5G Telecom Power Target Network

White Paper

GLOBAL ICT ENERGY EFFICIENCY SUMMIT

POWERING 5G TOGETHER

This white paper is the culmination of the wisdom gathered at the 5th Global ICT Energy Efficiency Summit. We thank all participants for their contribution.

Contents

1. Abstract

5G is accelerating. To achieve large bandwidth, massive connections, and ultra-low latency, the telecom network will have three significant changes: new technology and spectrum, increasing sites and MEC sinking. These will further increase network energy consumption and ask for more complex O&M and more diversified power supply modes. Facing with these changes, the traditional telecom energy solution will lead to high deployment and reconstruction costs, network O&M costs and electricity costs. Based on the deep understanding of operators' energy pain points in network evolution, continuous verification and actual practice, the 5G Telecom Power Target Network White Paper defines the 5G telecom power target network in the direction of simple, intelligent, and green, helping to build a 5G network with simple deployment, simple O&M, and simple evolution.

This white paper focuses on the following aspects:

1. 5G target network evolution direction: new bands and technologies, increasing sites, sinking MEC
2. New challenges on 5G target network: increasing power consumption, difficult site acquisition, expensive maintenance, flexible power supply request
3. How to build a simple, intelligent and green telecom power network oriented to the 5G target network
4. Analyze the optimal 5G telecom power solution in different network construction scenarios

We hope that we can discuss and cooperate with the industry on this basis to promote 5G communication energy innovation and embrace the 5G era.

2. 5G New Requirements for Telecom Power

The 5G technology has excellent performance in eMBB, mMTC and uRLLC. A large number of new applications for future new services are concerned by the industry, including low-latency edge computing, 4K ultra-HD real-time video, telemedicine, and networked devices and places such as UAVs, gymnasiums, and cars. With the large-scale deployment of 5G and the popularization of 5G terminals, 5G's new services are in full swing.

By June 2019, the 5G spectrum has been released in 33 countries around the world, and 25 countries have begun commercial use. In the current frequency bands, C-BAND is still the dominant frequency while mmWave represented by South Korea and the United States are increasing.

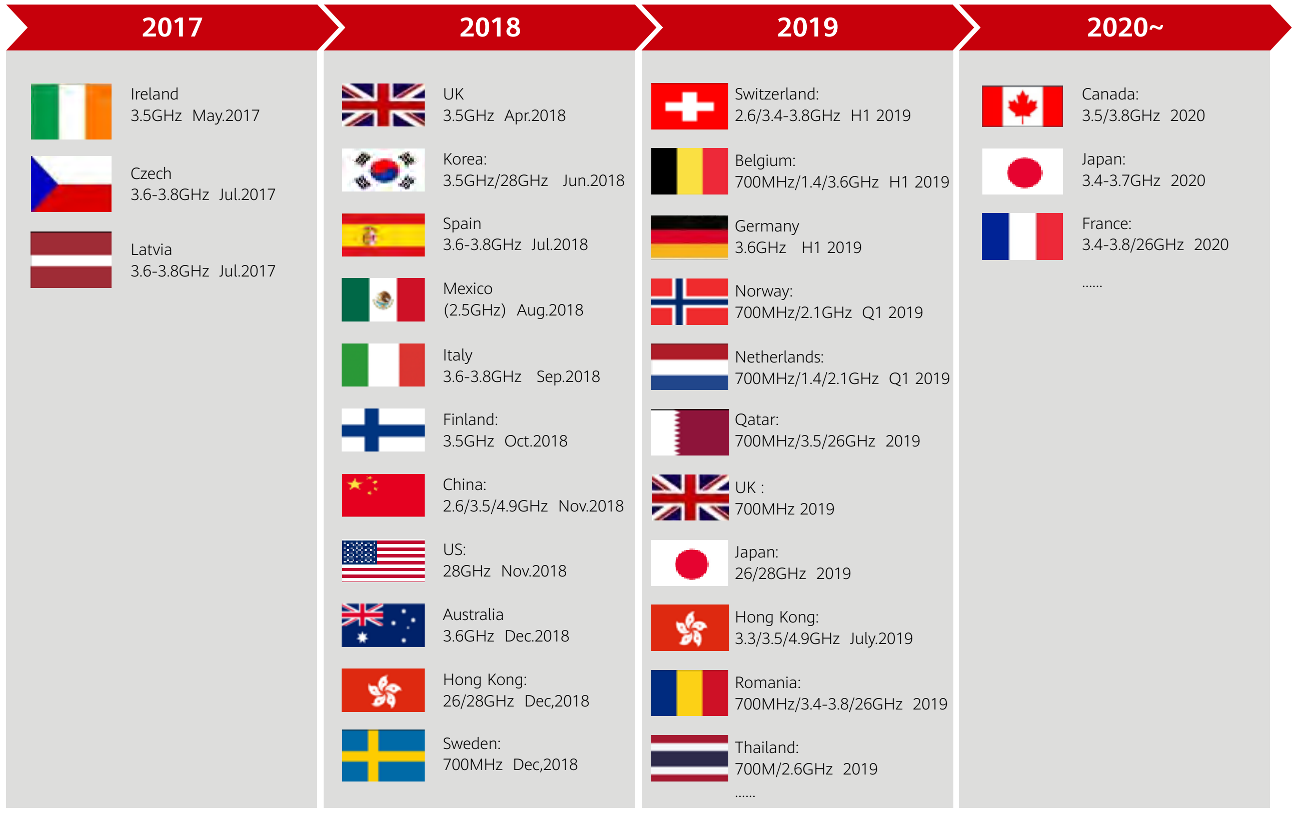

Figure 1 global spectrums

2.1 5G Network Evolution Trend

There will be three significant changes in telecom network in the 5G era: new technology and spectrum, increasing sites, MEC sinking.

- New technology and spectrum

Currently, the theoretical limitation of transmission bandwidth of the 2G/3G/4G network is about 150Mbps (excluding carrier aggregation), which cannot meet the requirements of the services in 5G era. To achieve higher bandwidth, the 5G network uses a higher frequency such as C-band.

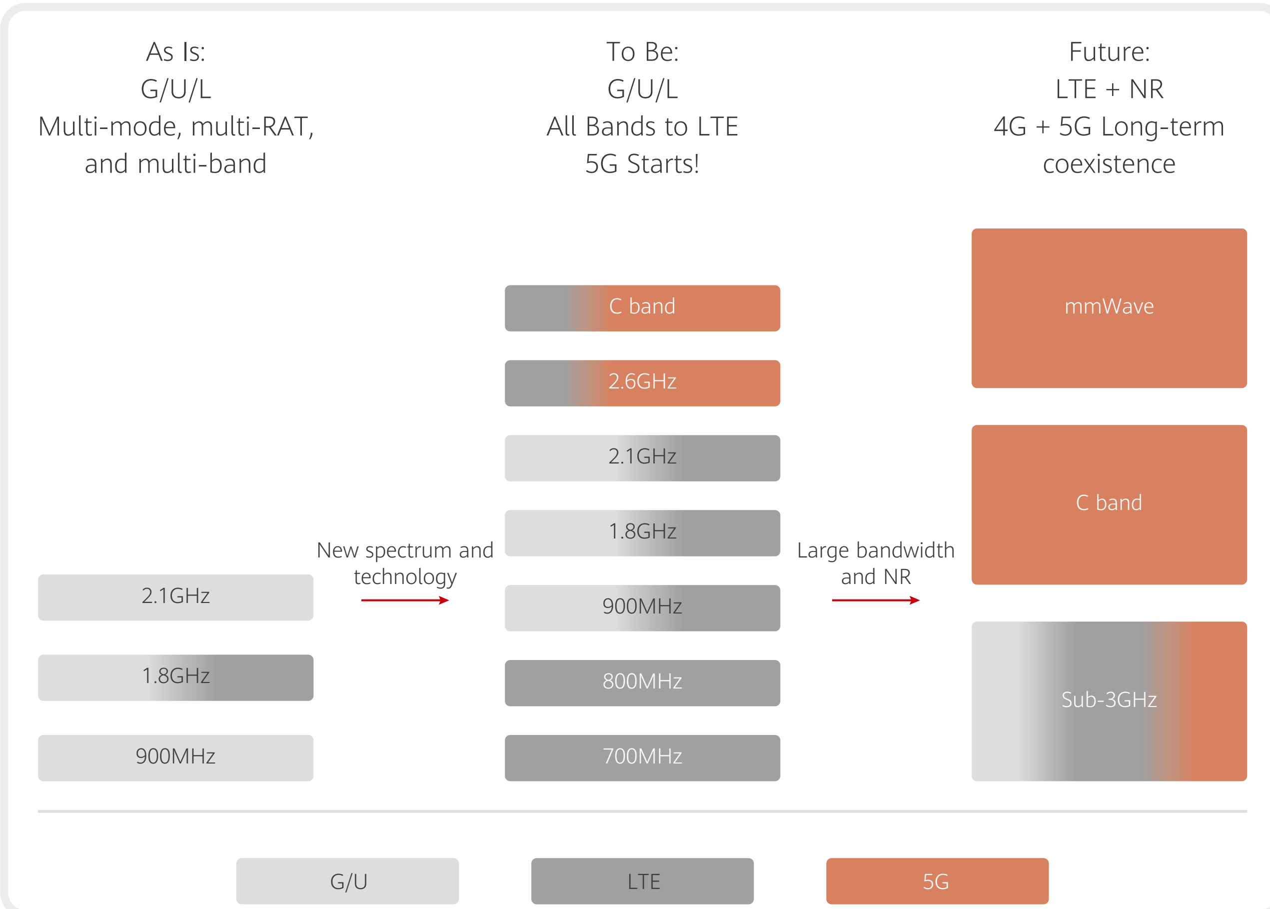

Figure 2 Trend of spectrum evolution

More and more countries have clear 5G spectrum releasing plans and 5G network deployment plans. With the deployment of 5G, the number of sites will increase. Considering the continuity of services, the 2G/3G/4G on the live network will coexist with the 5G RAT for a long time. Currently, over 70% operators have more than 5 bands. When millimeter-wave are deployed in the future, the band number of a site will reach 7 to 10 or more.

In the 5G era, massive MIMO is the key technology for 5G to improve throughput. It uses the diversity of multipath propagation, allows the base station and multiple terminal equipment to use the same frequency resources for data transmission at the same time, and supports higher cellular capacity and efficiency in high-traffic urban areas. This feature combines the large capacity of the system and the high-speed user experience of a single user. It can provide xGbps ultra-high cell throughput and ultra-large user capacity.

- Increasing sites

To improve the experience rate for users and achieve continuous coverage in hotspot areas and high-capacity service scenarios, operators need to build more sites. Take China as an example, by 2026, the number of 5G macro base stations is expected to be 4.75 million, achieving 4G equivalent coverage. The number of 5G micro base stations in millimeter-wave high frequency bands will be twice the number of macro base stations, which is expected to reach 9.5 million.

- MEC Sinking

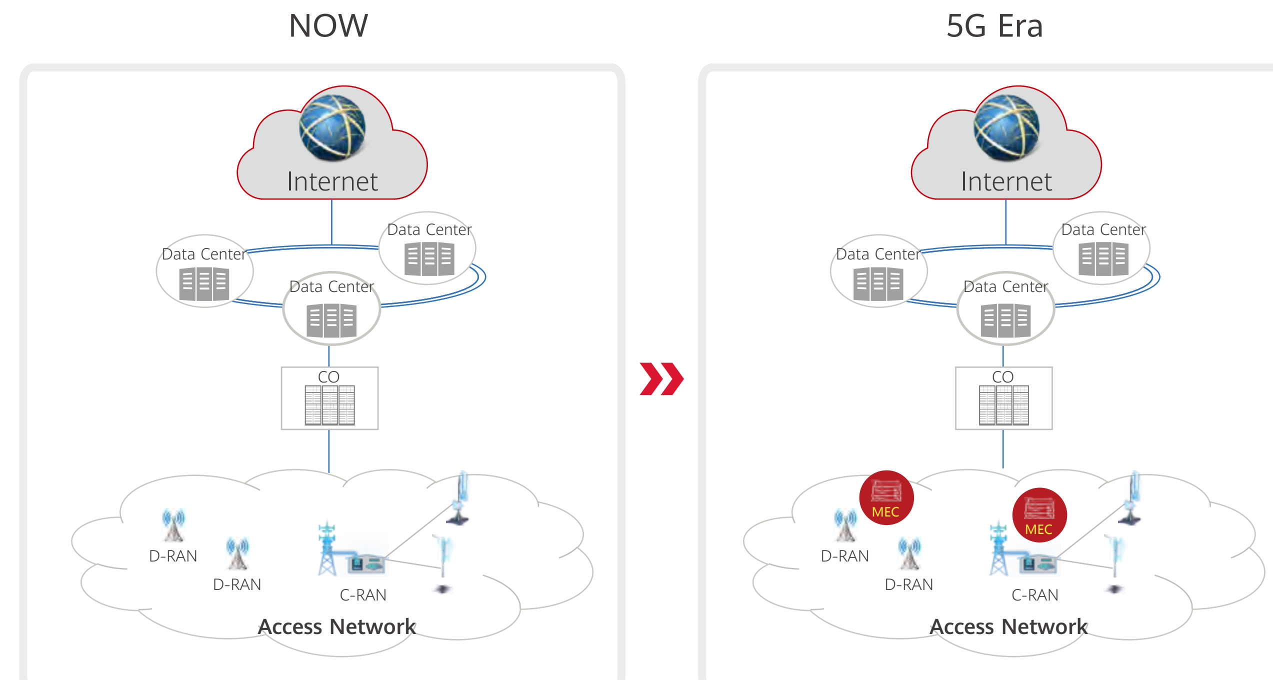

Figure 3 MEC in RAN

Internet of Things (IoT) services such as Internet of Vehicles (IOV), unmanned driving, and smart manufacturing require high timeliness. From the perspective of the network structure, the server will be moved from the data center to the access network equipment room and site to reduce the delay impact during communication.

At the same time, in the face of massive data processing requirements, the communications equipment room (CO) will further develop towards ICT convergence. As more IT devices and auxiliary energy devices enter the equipment room, the installation space of the equipment room and load-bearing capacity will be prominent. The power consumption of the equipment room will also increase, and the continuous improvement of energy efficiency will become more and more important.

2.2 Impact of 5G Network Evolution on Telecom Energy

- Challenge on entire power supply system with high power consumption

According to the measured data of multiple operators, the power consumption of one band 5G equipment (64T64R, 3.5 GHz Massive MIMO, including one BBU and three AAU/RRUs) is 300% to 350% of 4G with the same configuration. A 5G BBU is about 300 W while an AAU is about 900 W at 30% load rate (peak is about 1200 W to 1400 W).

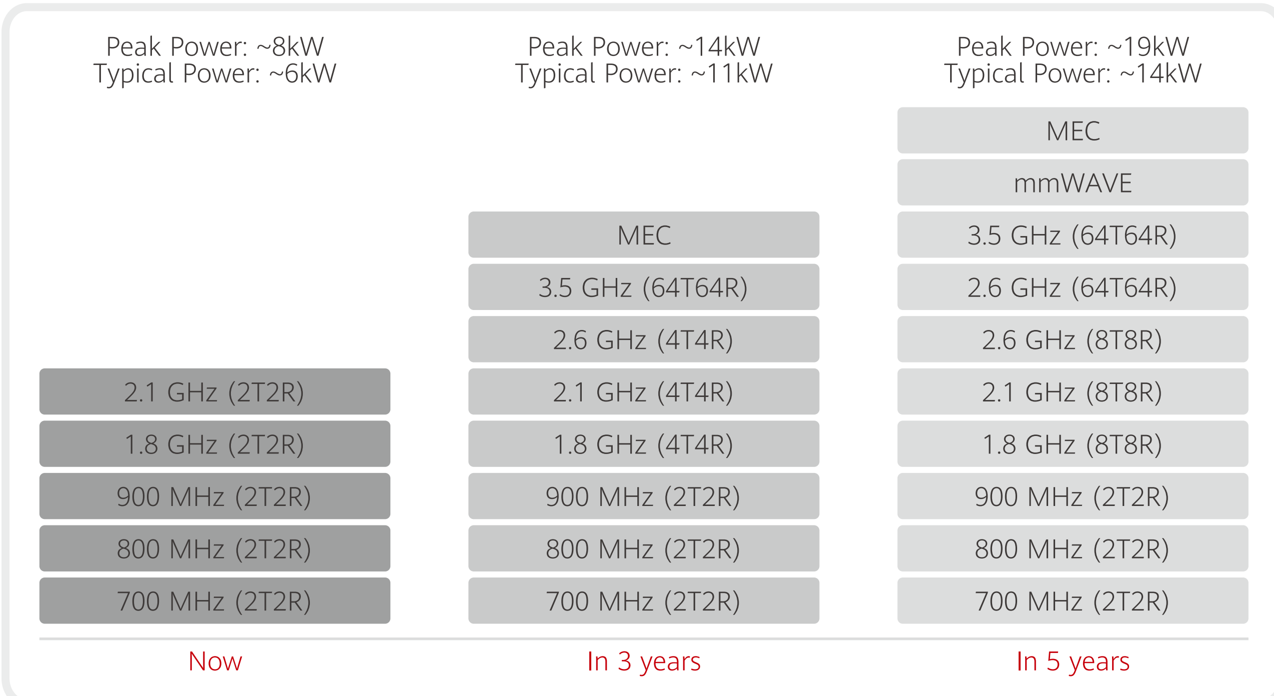

Figure 4 power consumption of frequency evolution

During the evolution, the peak power consumption of typical sites will increase significantly in the next few years. Take an example showed in the above figure, in the next three years or so, the peak power consumption of the site will increase to about 13,700 W after the 5G FR1 is deployed. In the next five years, the peak power consumption of the site will increase to 18,900 W with the application of the millimeter wave and new technologies in the existing frequency band.

The increasing power consumption of the 5G brings challenges for the entire power supply system of a site, involving the grid capacity, rectifier capacity, backup power, and cooling capability. According to the site survey of each operator in the world: The grid capacity of about 32% sites is insufficient while the power capacity of about 30% sites is insufficient. The backup power of about 65% sites cannot meet the backup power requirement when 5G accesses. About 77% sites cannot meet the power supply requirement of remote AAU because of high cable loss caused by high power consumption.

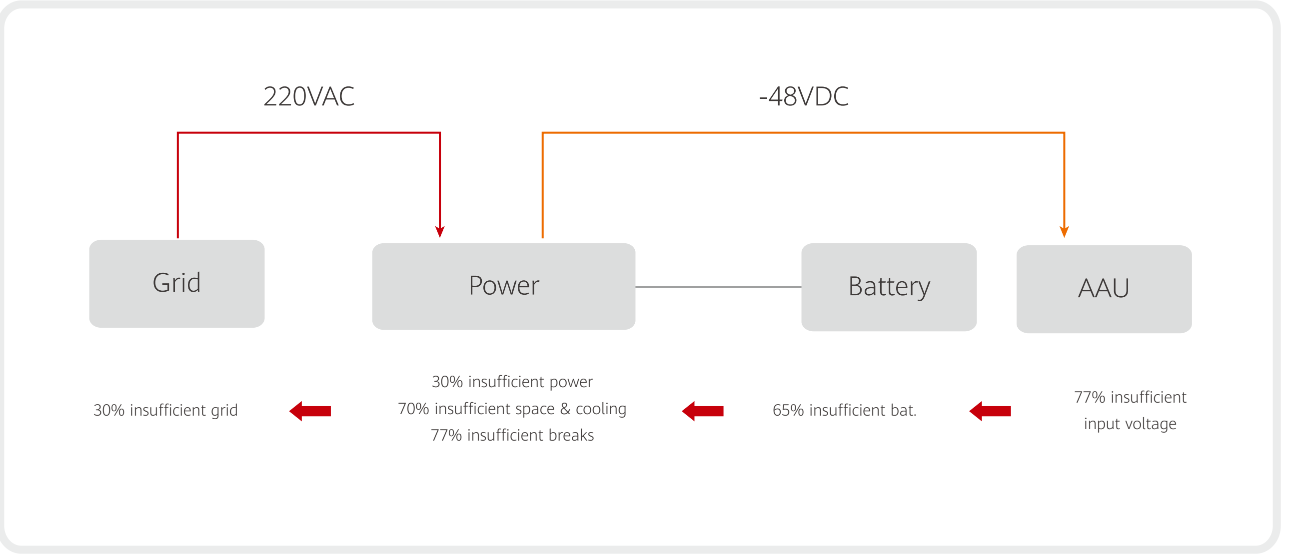

Figure 5 5G evolution challenge

With the increase of network power consumption in the 5G era, the energy efficiency of the site power needs to be improved, and the large-scale application of green energy in the communications network is continuously driven. For example, to reduce the overall power consumption cost, more and more operators choose to access solar energy to the site. Therefore, the power system shall support solar access for future evolution.

- Increasing sites lead to hard site acquisition and O&M

Operators have difficulties in site acquisition for a long time, especially when the site equipment has certain requirements on the floor space and installation environment. Therefore, it is difficult to obtain approval permission. In addition, the site construction cost is high, including the approval cost, engineering cost, and TTM cost. In the 4G era, about 80% of site O&M relies on manual site inspection, problem locating, and troubleshooting. The average O&M efficiency is about 10 to 40 sites/person, and the site maintenance cost accounts for 2% to 5% of the total revenue. In the 5G era, the number of sites is expected to be 2 to 3 times that of the 4G era. Whether the site maintenance cost can be effectively saved is related to the healthy operation of telecom operators.

- MEC sinking and other device access require a flexible power supply system

As MEC sinks to sites and CO equipment rooms, it requires sites and CO room not only meet the DC power

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backup requirements of traditional CT devices, but also meet the AC power supply and backup requirements of IT devices. In addition, video surveillance devices deploying at some key sites requires 12VDC and 24VAC for cameras.

2.3 Development Trend of New Technologies in the Telecom Power Industry

In recent years, new technologies such as lithium-ion, photovoltaic, AI and digitalization are accelerating the entry into the telecom energy domain for system performance improvement.

- High density power: With the improvement of the structure and power technology, the power supply continuously evolves toward high density, which effectively saves the space inside the cabinet.

- Lithium-ion battery: Lithium-ion is widely used in electric vehicles, energy storage, and terminal equipment, considering its obvious advantages in energy density and service life compared with lead-acid batteries. Furthermore, the shipment of lithium batteries for telecom sites grows rapidly in the last two years.

- Solar: Thanks to the increasingly mature solar technology and continuously power generation cost reduction, adopting solar energy to reduce network energy consumption has been a trend for telecom network.

- AI: With the rise of AI technology, its advantages in image recognition and production control will be widely used in telecom power systems to promote automatic power control and continuously improve site energy efficiency and reliability.

- Digitalization：Mature application of sensor, cloud, and IOT in the industry propels telecom network digitization, turning traditional dumb devices to digital ones with site information online, problem solving online, and problem processing in advance, which effectively improves the O&M efficiency of massive sites.

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3. 5G Telecom Power Target Network

3.1 5G Telecom Power Challenge

AC modernization: In the traditional construction solution, each subsystem of the power supply link is designed independently. From the front-end grid capacity to the specifications of the power equipment, the power supply links are amplified at layers based on the peak requirements of the lower-level equipment. As a result, the front-end grid capacity is much higher than the typical operating status of the equipment. For example, in an indoor site, the power consumption in typical working conditions is about 3kW, but the grid design capacity is more than 10kW, and the grid capacity usage is less than 30%. In the 5G era, if the traditional construction method is used, the grid capacity needs to be reconstructed again. The reconstruction period is three to six months, while the cost is up to 5000 euros. This will bring a large amount of infrastructure reconstruction and waste of resources on a large scale.

Adding new cabinet: At the same time, the power and energy density of each component of the traditional site communication energy are low. As a result, when 5G accesses, new cabinets is required, increasing the site rent. Take Netherlands as an example, adding one cabinet increases the annual rental by 8000 euros. In addition, the approval of new footprint greatly prolongs the commercial TTM of 5G.

High energy consumption: When 5G accesses, the site consumption doubles. The energy consumption of the 5G network will be doubled based on the site energy efficiency level in the 4G era. How to improve the energy efficiency of the power supply solution is urgent.

High O&M cost: Facing such a large number of 5G sites, the average annual O&M cost of most operators varies from thousands of dollars to tens of thousands of dollars. If the operators continuously adopts traditional O&M which requires manual site maintenance, the site visit cost will increase greatly. Therefore, improving site O&M efficiency to reduce O&M costs is urgent for 5G network. In addition, global high theft rate of lead-acid battery leads to severe asset loss and greatly impacts the quality of the network service. Take Latin America as an example, the theft rate is up to 10% to 20%.

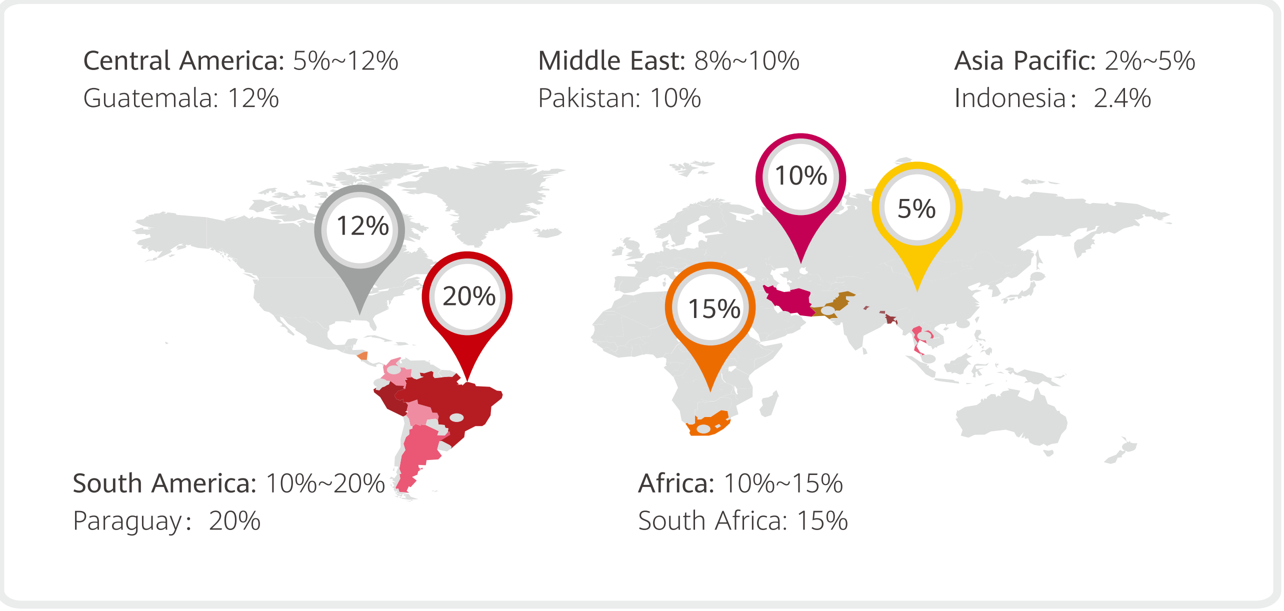

Figure 6 Global theft rate of lead-acid battery

3.2 5G Telecom Power Target Network Design

To tackle the above challenges, it is recommended that the 5G communication energy target network focus on future-oriented networks on basis of comprehensive digitalization. Through key component engineering design innovation, digital, and AI control technologies, a three-layer target network can be build, which is simplified, intelligent, and green.

- 5G telecom power simple deployment, simple O&M, simple evolution
- Improve resource utilization efficiency, reduce modernization such as grid and cables
- Improve energy utilization efficiency, reduce energy consumption cost

The first layer-the physical sites consider integrated power solution for multiple scenarios, and the power controller is used as the executor of the intelligent feature. The second layer-the intelligent network management implements intelligent O&M of the access layer. It is also the controller of the intelligent feature and manages the IOT networking of the intelligent equipment. The top layer is the training platform and data pool of the AI function to automatically optimize network energy efficiency.

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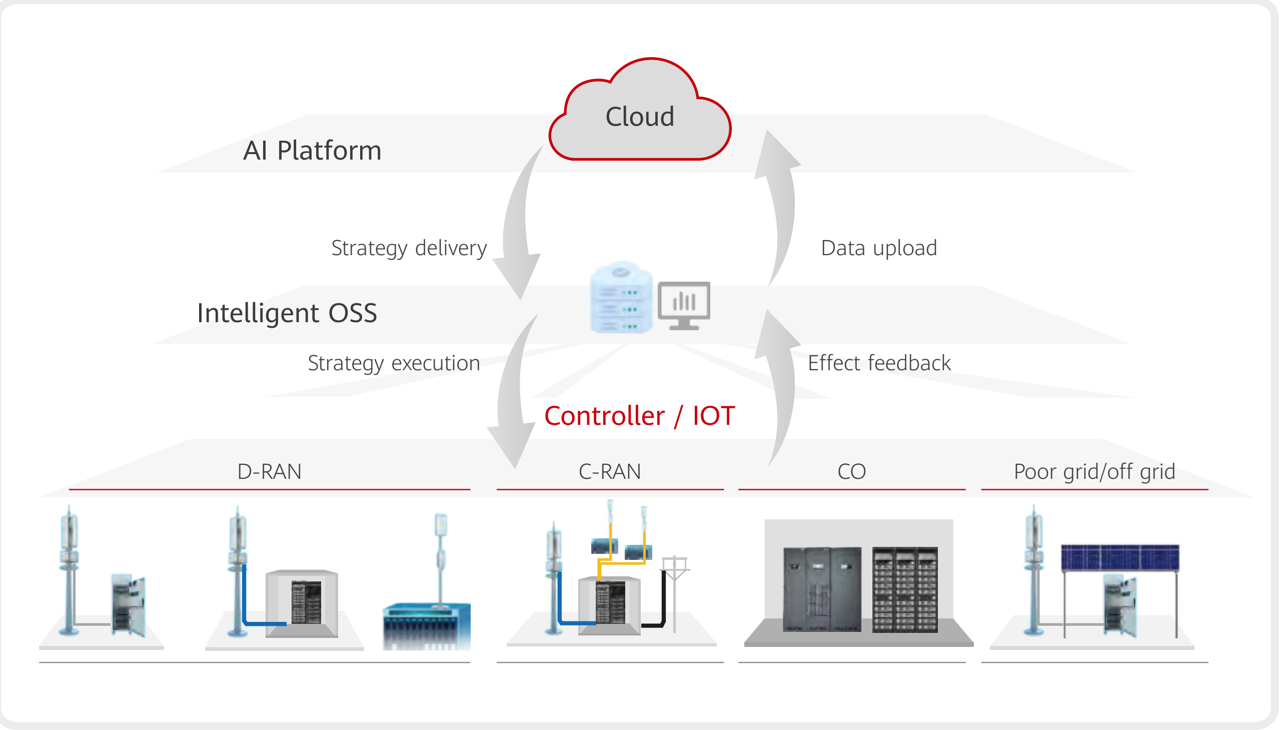

Figure 7 Simple, intelligent, green target network

Simple: Sites in the 5G era should be characterized by simple deployment, simple O&M, and simple evolution.

- Simple deployment: It is required that no cabinet be added during the 5G NR deployment. This requires that the power supply system of the site further improves the power density so that higher power and backup equipment can be accommodated in the same space. Take the current mainstream outdoor cabinet as an example: With a total space of around 30U, the remaining cabinet space for power in only 4U except 18U for battery, 4U for two BBU, and 2U for transmission. Since the power capacity requirement is about 24 kW, the power density of a power to be installed in 4U space is 6 kW/U. Currently, the power density of mainstream power products is about 2 kW/U, which must be increased by at least three times. For the site backup power system, it is recommended that lithium batteries with higher energy density be used instead of traditional lead-acid batteries to provide large-capacity in the same space.
- Simple O&M: Facing with the future massive site network, the traditional O&M methods must be changed to reduce the O&M costs. The 5G network energy O&M system should first complete the equipment digital transformation, thereby the site equipment information will be

uploaded to the O&M management system. On the NE side, the upgrade of the dumb device through the power controller + wireless sensor will be the main technology, and some products will also be networked through IOT technology. Secondly the O&M management system needs to change from information collection and centralized display to active risk management and active O&M, such as the health management of battery and temperature control, risk warning in advance and precise maintenance, thereby effectively reducing network failures and improving KPI. In addition, the system should have intelligent analysis capabilities and actively extract information of massive sites. Take the site failure as an example, the system should establish a fault occurrence model from historical state data and alarm data to extract the root cause of the fault, guide maintenance actions and improve efficiency. In addition, by adopting natural anti-theft lithium battery as backup with multiple additional anti-theft measures such as gyroscope, buzzer and software lock, battery stolen can be reduces effectively to decrease O&M cost.

- Simple evolution: the full completion of the 5G network will go through several phases to finally achieve full coverage of the 5G network:

Phase 1: In the early deployment phase of 5G, small-scale deployment of 5G sites is accompanied by 4G site deployment;

Phase 2: Comprehensive 5G FR1 band deployment and small-scale FR2 band deployment

Phase 3: FR2 band continuous coverage deployment

Currently, the telecom power system only modulates the rectifier and circuit breaker. However, the evolution-oriented modular design includes but is not limited to the following: power, power distribution, eMIMO, backup power, and temperature control. At present, multiple sets of power are used to supply power to different devices, which causes overlapping investment. A power system with full-modular expansion has the following advantages:

1: One-time deployment, simplifying subsequent deployment and shortening TTM

2: Simple management of a single system, quick and accurate fault locating, high maintenance efficiency, and short mean time to repair (MTTR)

3: Power supply capability pooling, strong disaster recovery capability, and small impact on component faults

Diversified energy input and output scheduling management is one of the requirements of the future network power supply system. If traditional solutions are used, a site need to deploy multiple power systems which wastes investment and increases management difficulty. Therefore, it is recommended to use one power supply system with eMIMO:

Multiple input: solar, D.G, grid, etc.

Multiple output: HVDC, 12VDC, 24VAC, 220VAC, etc.

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Intelligent: Intellectualized telecom power improves resource utilization efficiency and reduces related modernization;

The traditional power solution has problems of low energy utilization, and serious investment waste. For example, the utilization of the existing grid capacity is low while 5G deployment requires the grid capacity to be expanded to a larger capacity. Batteries are used only as backup power so its cycle performance is wasted. These problems can be tackled by intelligent methods, which can link the power system with other devices to optimize the schedule among subsystems, improve utilization, and avoid large-scale engineering reconstruction.

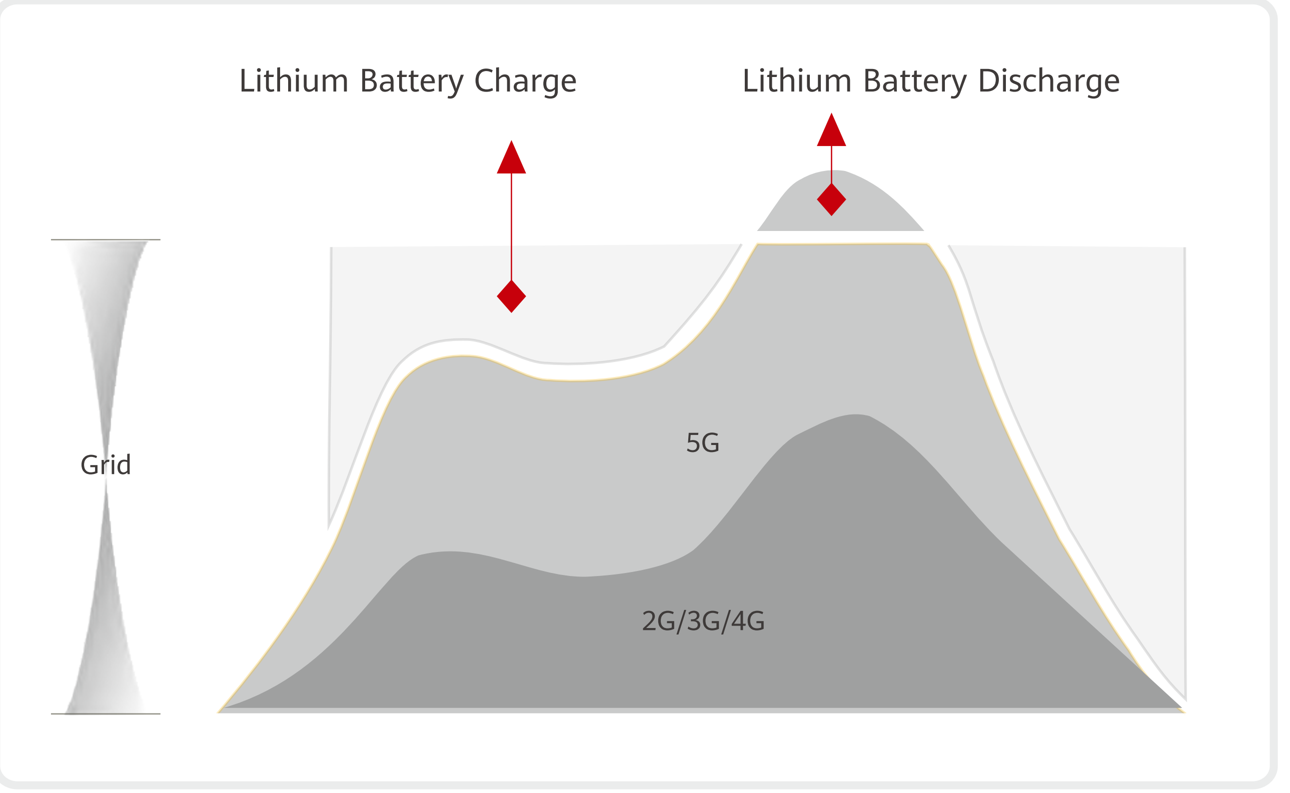

Figure 8 Intelligent peak shaving

For example, when the power consumption reaches the peak value, batteries are scheduled to discharge. When the power consumption is lower than the grid capacity, batteries are scheduled to charge. At the situation of long period and high cost of grid capacity expansion, this design can save a large amount of deployment time and save costs. Therefore, this design should be a standard function of the power supply system.

Load(W)																							
1700	48	48	57	57	57	57	57	57	57	57	57	72	72	72	72	72	72	72	72	72	72	72	72
1600	48	48	57	57	57	57	57	57	57	57	57	57	72	72	72	72	72	72	72	72	72	72	72
1500	48	48	48	57	57	57	57	57	57	57	57	57	57	72	72	72	72	72	72	72	72	72	72
1400	48	48	48	57	57	57	57	57	57	57	57	57	57	57	72	72	72	72	72	72	72	72	72
1300	48	48	48	48	57	57	57	57	57	57	57	57	57	57	57	57	72	72	72	72	72	72	72
1200	48	48	48	48	57	57	57	57	57	57	57	57	57	57	57	57	57	72	72	72	72	72	72
1100	48	48	48	48	48	57	57	57	57	57	57	57	57	57	57	57	57	57	57	72	72	72	72
1000	48	48	48	48	48	48	57	57	57	57	57	57	57	57	57	57	57	57	57	57	57	72	72
900	48	48	48	48	48	48	48	57	57	57	57	57	57	57	57	57	57	57	57	57	57	57	57
800	48	48	48	48	48	48	48	48	57	57	57	57	57	57	57	57	57	57	57	57	57	57	57
700	48	48	48	48	48	48	48	48	48	48	57	57	57	57	57	57	57	57	57	57	57	57	57
600	48	48	48	48	48	48	48	48	48	48	48	48	57	57	57	57	57	57	57	57	57	57	57
500	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	57	57	57	57	57	57	57
400	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	57	57	57
300	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48
200	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48
100	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48
Cable Length (m)	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130

Figure 9 Relationship among voltage, cable and distance

The 5G AAU power supply problem can also be solved by intelligent technology. Under the condition of high power consumption, using the traditional power system with thin cable to supply 5G AAU will cause huge cable loss and limited power supply distance. Compared with replacing thin cable by thick one, adopting voltage boosting has more advantages in engineering and cost saving. But considering the difference of AAU power consumption at different load rates, the voltage boosting needs to have certain intelligence: power the AAU with different voltages by tracking the AAU power consumption change to minimize cable loss at high load, and automatically adjust the output voltage at low load to ensure the AAU works normally.

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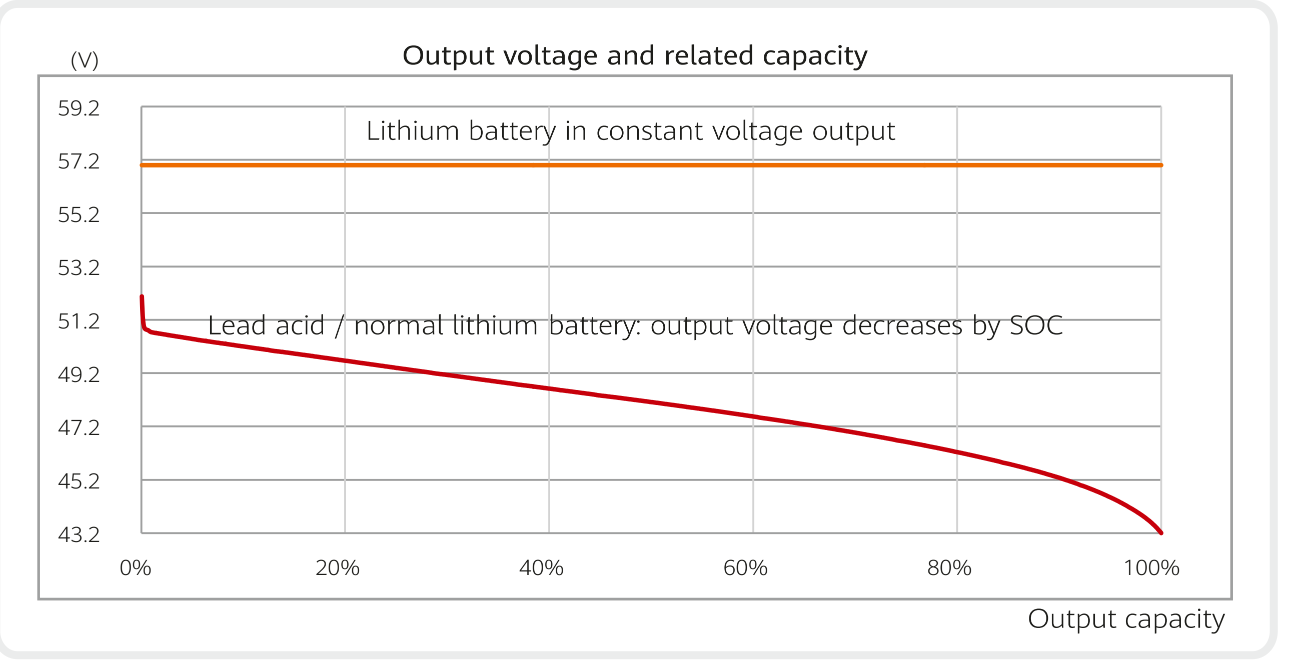


Figure 10 Relationship between output voltage mode and output capacity

The voltage of the traditional backup system declines with the battery discharging. Under high power consumption and a certain power distance, the battery capacity cannot be fully discharged. In this case, the AAU stops working due to low input voltage. Therefore, the backup system must also support constant voltage output to ensure that the site can still work normally when a power failure occurs.

Green: system efficiency improvement and renewable energy application

- Solar access: At present, the solar power cost within service life is as low as 3 to 5 cents / kWh, which is far lower than the cost of thermal power generation. A large-scale application of solar energy will happen in 5G era. Through solar & grid intelligence scheduling and solar power generation control technology, the solar power generation efficiency can be further improved to reduce the cost to use solar, accelerating the large-scale application of green energy. This is not only part of corporate social responsibility, but also significantly reduce electricity bills and reduce OPEX.
- From indoor to outdoor: Currently, a certain proportion of sites are indoor sites. The cooling system in these indoor sites consumes a large amount of power, resulting in high site energy consumption. The energy efficiency of typical indoor sites is about 60%. Through outdoor reconstruction, the site energy efficiency can be increased to 85% to 90%, which greatly reduces the cooling energy consumption and reduces the OPEX.

- Low efficiency power modernization: In the site and core equipment rooms, there are still a large number of inefficient old power with lower than 90% efficiency. Replacing the low efficiency rectifier by 98% can save power consumption and reduce OPEX.

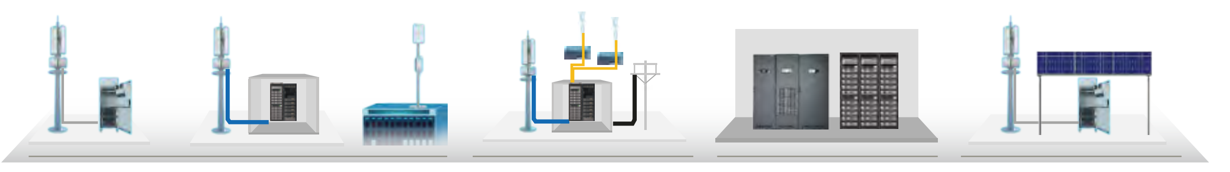
- Diesel removal: For poor grid or off grid sites, the traditional solution generally uses dual-D. G. to generate electricity, with lead-acid batteries as energy storage and simple patched construction, resulting in low system efficiency and high operating costs. The typical D.G. site consumes more than 10,000 liter per year, and the average annual maintenance cost of the D.G. is more than 5000 USD. It is recommended to adopt an integrated design for this scenario, introducing solar energy, high-performance circle lithium battery, and incorporating AI algorithm to improve system efficiency and reduce fuel consumption and O&M costs.

- Efficiency improved by system synergy: The system efficiency can be improved through the linkage scheduling between systems. For example, with AAU linked with power, the power supply voltage will be adjusted based on the AAU load rate to minimize the line loss. Site power linked with services and on-demand power supply can achieve the lowest ECT (energy consumption per traffic). The AI technology is introduced to adjust system operating parameters in real time based on the site temperature, humidity, energy status, and service status to achieve the highest system efficiency.

4. 5G Telecom Power Target Network Scenario

With high density, comprehensive modular, digital, intelligent, and green energy use, multiple performance improvements and new technologies are introduced to implement simple deployment, simple O&M, and simple evolution for telecom networks, maximizing resource utilization, reducing related reconstruction, saving OPEX and reducing emissions. The following table lists the requirement analysis and solution suggestions for different scenarios of the 5G telecom power target network.

	D-RAN scenario	C-RAN scenario	CO scenario	Poor grid / off-grid scenario



	Key capability requirements	Key capability requirements	Key capability requirements	Key capability requirements
Simple	· 20-36 kW power supply capacity · Accommodation evolution capability · MEC Evolution capability · Full-Blade	· 20~60 kW power supply capacity · MEC Evolution capability · Hosting evolution capability · Remote power supply capability	· 50~120 kW power supply capacity · MEC evolution capacity · High-density, full-modular · Remote power supply capability	· 20-36 kW power supply capacity · Hosting evolution capacity
Intelligent	· AI scheduling capability · Digitalization management capability	· AI scheduling capability · Digital management capability	· Digital management capability	· AI scheduling capacity · Digital management capacity
Green	· Site level energy efficiency improvement · Renewable Energy	· Overall station level energy efficiency improvement	· Overall station level energy efficiency improvement	· Overall station level energy efficiency improvement

Figure 11 Requirements of different 5G scenarios

4.1 D-RAN Scenario

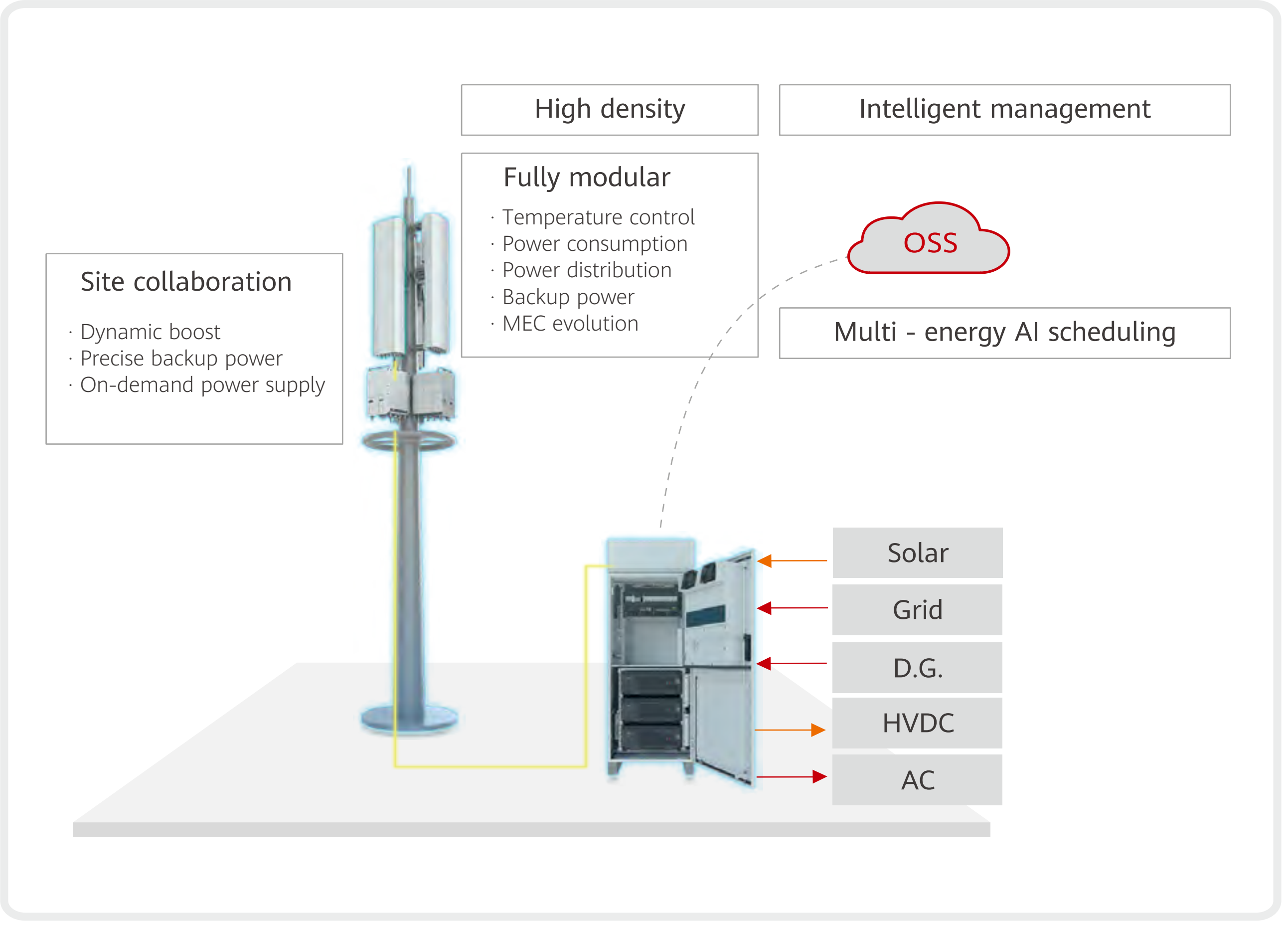


Figure 12 Cabinet power solution for D-RAN scenario

In D-RAN scenarios, modular, high-density power, and lithium batteries are recommended. One cabinet supports simple evolution of future-oriented target networks, avoiding new cabinets. The power system supports multiple energy and voltage modes to meet the requirements of solar energy access and AC power supply for MEC which may sink to D-RAN. Through high-density design, the D-RAN site can house all sites in one cabinet, saving construction costs. In addition, the sites can be managed remotely by the intelligent O&M system to improve O&M efficiency.

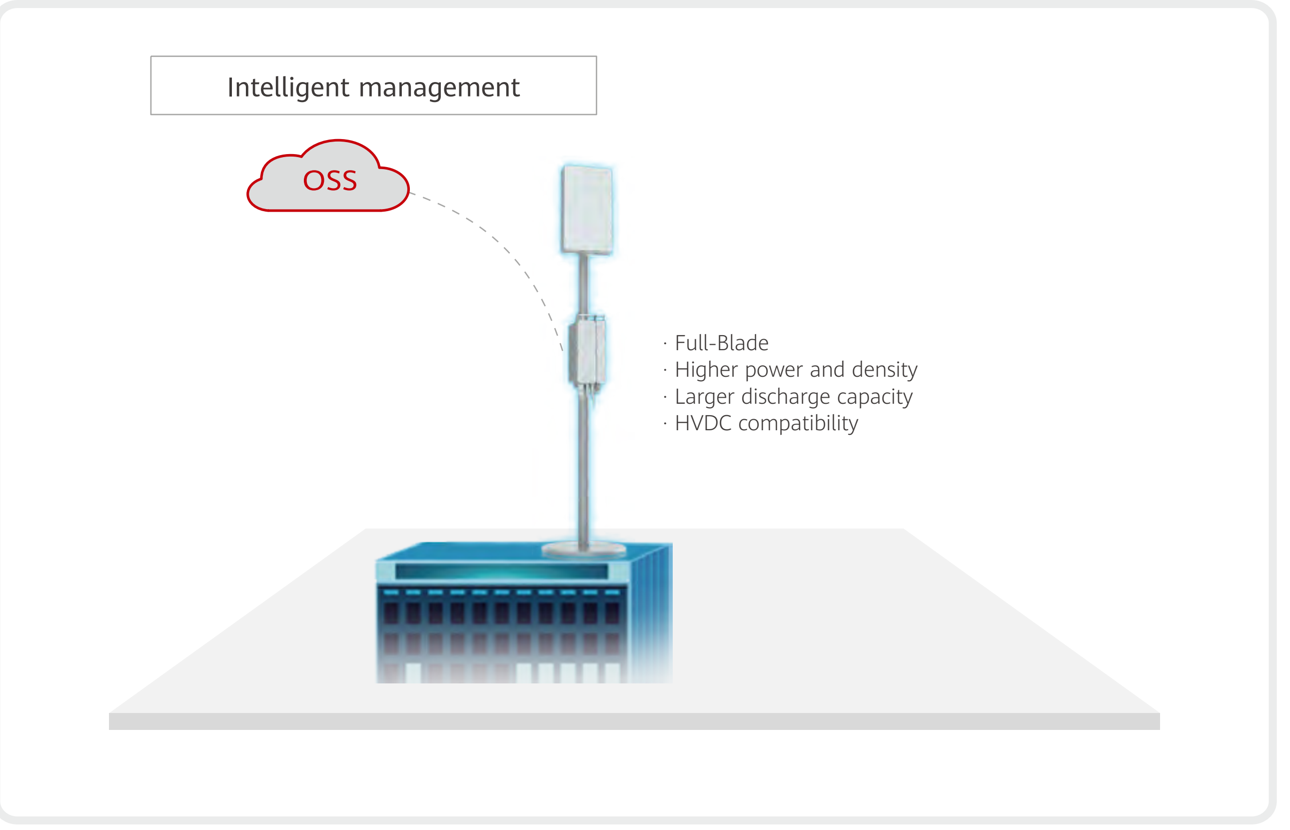


Figure 13 Blade power solution for D-RAN scenario

In scenarios where site acquisition is difficult, it is recommended to adopt outdoor natural heat dissipation blade power and battery system. In this way, the cabinet is not required and simple deployment is achieved. The site realize free of cabinet construction, which can save engineering costs and rents. No heat dissipation loss improves energy utilization efficiency. The all-natural heat dissipation design greatly reduces O&M frequency and reduces OPEX.

4.2 C-RAN Scenario

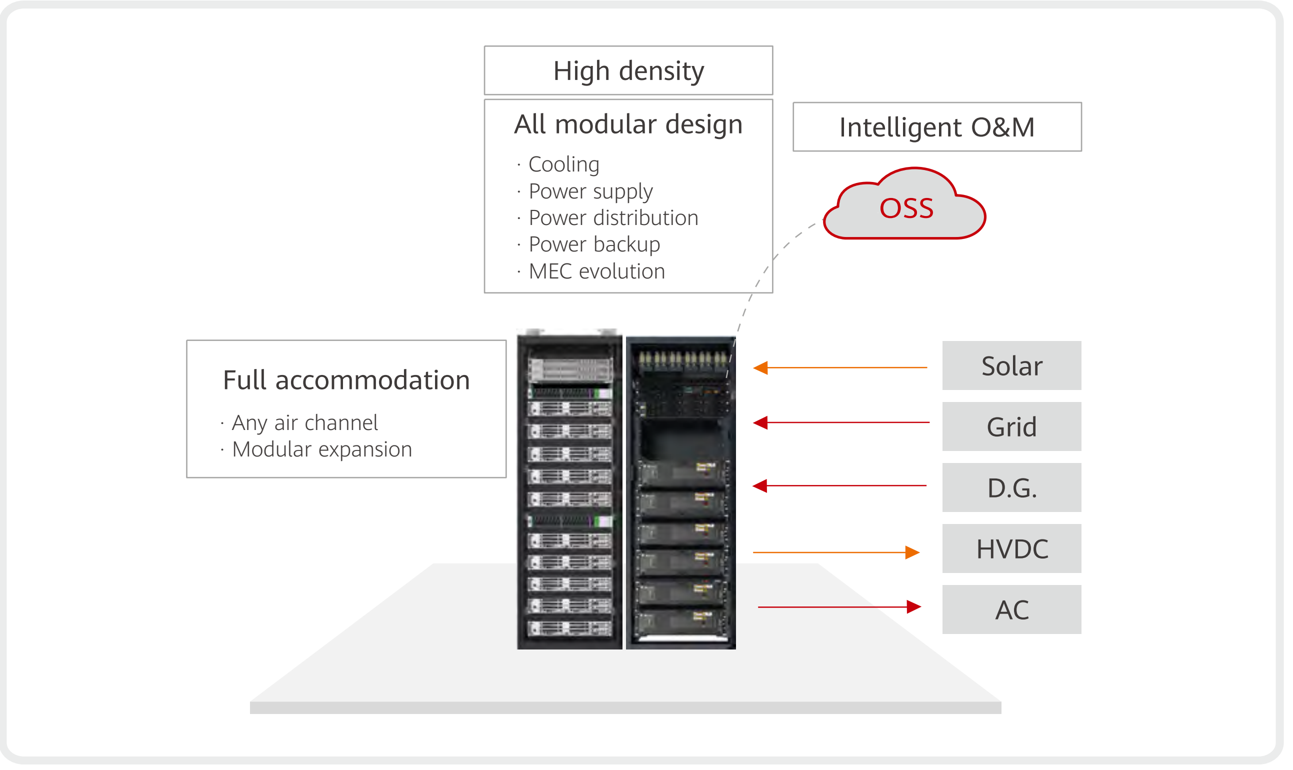


Figure 14 Power solution for C-RAN scenario

The C-RAN accommodates a large number of BBU devices. The heat dissipation efficiency of the equipment room greatly affects the energy efficiency. In addition, the C-RAN is the preferred site type for the MEC to sink. The power shall support AC output and solar access through evolution while the capacity of power, distribution and backup shall support flexible expansion according to the service capacity. Based on the preceding requirements, the power system of the C-RAN site should be able to fully accommodate BBU products and improve site heat dissipation efficiency and site energy efficiency through precise cooling and heat dissipation design. In addition, the power side should adopt full-modular architecture design to support continuous telecom and computing services in the future

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4.3 Core Room Scenario

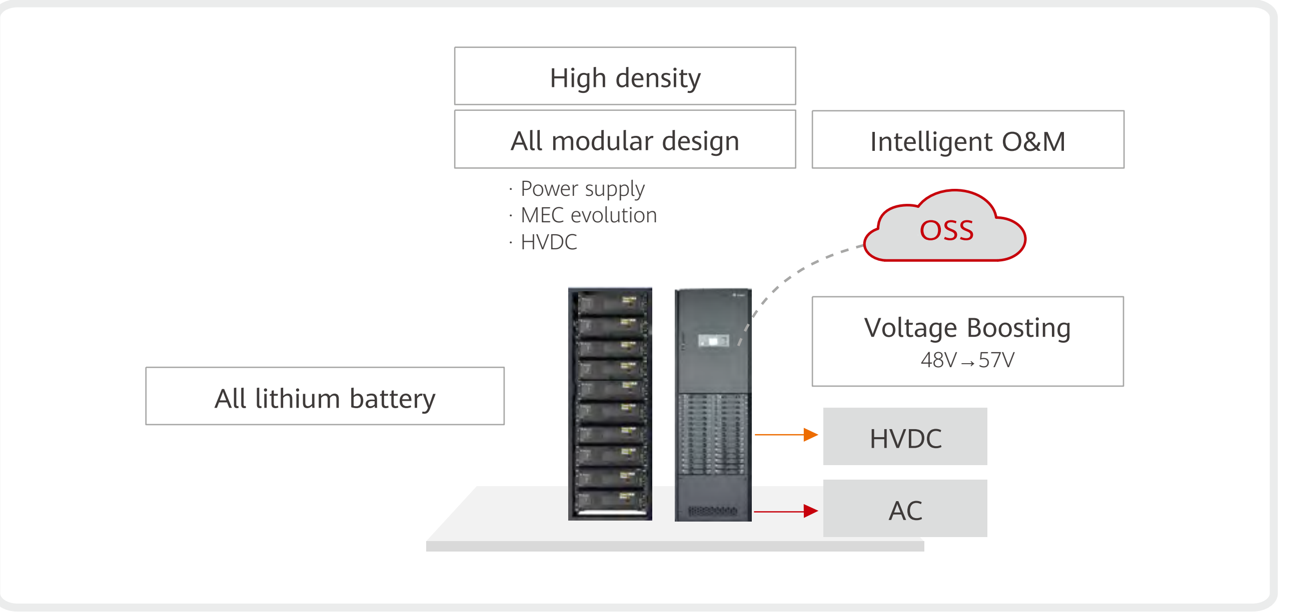

Figure 15 Power solution for Core Room scenario

The 5G core equipment room will further enhance the convergence of the CT&IT. The power of core equipment room shall have the AC power supply and backup capability to meet the deployment requirements of IT devices such as MEC. With scale application, the lithium battery industry is more mature. Lithium batteries are used to replace lead-acid batteries in core equipment rooms, reducing the bearing capacity by 50% and space by 50%. In addition, the power supply voltage of the CT is improved to reduce cable loss and improve energy efficiency.

4.4 Poor Grid Power Scenario

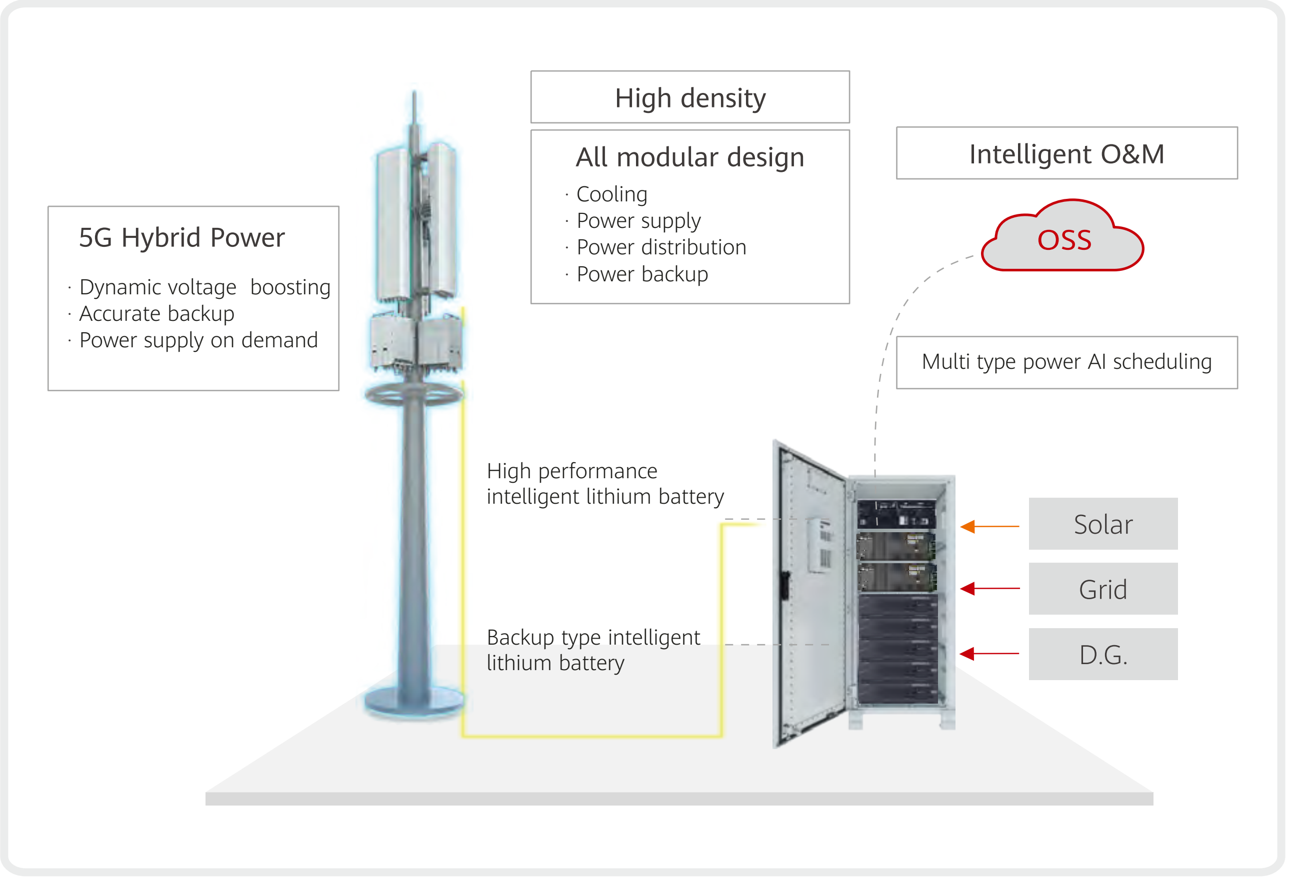

Figure 16 Power solution for poor grid Scenario

Although the 5G deployment in poor grid areas is later than that in densely-populated urban areas, the 5G network will eventually cover all types of areas. During the reconstruction or construction of the 5G network, the solution focuses on reducing the OPEX by means of intelligent scheduling and green energy. In addition, this solution for poor grid scenario shall consider 5G ready referring to the 5G site construction.

5. Summary

At present, many operators in different countries and regions have started 5G network construction. The traditional way of building 5G network by individual devices adding together will cause a big scale of energy infrastructure upgrading, which brings high cost of transformation and delays the 5G progress.

The way of 5G telecom energy construction needs to be changed. We suggest that we design the entire network power system in terms of simple, intelligent and green for the purpose of energy target network. This requires a change in the design mode of the site power system, from the independent design of each subsystem in the traditional way to the integrated design of the entire site power system, and from the improvement of the components performance to the entire site performance. More intelligent technologies are used to accelerate green energy application, to simplify O&M of the network, so as to reduce the energy consumption per bit and to build a better all-connected world.

Acronyms and Abbreviations

Abbreviations	Full spelling
AAU	Active Antenna Unit
D.G.	Diesel Generator
O&M	Operation & Maintenance
eMIMO	Multiple Energy Source Input, Multi-mode Output
SEE	Site Energy Efficiency
D-RAN	Distributed Radio Access Network
C-RAN	Centralized Radio Access Network
FR1	Frequency Range 1
MEC	Mobile Edge Computing
NR	New Radio (The new 5G radio access technology)
TTM	Time to Market
OPEX	Operating Expense
MTTR	Mean Time to Repair