中国电信 CHINA TELECOM ZTE中兴

Remake Green 5G

Mobile Innovation for Climate Action

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Foreword

The impact of global climate change is bringing increasingly severe challenges to the survival and development of all human beings, and it has become a global consensus to move toward carbon neutrality. To solve this problem, all parties need to coordinate to assist countries in their transition to a low-carbon economy. Major countries around the world have pledged to complete national-level carbon neutrality plans by mid-century at the latest. China has pledged to achieve Net Zero by 2060, which is a broad and profound change. As the world's largest developing country and also the largest carbon emission country, China faces the dual challenges of economic and social modernization and emission reduction. From carbon peak to carbon neutrality, it only takes half the time for developed countries to achieve carbon neutrality. The task of achieving carbon neutrality is short and challenging. As an important infrastructure for digital transformation, the mobile communication network focuses on three types of key facilities: data centers, communication base stations, and communication equipment rooms. The Ministry of Industry and Information Technology issued the " Action Plan for Green and Low-Carbon Development of the Information and Communication Industry (2022-2025) " [1] It is required to promote the application and promotion of energy-saving technologies for base station main equipment and supporting facilities and to increase the energy efficiency of 5G base stations by more than 20%. Empowering the whole society to reduce carbon, assisting the green and low-carbon transformation of industries, promoting low-carbon and environmentally friendly living of residents, and promoting the green and smart development of urban and rural areas. China Telecom has been enhancing the urgency and practicality of promoting the Net Zero, building green new cloud networks, and building green 5G base stations. The new green operation fully promotes AI energy saving, creates new green values, and becomes a greener and more Sustainable enterprise. China Telecom Sichuan Branch and ZTE have released a Remake Green 5G white paper, aiming to explore a practical and effective energy efficiency evaluation system with the industry, explore feasible energy-saving and efficiency-enhancing technologies for green networks, and realize the vision and goal of sustainable communication network development.

01 Network Energy Efficiency

Evolve towards a "perfect curve"

Over the past two years, the sudden pandemic has accelerated digital transformation. Telecommuting and online education have been widely accepted. To meet the demand of the public for good network performance anytime anywhere, mobile networks will continue to develop and network traffic will increase to support the digital transformation of society. It is predicted that by 2025, [2] will see at least a threefold increase in network traffic compared with 2021, and the number of global 5G connections will reach 2.2 billion, accounting for 20% of all global mobile users. To avoid a continuous increase of invalid energy consumption of a mobile network, an energy saving and consumption reduction technology needs to be continuously developed.

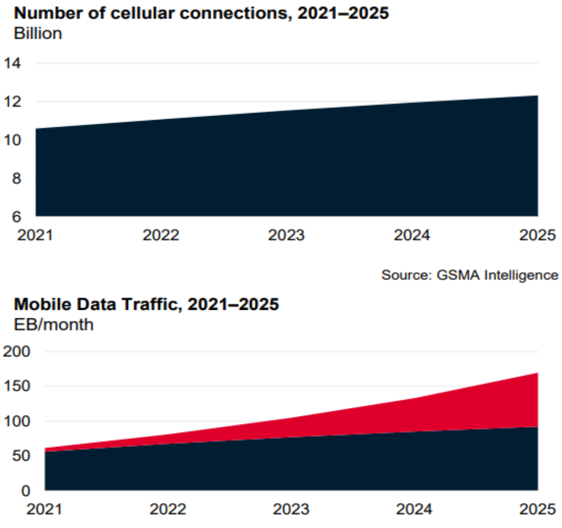


Figure 1 Number of users and data volume forecast (GSMA)

1.1 Energy Efficiency Evaluation Develops in Multiple Dimensions

Network energy efficiency is an effective indicator used to evaluate network energy efficiency. The key to evaluate network energy efficiency is to select reasonable indicators to characterize the rationality and optimization of network energy consumption. The wireless network energy efficiency research conducted by international standard organizations such as ETSI, ITU, and 3GPP focuses on different scenarios and different service types, and proposes the corresponding energy efficiency indicator definitions (energy efficiency indicators = effective network output/network energy consumption, effective output includes traffic, coverage area, delay, and number of connections, etc.):

- In terms of service types, 5G is used as an example to cover three scenarios: eMBB, URLLC, and mMTC.
- In terms of deployment scenarios, some new 5G scenarios are considered, such as slicing, VNF, and network co-construction and sharing.

The existing energy efficiency assessment method preliminarily considers the impact of business scenarios on energy efficiency. Taking ETSI ES203.228 as an example, for eMBB scenarios, coverage scenarios, and delay scenarios, the following energy efficiency indicators are defined:

eMBB scenario

$$EE = \frac{Traffic}{Energy\ Consumption}$$

Wide coverage scenario

$$EE = \frac{Coverage\ Area}{Energy\ Consumption}$$

Low latency scenario

$$EE = \frac{User\ Plane\ Latency}{Energy\ Consumption}$$

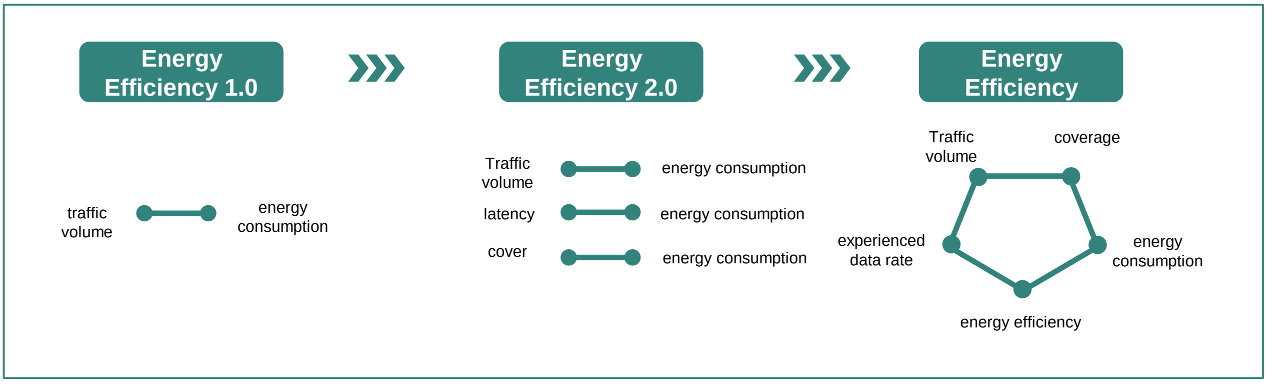
GSMA (Global System for Mobile Communications assembly , Global Mobile Communications System Association) is also continuously researching and evaluating the indicator system of wireless network energy efficiency, trying to describe network energy efficiency from multiple dimensions [4].

- *Energy per unit of traffic (kWh / GB)*
- *Energy per connection (kWh / connection)*
- *Energy per cell site (MWh / cell site)*
- *Energy per revenue (MWh / € million)*

Based on the statistics of thirty-one networks, a single site consumes 28,665 kWh of electricity per year, while the operator spends 140 million kWh/million ohm on electricity bills.

However, with the development of the network, new services and scenarios are constantly emerging. Different service types have completely different requirements for the network rate. Traditional "network-oriented" has been replaced by "user-oriented". Single traffic energy efficiency indicator cannot be used to represent network energy consumption and efficiency, and must be evaluated from traffic, coverage, delay evaluation to traffic, energy consumption, experience, and energy saving, all combined together.

In order to obtain more comprehensive network energy efficiency, guide the corresponding network energy saving strategies, and select the best energy efficiency network for service bearing, the energy efficiency identification system must be continuously updated and evolved. According to the differences of service focus in different scenarios in different phases of network development, more reasonable multi-dimensional indicators shall be selected for energy efficiency evaluation. Building a multi-dimensional energy efficiency model and selecting the optimal network layer are the first factors that guide the subsequent energy saving strategy selection.



1.2 "Perfect Curve" is the goal of energy efficiency of communication network

Facing 2030 and the future, human society will enter an intelligent era, the digital world and the physical world will be seamlessly integrated, social services will be balanced and high-end, social governance will be scientific and accurate, and social development will be green and energy-saving. The sustainable development of economy, society, and environment and the innovative evolution of technologies will drive the continuous iterative upgrade of mobile communications technologies from 5G to 6G, and promote the expansion of to ubiquitous interconnection, inclusive intelligence, multi-dimensional perception, full-domain coverage, green and low-carbon, and secure and trustworthy directions [5].

Table 1 Comparison of key indicators between

key indicator	5G	6G
peak rate	20Gbps	1 Tbps
experienced rate	0.1Gbps _	1Gbps
maximum spectrum efficiency	30 b/s/Hz	60 b/s/Hz
maximum bandwidth	1GHz	100GHz
efficiency	undefined	1Tb/J
latency	1 ms	0.1 ms
jitter	undefined	1 μs

In addition to the key values of energy efficiency, the key indicators of the 6G network also put forward the technical requirement of "zero-load zero-carbon". It is necessary to incorporate the energy-saving and emission-reduction concept into the system design, technical innovation, product design, and network O&M to support the green and sustainable development of the network.

However, the energy consumption of existing network equipment increases stepwise and leapfrog. There is still a great waste of energy consumption under zero load, and the network energy efficiency cannot be kept in a high efficiency state. We define linear increase of energy consumption and load requirements as "perfect curve", that is, the energy consumption perfectly matches the requirements.

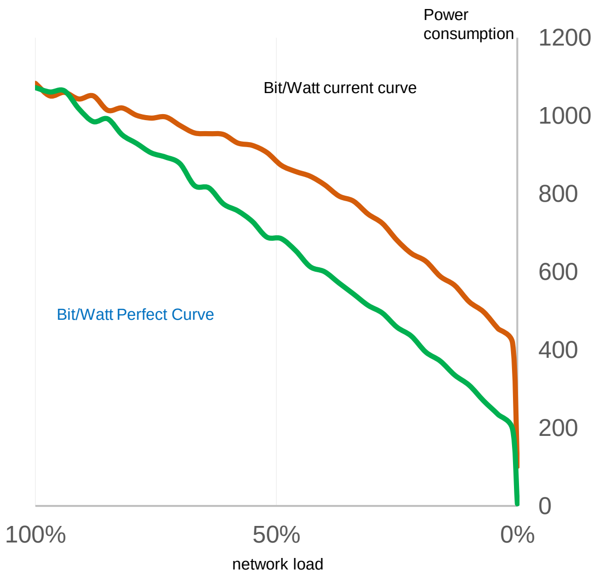


Figure 2 Bit/Watt perfect curve

02 Technology Innovation

Explore “zero-load zero-carbon”

In China, 5G base stations are being constructed as planned. As of August 2022, there are totally 2.102 million gNodeBs in China and 677,000 new in 2022, accounting for 19.8% of the total mobile base stations [6]. The GSMA reports that the power consumption of the wireless access network accounts for 73% [4] of the communications network. In general, a 5G macro base station consists of one BBU and three AAUs. The power consumption of a gNodeB includes that of the main equipment (BBU and AAU), air conditioners, power distribution, and others. The energy efficiency and service load of the main equipment and auxiliary equipment such as power distribution for air conditioners affect the energy consumption of the gNodeB. With the change of the service load ratio, the power consumption of the main equipment also changes, especially the AAUs [7].

Table 2 Actual Energy Consumption of Main 5G Equipment(2020)

Traffic Load	Vendor A		Vendor B	
	Average Power Consumption of AAU (W)	Average Power Consumption of BBU (W)	Average Power Consumption of AAU (W)	Average Power Consumption of BBU (W)
100%	1130	295	1180	325
50%	895	295	960	325
30%	765	295	860	320
20%	735	295	800	320
10%	700	295	740	320
Idle	635	295	665	320
Deep dormancy	150	295	200	320

Table 2 shows that in the medium-low load scenario, the energy consumption is still high. Regarding the energy consumption of the equipment itself, the first is to tackle the problem of high energy consumption and low energy efficiency under medium-low load.

2.1 AAU hibernation, explore “zero-load zero-carbon”

To reduce the power consumption of base stations, vendors and operators are continuously exploring green technologies. The downlink power optimization, symbol shutdown, channel shutdown, 4G/5G co-mode collaborative shutdown of BS, and deep sleep effectively reduce the power consumption in static and low-load scenarios, however, there’s still a long way to go.

Currently, the energy consumption in deep sleep is kept at a hecto-watt level in industry. Although an external smart circuit breakers system can make the energy consumption less than 10 watts in zero-load state, problems such as equipment condensation, reliability decrease, repair rate rise, and abrupt user perception change cannot be solved effectively. "Zero-load zero-carbon" should start with the epuipment itself.

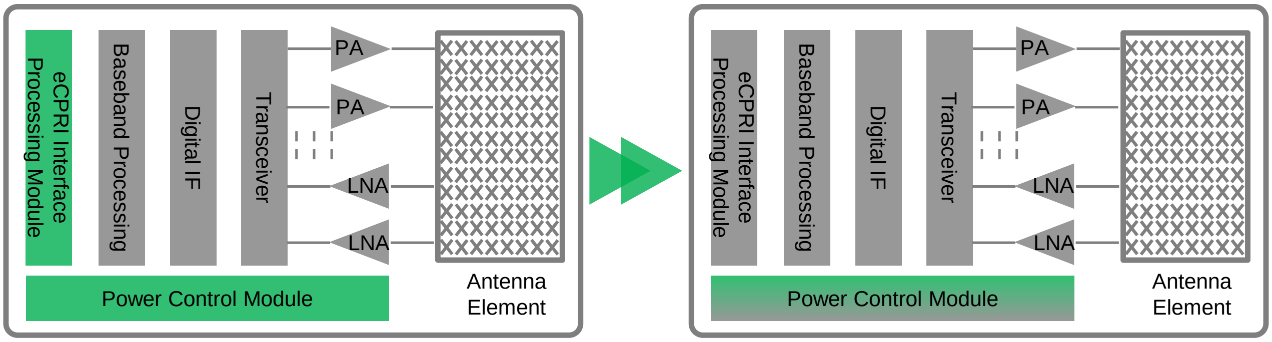


Figure 3 From Deep sleep to AAU hibernation

The AAU hibernation technology is a "zero-load zero-carbon" energy-saving technology that integrates software and hardware in a collaborative manner. It is a multi-mode hybrid modeling supported by in-depth multi-dimensional research to coordinate the self-adaptive energy-saving technology. Commercial trials have proved the nearly zero carbon emission. Working with the dynamic AI energy-saving policy of "one-site, one-plan", flexible network deployment and accurate energy-saving can be achieved. Meanwhile, it can collaborate with the symbol shutdown, channel shutdown, and deep sleep technologies in the existing network.

However, technology innovation is also facing huge challenges - impact on equipment imposed by frequent starts and stops. This requires continuous research and exploration in System on Chip (SoC), hardware shutdown, and software protection to promote the evolution and development of auto start and stop technologies.

Chip Design

During the architecture and hardware design of the chip, modules should be isolated and the intent be precise. The power-on and power-off sequence during the start-stop process must be simple and easy to control. The followings should be considered.

- Capable of flexible pin configuration and reverse current protection for the chips and components before AAU hibernation.
- Improves the capability of the pins to withstand the reverse current within a certain range.

Hardware Design

The AAU boards should be flexibly controlled in different levels. The board hardware should support natural protection of sensitive components such as power amplifiers and low-noise amplifiers before AAU hibernation.

- During the AAU hibernation process, the hardware should be designed to allow all levels of components to be started in accordance with specific time sequences, reducing the impact on power modules, digital chips such as digital IF chips, and power amplifiers.
- Frequent starts and stops may cause reverse current. Therefore, each core chip must work together to give protection. To provide reliable protection for chips and hardware, inter-chip communication and handshake collaboration ensure correct protection sequence.

Software Coordination

Initiation of AAU hibernation procedure (the user migration procedure must be completed in advance to ensure user experience):

- After receiving an AAU hibernation command, the AAU checks the command.
- The software protects the operating system and file system, and implements on-site protection and backup. It protects the detection and alarm system.
- The main control board notifies the baseband, digital IF, and IF chips to enter the shutdown flow of components capable of AAU hibernation through inter-chip communication.
- Shut down sensitive amplifier components such as PA, amplifier, and LNA.
- The driver layer shuts down internal modules in accordance with the specified protocol and time sequence, and manages/configures chip pins and prevents reverse current. .
- Notify the power management SoC to enter the shutdown process.
- The power management SoC, records the reason for shutdown, and configures the timer.
- The power management SoC can shut down the power buses of each part of the equipment.

Exit of AAU hibernation procedure (The entire duration should not be longer than five minutes, almost equal to that of a deep dormancy):

- The power management SoC automatically calculates the time and starts the exit process at the specified time.
- The power management SoC recovers the main control SoC. The main control SoC automatically completes the loading and initialization, and takes over the exit procedure.
- The main control SoC and the power management SoC work together to load and initialize core chips such as the baseband, digital IF, and IF through inter-chip communication.
- The baseband, digital IF, and IF chips respectively complete the component enabling flow of their corresponding links.

2.2 Envelope Tracking - MS-level Voltage Adjustment Improving PA Efficiency

RF equipment, including RRUs and AAUs, act as bridges to provide stable and reliable channels for user information exchange and ensure accurate and real-time delivery of information. They convert a group of baseband digital signals into radio waves through complex and intricate circuits, and sends them out through antennas. At the same time, they receive messages from UEs and transmit them to the core network for information interaction.

There are many dimensions for RRU/AAU performance evaluation, such as volume/weight, overall output power, number of channels, and overall energy efficiency ratio. On the premise of the same transmit power and the same number of channels, the key indicators of an RF equipment regarding competitiveness is the overall energy efficiency and RF indicators. Based on Table 2, the overall energy efficiency of the existing network products is relatively high when the service load is full. However, the overall energy efficiency drops sharply when the load is medium or low.

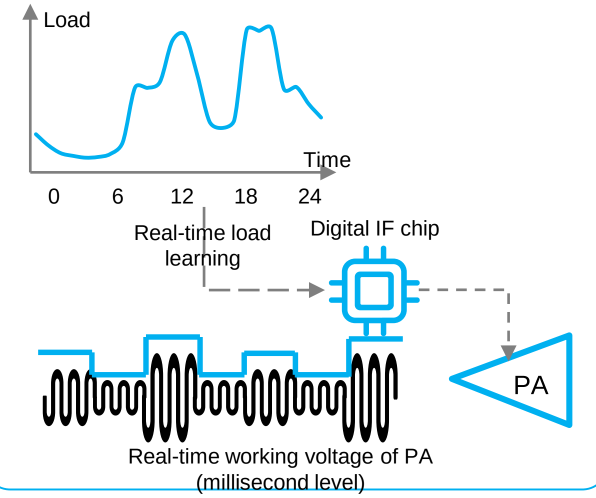
Table 3 Energy Efficiency of Main 5G Equipment

Traffic Load	64TR/320W	
	Avg. Power Consumption(W)	Entire Efficiency
100%	1130	28.31%
50%	895	17.88%
30%	765	12.55%
20%	735	8.71%
10%	700	4.57%
Idle	635	2.52%

The higher the energy efficiency of the RRU/AAU, the less the heat consumption. Among the RF equipment, the efficiency of a power amplifier which consumes the most energy greatly affects efficiency of the entire equipment. In order to achieve the stable 320W output, the working voltage of the PA is relatively high. However, when the output power does not reach 320W, higher working voltage means more invalid heat consumption, which reduces the entire efficiency. Currently, dynamic voltage adjustment is commonly used in the industry to match the actual transmit power to reduce the PA operating voltage and improve efficiency.

However, in the actual implementation of dynamic voltage adjustment, the values of EVM (Error Vector Magnitude) and ACPR (Adjacent Channel Power Ratio) are easily affected, resulting in the short-term deterioration of wireless performance. In addition, the dynamic voltage adjustment technology cannot match the load in real time. To pursue perfect amplifier design and improve the algorithm performance, the new-generation RF equipment supports the envelope tracking technology - millisecond-level voltage adjustment.

Figure 4 Envelope Tracking



To implement envelope tracking, the most important thing is the coordination between software and hardware. This is not simply hardware PA voltage adjustment. To better adapt to real-time load, deep load learning and prediction are required for millisecond-level adjustment. The algorithm in digital intermediate frequency processing needs to ensure that wireless performance does not deteriorate during the voltage adjustment process. Therefore, the real-time matching and coordination between hardware design and software algorithms are very important.

Time selection for adjustment: Common 5G frame formats include 2.5 ms single-period, 2.5 ms dual-period, and 5 ms single-period. The adjustment time is set to the uplink frame; when the downlink frame is sent, no adjustment is performed. That is, the operating voltage is adjusted at the millimeter level but is not adjusted every millisecond to reduce the impact on performance.

Real-time adaptation of the CFR (Crest Factor Reduction) algorithm: A peak clipping processing needs to be performed properly for EVMs of wireless transmit signals. Under different output powers and operating voltages, the peak clipping should be implemented adaptively in real time, so as to reduce a Peak-to-Average Ratio of output signals, thus decrease the rollbacks of output PAs, and ensure relatively high efficiency of the PAs. The proper CFR algorithm reduces the maximum peak-to-average ratio of signals, minimizes EVM deterioration, and ensures the integrity of transmitted signals after voltage adjustment.

Real-time adaptation of a DPD (Digital Pre-Distortion) algorithm: Pre-distortion processing is performed on a transmit signal, and parameters such as an amplitude, a spectral component, and a phase characteristic of an input signal are adjusted, so that when the input pre-distortion signal passes through an ACPR nonlinear circuit, nonlinear superposition correction is generated, so as to meet an ACPR requirement.

03 Intelligent Base Station

Edge decision-making boosts performance

Information flow moves from terminals – air interface - AAU/RRU/BBU – transmission network –core network to Internet. As the central part of information flow, base stations also known as gNBs are widely distributed. Located the nearest to end users, gNBs have more real-time data that can be used to balance network requirements and energy consumption.

The computing power enables gNB's additional perception capabilities, including user service requirements, real-time user location, network traffic/load, and network energy consumption. The gNB then can accurately predict user behaviors and network load to formulate near-real time energy-saving policies, and guarantee user experience and network performance in real time. This is an inexorable trend of network intelligence development.

The gNB can identify network coverage on the network layer based on frequency information and Measurement Report, and enable energy-saving technologies such as carrier shutdown, deep sleep, and automatic start and stop. It analyzes user locations and service requirements in accordance with grids, establishes a knowledge base, and predicts near-real time load based on second-level load information to accurately guide users and redistribute network users under the prerequisite of guaranteeing user perception. Intelligent multi-layer network carrier shutdown and on-demand wakeup are implemented in accordance with network energy efficiency to achieve optimal network services with optimal capacity, ensuring the network capacity, and minimizing network energy consumption.

Communication technologies such as real-time positioning and TTI-level resource scheduling can be integrated into the time series prediction (LSTM: Long Short-Term Memory) and K-Means clustering algorithm commonly used in the IT industry, implementing the gNB-level high-real-time and complex energy-saving policy, user perception, and closed-loop network performance. With accurate matching at the second granularity, the system can respond to traffic burst in real time, and implement rapid decision-making at the edge to boost network performance.

3.1 Flexible Multi-frequency-layer, Best Macro Coverage Energy Efficiency

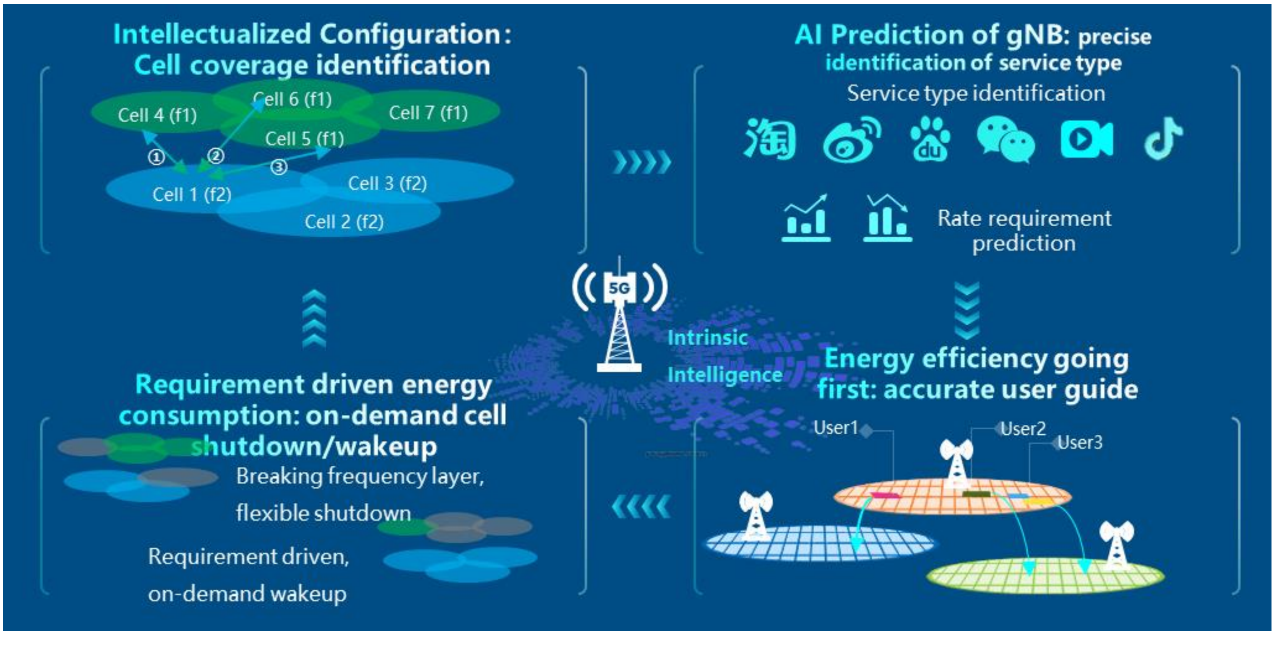
In the 24 hours of a day, services are divided into idle hours and busy hours, and the coverage of each network frequency layer is different. For example, the multi-frequency multi-system network is mainly used in towns and counties, and the network energy efficiency is also different.

Energy saving in the existing network is generally fixed at the frequency layer, for example, 5G energy saving or capacity layer energy saving. However, resources related to the capacity layer/coverage layer in many coverage areas are similar. This needs to break the fixed energy-saving relationship, implement flexible frequency-layer energy-saving as required, and wake up the minimum gNB set as required to improve macro-coverage energy efficiency.

Based on the current gNB's edge computing power and existing information data, the gNB performs real-time big data statistics and analysis on the measurement reports of UEs, calculates the coverage overlapping degree in accordance with the signal strength of the local cell and the signal strength of neighbor cells, implements cell-level frequency-layer coverage relationship groups, and provides reference for flexible frequency-layer energy saving in the future.

- A cell is divided into multiple logical grids in accordance with the measurement results in different locations in the cell. UEs in the cell periodically (every five seconds) report intra-frequency measurement, and sufficient valid sample data is filtered. Each sample data can contain the ID and RSRP value of the serving cell. Stronger cell ID and RSRP values of two intra-frequency neighbor cells.
- Locate the grid based on the triangle location of the local cell/strongest intra-frequency neighbor cell/second strongest intra-frequency neighbor cell. The events that occur on this grid are recorded, including inter-frequency/inter-system measurement reports (frequency point information, cell IDs in the measurement reports, and RSRP/RSRQ/SINR values in the measurement results), and handover success rate to a neighbor cell. Identify the service type of the UEs and predict resource requirements.

After the gNodeB predicts the related frequency-layer coverage relationship, user services, and resource requirements through large data analysis s and AIs, it can accurately implement network user redistribution, and coordinate and integrate multi-frequency and multi-system resources. In addition, the grid information of users can also guide flexible shutdown/on-demand wakeup.



3.2 Digital Indoor Distribution Auto-sensing

With the gradual improvement of 5G network construction, the focus of current network construction has moved from single-frequency 5G network to dual-frequency 5G network, from wide-coverage macro station construction to delicacy indoor distribution and hot-spot construction. Digital indoor distribution can effectively carry massive indoor services, and is a common solution for indoor deep coverage.

Currently, logical cells are the minimum energy-saving unit. However, in most cases, the digital indoor distribution system uses co-logical cells for RF combination as the common deployment scenario. Because indoor distribution usually has coverage impact due to corridors and partitions, RF combination can greatly reduce the indoor handover rate and improve user experience. However, the distribution of indoor traffic is not even. In the case of energy saving based on logical cells, many digital indoor distribution headend have no load requirement and are still transmitting blank signals, which not only consumes power but also causes interference to neighbor cell coverage. However, in shopping malls and supermarkets, the demands of cinemas, KTVs, and other single-point scenarios also cause the entire digital indoor distribution system to fail to enter energy saving status under low loads at night.

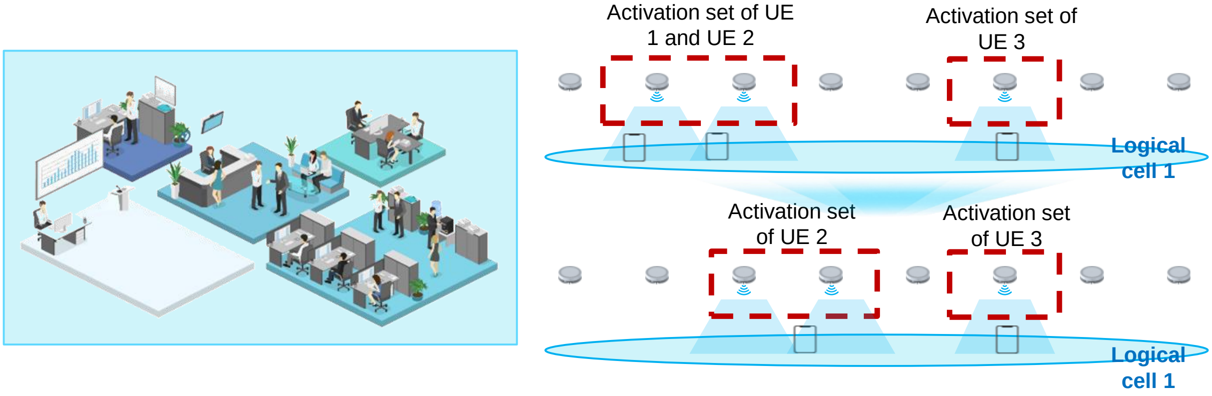


Figure 5 Motion sensor style auto-sensing energy saving

To solve this problem and improve the energy-saving efficiency of digital indoor distribution, it is necessary to break the limitation of energy-saving by logical cells and directly apply the technology to the headend signal equipment of digital indoor distribution. The gNB may determine, according to strength of an uplink signal received by each headend equipment , whether a UE user exists in a coverage area and whether a service requirement exists. Each headend pRRU is always sensed. Signals are sent only when users and service requirements are sensed in real time, and the rest time is in silent to implement precise energy saving of digital indoor distribution, and energy is consumed only when the requirement is met.

04 Platform Intelligence

Global control to approach the perfect curve

With the continuous development of machine learning, the application of IT technology to the CT domain (Communication Technology) can well solve the problem of in-depth deployment of energy-saving , and this is an inevitable trend brought about by platform intelligence in the industry. AI and big data analysis are used to realize scenario identification and deep learning of cell-level load development trends, coordinate energy-saving technologies in the time, space, frequency, and power domains, and approximate the "perfect curve" of network energy consumption/network traffic.

4.1 Overview of Intelligent Platform Design

- **Data processing :** Data collection and development, including performance data, cell scenario data, and cell configuration data. Single-domain inter-domain information of China Telecom.
- **AI algorithm design:** Time series model (such as ARIMA, multi-order exponential smoothing, and LSTM), regression tree model is used for classification, and K-Means or DBSCAN can be used for clustering.
- **Cell value evaluation:** Comprehensively evaluate the accuracy and accuracy of the model and the consumption of hardware resources (memory/CPU), and select the optimal model as the evaluation quantity of the cell.
- **Energy saving scheme design:** Based on the coverage identification information and user perception information, independent prediction and joint determination are implemented to achieve multi-frequency and multi-system all-network collaborative energy-saving.

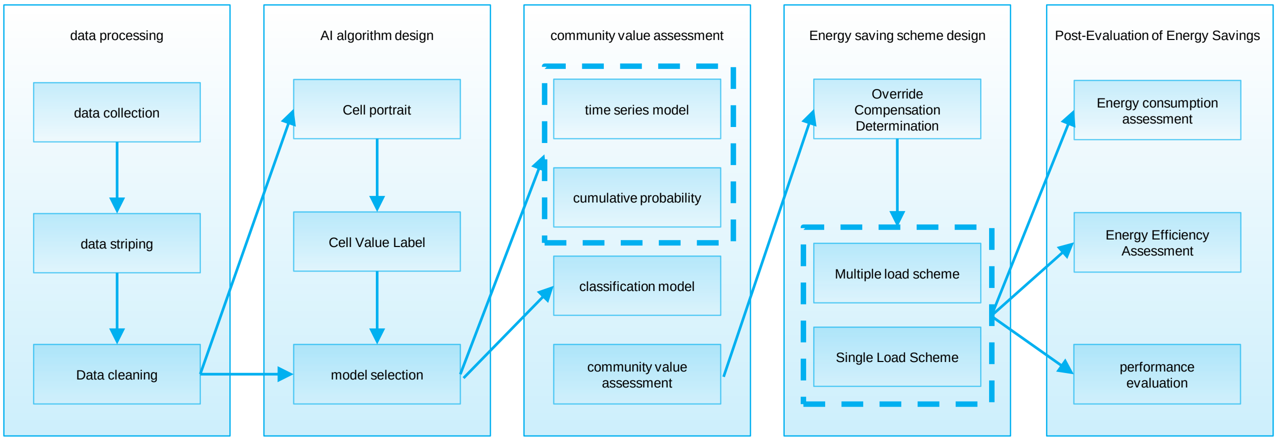


Figure 6 The whole process of intelligent platform design

4.2 "One Station, One Strategy“: Identification, Deployment and Self-optimization

Scenario Identification

The traffic distribution of cells in different application scenarios shows a certain aggregation rule, including the weekly trend and daily trend. The system obtains network capacity information from the existing network data, and uses the AI clustering algorithm to obtain the traffic load distribution characteristics of related coverage scenarios for subsequent scenario identification.

- College/Office buildings: High in the week, low in the weekend, and single peak fluctuations in the weekends.
- Supermarket/Park: Low weekends and high peaks in the evening, higher on Saturday than Sunday
- Residential area: It has the same trend at weekends, but shows a small peak at noon and a large peak at night.
- Subway: Obvious heavy load and double peak load in the week, and stable load without peak load on weekends

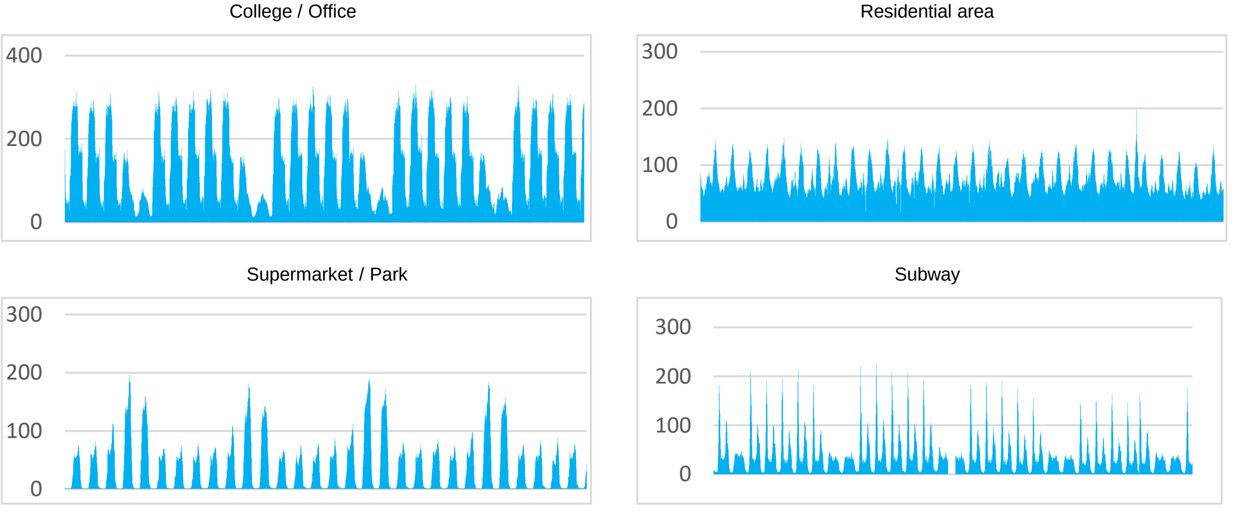


Figure 7 Load variation characteristics in different scenarios

Strategy deployment

Based on the prediction result of the cell service change trend and operator requirements, the system distinguishes coverage scenarios, blacklists and whitelists, and value areas, and generates the optimal energy-saving policy for energy-saving cells.

- Service load prediction analysis: AI service load is predicted through deep learning. Select low-load energy-saving cells based on the service load prediction result of each cell.
- Service sharing capability analysis: Capacity layers and coverage layers are distinguished, and co-covered cells are selected as compensation cells to share service load.
- Energy saving policy matching: Generates an energy saving policy in accordance with the policy rule (shutdown threshold, time period, duration, and power saving type).

Self-optimization

For energy saving, the higher the shutdown threshold is, the better the energy saving effect is. However, in the traditional energy saving solution, the shutdown threshold is set to a conservative value to avoid energy saving effect. By using the KPI rollback self-optimization policy, you can find the turning point between the energy-saving threshold and network performance to maximize energy saving.

Based on the full-scenario traffic model, energy saving effect, KPI trend data analysis, the intelligent platform strengthens self-learning and continuously iterates and optimizes online. The performance data of each cell is extracted every day. The clustering algorithm (K-Means) is used to find the optimal adjustment step for different threshold parameters. After the daily KPIs are optimized and refreshed, the core KPIs (including setup KPIs, call drop KPIs, handover KPIs, and user experience KPIs) of the network are monitored. The prediction model is continuously iterated within the allowed floating range to finally reach the optimal balance point between energy saving and system performance.

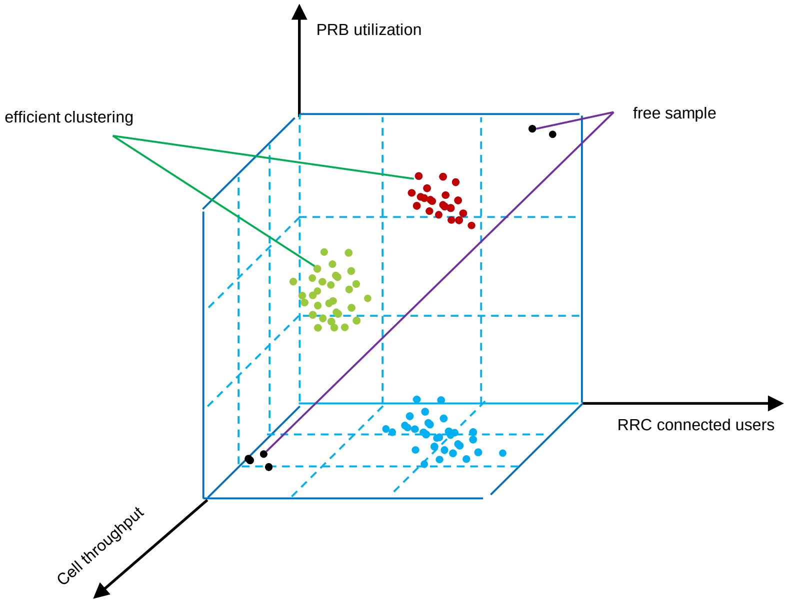


Figure 8. Threshold parameter discrete separation

For different energy-saving enabling/disabling thresholds (including PRB usage, RRC connection users, and cell throughput), the generalization model can be learned. The time sequence relationship between performance data and threshold parameters can be effectively discrete separated, generalization prediction can be performed by using the clustered model, and related threshold iteration can be performed.

05 Ten Times Leverage

Mobile industry enablement effect

In the post-pandemic era, "digitalization" and "greening" have become the main theme of global economic recovery, and Net Zero is a solemn commitment to building a community with a shared future. Due to its technological capabilities, 5G can be deeply integrated with all social and economic fields, facilitating the digital transformation of the whole society, and deeply embedding the digital transformation into the whole production and operation processes of all industries, so as to achieve process optimization, precise control, and efficient operation. In this way, the energy use efficiency of traditional industries can be improved, and the whole society can lower carbon footprint. In GSMA’s report *The Enablement Effect*, it predicts that every time a kWh of electricity is consumed by a mobile communication network, 10kWh [8] of electricity can be reduced to in 2025.

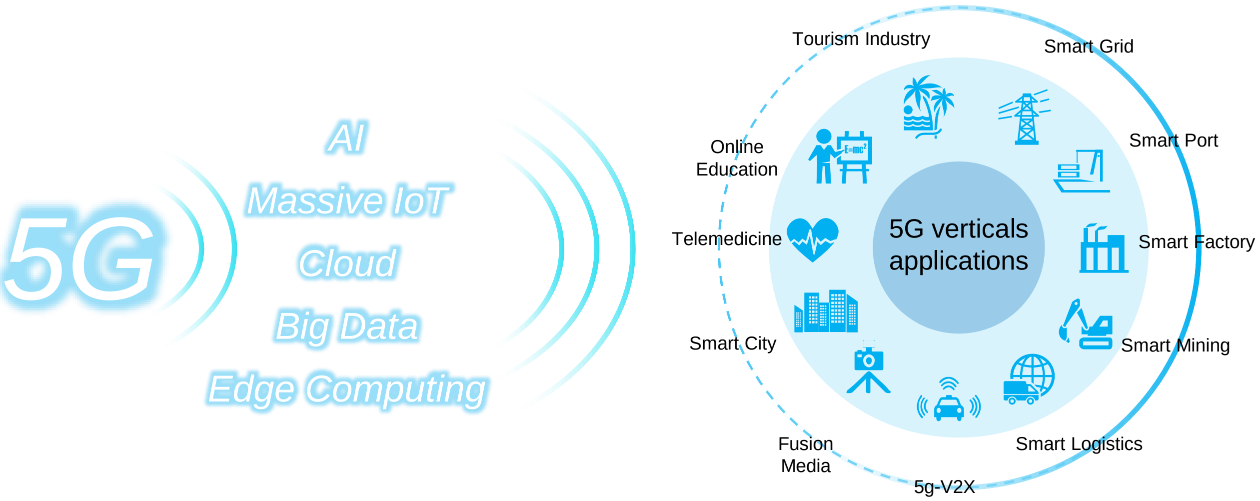


Figure 9 5G Will Enable Industry-wide Digitization

Oriented to the digital, intelligent, and green transformation requirements of various industries, focusing on green and low-carbon industrial transformation, low-carbon environmental life for residents, and green and smart urban and rural development, the service supply capability of in-depth integration of digital technologies and vertical industry applications is accelerated, and the requirements of the action plan are clearly proposed.

With the goal of green and low-carbon cycle development, we should continuously improve the green communications network infrastructure, and make full use of the 1: 10 leverage of information technologies to promote green and low-carbon networks in the whole society. This is the only way to support the “Net Zero" and "digital transformation" of the country.

China Telecom Sichuan Branch Power Saving Memorabilia

2020

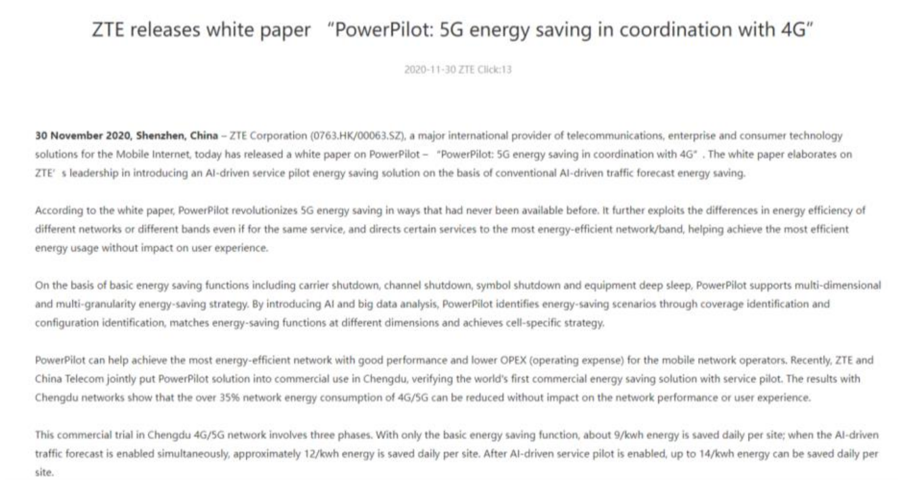
2020 , China Telecom, together with ZTE and other partners, jointly established the TMF "5G Green Telco" catalyst project, discussed the approach to 5G sustainable development together, and shared the **social value of AI energy saving after successful deployment by China Telecom Sichuan branch**, with global business leaders and guests in July 2020, which was highly recognized and praised by TMF experts.

TM Forum

Best Social Impact Award

The industry's first NSA/SA network service pilot verification: After commercial tests, it is verified that when one site energy-saving function is enabled, the daily energy-saving is about 9.3kWh. When the AI load prediction is added, the daily energy-saving of one site is about 12.2kWh. After the service pilot technology is applied, the daily energy-saving of one site can reach 13.7kWh, which is 47% higher than the basic function.

2020



ZTE releases white paper "PowerPilot: 5G energy saving in coordination with 4G"

2020-11-30 ZTE Click:13

30 November 2020, Shenzhen, China – ZTE Corporation (0763.HK/00063.SZ), a major international provider of telecommunications, enterprise and consumer technology solutions for the Mobile Internet, today has released a white paper on PowerPilot – "PowerPilot: 5G energy saving in coordination with 4G" . The white paper elaborates on ZTE' s leadership in introducing an AI-driven service pilot energy saving solution on the basis of conventional AI-driven traffic forecast energy saving.

According to the white paper, PowerPilot revolutionizes 5G energy saving in ways that had never been available before. It further exploits the differences in energy efficiency of different networks or different bands even if for the same service, and directs certain services to the most energy-efficient network/band, helping achieve the most efficient energy usage without impact on user experience.

On the basis of basic energy saving functions including carrier shutdown, channel shutdown, symbol shutdown and equipment deep sleep, PowerPilot supports multi-dimensional and multi-granularity energy-saving strategy. By introducing AI and big data analysis, PowerPilot identifies energy-saving scenarios through coverage identification and configuration identification, matches energy-saving functions at different dimensions and achieves cell-specific strategy.

PowerPilot can help achieve the most energy-efficient network with good performance and lower OPEX (operating expense) for the mobile network operators. Recently, ZTE and China Telecom jointly put PowerPilot solution into commercial use in Chengdu, verifying the world's first commercial energy saving solution with service pilot. The results with Chengdu networks show that the over 35% network energy consumption of 4G/5G can be reduced without impact on the network performance or user experience.

This commercial trial in Chengdu 4G/5G network involves three phases. With only the basic energy saving function, about 9/kwh energy is saved daily per site; when the AI-driven traffic forecast is enabled simultaneously, approximately 12/kwh energy is saved daily per site. After AI-driven service pilot is enabled, up to 14/kwh energy can be saved daily per site.

The first to initiate the "zero-load zero-carbon" demand of AAU : In August 2021 , the Sichuan Telecom Network Department first proposed the "zero-load zero-carbon" demand, hoping to study the feasibility together with equipment manufacturers.

2021

August 2021

China Telecom Network Department first proposed the concept of 5G AAU "zero-load zero-carbon", hoping to work with equipment manufacturers to study its feasibility.

May 2022

ZTE realizes the “AAU hibernation" function based on demand, incubates innovation, supports timing strategies, and conducts reliability risk verification in the laboratory.

July 2022

Completed the functional test in Leshan, Sichuan, and the energy consumption was less than 5W after the “AAU hibernation" function was activated, which was in line with expectations.

August 2022

Completed the deployment in over 2,000 5G AAUs in Leshan, Sichuan, and more cities and regions queuing for deployment.

China Telecom Sichuan Branch as one of the pioneers in China Telecom Group has continuously carried out 5G+ industry application innovation, biodiversity protection, rural revitalization, urban pollution prevention and control are the crown jeweler of 5G enabled verticals digitalization best practices among tens of thousand digitalization projects, and several "5th Bloom Cup" awards are rewarded.

2022

Biodiversity protection with green 5G. in the massive giant panda’s natural habitat in Sichuan, there are only about 70 giant pandas left in Sichuan, with 5G they can be effectively tracked and monitored, and normal and infrared surveillance cameras and geo-fence are used, AR with the geographic sand table are under discussion for future. Rural revitalization using green 5G. Electric power as another important infrastructure is vital for rural regions, Chengdu plain is full of high-quality farmland, and electricity interruption may lead to severe consequences, China Telecom held hand with National Grid, using 5G to achieve self-healing electricity distribution system, it reduced the electricity failure recovery time from over 3 hours to less than 1 second, minimized the electricity failure impact. Urban pollution prevention and control with green 5G. The key to metropolitan city pollution management is to measure, monitor, and fast respond, which makes 5G ideal for this task. Hundreds of specially designed pollution data collet poles are deployed using China Telecom’s 5G, measuring vital parameters and HD video surveillance, greatly improving Chengdu’s air quality. Using green 5G networks can realize the digital transformation of thousands of industries and help achieve the goal of "double carbon", Sichuan Telecom has carried out various research, and countless vertical success stories meanwhile pocketed a bunch of bloom cup awards.

Conclusion

This year's hot summer has brought everyone's attention to "climate change" again. As a major hydropower province, Sichuan used to be the main power source for the "West-to-East Power Transmission" . However , the news of "Chengdu 's power cut" became hot news in July this year .The extreme high temperature lasted for a long time, which makes Sichuan face the " power shortage challenge". How to "save energy and reduce consumption, and prioritize electricity to the people" is a question that Sichuan Telecom has been thinking about all the time.

Green mountains, green water and giant pandas are the most valuable human ecology in Sichuan. As early as 2020 , 4G and 5G intelligent energy saving has been applied to the entire network of Sichuan Telecom, and won the TMF “Outstanding Catalyst-Impact for Society” award that year, completed the first 5G SA network traffic pilot, and put forward the zero-carbon vision. The nature of power-saving technology is the endless pursuit of higher energy efficiency and lower power consumption through technology innovations.

Innovative technology leads the wireless communication network to continuously strive to approach the "perfect curve" of energy consumption , from deep sleep to automatic start and stop, from dynamic voltage regulation to envelope tracking, from platform intelligence to base station intelligence, from macro station to digital indoor distribution Systematic philosophy runs through the way to achieve Net Zero, hoping that a green and low-carbon network will enable a better and sustainable digital life.

Abbreviation

abbreviation	english full name
AAU	Active Antenna Unit
ACPR	Adjacent Channel Power Ratio
AI	Artificial Intelligence
ARIMA	Autoregressive Integrated Moving Average model
BBU	Building Baseband Unit
CFR	Crest Factor Reduction
DBSCAN	Density-based Spatial Clustering of Application with Noise
DPD	Digital Pre-Distortion
ECPRI	Enhanced Common Public Radio Interface
EE	Energy Efficiency
EMBB	Enhanced Mobile Broadband
ET	Envelope Tracking
EVM	Error Vector Magnitude
ICT	Information and Communications Technology
K-Means	K-means clustering algorithm
KPI	Key Performance Indicator
LNA	Low Noise Amplifier
LSTM	Long Short -Term Memory
MMTC	Massive Machine Type of Communication
MR	Measurement Report
PA	Power Amplifier
PAR	Peak-to-Average Ratio
PRB	Physical Resource Block
RRC	Radio Resource Control
RRU	Remote Radio Unit
RSRP	Reference Signal Receiving Power
RSRQ	Reference Signal Receiving Quality
SINR	Signal to Interference plus Noise Ratio
SoC	System on Chip
URLLC	Ultra- relaible and Low Latency Communication
VNF	Virtualized Network Function

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