 5G transmission rate will be doubled, and 5G base stations will process massive data. The computational power consumption of the 5G indoor baseband processing unit will be higher than that of 4G.Great improvement. As far as the single macro base station is concerned, according to China Tower Materials, 5G, The typical power consumption of a macro base station single system is 3~5 kW. The manufacturer announces a single Active antenna unit (AAU) power consumption. At around 1 000 W, some manufacturers in the industry have announced the configuration of S1/1/1 single station, and the minimum energy consumption is up to 2 660 W. In-room baseband processing unit (Building baseband unit, BBU) The power consumption of the equipment is single half-width board is about 250 W [3]. The long-term 5G single base station power consumption is expected to be reduced to 2.5 kW. About 2 times the power consumption of a 4G single base station; on the other hand, 5G. The number of network base stations is larger because 5G networks are mainly deployed in High-frequency band, single station coverage becomes smaller, to achieve the same as 4G network

2. Literature Review

In traditional cellular networks, base stations are usually densely deployed To meet the peak business load, which will be in the low business load period. It is like early morning, causing unnecessary energy consumption to many lightly loaded base stations. Consumption [3]. Taking this observation as a reference point, the main point is that the shutdown does not have Excessive resources needed to avoid energy waste [4]. Based on network architecture set Sinochem processing, cloud computing platform and wireless energy-saving solution technology application, benefit Use the volatility of network service load in time and space to achieve In the case of low traffic, turn off the high frequency and try to migrate users to the low frequency, that is Carry out communication load transfer, especially in the 00:00-06:00 time period Take base station sleep mode. Available through the artificial intelligence big data application association, At the same time, build a correlation model between energy saving and performance. According to the communication load, Divide the working status of mobile networks or base stations with different load levels, and Dynamically adjust energy-saving parameters according to mobile network or base station load, for example, Adopt the off system, of the carrier, off the channel, off the frequency band and load balance, etc. Dynamic adjustment measures to adjust the transmission power of each base station to achieve the basic. The effect of station coverage area expansion and contraction [3].

A large part of the energy consumption of the base station is used for main power, cooling, Idle mode processing with little or no traffic load. The base station may consume more than 90% of the peak energy of the base station itself. The unloaded Pico base station consumes less of the power consumed by the fully loaded Pico base station 92.9%. The use of base station sleep technology needs to consider user perception, Base station type, base station location, and signal coverage. Literature [28] is A survey of green 5G systems shutting down base stations in HetNet. Should The literature focus on pure energy saving or other performance

trade-offs related to energy saving, questions ranging from random, distance-aware, load-aware, auctions, etc.
From the perspective of calculation, various base station shutdown strategies are proposed, and base station shutdown strategies are also considered Interruption strategy and user association, resource allocation, physical layer interference cancellation, etc.
Slightly joint design. Literature [9] is analyzing the 5G ultra-dense base station network Based on the network structure, through the analysis of the status quo and user needs, in With the support of genetic algorithm, a cluster sleeper based on genetic algorithm is constructed. Sleep method, realizing the dynamic matching of energy consumption in time and space The low-load base station enters the dormant state.

2.1 Distributed clean energy power generation

In the wireless communication network, deploying an energy collection base station (Energy-harvesting base station, EHBS) is a very Prospective solution [3]. Energy harvesting base stations can use distributed Energy harvesting facilities such as photovoltaic power generation and distributed wind power generation to meet Base station energy requirements. In the energy Internet system, configure the base station. A certain amount of distributed clean energy has become a solution to mobile networks.
A potential solution to high energy consumption and environmental problems [1]. So we Can obtain cheap and clean renewable energy, reduce or even replace energy purchased by the grid [12]. At the same time, widely distributed in various regions. 5G network can alleviate the difficulty of clean energy generation and consumption in some areas.
The status quo increases the penetration rate of clean energy. However, affected by the weather, Renewable Energy is usually randomly distributed in time and space. It is difficult for different base stations to operate for them using only the energy they collect. Provide power to overcome the instability of distributed clean energy, based on. The station can be configured with a responsive energy storage system and keep the supply and demand relationship with Tie's distribution network.
Literature [3] pointed out that cooperative renewable energy management Optimize together among multiple users who have common economic or environmental goals Strategies for energy harvesting facilities. This model can be applied to bee Network, operators can deploy a centralized energy field in it To power base stations in a given area. This method is for each base station Equipped with your energy harvesting device and alternative method of storage equipment Compared with the traditional power grid, the energy Internet system allows Two-way communication and energy flow between the two [3], which promoted the 5G network and The concept of grid energy cooperation allows 5G network operators to communicate Over-configured clean energy system or energy storage system, and grid operators Interactively reduce electricity expenditures and carbon emissions. Through big data technology, Grid operators can Stations perform power scheduling, allowing 5G network operators to participate in power grid peak shaving, Reduce costs, increase profits, improve resource allocation, and strengthen Clean energy consumption.

2.2 Energy storage applications

5G networks are popularized, and the functions of 5G base stations are developing towards comprehensive functions. To meet its reliability, there is a more diversified power supply for base stations Require. The ``2019 China 5G Communication" issued by the Advanced Industry Research Institute Analysis Report on the Development of the Lithium Battery Industry " [4] Show that China 5G Communications. The deployment of base stations will drive the demand for 160 GW·h of distributed energy storage systems. To prevent power outages caused by bad weather or man-made accidents, base stations usually Install the battery pack as a backup power source. The length of the battery system in the communication base station Period is in the backup power work mode, resulting in lower asset utilization [5]. Large-scale distributed energy storage systems can be configured by grid operators, It can also be configured by 5G network operators. To ensure the real-time and reliability of communication, it is equipped with an uninterrupted power supply Uninterruptible power supply, UPS), which has power storage. The pool has become a dual cluster of electrical equipment and energy storage equipment. Also, to improve reliability, the base station uninterruptible power supply is usually a redundant configuration.
The macro base station has wide signal coverage and high base station power, which requires energy storage. The system is used as a backup power source to ensure the stability of the power supply [6]. Foresight China's 5G base station energy storage for 2019-2023 compiled by the Industrial Research Institute Demand budget situation [7] Shows that the power of the 5G macro base station is 2.7 kW, The emergency duration is 4 hours, and the capacity of a single base station is 10.8 kWh. Existing 4G, 5G small and micro base stations are not equipped with backup battery packs and generally communicate directly.
Directly supply power through the city grid, but with the increase in the number of small base stations, The proportion of business in the 5G network has increased, and its power outage will affect the operation of the 5G network. The influence of indicators and customer perception cannot be ignored. Therefore, for the future small cell, It is imperative to configure backup power. Literature [11] introduces China's migration Dong Henan Zhoukou Branch independently developed 4G and 5G small and micro base stations. A new type of integrated uninterruptible power supply with a full configuration of 1 000 VA, which can improve It provides two outputs of AC and DC, which solves the problem of 4G, 5G small and micro base stations and pull The remote station has no backup power problem. The backup power supply for traditional communication base stations is mainly lead-acid batteries. Compared with the echelon lithium iron phosphate battery, the battery has a short service life, Disadvantages of low performance and a large amount of heavy metal lead. The battery only serves as The use efficiency of standby power is extremely low. Echelon use of lithium iron phosphate batteries It has a very high energy density and supports high charge and discharge cycles, which can be Participate in power grid peak and frequency modulation as an energy storage power source. Although the current echelon.
The application can bring the following to grid operators and 5G network operators three advantages. Such as follows:

1) Large-scale access to volatile and intermittent renewable energy will Cause the uncertainty of power grid stability and green base station power supply, with the help of Distributed energy storage technology can improve the impact of 5G networks on distributed clean

Energy Absorbing capacity, which can smooth the fluctuation of the access to renewable energy. The role of slippery and friendly access.

2) In the context of the Internet of Energy, the traditional source-network-load model has no Method to solve the problem of resource constraints and load demand differences due to the layout of transmission corridors. The contradiction between continuous growth and the introduction of large-scale loads such as 5G base stations Distributed energy storage can effectively alleviate conflicts and delay the renewal of grid equipment. Invest to improve the utilization of network resources and facilities.
3) The energy consumption of the 5G network is schedulable to a certain extent and coordinated with the distributed energy storage can be used as an excellent demand response resource, providing high-quality, individual.

2.3 Collaborative energy consumption management and control methods

Most of the literature does not use a single technology or method to advance to solve the problem of energy consumption management and control, as the problem of energy consumption management and control involves at least. There are two main bodies: grid operators and 5G network operators. To achieve the energy consumption management and control target with a more satisfactory effect will involve two main Collaborative optimizations of multiple technologies. From different perspectives, synergy. There are many ways of synergy.

From the perspective of 5G networks, 5G network operators can Information technology to achieve business collaborative optimization; from an energy perspective, energy storage can be Technology, energy harvesting technology, etc. interact with grid energy to achieve energy cooperation Same optimization; combined with the above 2 points, 5G network and energy interconnection can be realized network system collaborative optimization. Literature [12] through 5G network and energy cooperation. At the same time, different base stations use the aggregator in the energy Internet system.

To exchange or share energy, and share wireless resources and transfer to each other Load to reduce the total energy cost; literature [6] Coordinated multiple points of mobile communication operators points, CoMP) transmission technology, base stations and local renewable energy. Power station energy transaction, base station and energy Internet system two-way energy exchange.

3. Methodology

The essence of 5G network energy consumption control technology is energy flow and data flow control, interactive control of data flow and energy flow can be realized by the market the mechanism guides the electricity consumption behaviour on the load side, so as not to affect the electricity consumption experience under the premise of adding additional balanced resources to the grid [5], increasing resource utilization.

3.1 5G Energy Consumption Control Optimization and Energy Internet

Base stations cooperate through wireless communication mechanisms, such as power control, Bandwidth control, sleep mode, and traffic offloading, usually not through a physical connection Connect to form a microgrid [5]. On the energy input side of the micro energy grid, wind. Renewable energy such as light, grid power supply, heating network heating, natural gas, etc.

Various forms of energy complementation can be achieved through the consumption of natural gas, wind/light energy Wait to buy electricity from the grid; on the output side, it can directly provide users with electricity. Comprehensive energy services such as heating and cooling can be realized by direct heating and cooling, To replace the power supply, to realize the use of energy instead. The introduction of AC power in traditional base stations is taken from the owner's distribution box nearby. In the context of the Internet of Energy, 5G network operators can pass the initial Invest in the construction of energy collection devices and energy storage devices supporting 5G base stations. Design an energy self-sufficient power supply, through the energy collection tube Realize that the base station uses renewable energy for off-grid or grid-connected operation, At the same time, the two-way interaction with the grid is realized by adding distributed energy storage devices. To provide ancillary services for the power grid, to obtain the power of the power grid operator Economic incentives. In a certain area, base stations cooperate with distributed clean energy. Distributed resources such as power generation and distributed energy storage devices can manage the transmission lines to form a certain scale of micro-grid, through the connection with the main grid.

Turn 5G network into a flexible load to participate in demand-side management;

The computer room configured in the 5G macro base station has a certain amount of redundant calculation, which can be beneficial Use the superior communication transmission characteristics of the 5G network to satisfy user service In the case of quality, perform communication tasks between the base station and the base station network transmission, thereby changing the number of calculation tasks in the computer room of each macro base station, and then change the energy consumption of base stations in 5G networks.

Above 5G network energy management, the possible development trend of control can be compared with the existing 5G network energy consumption control the methods are combined to form a flexible 5G network energy consumption management and control system.

4. Discussion of Technological innovation and application

5G network energy consumption management and control relies on technological innovation and various aspects of flexible application of Technology. In this regard, this article discusses 5G from the following four aspects Prospects for research and application of network energy consumption management and control.

1) A new generation of low-voltage: DC power supply system from the perspective of grid operators, new power supply technologies can be applied to reduce 5G network energy consumption, literature [6] introduced a new generation of low-voltage DC supply the electrical system directly supplies power to the 5G base station, which not only reduces energy consumption but also avoids the problem of 5G base station power supply AC/DC mixing and electromagnetic induction interference.

2) Mobile charging Technology: When the application of energy storage technology is difficult or impossible, it can apply mobile energy storage to solve the power supply problem of 5G base stations. Literature [4] propose a mobile charger as a mobile data collector and energy transmission device, periodically moving around all sink nodes, due to insufficient energy of 5G base stations to charge or collect the remaining energy.
3) Application of new energy-saving technologies for 5G networks from the perspective of 5G network operators, the application communication load can be deployment and planning technology, base station sleep technology, multi-antenna Technology, collaboration multipoint transmission and other wireless communication energy-saving technologies to realize 5G network energy consumption control. In the application 5G network control symbol turn-off, channel turn-off, Load in terms of wave turn-off energy saving, the literature [7] introduced 5G/Long Term Evolution technology deep symbol shutdown, 5G/Long Term Evolution technology carrier smart shutdown, etc. Energy-saving ideas, by aiming at 5G technology to achieve "people go to the Internet", thereby realizing the energy saving of 5G network.
4) Application of AI big data technology and Internet of Things technology AI big data technology and Internet of Things technology can be combined with 5G network operation. The resources of business operators and grid operators conduct 5G network energy consumption management and control.

Integrate with the monitoring of 5G equipment, and analyze the data collected by 5G base stations through AI information, using machine learning algorithms to analyze 5G network coverage, user analysis. Analyze and calculate the distribution characteristics and scene characteristics, and define the network through software, Adaptive regulation of 5G power allocation and signal processing energy consumption by means And so on, to achieve energy-saving control of 5G network energy consumption.

5. Conclusion

With the popularization of 5G networks and the development of "new infrastructure", power grids are facing more diverse new loads. This article is equipped with an energy harvesting device based on the 5G base station, combined with the characteristics of the 5G network, Distributed clean energy systems, energy storage systems and demand response technologies are in Collaborative application in 5G network energy consumption management and control, through energy flow and data Flow control to reduce the operating costs of 5G network operators. The purpose of a green 5G network. To build a green 5G network, in the follow-up the research needs to increase research efforts in the following aspects:

1) 5G Energy Consumption Management and Control Optimization Under the background of the Energy Internet, Harmonize with the integrated energy system and participate in comprehensive demand response.
2) Given the transferability characteristics of the 5G network data load, the research is based on the electricity consumption behaviour on the load side of the 5G network guided by the market mechanism, and the business model of 5G network operators participating in power transactions.

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