世界无线局域网应用发展联盟
WLAN Application Alliance

全球固定网络创新联盟
Network Innovation and Development Alliance

Green Campus WLAN White Paper

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Preamble

About

Climate warming has become one of the most important challenges in the world. With the continuous rise of global temperature, the stability of global society, economy and environment are facing unprecedented threats. In 1992, the signing of the United Nations Framework Convention on Climate Change (UNFCCC) marked the official launch of global climate action. As a global climate change agreement, the Paris Agreement aims to limit global warming within 2°C above the pre-industrial level. To achieve this goal, many countries have committed to developing nationally defined contribution targets (NDCs) that will be strengthen emissions reduction efforts.

Industrial and business campus, as areas with intensive economic activities and concentrated energy consumption, contain a large number of buildings and facilities, such as office buildings, factories, warehouses, etc. They are the main places of energy consumption, so how to realize energy saving in the campus is quite important. Now, campus' intelligence and digitalization have become key actions to improve campus management level and energy efficiency. As the intelligent infrastructure of Campus, WLANs are widely deployed. WLAN energy saving solutions have attracted more and more attention. In addition to the WLAN own energy saving technologies, WLAN also has the sensing capability that using wireless signals to identify people or objects in the environment. The WLAN sensing and the Building Management System working together can greatly optimize the energy consumption of the air conditioning and lighting system.

Overall, both social commitment and operation cost savings drive the deployment of energy saving solutions for WLANs. WLAN planner urgently need guidance on energy saving solution deployment to ensure network user experience and reduce energy in campuses to support the achievement of green campus.

Contents

Chapter 1
Background of Energy Saving Campus WLAN

1.1 Campus Introduction

As the basic unit of the city, the campus is the most important population and industrial agglomeration area. According to Huawei's Enterprise Business Market Insight, more than 90% of urban residents work and live in campuses, and more than 80% of GDP and 90% of innovation are generated in campuses.

Figure1-1 The campus is the basic unit of the city.

According to the campus list issued by the National Development and Reform Commission of the People’s Republic of China, 80% of the industrial enterprises are concentrated in the campus, and the total industrial output value of the campus accounts for more than 50% of the country's total industrial output value and 31% of the country's carbon emissions. Industrial campuses shoulder the important mission of carbon reduction. Low-carbon campuses play an important role in energy saving.

Low carbon campus refers to an industrial campus guided by sustainable development theory, taking carbon emission and sustainable development into account, improving energy efficiency by adopting cleaner production technology. The construction of digitally enabled smart building has become a powerful support for the operation of low-carbon campuses. With the support of digital technologies, enterprises can realize the ‘one enterprise, one strategy’ flexible energy saving solution by using various energy saving technologies.

1.2 Campus Network Introduction

A campus network refers to a network in a campus. (Campus generally contain multiple buildings, and is a limited geographical area which is smaller than the city). Typically, the campus network is fully owned by the campus tenant/owner (Enterprise, university, hospital, school, government, etc.), as shown in Figure1-2. With the deployment of a campus network, a building, one floor, or even several areas (using an enterprise as the border) can also be called a small campus network or an enterprise network.

Figure1-2 Campus network is the intelligent infrastructure of campus.

The campus network is to connect services and terminals. Campus networks are required to provide high-quality connections with ultra-large capacity and ultra-low latency. Both the IoT technology and wireless technology drive the revolution in data production, transmission, processing, and application on campuses. Ultimately, the production efficiency of the enterprise is greatly improved.

As the mainstream technology of campus wireless networks, WLAN has become the infrastructure of campus networks with flexible deployment, comprehensive network coverage, high communication rate, high cost efficiency, rich device ecosystem, strong capability of multi-service expansion. Stations of WLAN have rich device ecosystem also. Smart phones, wearable devices, tablets, laptops, videoconferencing terminals, printers, logistics vehicles, drones, and medical devices, all these devices using WLAN technologies. According to a report from a third-party consulting company, more than 70% of the world's end traffic uses the WLAN technology to access the network.

Figure1-3 Diagram of Building network

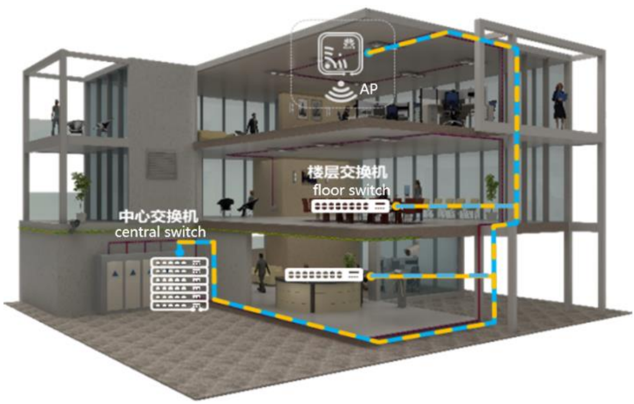


Figure1-3 shows the network deployment diagram of a typical building. Each floor of the building is divided into multiple areas, such as office areas, conference rooms, labs, rest areas, and equipment areas. Generally, AP is deployed every 15 meters, multiple APs are deployed on each floor, and an Ethernet switch supporting the Power over Ethernet (PoE) function is deployed on each floor.

Wireless access points connect to Ethernet switches through Ethernet cables or optical/electrical hybrid cables. Multi-floor Ethernet switches in buildings converge to the central switch and connect to the wireless access controller. The PoE switch can remotely supply power to the wireless access point through the Ethernet cable. When the network is not in use, the wireless access point device can be power off by shut down the POE port. In this case, the wireless access point device does not consume any energy.

1.3 Energy Saving Campus WLAN System

As shown in Figure1-4, a WLAN system includes a plurality of components, Station (STA), wireless Access Point (AP), Ethernet switch with Power over Ethernet capability (PoE switch), Wireless Access Controller (AC), SDN Controller, and Intelligent Analyzer. A WLAN system that supports energy saving requires multiple components to be capable of sensing and identifying traffic, terminal types, and service types. Combine with the AI technology, the WLAN energy saving configuration solution is automatically generated based on service usage. For example, the PoE switch shuts down ports periodically to save energy. In addition to WLAN own energy saving technologies, WLAN can realize WLAN sensing and collaborate with the Building Automation System (BAS), including but not limited to building lighting and air conditioning, to save energy for the entire building.

Figure1-4 WLAN component architecture

To achieve energy saving, the network devices will be shut down. Therefore, the impact on services must be considered when deploying energy saving solutions. Some impacts on non-significant services are acceptable. However, service availability and reliability must be the first priority for important services. Currently, many types of devices (services) are commonly used on campus WLANs: office terminals, mobile devices, industrial control devices, Internet of Things (IoT) devices, and security monitoring devices. The following describes the service bearers in detail.

1. **Office terminals:** Office terminals include desktop computers, laptops, and office peripherals (such as printers and scanners). These devices are typically used for daily office operations, document processing, e-mail, video conferencing, etc..
2. **Mobile devices:** Mobile devices include portable devices such as smartphones, tablets, and laptops. These devices are mainly used for mobile office, instant messaging, information query, and multimedia entertainment.

3. **Industrial control equipment:** Industrial control equipment includes industrial controllers, sensors, actuators and automation systems. These equipment are mainly used for production line control, environmental monitoring and equipment status monitoring.
4. **Internet of Things (IoT) devices:** IoT devices include various smart sensors, smart meters, smart lamps, and environmental monitoring devices. These devices are used for data acquisition, remote control, and condition monitoring. A large number of IoT devices require a WLAN to support simultaneous connections of a large number of terminals and maintain good network performance.
5. **Security monitoring devices:** include cameras, access control systems, alarm devices, and environment monitoring sensors. These devices are mainly used for security monitoring and protection of the campus.

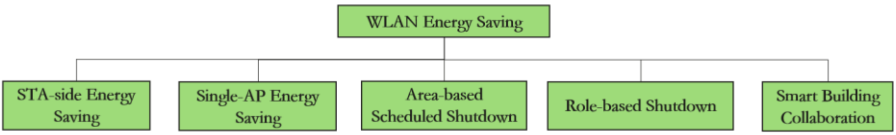
Office terminals and mobile users usually need to access the Internet, send and receive emails, upload and download files, organize or participate in voice or video conferences, watch entertainment videos in leisure areas, and make audio & video calls. For details about user experience, please refer to the Campus WLAN Performance Experience White Paper released by WAA in 2023, which defines multiple service and experience requirements for office campuses. Industrial terminals, sensors, and security monitoring terminals are IoT terminals. Some of them are usually online for a long time, and do not require high bandwidth for network communication. Meanwhile, some of them require high-quality network connection services.

When deploying energy saving solutions, wireless network administrators must consider the network user experience, network reliability, and IoT connections always online. Administrators need to manage and visualize the energy saving and service quality of the entire network, consider multiple deployment solutions to save energy, and make necessary commitments on network service quality. In fact, the challenge for network administrators is to balance service experience and energy efficiency.

Chapter 2

WLAN Energy Saving Solution Introduction

Figure2-1 Classification of the WLAN energy saving solution.



This chapter describes multiple WLAN energy saving solutions, including STA-side energy saving, single-AP energy saving, Area-based scheduled shutdown, Role-based shutdown, and smart building collaboration, as shown in Figure2-1.

STA-side energy saving supports the periodic sleep and wakeup of the site, which focuses on reducing the energy consumption of stations instead of saving energy in Building's WLAN network. Thus, this chapter will not go into detail. Energy saving for a single AP is implemented by defining the working status of the AP. For example, the power consumption of a single AP can be reduced when the AP is idle. Scheduled group shutdown and role-based shutdown, which this chapter focuses on, are the functions of shutting down some APs on specific periods and by role to achieve system-level energy saving. In addition to WLAN network energy saving, this chapter also describes how WLAN networks work with the building management system to save energy for the other building energy consuming system such as air conditioning and lighting.

2.1 Single AP Energy Saving

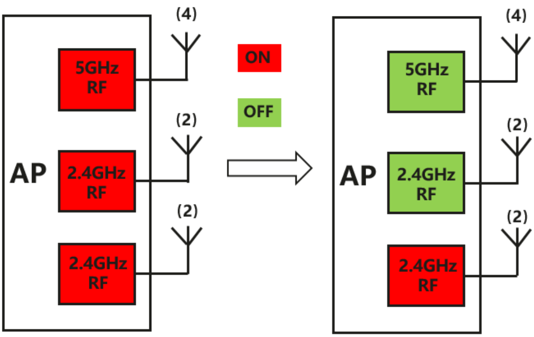
Smart terminals transmit data intermittently and centrally, which lead to the traffic fluctuates on network and that not all devices work under work model (full load). If different traffic consumes different power, compared with the network devices running under work model (full load), power can be saved by the network devices running under less load. Based on this principle, defining the energy saving mode of a single AP under different loads becomes a method of network energy saving. For example, define the sleep mode or standby mode for 0% traffic load, define the low power mode for low traffic load.

In a WLAN system, the number of AP nodes is the largest comparing to the other components. Therefore, the working status of the AP is the core of the energy saving solution. Because the AP is usually powered by a PoE switch, the new AP state of PoE power-off mode, is added. Here's a detailed description of the various modes:

- **PoE power-off mode:** In this mode, the PoE switch shuts down the port and stops supplying power to the AP. The AP does not consume power at all. When the AP is started, the port provides power again. In this mode, it usually takes a few minutes for the AP to recover.

- **Sleep mode:** Only low power consumption is used to protect key hardware such as the CPU, and other hardware are shut down. In sleep mode, a single AP can save 80% to 90% energy and recover within one minute.
- **Low power mode:** Compared with the sleep mode, the low power mode maintains a certain communication capability. For example, the AP work only one the 2.4 GHz band and disables other radio bands. Figure2-2 shows the AP with 2 + 2 + 4 traffic signals. In the energy saving state, only the one-receive and one-transmit circuit is enabled to save energy. In low power mode, a single AP saves about 30% energy and recovers in tens of seconds.

Figure2-2 RF shut down for a single AP

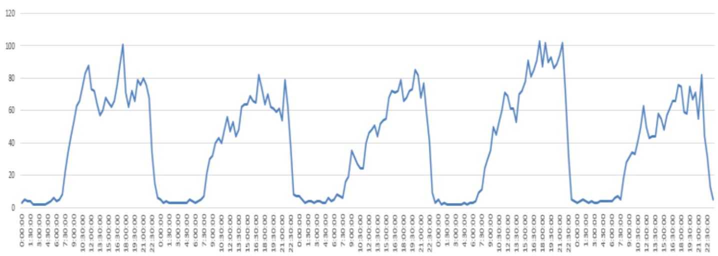


Energy saving for a single device proposes a feasible energy saving idea, however, the traffic of network devices changes very quickly, and the traffic per second varies greatly. Therefore, the recovery time of more than seconds does not meet the requirements of network experience in the working state. Single AP energy saving cannot balance the energy saving benefits and the committed service requirements of the network, at the same time the single AP energy saving cannot provide a manageable and controllable deployment solution to the network administrator. Therefore, the entire network energy saving solution must be consider to support manageable and visualize deployment.

2.2 WLAN System Energy Saving

In the campus environment, network usage is change regularly in statistics (tidal traffic). Figure2-3 shows the network traffic statistics of a teaching building in five days. The network usage increases significantly at 7:00 a.m., reaches the peak in the morning and afternoon, and does not use the network after midnight.

Figure2-3 Five-day network traffic statistics chart of a teaching building of a university



As described in section 1.2, a campus network consists of multiple components. APs connect to the POE switches on the building floors and then to the aggregation switch. This section describes the overall energy saving solution for WLAN networks, which can minimize power consumption by shutting down some APs during off-peak hours.

2.2.1 WLAN Energy Consumption Visualization

The WLAN energy consumption visibility system is usually a part of the network management system （NMS） or SDN controller. The NMS collects energy consumption information reported from devices such as APs. The NMS can monitor the energy consumption on campus-level, buildings-level, floors-level, and specific APs in real time, and analyze and display the information on the intelligent analysis system. As shown in Figure2-4, the system can display the entire network status at the area level, including but not limited to the overall energy consumption statistics by day/hour, network utilization (channel utilization), and overall network quality information by day/hour at the area level. The visualized management helps network administrators learn the energy usage status of an area and select an appropriate time oriented and area-oriented solution based on the network energy consumption and usage.

Figure2-4 WLAN Network Visualization System Campus Energy Consumption Monitoring

The WLAN energy consumption visualization system can select a specific time segment from the campus-level to building-level, floor-level, and device-level, analyze energy consumption in detail, and adopt specific energy saving policies for different areas. The left and right figures in Figure2-5 show the building-level and AP-level energy consumption and network usage.

Figure2-5 Building-level and AP-level energy consumption monitoring

To better illustrate the energy saving gains brought by different energy saving policies, the system also provides the comparison of energy consumption in a specified period. Figure2-6 shows the energy consumption curve of different policies in different time periods and compares different energy saving policies, helping network administrators optimize and select policies.

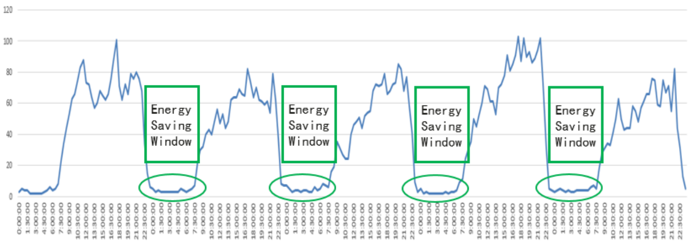
Figure2-6 Energy saving performance comparison

The WLAN energy consumption visualization system displays real-time energy consumption data in various forms, such as charts and dashboards, and is the basis for analyzing and formulating overall energy saving policies for WLAN networks. Users can select different campuses, buildings, floors, and specific APs on the GUI and view the APs by time segment to quickly locate high energy consumption cases. In addition, the system provides the energy consumption alarm function to help the network management team take measures in a timely manner before the energy consumption problem deteriorates, avoiding unnecessary energy waste. This helps the O&M team manage the energy consumption of the campus WLAN network in an intelligent and accurate manner.

2.2.2 Manually Scheduled Shutdown Solution

Based on the characteristics of tidal traffic on campus networks, the concept of **Energy Saving Window** is introduced here. The energy saving window indicates that the network is not in use or low-use state. powering down APs during the window can save energy. The energy saving window needs to be set independently on workdays and holidays, or accurately calculated by day in a specified period (such as a week).

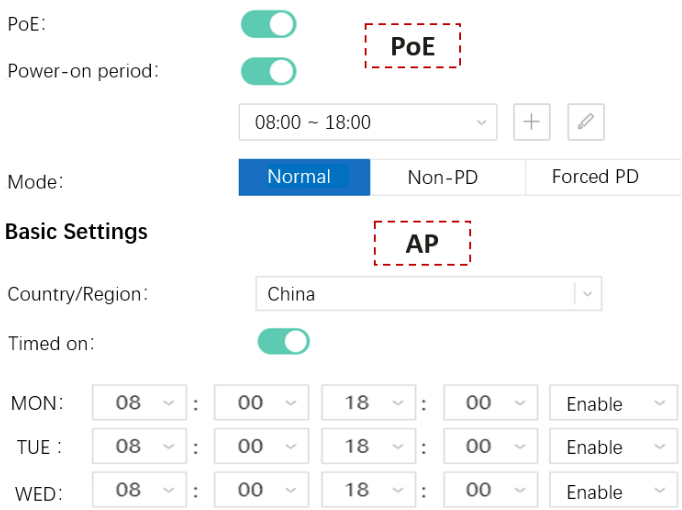
Figure2-7 Description of the Traffic Usage and Energy Saving Window



For the energy saving window, the PoE switch shuts down the interfaces connecting to the AP so that the AP can be completely shut down within a specified period of time, achieving 100% energy saving on a single AP. As shown in Figure2-8, the SDN controller performs manual configuration and the like to shut down all APs in the target building/floor at a scheduled time. Assuming that the network is shut down for 7 hours (00:00 to 07:00) every day, the power consumption of APs on the entire network can be reduced by 29.2% (7/24).

Based on the energy saving window, network manager can manually configure the scheduled AP shutdown on the SDN controller to save energy. The energy saving solution allows the campus network administrator to configure the scheduled switch for ports based on the overall analysis of the historical usage, service types, and energy consumption data of APs and PoE switches in the WLAN Energy Consumption Visualization system.

Figure2-8 Configuring Scheduled AP Shutdown on the SDN Controller



The energy saving window is usually 7 to 10 hours, which can reduce the power consumption of the WLAN by 30% to 40%. However, if the energy saving window is manually set, the deployment difficulties are as follows:

1. **Complex configuration:** There are a large number of APs in large-sized and medium-sized campus networks. Manual configuration workload is heavy and configuration errors are prone to occur. If campus services are adjusted,

policy modification workload is heavy, and deployment implementation is difficult.

2. **'One zone, one policy' cannot be implemented:** The usage mode and requirements of different areas in the campus vary greatly, and the energy saving window in each area is different. If the unified energy saving window is used, the energy saving effect cannot be maximized. Analysis by area network usage and energy consumption brings heavy workload to the administrator.
3. **Inflexible service:** Campus services are not immutable. Employees may need to work overtime at midnight. Manual network configuration and restoration bring unacceptable extra work and costs to administrators.

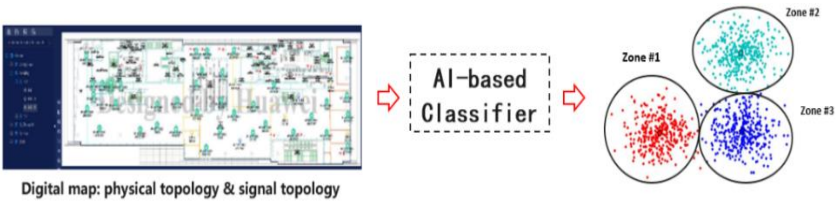
To sum up, this solution has great limitations on applicable scenarios. To balance the requirements of energy saving window selection, complex scenarios, and user experience assurance, the intelligent analyzer (AI-assisted) needs to be introduced on the basis of the SDN controller to help network administrators analyze and deploy energy saving policies.

2.2.3 Area-based Scheduled Shutdown

To meet the deployment requirements of complex configurations and diverse energy saving window scenarios, the network grouping and energy window prediction functions are introduced. Networks are grouped first, and then the tidal traffic is predicted for different network subgroups. Energy saving configuration policies are independently recommended for each group. In this way, energy saving windows can be deployed and adjusted in multiple scenarios.

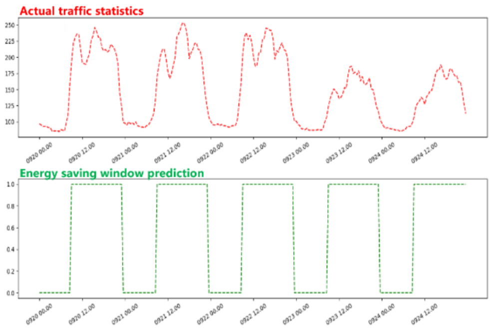
Network grouping: The tidal traffic varies in different areas on different floors. For example, the use time of exhibition halls, canteens, and office areas is different, and the use time of the similar office areas for different floors and different departments is different. Based on the physical topology and signal topology (wireless signal strength distribution diagram) shown in the WLAN visualization system, the AI algorithm is used to divide the network into multiple groups (for example, a building can be divided into multiple groups with each floor as a group) and formulate energy saving policies for each group. Figure2-9 shows the network grouping process.

Figure2-9 Network grouping based on AI algorithms



Energy saving window prediction: Based on the historical traffic data of each network group, the AI-based classifier extracts multi-dimensional (such as time and space) traffic characteristics, predicts future traffic patterns combined with the anomaly detection mechanism, recommends the optimal energy saving window, and supports precise energy saving policy formulation. Figure2-10 shows the mapping between actual traffic and energy saving windows.

Figure2-10 Predicting Energy Saving Window Based on Tidal Flow Characteristics



Based on the network grouping and energy saving window prediction, we propose a solution of 'Area-based Scheduled Shutdown. It can properly group different floors or different areas on the floor, predict tidal traffic for each group, select an appropriate energy saving window, and use the SDN controller to implement batch deployment and optimization, simplifying maintenance in the manually configured energy efficiency window and achieving a manageable energy saving solution. Table2-1 shows the energy saving policies automatically generated by using AI-assisted network area energy saving in an office building. We can find the functions of different office floors are different, and the corresponding energy saving windows are different.

Table2-1 AI-assisted network grouping energy savings (partial)

Grouping result	Energy saving window	Total number of APs	Energy saving per AP/h	Benefits of Single-Floor Deployment
ZGTY_E09-01F	['20:00:00','06:30:00']	4	10.5	43.8%
ZGTY_E09-03F	['19:00:00','06:30:00']	11	11.5	47.9%
ZGTY_E09-04F	['19:00:00','10:30:00']	16	15.5	64.6%
ZGTY_E09-05F	['19:00:00','05:00:00']	20	10	41.7%
ZGTY_E09-06F	['19:00:00','08:00:00']	18	13	54.2%
ZGTY_E09-07F	['18:30:00', '07:00']	29	12.5	52.1%
ZGTY_E09-08F	['19:30:00', '06:30:00']	20	11	45.8%
ZGTY_E09-09F	['18:00','07:30:00']	16	13.5	56.2%
ZGTY_E09-10F	['16:00:00','08:00:00']	16	16	66.7%

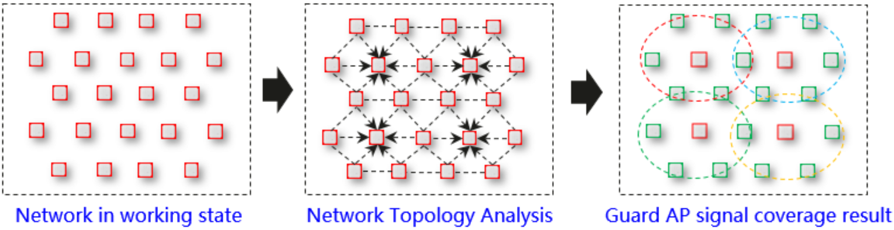
2.2.4 Role-based Shutdown

The area-based scheduled shutdown energy saving solution is refined based on the energy saving window and network grouping, which greatly saves energy on the network. However, during the energy saving window, the network cannot provide services, and cannot support requirements of urgent work scenarios such as unexpected work overtime and continuous networking applications (e.g., IoT devices). WAA released the White Paper "Building High-Quality WLANs in Typical Enterprise Scenarios" in 2023, which describes the importance and necessity of ensuring network services. To meet the energy saving target and ensure the continuous service of the network, user experience assurance needs to be considered with the energy saving solution based on the network area. That is, the energy saving policies in network groups need to be further specified.

The network performance requirements for unexpected work overtime support and IoT networking, in which the traffic requirements are low, are different from those for normal office work. In this case, enabling some APs are sufficient to provide the basic network coverage, which can also greatly save energy. According to multiple customer surveys, one AP can be enabled for every six APs to ensure basic network services. Thus, in order to guarantee the performance with energy saving, classifying and configure APs' role is necessary.

AP role classification: APs are classified into energy saving APs and working APs. As shown in Figure2-11, the red APs are working APs which can be in the low power mode or the working mode. The green AP are energy saving AP, which will be in PoE power-off mode in the energy saving window.

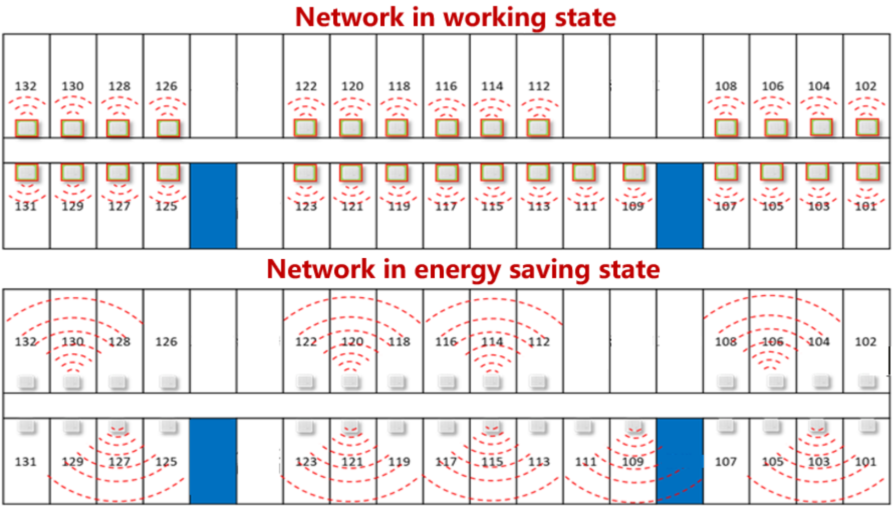
Figure2-11 AP role classification (red APs are working APs and green APs are energy saving APs after grouping)



Generally, APs are deployed in the optimal network experience design mode. APs adjust their transmit power based on the distance to reduce interference between themselves. In energy saving deployment, after the surrounding energy saving APs are shut down, the working APs need to automatically adjust their transmit power to achieve the coverage of the entire area. The network administrator can select the working mode of the AP, such as the 2.4Ghz deployment. (wide coverage, good IoT adaptation, and low performance)

When selecting a working AP, multiple factors need to be considered. First, ensure the coverage of the area. Based on the signal topology, the intelligent analyzer uses the AI-assisted differentiation algorithm to calculate the AP that provides the optimal physical coverage. During the calculation, the intelligent analyzer also needs to consider the requirements such as historical network traffic. Figure2-12 shows the working state and energy saving state network APs.

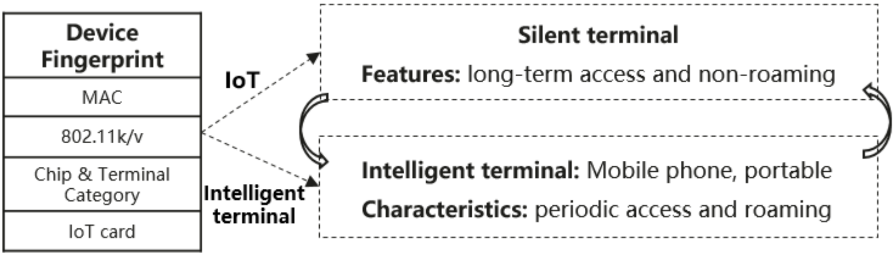
Figure2-12 Roles of energy saving APs in dormitories



When classifying and selecting AP roles, one need to consider not only the network coverage, but also the actual services in the scenario, such as the persistent connection requirements of IoT devices, security protection devices, and printers. For example, a large number of wireless sensors exist in one area, if the AP is powered off, these sensors cannot report information, resulting in security risks. IoT terminals that need to be identified include not only terminals connected by using the IEEE 802.11 technologies, but also terminals that use built-in Bluetooth and FRID of APs to communicate.

Due to the large number of silent terminals on the network, terminal classification and assurance require AI assistance. Figure2-13 illustrates a method for identifying silent terminals and smart terminals by dynamic analysis of device MAC addresses and communication behavior.

Figure2-13 Examples of Terminal Identification and Classification



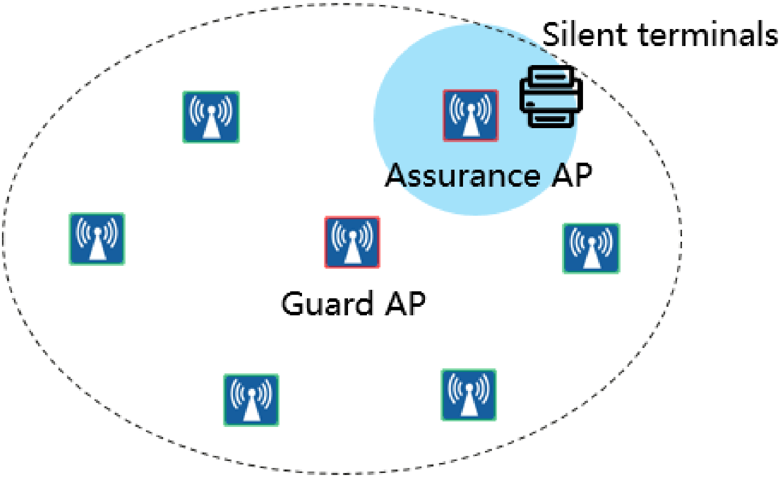
Based on the requirements of coverage services and long-term connection for silent terminals, working APs can be further classified into assurance APs and Guard APs.

- Assurance AP: APs that guarantee services of silent terminals. The coverage area and power can be adjusted.
- Guard AP: It ensures basic services within the network packet range. The coverage area and power can be adjusted as required. Monitor the network availability status within the environment to cope with emergencies.

In some network, an AP can serve as both the assurance AP and the Guard AP.

As shown in Figure2-14, one assurance AP and one Guard AP are selected under the AP role classification energy saving policy. Different policies can be used for the assurance AP and Guard AP. For example, the assurance AP enables the 5Ghz 2T2R, and the Guard AP uses the 2.4 GHz 1T1R. This meets the burst performance requirements and ensures long-term connection of silent terminals.

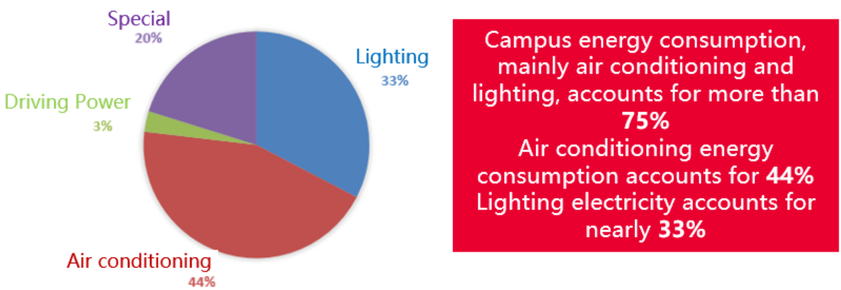
Figure2-14 AP Role Classification with Coverage and Silent Terminal persistent connection Considered



Role-based energy saving: This solution further optimizes energy saving policies based on area-based energy saving and uses an intelligent AP role classification and scheduling mechanism. It considers burst performance requirements and ensure continuous running of key devices, such as IoT devices, security protection monitoring, and environment monitoring. This solution allocates resources properly to ensure the normal running of various terminals and maximizes the energy saving effect of the energy efficiency window.

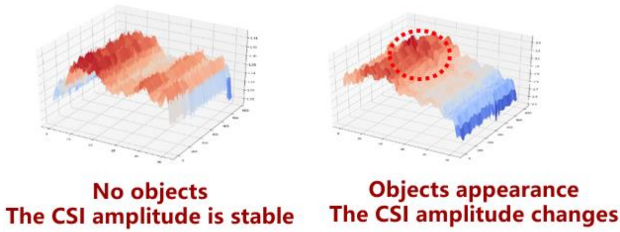
2.3 WLAN and Smart Building Collaboration

Figure2-15 Building Energy Consumption Distribution Chart



With the development of technologies, WLANs not only realize communication functions, but also have the capability of sensing environments information and people. The WLAN sensing technology uses the existing WLAN infrastructure to sense environment and people through the Channel State Information (CSI) of the WLAN. Figure2-16 shows the principle of CSI awareness.

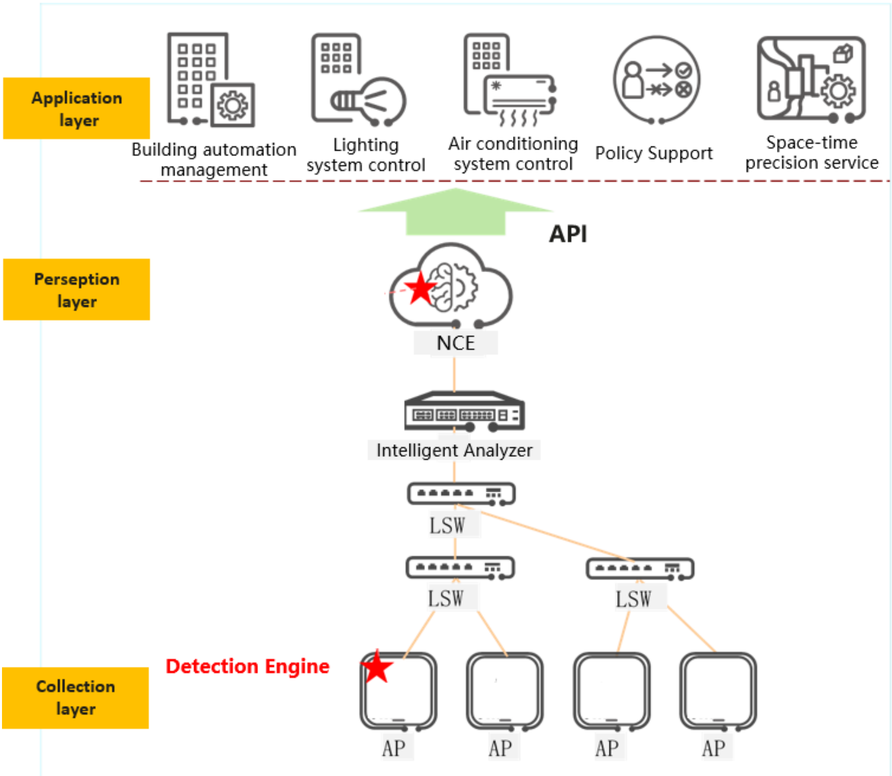
Figure2-16 Principles for CSI Detection Personnel



The IEEE 802.11bf task force, which is belonged to IEEE802.11 standard working group, was established in September 2020 and is planned to release the standard in June 2025, means the maturity of the WLAN sensing technology. This standard is based on the CSI technology to realize the awareness of the surrounding environment. To avoid interfering with normal WLAN communication, WLAN sensing uses Orthogonal Frequency Division Multiplexing (OFDM) waveforms and calculates spatial interference through mathematical models. Unlike high-frequency radars and cameras, WLAN sensing does not measure accurate pictures. It senses motion and protect personal privacy.

With WLAN Sensing, the wireless network in a building can detect and analyze dynamic changes in the environment in real time, for example, detecting whether there are people in a room. With the combination of the WLAN sensing technology and building management system, the Air Conditioning and lighting power consumption can be flexibly adjusted, reducing the overall energy consumption of the building. In terms of energy saving, the benefits are greater than energy saving just for WLAN self.

Figure2-17 Coordinated energy saving between WLAN and intelligent building management system



As shown in Figure2-17, the CSI detection engine is deployed on the AP side, and the personnel awareness engine is deployed on the intelligent analyzer. The building management system opens the AP location and personnel awareness engine analysis results to the building management system. The building management system implements energy saving measures. Through this solution, the area which people intensively use and the area which people do not intensively use can be distinguished, and the air conditioning load and air volume can be dynamically adjusted. Lighting and air conditioning can be turned off in areas where no one is detected. This deployment is especially applicable to closed areas such as conference rooms and exhibition halls. This collaborative energy saving based on fine-grained data and intelligent algorithms not only greatly reduces energy consumption, but also ensures the comfort and experience of the building environment.

With the collaboration between WLAN sensing and the intelligent building management system, the running time of the air conditioning and lighting system can be reduced. Compared with without WLAN sensing, the energy consumption of the air conditioning and lighting system can be reduced by 15% to 30% respectively. This reduces the power cost for building operators, and the economic and environmental benefits are significant.

2.4 Summary of the WLAN Energy Saving Solution

Based on the previous sections, the advantages and disadvantages of several solutions are compared and the suitable deployment scenarios are suggested.

- Single AP Energy saving: The PoE power-off mode, sleep mode, low power mode, and working mode are defined. Considering the commitment to the network experience, it is difficult to deploy the power saving solution independently. Therefore, the entire network service capability is required to build a complete energy saving solution.

- **Area-based scheduled shutdown:** Networks are grouped based on the physical network topology and service aggregation. Based on the historical traffic data of the group, the energy saving window for each group is calculated. Then, the PoE switch is used to periodically shut down APs to save energy. This solution saves 30% to 45% of the APs energy. However, the WLAN cannot provide network services during the energy saving window period. It is applicable to places where the network has fixed open and close rules, such as teaching buildings, canteens, and exhibition halls.
- **Role-based shutdown:** Based on the Area-based scheduled shutdown, this solution calculates the on-duty APs based on the network coverage requirements and IoT persistent connection service requirements. This solution can provide basic network connections and ensure IoT terminals do not go offline. It is applicable to scenarios where emergency work is required in the energy saving window and IoT devices are persistently connected, such as enterprise office areas. This mode saves 20% to 40% of AP energy and ensures network experience. Combined with the single-device energy saving mode, it can be optimized for further.
- **WLAN and Smart Building Collaboration:** The open network sensing capability enables intelligent services for energy consuming devices such as lighting and air conditioning, greatly reducing building energy consumption. Currently, the mapping between the network awareness capability and energy consuming devices is clear and can be deployed in areas with clear

partitions. The combination innovation of WLAN sensing and service (building energy saving system) is an important innovation direction in the future.

Table2-2 Benefits and network experience of multiple energy saving solution

Energy saving solution / Comparison Dimension	Manual configuration	Area-based scheduled shutdown	Role-based shutdown	WLAN and smart building collaboration
Energy Saving Policy	Manual operation	Energy saving prioritized	Experience and Energy saving both prioritized. Basic network service	Network CSI
Network power saving gain	29% - 45%	29% - 45%①	24% - 37% ②	Building energy consumption: around 10%
Network Experience	Energy saving status No network service	Energy saving status No network service	The power saving status is Basic Network Services	No impact.
Managing Complexity	Very high. Large-scale deployment is not supported.	Large-scale deployment	Energy saving status. Basic Network Service	Large-scale deployment. Matching relationship needs to be configured.
Application Scenario	Scenarios with a fixed start/stop schedule, such as small office, canteen.	Energy saving window No network SLA Not applicable to persistent connection scenarios, such as IoT and monitoring.	Multi Scenarios	Meeting room. Hotel. Partition space. Etc.

① Calculated based on AP power consumption. The energy saving effect is calculated based on the 7-hour and 11-hour energy saving windows.

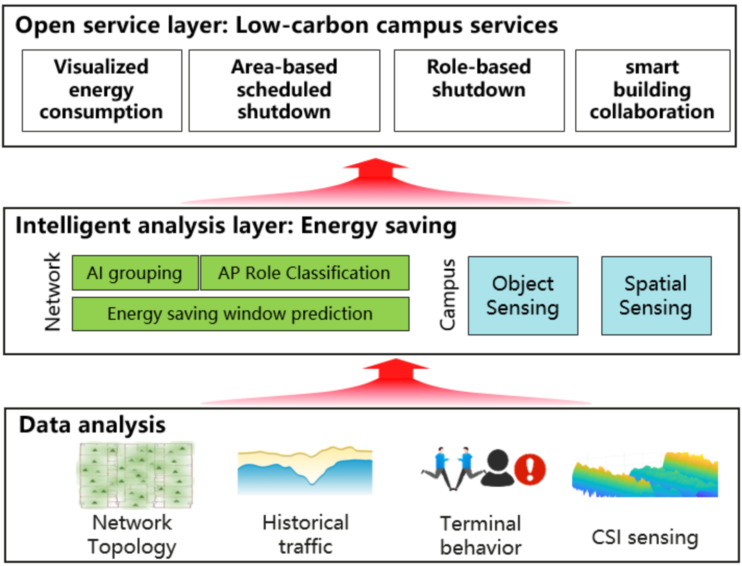
② Calculated based on AP power consumption. The power saving effect is calculated based on the assumption that five of the six APs are shut down.

Those solutions greatly reduce the power consumption of APs. The energy saving efficiency of APs ranges from 24% to 40%, and the annual power saving ranges from thousands to hundreds of thousands of kWh. It is recommended that the network administrator deploy two solutions: **Area-based Scheduled Shutdown and role-based shutdown**. In the scenario where the service window is specified, the area-based scheduled shutdown solution should be used. In the scenario where the user experience needs to be ensured 24 hours, the Role-based shutdown solution should be deployed. Especially in education, enterprises, government and other industries with obvious work cycles, this energy saving achievement not only reduces the operating costs, but also promotes the sustainable development of society. The collaboration between the WLAN sensing and the intelligent building energy consumption system can greatly reduce the energy consumption of the building. It can be deployed in areas with clear partitions. The collaboration between WLAN sensing and intelligent building energy consumption system is an important innovation direction in the future.

2.5 Reference Architecture for Energy Saving WLAN

The energy saving WLAN reference architecture consists of three layers: **data collection layer, intelligent analysis layer, and open service layer.** At the data analysis layer, APs and PoE switches provide network topology data, historical traffic data, terminal access data, and CSI channel data. Based on multiple types of data, the intelligent analyzer integrates the preceding data to implement the network grouping function, traffic tide prediction capability, AP role identification capability, personnel awareness capability, and space awareness capability. Based on these capabilities, network administrators can be provided with the energy consumption visualization service, network area-based scheduled shutdown service, Role-based shutdown service, and intelligent building management system collaborative energy saving service. Figure 2-18 shows the hierarchical architecture of the WLAN energy saving reference architecture.

Figure2-18 Layered reference architecture for energy saving WLAN



Chapter 3

Deployment Case

This section describes the implements of the WLAN energy saving in industry, providing further reference for WLAN administrators.

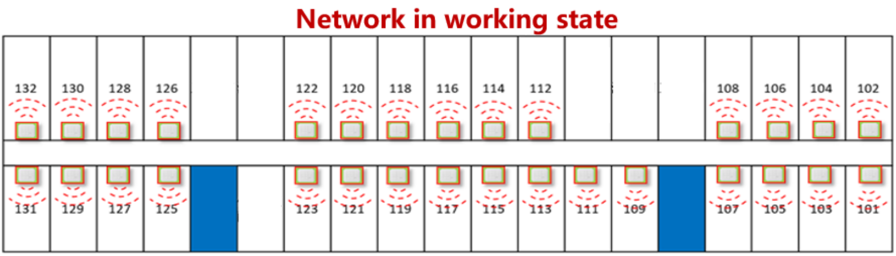
3.1 Case 1: Henan Normal University Dormitory Deployment

3.1.1 Scenario Overview

Henan Normal University is a 'double first-class' university in Henan province, with an area of 1.3953 million square meters and a building area of 1.1 million square meters, with more than 50,000 students, more than 40,000 concurrent online users during peak hours, and nearly 50,000 active daily campus network users. The dormitory room scale is 9,000 (Mainly rooms for 6 people). More than 10,000 APs and 500 switches are deployed on the campus network. A typical dormitory building is used to describe the deployment of the WLAN energy saving solution.

3.1.2 Scenario Analysis

Figure3-1 Typical layout of dormitory



The dormitory building of Henan Normal University was built in the 1990s. A typical dormitory building is 6 floor, with a corridor in the middle and dormitories on both sides. The typical layout of rooms on each floor is shown in Figure 3-1. There are mainly 6 person dormitories, and one AP is deployed in each dormitory. The AP is mounted on the wall to the right of the door.

Choose to carry out trial operation of WLAN green energy saving solution during holidays

Figure3-2 Top 20 high-traffic-loaded dorm traffic

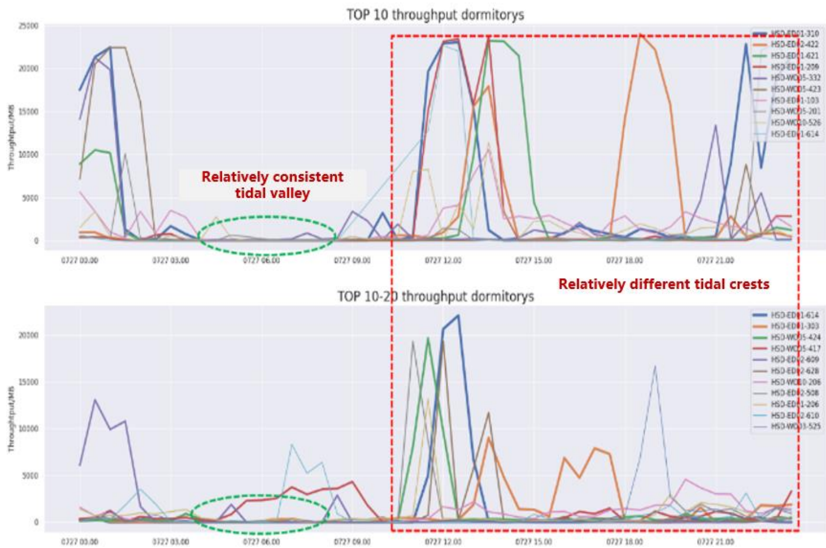


Figure3-2 shows the dormitory traffic of the top 20 high traffic loads after deploying the intelligent analyzer. The analysis conclusions are as follows:

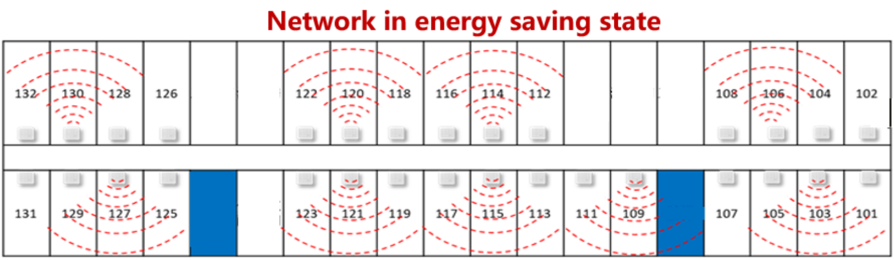
1. Multiple dormitories show overall similar traffic fluctuation cycles. For example, the traffic is very small from 04:00am to 07:00am.

2. The network usage in different dormitories varies greatly, including tide times and network traffic. For example, some dormitories are still using the Internet at 2am., while some dormitories basically have no traffic after 11pm.

3. Specific to individual dormitories, the regularity is quite obvious. For example, some dormitories basically do not use the Internet around 12pm, and this rule remains unchanged for a period of time.

3.1.3 Energy saving solution and effect

Figure3-3 AP switch in 1+3 mode



After comprehensive analysis, it was found that different dormitories have different energy-saving time zones. It is recommended to select energy-saving zones according to floors and turn off energy according to roles.

At the trough of dormitory traffic, take power-off measures. Considering that some students' computers and mobile phones will continue to be connected to the Internet at night, and there are even nightly software upgrades and other operations, it is necessary to continue to provide network services to students. Therefore, the overall solution is designed as '1 to 1' for working APs and dormitories during the day, and '1 to 3' for energy-saving APs and dormitories in the early morning, that is, 1 AP covers 3 rooms in the early morning. At the same time, because the network traffic usage on different floors is different, the network is grouped according to different floors and different energy-saving strategies are adopted. Judging from the actual deployment effect, the overall energy saving effect in the dormitory area reaches more than 25%.

Table3-1 shows the different energy saving windows calculated by different groups.

Table3-1 Different energy saving windows for different group calculation

Grouping area	Recommended energy saving period	Energy saving duration/hour	AP power saving gain
XED01-1	['01:00:00', '06:30:00']	5.5	22.9%
XED01-2	['01:30:00', '06:30:00']	5	20.8%
XED01-3	['01:30:00', '06:30:00']	5	20.8%
XED01-4	['01:00:00', '06:30:00']	5.5	22.9%
XED01-5	['01:30:00', '06:30:00']	5	20.8%
XED01-6	['01:30:00', '07:30:00']	6	25.0%

3.2 Case 2: China General Technology (Group) Office Deployment

3.2.1 Scenario Overview

China General Technology Group is an important state-owned enterprise directly managed by the central government. It focuses on the three main businesses of advanced manufacturing and technical services, medicine and health care, and trade and engineering services.

From the national policy and planning level, the "14th Five-Year Plan" outline proposes to comprehensively promote the green transformation of production and lifestyle during the "14th Five-Year Plan" period: improve the production system for green, low-carbon and circular development, and accelerate the green upgrade of infrastructure. In February 2024, the Ministry of Industry and Information Technology, SASAC and other seven departments issued the ‘Guidance on Accelerating the Green Development of Manufacturing Industry’ to accelerate the green and low-carbon technological transformation of traditional industries. Regularly update and release the catalogue of green and low-carbon technologies in the manufacturing industry, select and promote key common technologies with high maturity, good economy, and remarkable green results, and promote the comprehensive implementation of a new round of green and low-carbon technology transformation and upgrading in enterprises, campus, and key industries. At the end of July 2024, the Central Committee of the Communist Party of China and the State Council jointly issued the ‘Opinions on

Accelerating the Comprehensive Green Transformation of Economic and Social Development' to promote green and low-carbon economic and social development. This is an important symbol of the new concepts and practices of party governance in the new era and the realization of high-level A key link in quality development.

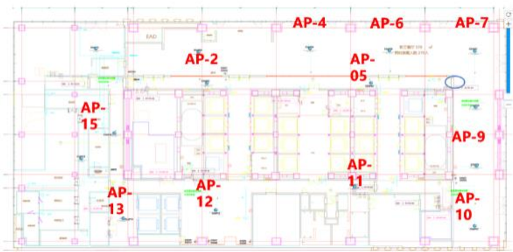
From the group level, China General Technology Group has always adhered to the development concepts of innovation, coordination, green, openness and sharing, with the strategic goal of building 'green general technology'. General Technology Group has continuously increased its investment in green technology in recent years; taking 2022 as an example, it has invested 200 million CNY.in energy conservation and environmental protection, and 2 factories have won the title of 'National Green Factory'. Won the title of 'Leader' enterprise in the first China Industrial Carbon Peak. At the same time, General Technology Group is also seeking breakthroughs in green and energy-saving technology for park office scenes.

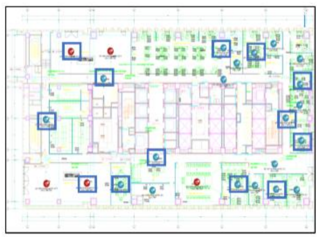
3.2.2 Scenario Analysis

According to the industry's 2024 statistics report, the HVAC system energy consumption of large office buildings accounts for the highest proportion, accounting for 41% of the total power consumption. Lighting power consumption, accounting for 26.4% of the total power consumption, power system energy consumption, accounting for 18.3% of the total power consumption, and special power consumption (network equipment) accounting for 13.4%. Energy saving technologies in office scenarios can be divided into two scenarios: network device energy saving and environment energy saving. Limited by the time schedule, China's general technology is currently focusing on the former direction.

The headquarters building of China General Technology Group mainly includes offices (such as office stations and meeting rooms) and other public supporting areas such as canteens and parking lots. Take office building No. 8 of the headquarters as an example. There are 40 sites and 772 APs. The annual WLAN electricity fee in the building is 300,000 CNY., and the total electricity fee for network devices in the headquarters building is millions of CNY.. Energy saving of network equipment in large office buildings can also save operating expenses for the group.

Figure3-4 WLAN device deployment location diagram



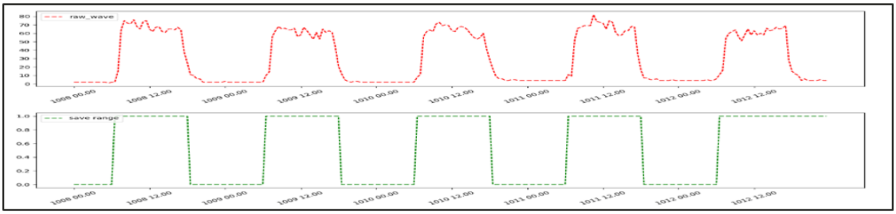


3.2.3 Energy saving solution and effect

Figure3-5 Traffic tide and single AP energy saving benefits

AP Counting	Total AP: 29	Guard AP: 13	Assurance AP: 0

Energy saving window['18:30:00', '07:00:00']



Energy saving mode	Economy First	Experience-first	Average annual power saving of a single AP (yuan)
Energy saving gain	52.1%	28.7%	200+(Economy First)

In enterprise office campuses, the traffic characteristics are very clear and tidal phenomena. According to the data analysis, the recommended energy saving window is ['18:30', '07:00']. Take an office area on a floor as an example. During the trough, 13 APs are recommended as monitoring APs and other APs are powered off by PoE. According to the economic model, the overall power saving is about 52.1%, and the annual electricity cost of each AP is 205.31 CNY.

Assuming that there are 772 APs in an office building, the annual electricity cost is 78,000 to 138,000.

Table3-2 Energy Saving Benefits in Different Energy Saving Solutions

Energy saving site	Scenario	Number of APs	Economic model gain	Gains in experience-first mode	Annual power saving estimate
Headquarters Building 8	Office	40 floors and 772 APs	45.2%	25.7%	7.8w-13.8w
Headquarters Building 9	Office	40 floor and 601 APs	53.8%	29.1%	6.9w-12.7w

3.3 Case 3: Huawei Office Environment Energy Saving

3.3.1 Scenario Overview

Huawei is a leading global ICT infrastructure and smart device provider. Its 207,000 employees are in more than 170 countries and territories and serve more than 3 billion people worldwide. It is a typical large-scale office enterprise campus scenario. The operation expenses of a large number of campuses are huge.

3.3.2 Scenario Analysis

Based on the previous analysis, we can see that the main energy consumers in the office park are air conditioning and lighting, which account for 67% of the total energy consumption and are the absolute main body of energy consumption. At present, environmental energy conservation in office buildings is generally turned on and off based on unified time rules. The management is extensive and it is difficult to conduct refined analysis and control. If you want to carry out refined management, you need to turn off air conditioners and lighting through manual inspections, which is difficult to achieve in real time. Such as office staff leaving after inspection. At the same time, if real-time control is achieved by adding sensors, this solution will bring about sensor investment costs and maintenance problems.

That is, the above solutions have additional expenses such as personnel investment and sensor procurement, and bring problems such as management costs and maintenance costs. Huawei office campuses can work with process IT teams to jointly innovate based on WLAN sensing enable devices. With the space awareness capability of WLAN devices, it becomes a better technical direction to link with environment and energy saving. The technical direction goal is to manage the air conditioning and the lighting.

3.3.3 Energy saving solution and effect

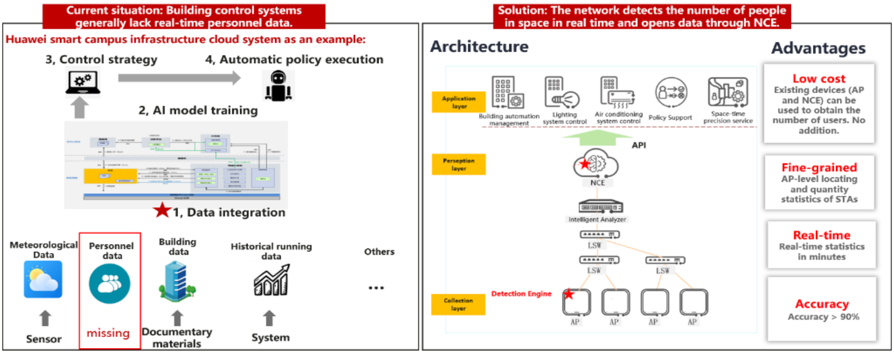
The core of the solution includes two parts: 1. Spatial awareness capability: based on the WLAN device to sense whether there are still office workers in its coverage area, especially the presence of office workers when WLAN access is not used; 2. Network device linkage building automation: based on the WLAN sensing results to make decisions on appropriate energy-saving control for zones.

WLAN sensing: Users are identified based on the number of WLAN users and the spatial awareness capability of subcarriers. On this basis, AI technology is used to predict the trend.

- **Headcount trend estimation:** The trend change is consistent with the trend change of employees' commute, mealtime, and overtime hours, which can effectively evaluate the headcount change trend.
- **Real-time estimation of the number of people:** From September 28th to September 30th, H1 floor, manual counting during the day, the average accuracy of the total number of people counted by the system and the number of people counted on site is about 94.42%; From November 25th

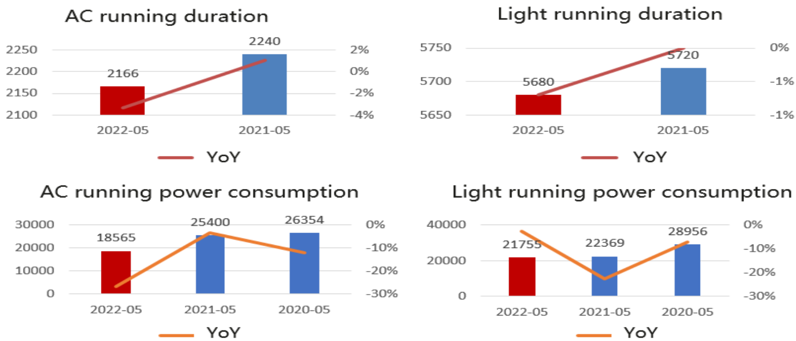
to November 28th, from December 6th to December 8th, Building H1, the average accuracy rate of the total number of people counted by the system and the number of people counted on site during the core time period for night business decision-making is about 94.12%.

Figure3-6 Analysis of the Environment and Energy Saving Status and Improvement Points



Energy saving effect: The running time of the air conditioning in Building L6 is reduced from 2240 hours/month to 2166 hours/month, which is 74 hours/month (about 1480 KWH/month). The lighting running time is reduced from 5720 hours/month (accumulated by office area) to 5680 hours/month, that is, 40 hours/month (about 614 KWH/month). It is estimated that the annual electric energy will be saved by 1.44 million KWH, and the electricity fee will be earned by more than 1 million RMB. The number of complaints is zero.

Figure3-7 Analysis of the energy saving effect



3.4 Case 4: Beijing Normal University Teaching Building Energy saving

3.4.1 Scenario Overview

Beijing Normal University is a “double world-class project” included university directly under the Ministry of Education, which engaged in teacher education, educational science and stream infrastructure of arts and sciences. It is composed of five campuses in Beijing area and Zhuhai area. The number of students is nearly 40,000, including 27,000 in the Beijing campus. More than 50,000 concurrent online terminals during peak hours in nearly 300 classrooms and 2500 offices. The campus network has more than 17,000 APs and 3,000 switches. A typical academic building will be used to describe the deployment of the WLAN energy-saving solution.

3.4.2 Scenario Analysis

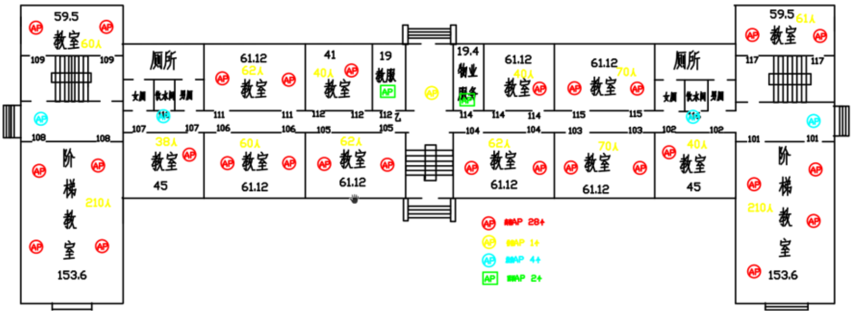


Figure3-8 Typical Layout of the teaching building

The building has four floors, with corridors in the middle and classrooms on either side. The typical layout of each floor is shown in Figure 3-8. There are 5 PoE switches and 61 APs, most of which are high-density APs. For a classroom with 60 students, and an area of about 60 square meters, two high-density APs are deployed. For a classroom with an area of less than 45 square meters, one high-density AP is deployed. Amphitheatre covers an area of 120-180 square meters and four high-density APs are deployed. APs are mainly deployed on the wall on both sides.

Figure 3-9 Tidal regularity of the teaching building

Figure 3-9 shows the online trend of user terminals in the teaching building. The analysis features are as follows:

1. The classroom is open from 6:30 to 23:00, and the number of users fluctuates in a similar period.

2. Different classrooms vary greatly in using the network, and the tidal phenomenon is obvious for during class and after class time.

3. During the winter vacation, there are fewer students, and some teaching buildings will be closed, so the users and traffic will be reduced to zero.

3.4.3 Energy saving solution and effect

The trial run of the WLAN energy saving solution is chosen to be carried out during the winter vacation. AI automatically recommends energy saving policies based on the big data intelligent tidal algorithm. It is recommended that energy saving be enabled from 23:00 to 06:00. In the AP distribution location diagram on the third floor of the building, three on-duty APs are evenly distributed and work normally. Other APs adopt the energy saving solution, as shown in Figure 3-10.

Figure 3-10 AP distribution on the third floor of the teaching building

Energy saving effect: After the energy saving policy is delivered to the floor, about 2.19 kWh power consumption is saved per night. The number of energy-saving APs divided by the total number of APs = 19/22. The AP power consumption of the entire floor is reduced by about 25%.

Figure3-11 Energy Consumption Comparison of the Three Floors of the Teaching Building

The same energy saving strategy is also deployed on the second, third, fourth floors of the building. The following table lists the specific energy saving results. The overall AP power saving is about 20%.

Energy saving area	Power-Saving AP Quantity	Total number of APs	Power saving every night	Energy consumption reduction
Second floor	21	26	2.36KWh	19%
Third floors	19	22	2.19KWh	25%
Fourth floors	11	13	1.54KWh	25%

Table 3-3 Energy Consumption Statistics of the Teaching Building

Chapter 4

Conclusion

Climate warming has become one of the most severe challenges in the world. In terms of social responsibility and energy saving, campus networks need to provide green and energy saving solutions. Currently, campus network administrators do not have a deployment guide for the energy saving WLAN solution. This white paper describes multiple energy saving WLAN solutions and compares the energy saving benefits and deployment scenarios of these solutions. We recommend WLAN network administrators to deploy **Area-based scheduled shutdown solution** and **Role-based shutdown solution**. Area-based scheduled shutdown solution can reduce 29% to 45% AP energy consumption but no network service during the energy saving window. Role-based shutdown solution can reduce 24% to 37% AP energy consumption and provides basic network services during energy saving window.

Based on WLAN sensing technology, **WLAN and Smart Building Collaboration** can greatly reduce the energy consumption of buildings and achieve around 10% overall energy saving benefits. We encourage more innovation to be based on WLAN sensing technology.

A Terms

TableA-1 Glossary of terms

English abbreviation	English full name
AC	Access Controller
AI	Artificial Intelligence
AP	Access Point
AI/ML	Artificial Intelligence/Machine Learning
CSI	Channel State Information
IoT	Internet of Things
MAC	Media Access Control
PoE	Power over Ethernet
SDN	Software Define Network
STA	Station
WLAN	Wireless Local Area Network