ZTE

# PowerPilot
# 5G energy saving in coordination with 4G

# Contents

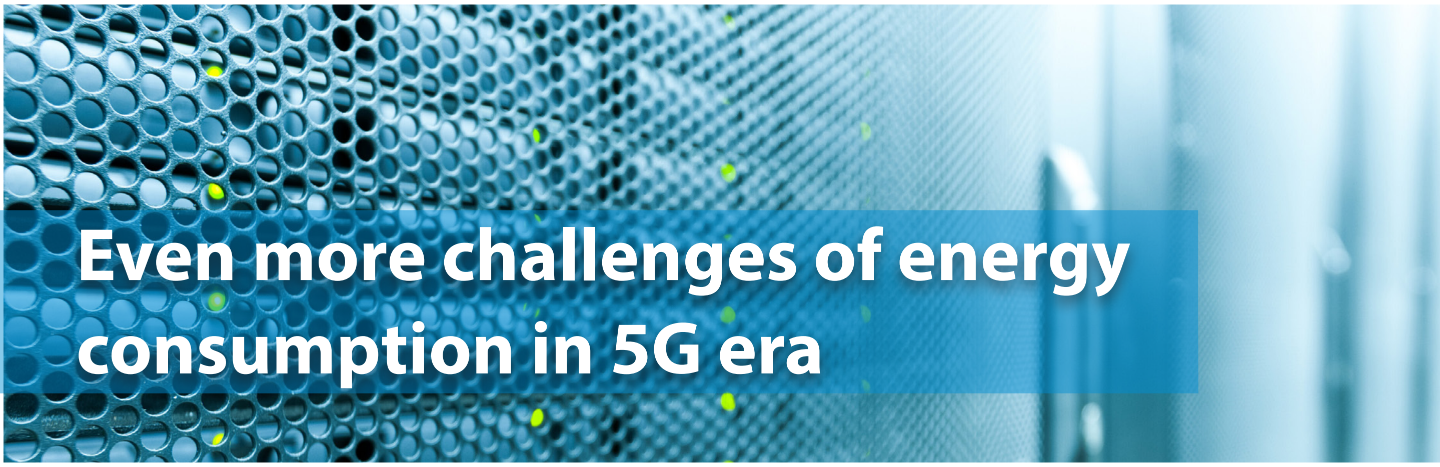
# Executive Summary


*Nowadays the 5G network deployment is on the fast track around the world. Many MNOs (mobile network operators) are currently running 2G, 3G, 4G and 5G networks at the same time. A report from GSMA about 5G network cost suggests up to 140% more energy consumption than 4G. Energy saving measures in MNOs are needs rather than nice-to-have.*

*As the impacts of climate change become increasingly critical around the world, reducing the energy consumption of cellular network and curbing GHG (greenhouse gas) emissions should be the responsibility to both mobile network operators and vendors.*

*In this paper, we will provide an overview of the challenges of energy consumption in 5G era, and explain in more details how MNOs and vendors reduced cellular network energy consumption in last two decades, then elaborates what PowerPilot is and how it can reduce 5G energy consumption in coordination with 4G.*

*Thanks to our advanced technologies and abundant experience in commercial applications, PowerPilot helps achieve the most energy-efficient network with good performance and lower OPEX (operating expense) for the mobile network operators.*



# Even more challenges of energy consumption in 5G era

5G is the most advanced cellular technology in commercial deployment of our era. While 5G offers much faster speed, massive connections and much shorter latency, and would enable a much bigger variety of new applications for both people's lives and vertical industries, it does increase the energy consumption of the cellular networks.

While the overall energy efficiency of 5G is better than any of the previous generations, it might not be the case at the initial stage of 5G when the terminal penetration rate is not very high and new killer services still need time to materialize, then the energy efficiency issue of 5G can be a problem for lowering network operation cost.

What's more important, energy consumption and carbon emissions reduction are also a social responsibility and commitment of operators. In the guide for the MNOs by GSMA about climate target, the goal is to reduce carbon emissions by 45% from 2020 to 2030.

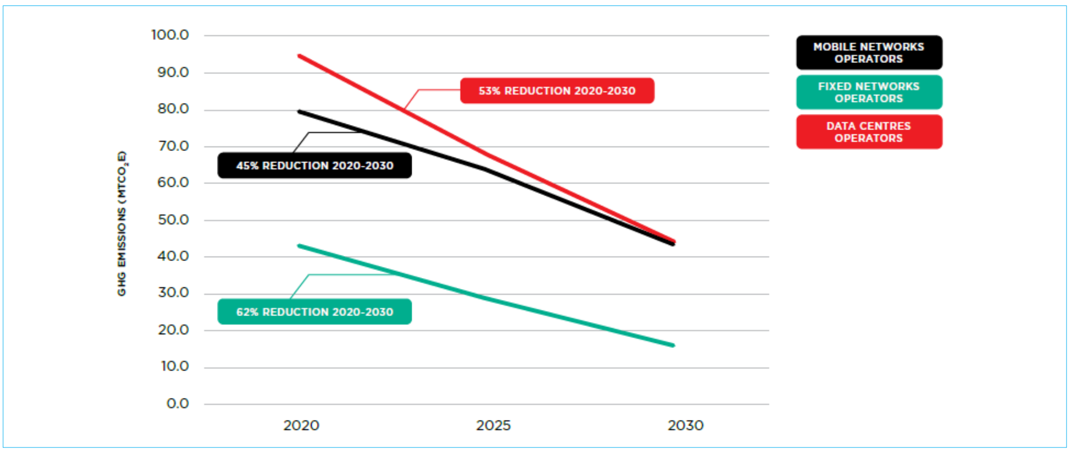



Figure 1 Sub-sector GHG percentage reductions from 2020-2030

The research of "The Shift Project" showed the carbon footprint of the ICT (information and communications technology) industry amounts to 2% of global emissions, with a CAGR (compound annual growth rate) of 9%. Sustainability has risen to the top of the agenda for many industries, including telecoms. MNOs need to rethink the usage of energy and their impact on the environment, and this will have a profound effect on the way they plan and deploy the next-generation networks. Thus a collaborative energy saving solution among equipment, sites and network will become an inevitable trend in the 5G era.

# 5G energy saving does not have to start from scratch

In response to climate change, MNOs and vendors have been developing network energy saving technologies since 2G era. In the past 10 years, these technologies contributed over 50% energy saving for the most advanced operators. This is not an overnight result but has gone through several stages of technical development.

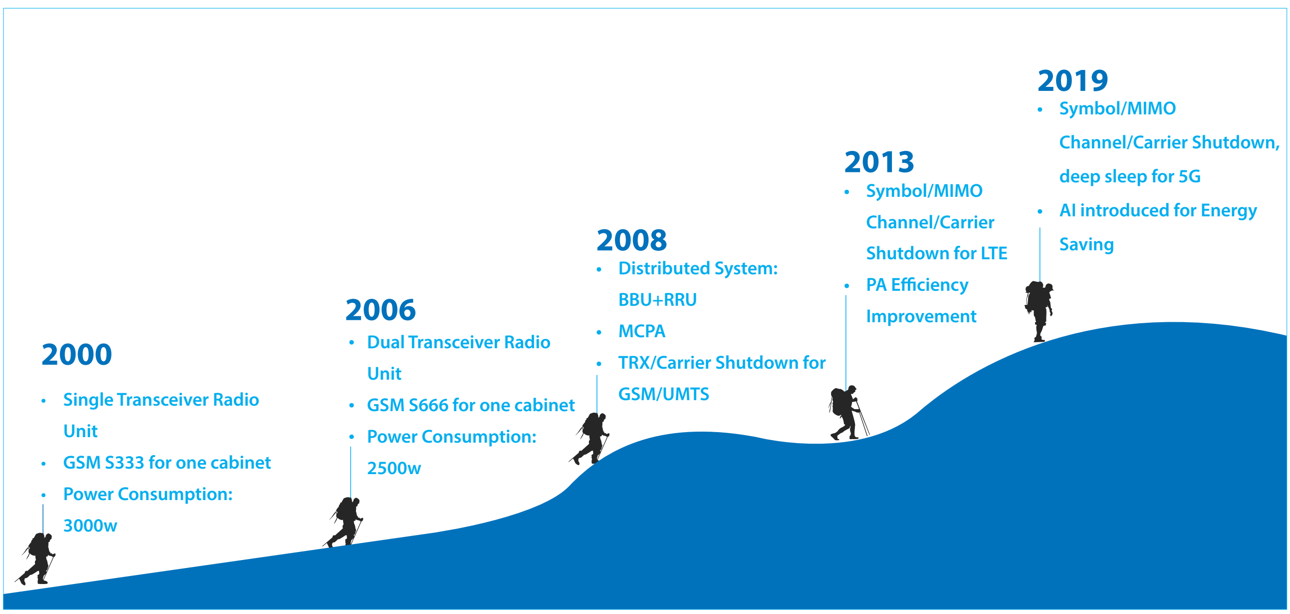



Figure 2 Energy saving technology development in the past two decade

New technologies used in 5G provide faster and more services which make 5G system more complexity than 4G. However, providing services with cellular network, transferring signals with multiple channel, etc., 5G and 4G have something in common. Thus 5G energy saving does not have to start from scratch, many network energy saving technologies developed from 2G era can be leveraged.

The biggest challenge for cellular network energy saving is about the base stations, which account for about 70% or sometimes even 80% of total energy usage of a typical cellular network. The energy consumption of a base station varies by environment temperature, power grid and traffic. According to a research (Chunming Meng, 2020), the cooling system accounts for 20% to 40% of total energy consumption, the power distribution system about 5% to 20%, and the base station equipment over 50%, which gives it the top priority in terms of reducing energy consumption.

The challenge to reduce the energy consumption of radio system can be addressed with both hardware and software measures.

## Hardware: equipment energy consumption reduction

Thanks to the improvement of semiconductor and fundamental other technologies, their massive-scale commercialization, and product design and development, the mobile industry has come a long way for reducing equipment energy consumption.

Under the distributed architecture of base station, deployed in the most of cellular networks, energy consumption of radio frequency unit accounts for 75% (single band with 3 sectors for example). With the increasing of spectrum resources and sectors, the proportion can even be over 90%, which makes that energy consumption reduction of radio frequency units should be the primary task.

In order to reduce the energy consumption of radio frequency units, it is necessary to analyze the energy consumption proportion of each component. Taken AAUs (active antenna units) of 5G for an example, energy consumption consists of power supply unit, baseband processing unit, DIF (digital intermediate frequency) processing unit, transceiver and small signal unit and PA (power amplifier). In the white paper “Energy saving technologies of 5G base station” from China Mobile, it shows that the energy consumption proportion of each unit varies from traffic load.

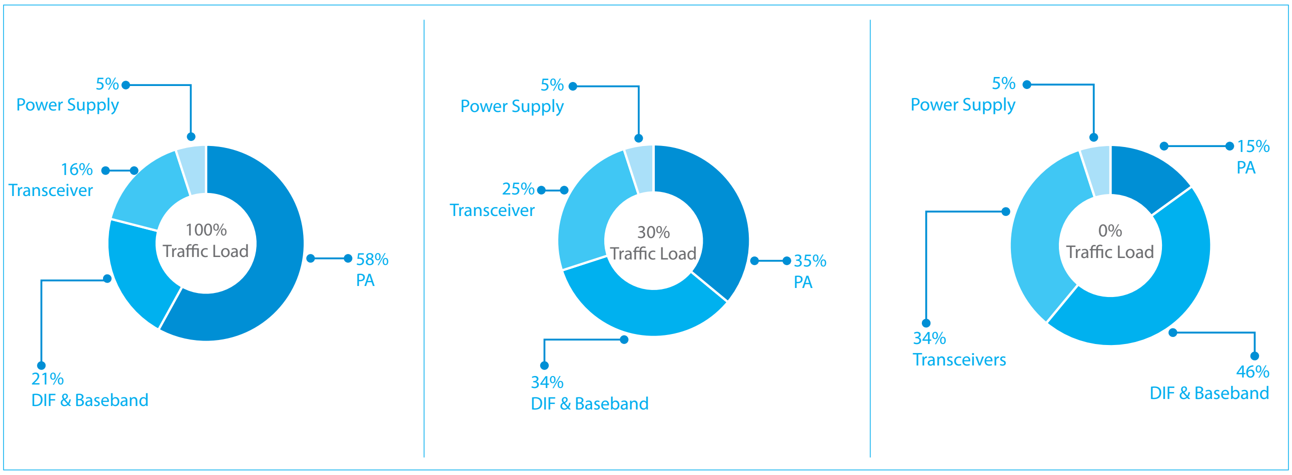



Figure 3 AAU energy consumption proportion

ZTE facilitates green network with our latest technology innovations. 5G AAUs powered by latest generation in-house design chipsets with high computing capacity, including baseband processing and DIF processing chipsets, and high efficiency PAs reduce energy consumption.

## Software: site and RAN energy consumption

In the commercial networks, the traffic pattern may vary from site to site, and/or hour to hour. Turning off equipment or parts of the equipment or even putting it into sleep mode when there is little or no traffic to serve can save energy.

Based on traffic load and resource requirements, the base station software can shut down power amplifiers, transceivers and other different network elements to save energy, which has been basic function requirement to MNOs.

All these technologies can be applied in 5G network to reduce the energy consumption. However, it is far away from being enough, thus a revolutionized energy saving solution needs to happen in 5G era.

PowerPilot revolutionizes 5G energy saving in ways that had never been available before. With basic energy saving functions and AI-driven traffic forecast, PowerPilot further exploits the differences in energy efficiency of different types of services to deliver certain services to the most energy-efficient network, which helps achieve the most efficient energy usage and lower OPEX for the MNOs.

# PowerPilot: 5G energy saving in coordination with 4G

## Highest energy efficiency: coordination of energy consumption and network capacity

Relatively speaking, the growth of network traffic is often progressive, whereas the growth of network energy consumption can be sudden and dramatic, particularly at the time of new deployment and major expansion. Any rollout of new generation of network technologies would pose big pressure on the network energy efficiency, and result in a pattern of energy efficiency evolution that does not always follow that of cellular network technology evolution.

Such phenomenon is now probably at its peak in history, when 5G is getting deployed with so many new technologies and new spectrum bands to incur much higher network energy consumption. Yet the traffic can only grow at a much slower pace than the fast rollout of the network, due in no small part to 5G terminal penetration and new service introduction. It is therefore not really a surprise that the initial deployment of 5G is when the cellular network performs worst in terms of energy efficiency.

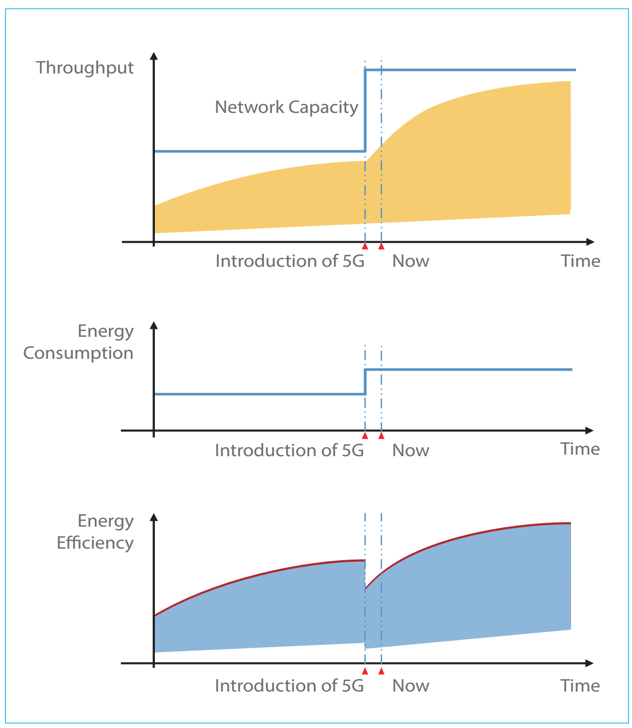



Figure 4 Trend of traffic load/energy consumption/energy efficiency

To address such challenges, it is very important to find the most efficient match of traffic load and network capacity in a flexible and dynamic way, in addition to improvements on air interface technologies and hardware equipment. This is in fact how PowerPilot works.

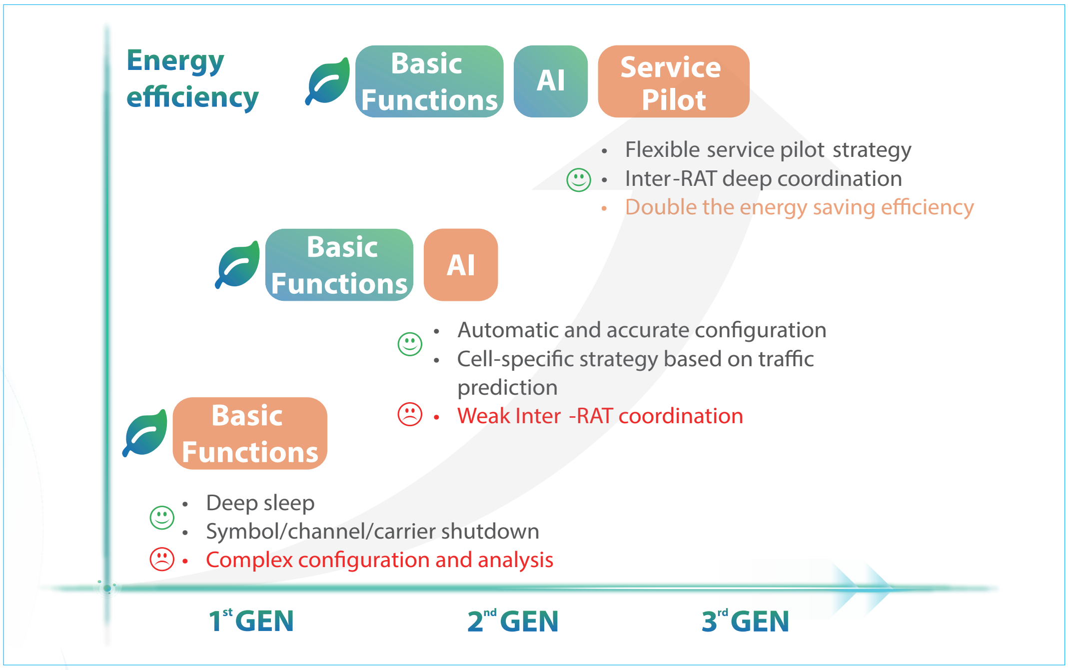



Figure 5 PowerPilot solution evolution

### Network capacity adjustment based on traffic load

By shutting down the resources that are not utilized and keeping network capacity adequate yet minimum, network energy consumption can be optimized in line with the network traffic load.

### Subscribers distribution optimization based on network capacity

By directing users from their less power-efficient spectrum band(s) to other band(s) that are more power-efficient, more radio resources can be shut down to lower network energy consumption.

## 1st generation: the fundamentals

The beginning of network energy saving came with the fact that many sites had their traffic peaks and troughs, which means certain parts of the base stations could be shutdown to save energy, and these included carrier shutdown, channel shutdown, symbol shutdown and equipment deep sleep.

## Carrier shutdown

In commercial cellular network, there are often multi-frequency and multi-mode networks. As usual, low frequency or legacy network mode is the basic coverage and capacity layer, while high frequency or advanced network mode is the extra capacity layer. During no traffic or extremely low traffic period, the extra capacity layer could be shut down, thus carrier shutdown is the first developing technology deployed for energy saving. When the traffic load exceeds the capacity of basic coverage layer, the extra capacity cell should be woken up.

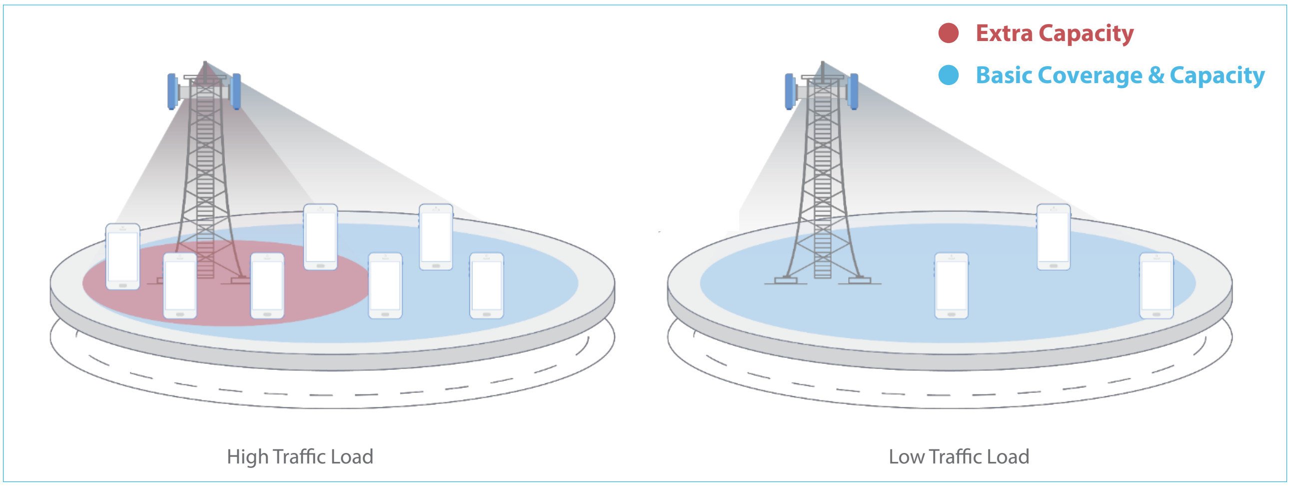



Figure 6 Carrier shutdown

## Channel shutdown

Since 4G era, MIMO (multiple input and multiple output) has been introduced so that cells can transfer the signal with multiple channels. When network traffic load is low, parts of channels (PAs and transceivers) can be shut down for energy saving. After these parts are shut down, the power spectrum density of the remaining channels should be increased in order to ensure that the entire cell coverage is unaffected. The PRB usage rate, RRC connected users and voice users will be taken into consideration for cell traffic load judgement. In 5G era, more channels of AAUs can be shut down.

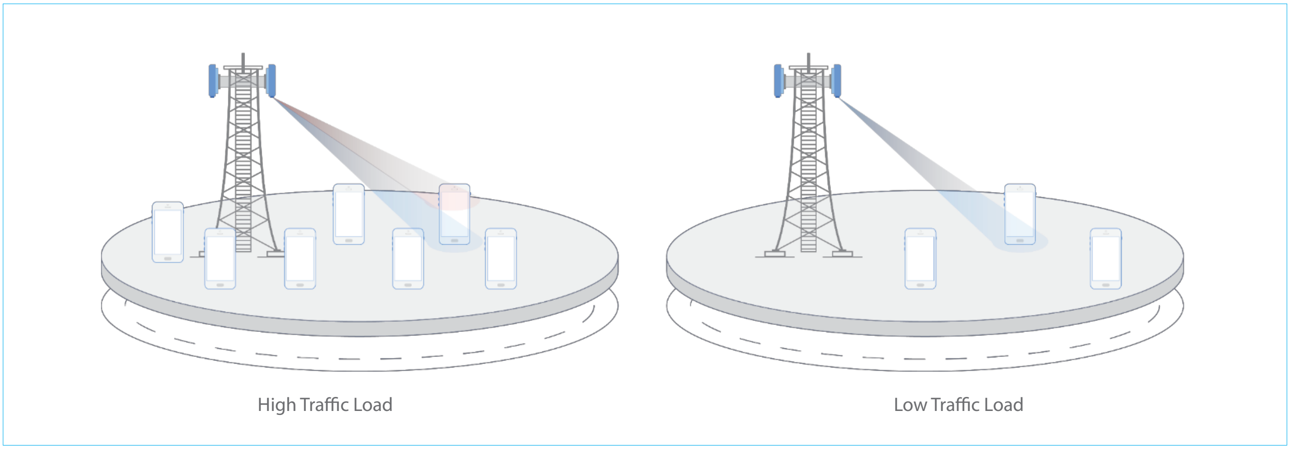



Figure 7 Channel shutdown

## Symbol/Slot shutdown

Symbol shutdown has been developing in the network during medium traffic period in which carrier shutdown and channel shutdown are unavailable. Symbols in sub-slots are not always in effective use in LTE (long term evolution), NR (next radio) and NB-IoT (narrow band internet of things) system. The scheduler allocates a certain number of symbols for downlink data in accordance with the system load and service data forecasts, and turns off the PA to save energy when there is no information being transmitted. In particular, symbols without cell reference signal (CRS), synchronized signal (SS), or broadcast messages can be shut down. The scheduler can even concentrate the user data in just a few sub-slots, so that more sub-slots without user data can be shut down, reducing energy consumption more often.

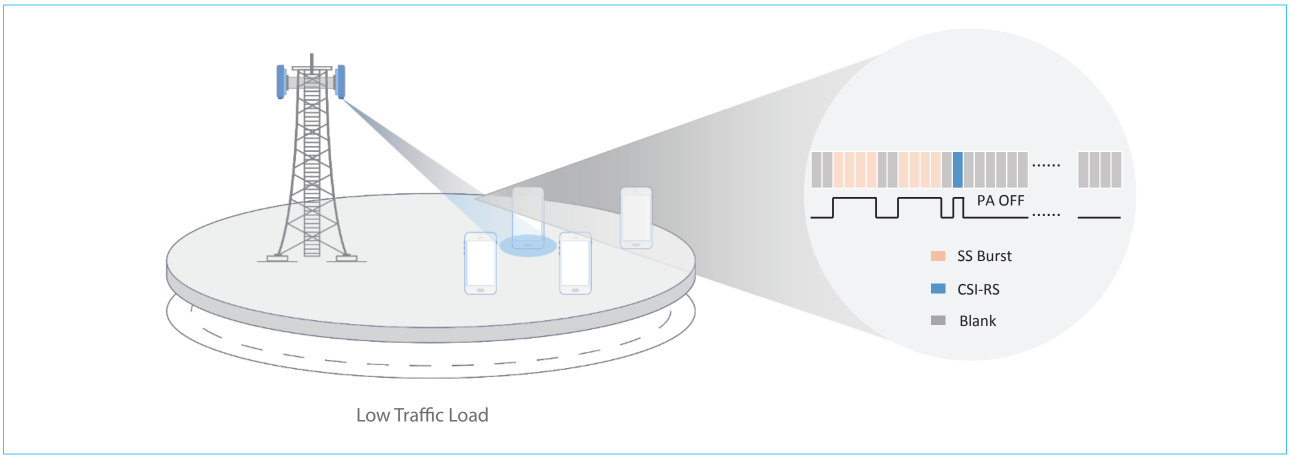



Figure 8 Symbol shutdown

## Equipment deep sleep

Equipment deep sleep, basic function which is introduced in initial stage of 5G deployment, can be applied to maximize the energy saving efficiency. During no traffic or extremely low traffic period, radio frequency unit could be put into deep slept with only eCPRI (enhanced common public radio interface) processing unit and power supply unit remaining active. Others units like transceiver, baseband, DIF, etc. could be completely shut down for further energy saving. In order to have little impact on user experience, the connected users will be migrated before the deep sleep.

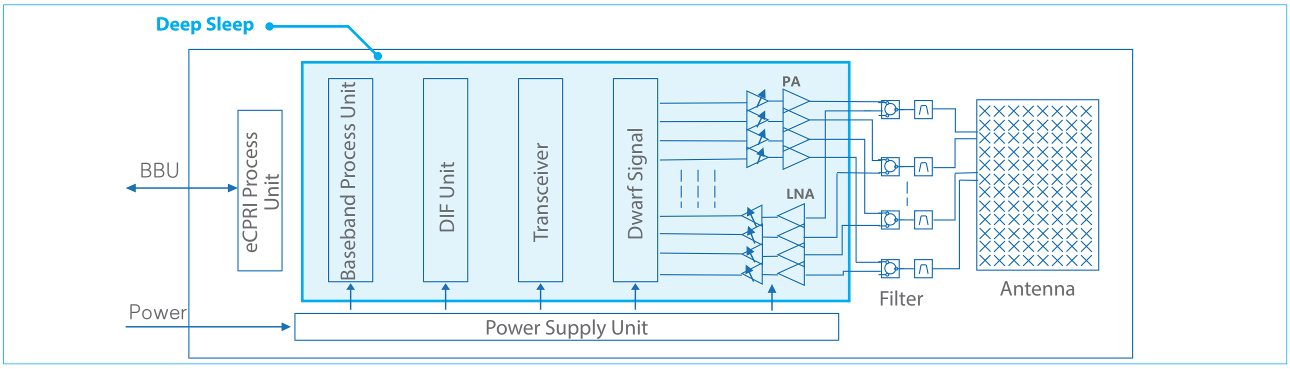



Figure 9 Deep sleep

The energy saving functions with multi-levels are designed for different coverage scenarios, time of day and traffic loads. Basic energy saving functions, 1st generation energy saving solution of ZTE, has been widely commercially deployed in more than 20 networks with over 600,000 sites, saving 5% energy in average for the whole cellular network.

## 2nd generation: the power of AI

The time distribution of cellular network traffic has often obvious peaks and troughs, while the network configuration keeps the same over a long period of time. One key of energy saving is to reduce inefficient consumption in low-traffic hours. In commercial network with various application scenarios, how to make traffic load match with energy saving strategy is essential.

Basic functions applied to the entire cellular network is not a site-specific strategy, resulting in less efficient due to ignoring the traffic and neighboring sites patterns varied from site to site. The shortcoming of unified and fixed strategies for the entire network is shown as following:

**Tedious data analysis**

- *Mass data analysis like KPI, traffic load for energy saving strategy confirmed*
- *1,440 man-hours required per 10,000 cells*

**Strategy without flexibility**

- *Non-differentiated energy saving scheme across area/network*
- *No scenario identification*
- *Poor matched-degree to traffic load variation*

**No real time optimization**

- *No timely optimization of energy saving and network performance based on network monitoring*
- *Difficult to find a balance between energy saving and KPI*

**Difficult energy saving strategy iteration**

- *New strategy required after frequency refarming or capacity variation*

In response to the requirement of an intelligent and self-adaptive energy saving solution, AI (artificial intelligence) and big data technology are introduced to form a more precise energy saving strategy based on specific site traffic and other site-related conditions, thus improving the efficiency and reducing the manpower required.

The key technologies include: cell-specific strategy based on application scenario identification and threshold optimization based on traffic forecast.

## Cell-specific strategy based on application scenario identification

Many MNOs are currently running simultaneously 2G, 3G, 4G and 5G networks. 4G carries the most of traffic load, while 5G is yet to take over. Based on traffic distribution, shutting down some less efficient frequency bands or network can significantly reduce total energy consumption.

To achieve an efficient energy saving strategy specific to a certain cell, the coverage of the cell and its neighboring cells' coverage and traffic load need to be all taken into consideration. The reason is that any shutdown of a cell with direction of its users to neighboring cell(s) has to rely on the good availability of the neighboring cell(s) including coverage and capacity.

### Coverage identification

Coverage identification depends on operating parameters (site ID, longitude, latitude, antenna height and azimuth) and MR data (cell ID, RSRP (reference signal receiving power), SINR (signal to interference plus noise ratio), TA (time advanced)). Based on these information analysis, the cell coverage performance can be calculated to identify the relationship between the co-coverage cells.

### Configuration identification

A specific scheme of using the basic functions can be matched to its corresponding site after analyzing the site's network architecture (NSA/SA, network sharing), configurations (BBU, RRU, AAU, frequency band), neighbor cell relationship, all of which can be fetched from OMC (operation and maintenance center).

### Cell-specific initial strategy

Initial energy saving strategy can automatic configuration based on coverage identification and configuration identification by AI technology. The suitable energy saving strategy combined with different energy saving functions, including an initial relative threshold to the scenario and executable energy saving time schedule, will be enabled for the sites that are expected to have energy saving effects.

- *Idle or low traffic period based on historical traffic analysis*
- *Energy saving threshold based on network traffic load*
- *Energy saving activation time based on threshold*
- *Energy saving function combination*

## Energy saving strategy optimization based on traffic load forecast

Based on ZTE's in-house AI engine, AI-driven energy saving solution is self-adaptive to network real traffic requirement. In most cases, the forecast matches well with the actual traffic, which means that energy saving can be enabled in far more occasions. The modeling is based on historical traffic data (PRB (physical resource block) utilization, RRC (radio resource control) connected users, online users), special days, etc. and then time series algorithms will be applied for traffic load forecast.

### Traffic load forecast

Based on historical traffic data, three types of cells will be distinguished in modeling:

***Positive cells:*** *cell throughputs, users, and PRB utilization increase during weekend or special days.*

***Negative cells:*** *cell throughputs, users, and PRB utilization decrease during weekend or special days.*

***Neutral cell:*** *cell throughputs, users, and PRB utilization keep the same during weekend or special days.*

The intra-week sub-sequence split prediction method, in which each of the seven days in a week needs to be put into the series of its responding days of all the weeks, is combined with cell types, holiday factors and forecast of network traffic load. After putting all the algorithm candidates (linear regressive, ARIMA (autoregressive integrated moving average model) and LSTM (long short-term memory), second-order exponential smoothing, etc.) into tests, the one with the best results is selected.

The result of commercial application cases showed that the prediction accuracy exceeds up to 90% for uplink/downlink PRB utilization and RRC connected users.

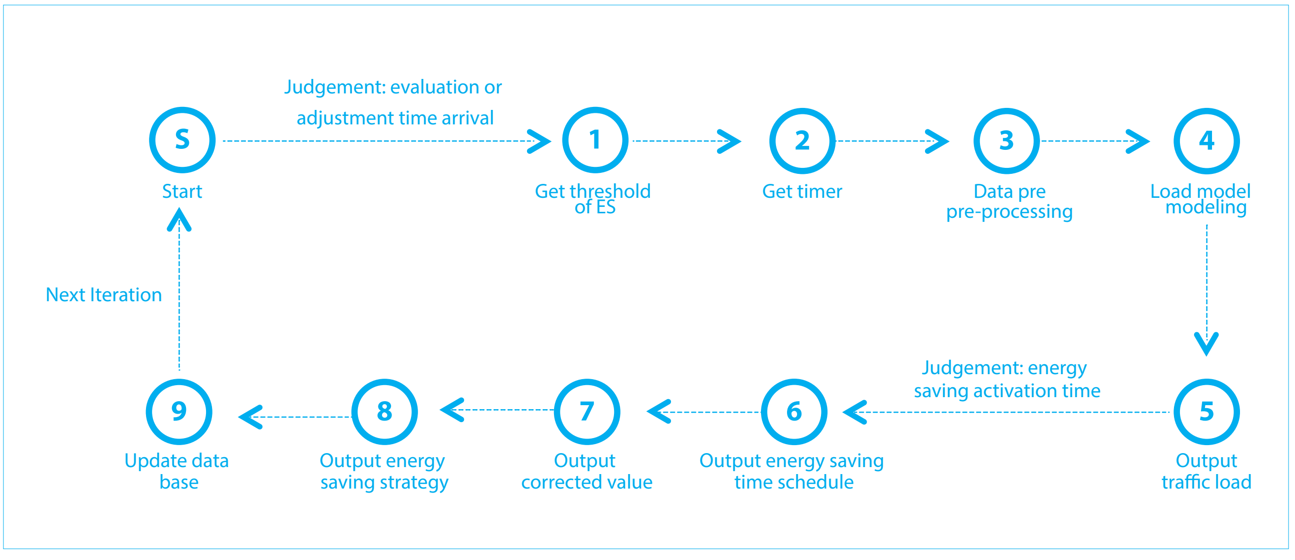



Figure 10 Traffic load prediction

## Online iteration and optimization of the threshold

In order to improve the energy saving efficiency, online iteration and optimization of the threshold can be used instead of the traditional ways which does not take site variations into consideration and results in safe but inefficiency energy saving settings.

Clustering algorithm is used to find out the optimal energy saving threshold settings with the best efficiency and shortest time. In any case when the KPI baseline is compromised, the threshold can be rolled back.

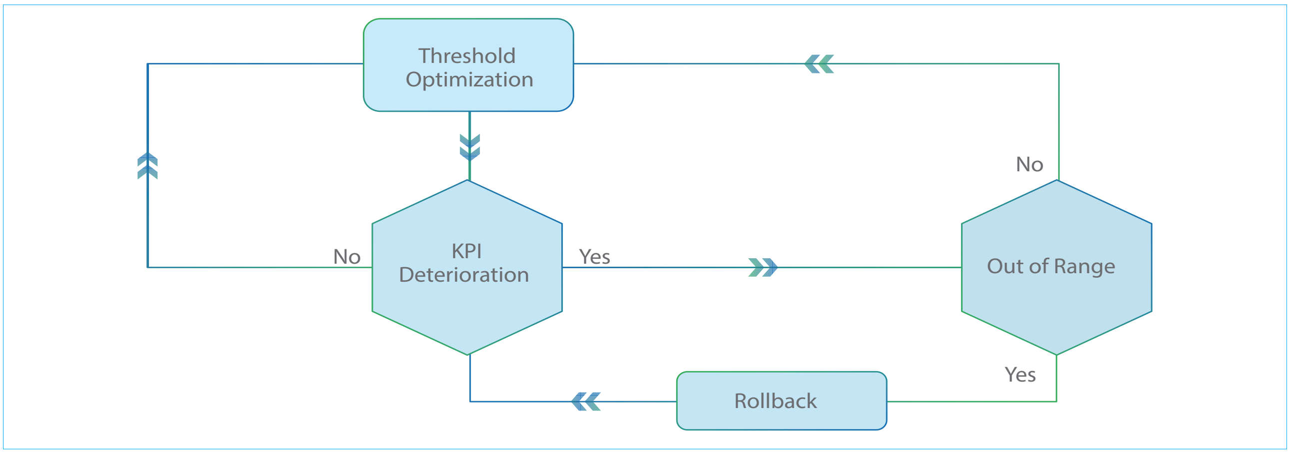



Figure 11 Online threshold optimization

AI-driven energy saving based on traffic prediction has been widely deployed since 2019, starting in China with over 100,000 cells, and also in other countries such as Malaysia, South Africa, Italy and Indonesia. The results showed that 80% activation time has been increased and over 10% energy consumption has been saved in the entire network.

# 3rd generation: the service awareness

Though 5G can provide faster and more services, its energy efficiency is not always optimal especially at the initial stage of deployment or with low traffic.

AI-driven traffic forecast does improve the energy saving efficiency of basic functions. But in most multi-mode and multi-frequency cellular network, it still has some limitation that service efficiency varies from mode to mode, and/or band to band. And if all services/users are concentrated in part of the network/band, more energy consumption could be saved after idle network/band shut down or deep sleep.

AI-driven service pilot exploits the differences in energy efficiency of different types of services to deliver certain services to the most energy-efficient network, helping achieve the most efficient energy usage without impact on user experience.

The key technologies of AI-driven service pilot include: user network/band distribution with respected of energy efficiency and user direction in coordination with other strategies.

## User network/band distribution with respected of energy efficiency

To improve the network energy efficiency based on user redistribution, there are three main steps: target network/band selection, suitable user selection and consequent user direction. Service efficiency varies from network to network, and/or band to band, the most energy-efficient network/band will be selected as target and the most suitable users will be selected. Also, energy efficiency pattern may change after user direction, leading a new round of optimization. Thus the three steps together form a closed loop.

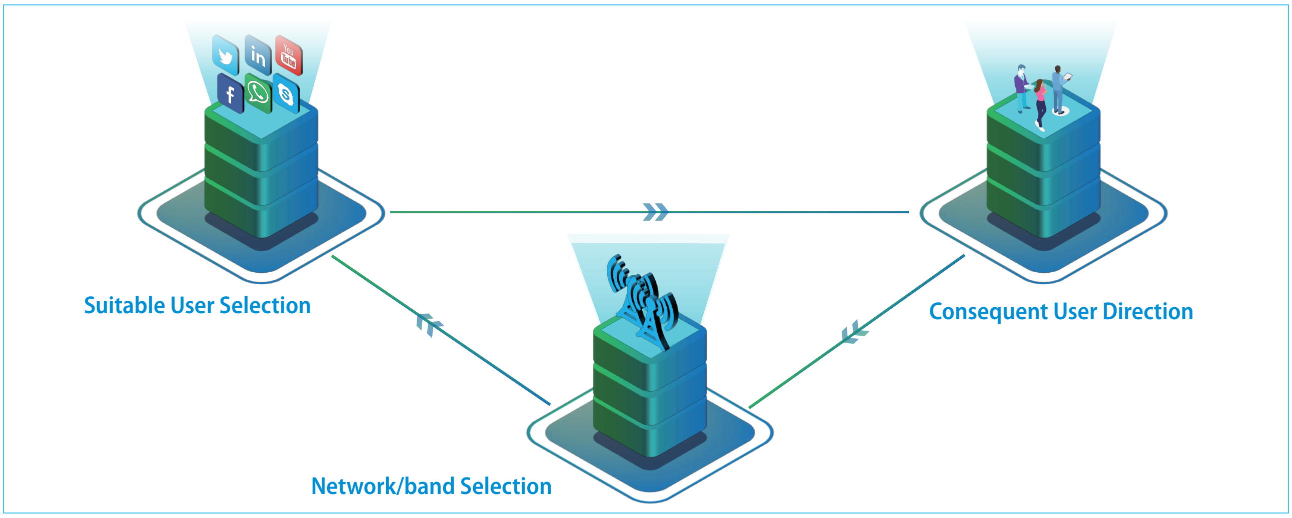



Figure 12 User network/band distribution

### Target network/band selection

Source network/band and target network/band can be defined based on coverage identification, traffic load forecast and energy efficiency analysis. Some factors should be taken into considerations in selection:

- *Source network/band and target network/band have co-coverage;*
- *In source network/band, there are suitable users who can be directed to target network/band;*
- *For source network/band, there will be more energy saving functions can be activated;*
- *For target network/band, energy saving functions will not be disabled after user direction*

Source network/band and target network/band defined here is a cluster rather than a cell. Defining a cluster needs to meet the following preconditions:

- ***Coverage:*** *each one of the cells included in a cluster should be a part of the same coverage area such as a building or an industry park.*
- ***User Mobility:*** *mobility management of users should only occur within one cluster.*
- ***Scale of the cluster:*** *5 to 10 cells in one cluster are most suitable because over 10 cells may bring higher requirements of storage and computing capacity for cluster traffic load analysis and parameters for mobility management modification, whereas below 5 cells may cause no enough suitable users.*

### Suitable user selection

After target network/band selection, users in source network/band should be evaluated before service piloting. Serval factors should be taken into consideration for less impact on the user experience.

***The service can be supported by the target network/band***
*Considering terminal ability, user mobility policies at core network, network slicing, etc. the user/service will be selected only when it  can be supported by the target network/band.*

***There will be little impact on user experience after direction***
*Since user experience may vary from network to network, and/or from band to band, in order to guarantee the user experience, user/service selection should be based on:*

***Precise service identification***
*Services with 5QI (5G QoS identifier) only could not help identify their application types, so DPI (deep packet inspection) can be used by the base station to precisely identify user/service.*

***Evaluation based on big data***
*Evaluation report should combine KPI of network performance with MR (measurement report) data, CQT (call quality test) and DT (driver test) instead of only counters or KPI.*

***Specific business requirement***
*Some VIP users, network sharing users, roaming users may be limited in network direction. Their business requirements should also be taken into consideration.*

### Consequent user direction

The selected users, either in idle mode or connected mode should be directed to the target network/band for user network/band distribution.

***Connected mode***
*Inter-RAT (radio access technology) handover and intra-RAT handover should be supported between source and target network/band. Redirection should also be supported in case of terminal ability limitation.*

***Idle mode***
*Source network/band priority should be modified to the lowest after user direction to avoid "ping-pong" reselection between source and target network/band.*

## User direction in coordination with other strategies

Besides user network distribution with respected of energy efficiency, there are some other strategies, such as camping priority, mobility load balance, network/service slicing, etc. that may not agree with energy saving strategy. User direction in coordination with other strategies is another important part.

### Coordination with coverage and camping strategy

In commercial network, advanced mode or new band will have the highest camping priority, which may not agree with energy saving strategy. So the network/band priority for camping should be modified when a more advanced RAT or new band adopts carrier shutdown or deep sleep for energy saving.

### Coordination with mobility load balance

Users in connected mode will be handed over to low traffic network/band for better user performance based on mobility load balance strategy which does not agree with energy saving strategy, either. In commercial network, mobility load balance strategy should have higher priority than energy saving strategy. User handed over to the source network/band due to load balance should not be selected as energy saving user.

### Coordination with service-based network/band prioritization

A common practice in commercial networks regarding supporting services over which network/band is that certain services, say VoLTE (voice over LTE), are supported over pre-defined network/band, such as 900 MHz for 4G VoLTE. When the priority of such network/band is higher than that of energy saving, to achieve even better energy saving results requires changing such priority settings to make energy saving for such network/band possible, which is of course a decision for the operators to make dependent on their specific requirements.

# Conclusion

*ZTE's network energy saving solutions have been deployed in more than 20 networks with over 600,000 sites, saving more than $1 billion electricity expense for the operators. The introduction of AI and big data in mobile network can make intelligent energy saving available to lower network OPEX. In addition, through 24x7 monitoring of network performance and energy consumption, not only can the operators reduce energy consumption, but also they can do so without impacting network user experience.*

*Climate change is indeed one of the most critical challenges of our time, and the mobile industry has to take responsibility of coping with it. What comes along with the mighty 5G is our task to have a greener 5G. PowerPilot is just one step towards a more sustainable future, yet demonstrates how we can think out of the box and leverage the most advanced technologies to achieve the goal.*

# Glossary

| | |
|---|---|
| AAU | Active Antenna Unit |
| AI | Artificial Intelligence |
| ARIMA | Autoregressive Integrated Moving Average model |
| BBU | Building Baseband Unit |
| CAPEX | Capital Expenditure |
| CQT | Call Quality Test |
| DPD | Digital Pre-Distortion |
| ECPRI | Enhanced Common Public Radio Interface |
| EMBB | Enhanced Mobile Broadband |
| ICT | Information and Communications Technology |
| ITU | International Telecommunication Union |
| KPI | Key Performance Indicator |
| LSTM | Long Short-Term Memory |
| LTE | Long Term Evolution |
| MIMO | Multiple Input Multiple Output |
| MMTC | Massive Machine Type of Communication |
| MR | Measurement Report |
| MNO | Mobile Network Operator |
| MTO | Multinational Telecom Operator |
| NB-IOT | Narrow Band Internet of Things |
| NR | New Radio |
| NSA | Non-Standalone |
| OMC | Operation and Maintenance Center |
| OPEX | Operating Expense |
| PRB | Physical Resource Block |
| RRC | Radio Resource Control |
| RRU | Remote Radio Unit |
| SA | Standalone |
| TA | Timing Advance |
| URLLC | Ultra-reliable and Low Latency Communication |

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