WLAN High-Density Coverage Technology White Paper

Issue 1.0

Date 2014-04-24

HUAWEI TECHNOLOGIES CO., LTD.

Trademarks and Permissions

Notice

Huawei Technologies Co., Ltd.

Address: Huawei Industrial Base
Bantian, Longgang
Shenzhen 518129
People's Republic of China

Website: http://www.huawei.com

Email: support@huawei.com

Tel: 0755-28560000 4008302118

Fax: 0755-28560111

About This Document

Keywords

High density, coverage, capacity, interference, wireless planning, software features

Abstract

With the popularity of Wi-Fi, more and more public places (for example, stadiums and other venues) offer Wi-Fi hotspot coverage, enabling people to connect to Wi-Fi networks anytime at anywhere. However, increasing Wi-Fi requirements in public places pose great challenges to Wi-Fi construction. This document describes how to implement proper network planning and use appropriate software features to improve high-density access performance and offer the best possible end-user experience in high-density scenarios with many concurrent users.

Abbreviations

Abbreviation	**Full Name**
EDCA	Enhanced distributed channel access
CCA	Clear Channel Assessment

Contents

1 Overview

1.1 Background

With the popularity of Wi-Fi, more and more public places (for example, stadiums and other venues) offer Wi-Fi hotspot coverage, enabling people to connect to Wi-Fi networks anytime at anywhere. However, increasing Wi-Fi requirements in public places pose great challenges to Wi-Fi network construction, especially Wi-Fi network construction in football grounds and basketball grounds. The constructed Wi-Fi network must be able to support high-density user access and many concurrent users for provision of excellent service experience for users. High-density scenarios are places crowded with a large number of users and terminals. To meet high-density access needs in these places, many APs are placed in close proximity, at most 10 meters between each other. In common scenarios, the distance is about 20 meters to 30 meters. Typical high-density scenarios include:

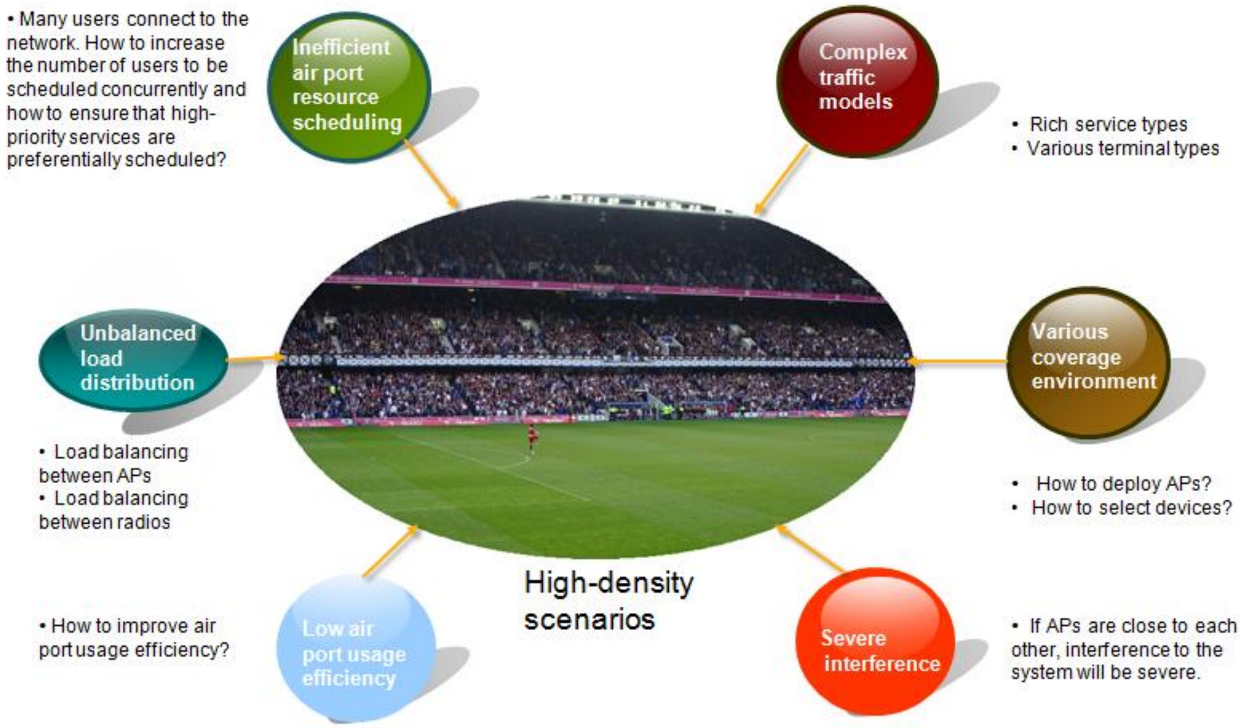
- Large conference rooms
- Lecture halls and auditoriums
- Exhibition centers
- Hotel banquet halls
- Stadiums, playgrounds, and play fields
- College classrooms
- Concert halls
- Airport lobbies
- Business centers

1.2 High-Density Coverage Challenges

High-density coverage requires good capacity and radio frequency planning as well as proper use of software features to improve wireless network performance.

High-density coverage faces the following challenges:

Figure 1-1 High-density coverage challenges



1. Service model

   What are the service models in high-density scenarios and their bandwidth requirements? What types of terminals are in use and impact of these terminals on the network capacity?

2. Coverage mode

   What types of APs and antennas are suitable for use in high-density scenarios and how to deploy them?

3. WLAN interference

   What interferences in high-density scenarios will affect network performance? Which measures can be taken to minimize the interference?

4. Air port efficiency

   High air port efficiency enables access of more users. How to improve air port efficiency in high-density scenarios?

5. Load balancing

   How to fully utilize the 5 GHz radio to avoid dual-band STA congestion on the 2.4 GHz radio? When users are unevenly distributed, how to load balance traffic on different APs?

6. Airtime scheduling

   How to optimize multi-user scheduling on the network to connect more users?

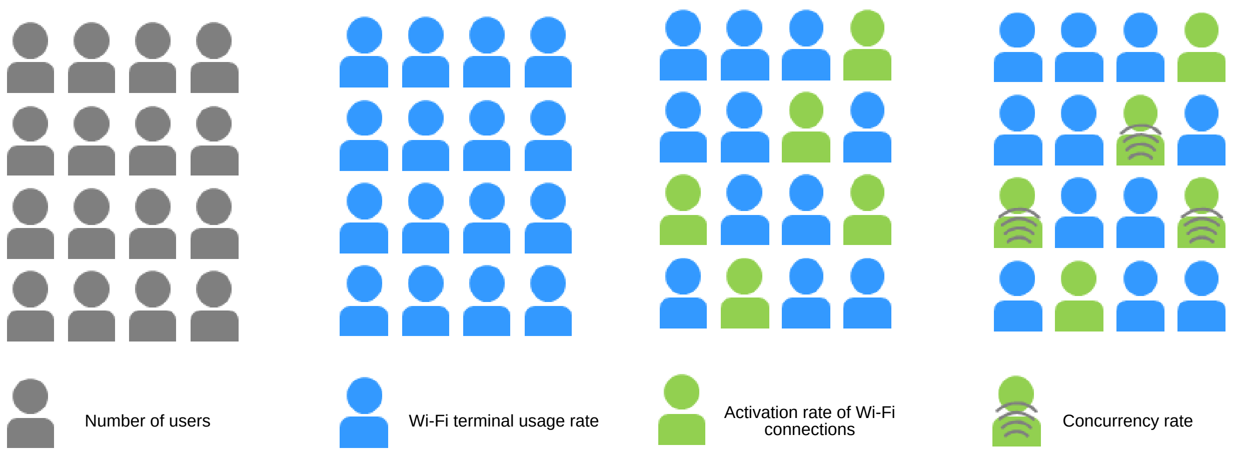
2 Technology Implementation

2.1 Service Model

1. **Number of concurrent users**

   Smart terminals gain increasing popularity nowadays. Nearly all smart terminals support Wi-Fi functions. In other words, the Wi-Fi terminal usage rate reaches nearly 100%. Among all Wi-Fi terminals, Wi-Fi connections are activated only on certain Wi-Fi terminals. The proportion of these Wi-Fi terminals is the activation rate of Wi-Fi connections. Not all Wi-Fi-activated terminals use the Wi-Fi network concurrently. There is a concurrency rate, which is the percentage of concurrent users.

Figure 2-1 Usage rate, activation rate, and concurrency rate



The number of concurrent users on a network is determined by the three rates.

Number of concurrent users = Total number of users x Wi-Fi terminal usage rate x Wi-Fi connection activation rate x concurrency rate

The rates vary according to different scenarios, especially the activation rate and concurrency rate. In a stadium with 80,000 users, if the Wi-Fi terminal usage rate, Wi-Fi connection activation rate, and user concurrency rate are 100%, 30%, and 30% respectively, the number of concurrent users is 7,200.

Item	Percentage	Number of Users	Remarks
Total number of users	NA	80,000	
Wi-Fi terminal usage rate	100%	80,000	
Wi-Fi connection activation rate	30%	24,000	
Concurrency rate	30%	7,200	A total of 7,200 users use Wi-Fi services simultaneously.

2. **Terminal Type**

A wide variety of Wi-Fi terminals exist on a network, including the legacy 802.11b/g terminals, popular 802.11n terminals, single-band terminals, and dual-band terminals. There is a performance difference among these terminals. When the terminals connect to the network concurrently, the network rate of high performance terminals will be affected. Therefore, the high-density coverage planning must consider impact of different types of terminals on the AP capacity.

- Low-rate and high-rate terminals

  It takes a longer time for low-rate terminals to transmit the same packet than high-rate terminals. The AP connecting to low-rate terminals offers a lower capacity than it connecting to high-rate terminals.

	Average Throughput of 10 Users (Mbps)	Average Throughput of 20 Users (Mbps)	Average Throughput of 30 Users (Mbps)
100% HT20 11n	7.44	3.48	1.97
75% HT20 11n/25% 11a(g)	6.84	2.88	1.67
50% HT20 11n/50% 11a(g)	6.24	2.28	1.37
25% HT20 11n/75% 11a(g)	5.64	1.68	1.07
100% 11a(g)	1.86	0.87	0.49

  The preceding table describes AP capacity under different proportions of 802.11n and 802.11a/g terminals. The higher the proportion of low-rate terminals, the smaller the AP capacity. Therefore, the same number of low-rate terminals require more APs than high-rate terminals in order to provide the same bandwidth. Before starting the high-density coverage planning, learn about proportions of terminals at different rates.

- Single-band and dual-band terminals

  Generally, APs available on the market support dual bands. When more than half of the terminals on the network support both 2.4 GHz and 5 GHz radios, using dual-band APs will double the coverage capacity than using single-band APs because the 5 GHz radio is made full use of and terminals are distributed on both radios.

Currently, most smart terminals support dual bands (the following table lists support for the 5 GHz radio on some terminals). Since there is still a large number of legacy terminals in use on the live network, learn about the proportion of dual-band terminals before implementing network planning for a high-density scenario.

Product Model	Wi-Fi Standards	Support for 5 GHz Radio (Y/N)
Sumsung GALAXY S4	802.11 a/n/b/g/ac	Y
Apple iPhone5	802.11a/b/g/n	Y
HTC one	802.11 a/ac/b/g/n	Y
Sony Xperia Z	802.11 a/b/g/n	Y
GALAXY S3	802.11 a/b/g/n	Y
iPhone4S	802.11b/g/n	N
BlackBerry Z10	802.11 a/b/g/n	Y
LG Nexus 4	802.11a/b/g/n	Y
Nokia Lumia920	802.11 a/b/g/n	Y
BlackBerry Q10	802.11 a/b/g/n	Y

Most terminals support only one antenna, but the capacity design must consider terminals using multiple antennas. Check whether terminals on the network support MIMO antennas and clarify the proportion of these terminals before conducting the high-density coverage planning.

3. **Service Type**

   Service types vary in different high-density scenarios. For example, in a football stadium, the fans have video service requirements; in exhibition venues, users require instant messaging and sharing services, such as Microblog, WeChat, and SNS. Different types of services require different bandwidths and coverage capacities. The following table provides bandwidths required by typical applications.

APP	Required Data Rate	Remarks
Web	160-400 kbps	Size of a web page: 200 KB; delay: 4 to 10s
Streaming	280-560 kbps	Real time services
IM (such as QQ)	32-64 kbps	2 KB/Session, 0.5s
Email	400 kbps	100 KB/Session, 2s
SNS (such as Microblog)	200 kbps	50 KB/Session, 2s
VoIP	256 kbps	Real-time services, for example, 256 kbps GBR for Face Time
Game	200 kbps	25 KB, 1s

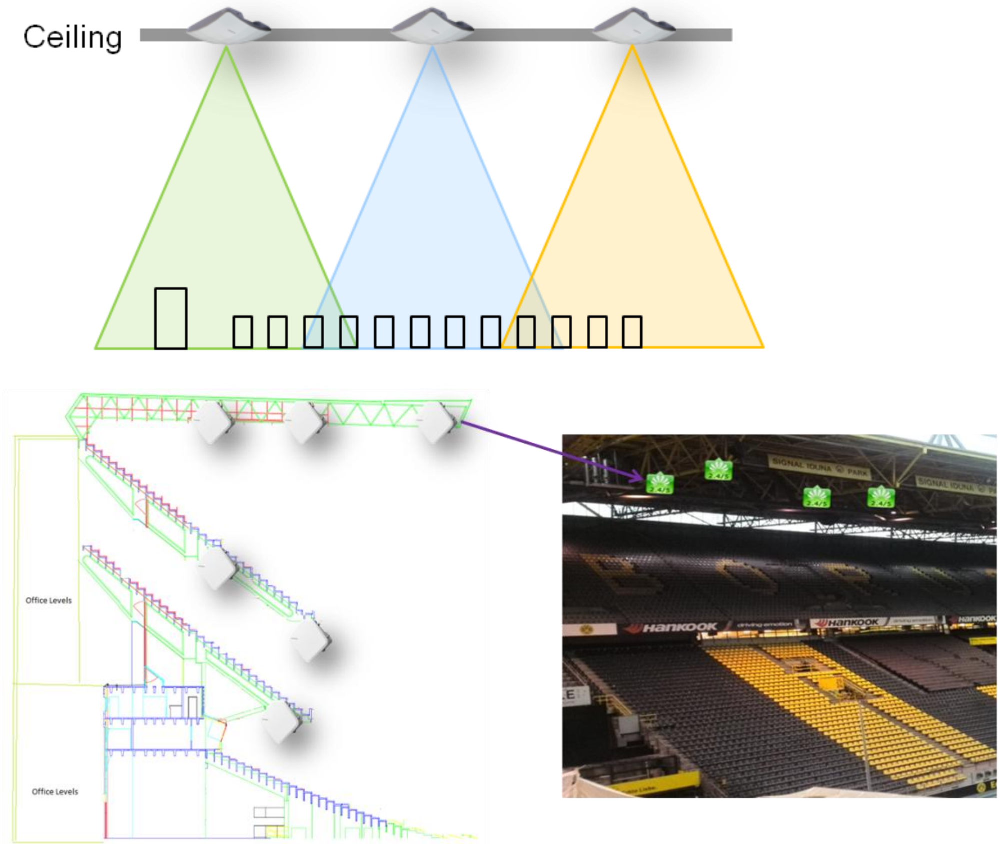
Usually, high definition (HD) video services require a bandwidth of 512 kbps while data services require a bandwidth of 256 kbps. A higher data rate brings users better experience but requires more APs for coverage.

2.2 Coverage Mode

APs must be properly deployed to ensure easy engineering construction and low interference. Directional antennas are used in high-density scenarios to control the AP coverage range and minimize interference. Outdoor APs with high ingress protection level, such as AP6510s/AP6610s are used for outdoor coverage and indoor APs such as AP7110s are used for indoor coverage. APs can be deployed in three modes: overhead, side, and floor.

1. **Overhead deployment**

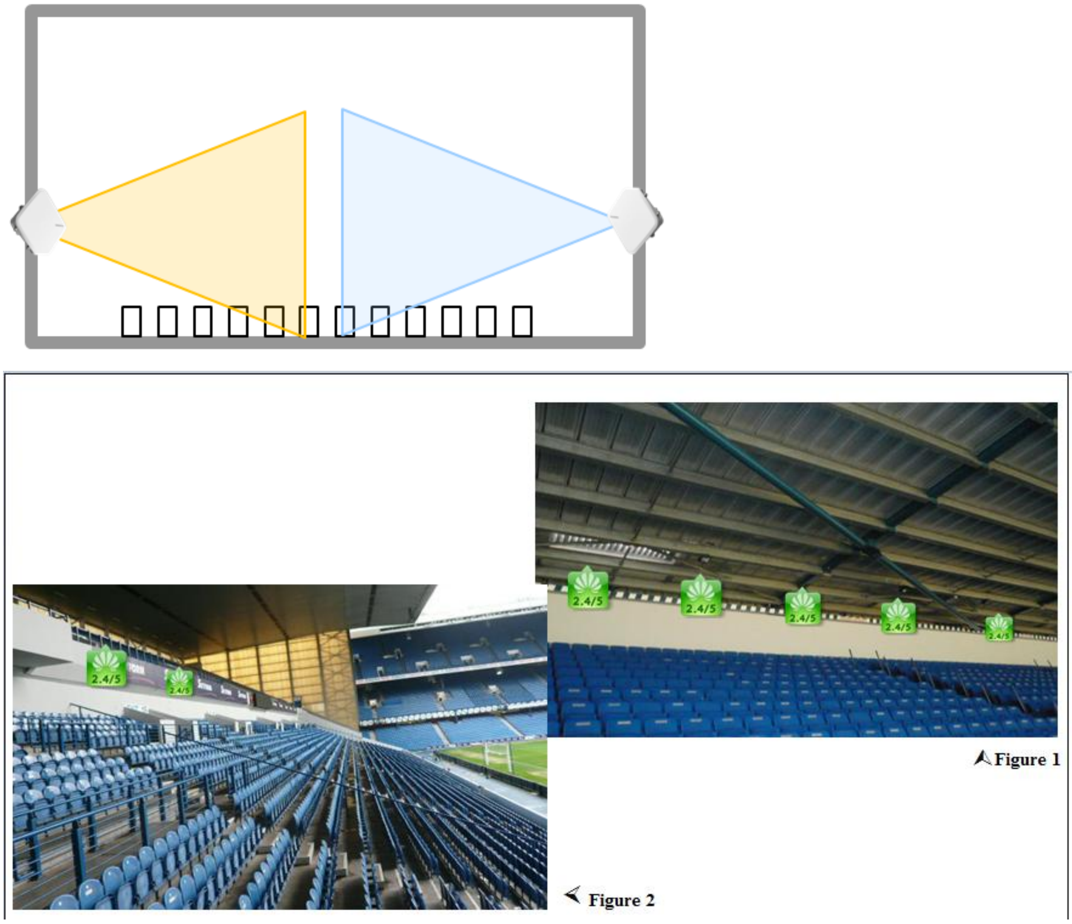
Figure 2-2 AP deployment in overhead mode



In overhead mode, APs are placed above the coverage areas, such as the ceiling of the stadium, as shown in Figure 2-2. APs are hidden and installed at a high position. This deployment mode provides high security and protects APs against intentional damage and theft. Since APs provide signal coverage in line-of-sight (LoS) distance, this mode causes no penetration loss and provides a good coverage effect. However, APs deployed in overhead mode are prone to interference, especially when they use antennas providing a poor radiation angle control capability. Moreover, this mode poses high requirements on construction conditions, such as the bearing capability of the ceiling. The height work cost is also high.

2. **Side deployment**

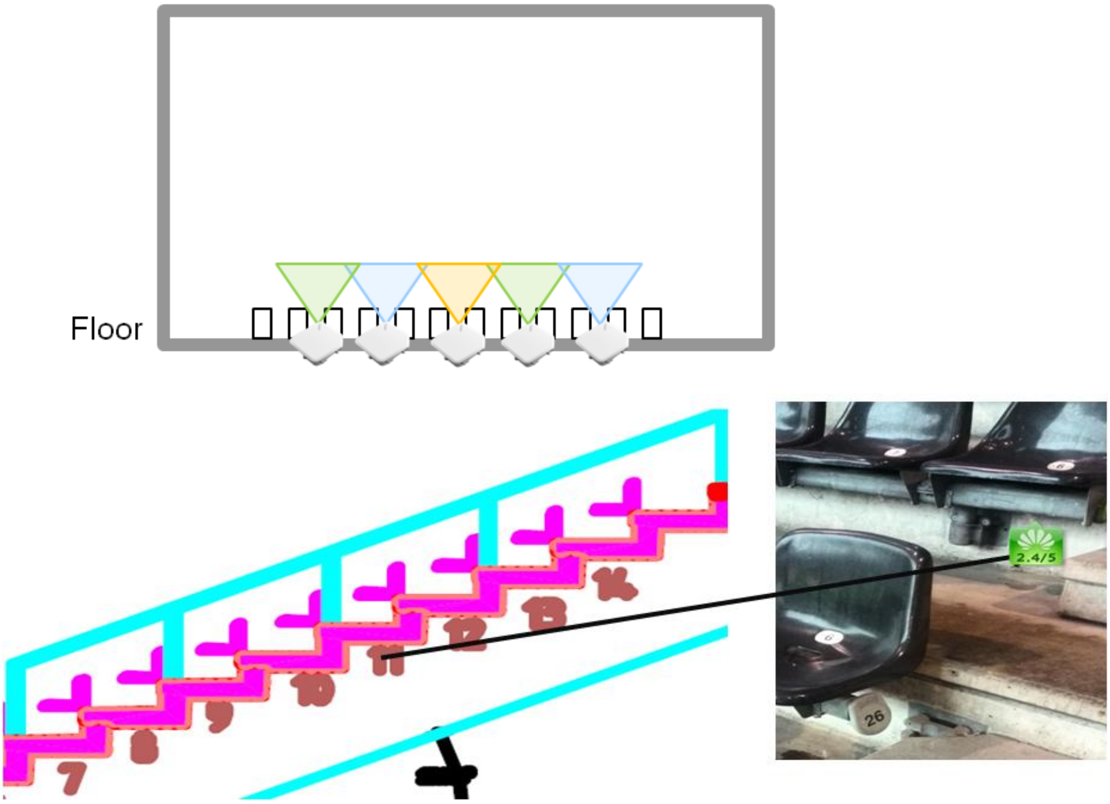
Figure 2-3 AP deployment in side mode



In side mode, APs are side-mounting to billboards, poles, or walls. This mode is easy to implement and provides a good coverage effect. APs deployed in side mode provide signal coverage in LoS distance; therefore, they cause serious interference to each other, especially when they use antennas of which radiation angle is difficult to control.

3. **Floor deployment**

Figure 2-4 AP deployment in floor mode



The floor mode uses a cellular coverage design. APs are installed under seats or at the rear of stands, as shown in the preceding figure. This mode makes good use of the seats, stands, and audience to isolate APs from each other. In this way, APs cause a little interference to each other and channels can be multiplexed. Densely deployed APs can connect more users. However, project implementation in this mode is difficult. Laying steel tubes or installing AP protection boxes may cause damages to the building surface.

When APs are deployed at the rear of the stand, use indoor APs if the signal attenuation caused by cement panels is small. If the cement panels cause severe signal attenuation, use outdoor APs with directional antennas vertical to the stand. Carry out corresponding tests to verify the signal attenuation and coverage effect.

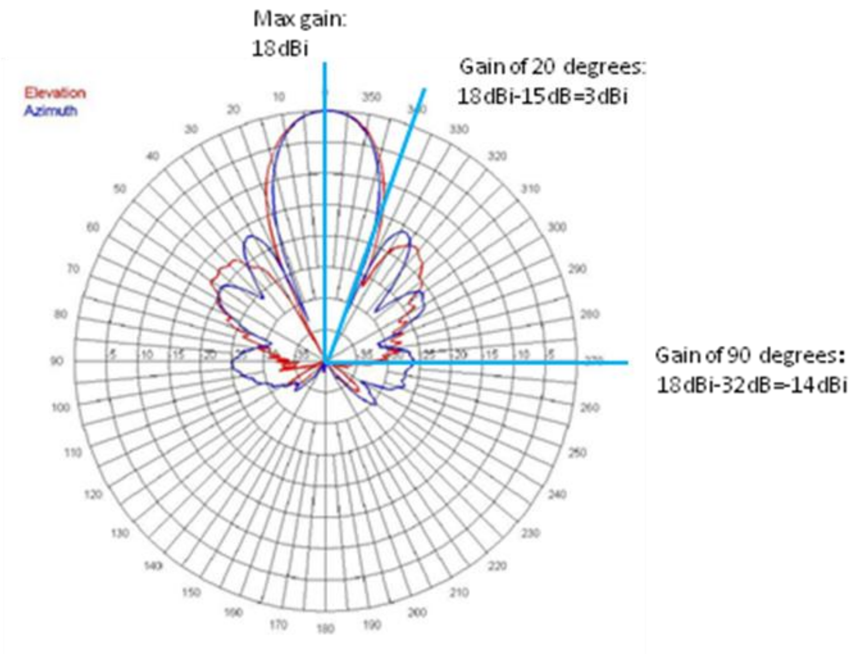
2.3 Interference Suppression

To meet high-density access needs, a large number of APs need to be deployed, which will result in severe interference. In addition to a proper network planning, deployment of rich software features is also necessary to reduce interference. Huawei uses small-angle directional antennas and advanced technologies, including CCA optimization, power control, and radio calibration to suppress interference in high-density scenarios.

1. **Small-angle directional antennas**

Interference among APs deployed in high density scenarios is more serious than that in common scenarios; therefore, it is very important to control APs' coverage areas in high density scenarios. When selecting antennas, select those whose signals transmit only within the target coverage areas but get fast attenuated in other areas. In a stadium, it is difficult to deploy APs in close proximity, so a directional antenna with a small beam angle is the optimal choice. This type of antennas is commonly used in high density scenarios.

Figure 2-5 Huawei 18-degree antenna used in high-density scenarios



As shown in the preceding figure, horizontal and vertical beam angles of the antenna are all 18 degrees. The blue lines show antenna radiation pattern in the horizontal plane and the red shows antenna radiation pattern in vertical plane. A good angle control capability allows the antenna gain to decrease to 3 dBi or below in coverage areas 20-degree deviating from the main lobe and decrease to -14 dBi in coverage areas 90-degreee from the main lobe.

Huawei offers several models of antennas with small beam angle. These antennas have good radiation angle control capability and can control AP coverage radius within the effective range to reduce interference.

	18° (2.4 GHz)	**15° (5 GHz)**	**60° (2.4 GHz)**	**60° (5 GHz)**
Appearance				
Number of Antennas Required by Each AP	1	1	1	1
Applicable Frequency	2.4 GHz	5 GHz	2.4 GHz	5 GHz
Gain (dBi)	18 *	19 *	11.5 *	12 *
Horizontal Lobe	18 °	15 °	60 °	60 °

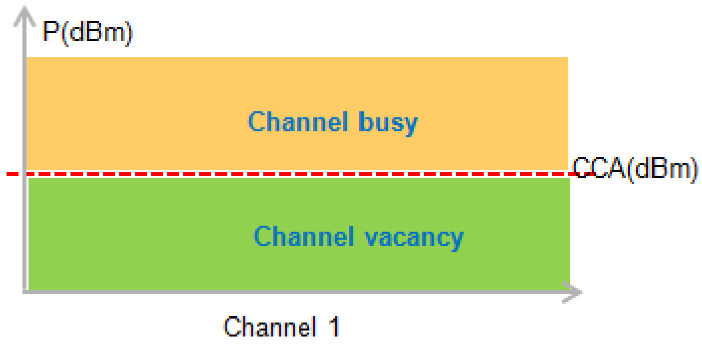
	18° (2.4 GHz)	15° (5 GHz)	60° (2.4 GHz)	60° (5 GHz)
Vertical Lobe	18 °	15 °	30 °	30 °
Polarization Mode	Dual-polarized	Dual-polarized	Dual-polarized	Dual-polarized
Interface	N-female*2	N-female*2	N-female*2	N-female*2
Applicable APs	AP6510DN AP6610DN	AP6510DN AP6610DN	AP6510DN AP6610DN	AP6510DN AP6610DN
Dimension (mm)	340 x 340 x 25	250 x 250 x 25	250 x 155 x 60	230 x 145 x 55
Part Number	27011344	27010890	27010812	27010889

*-Attenuators need to be configured to meet safety certification requirements of different countries.

2. **CCA Optimization**

   CCA, short for Clear Channel Assessment, allows an AP or STA on the WLAN to detect channel energy to check whether the channel is idle.

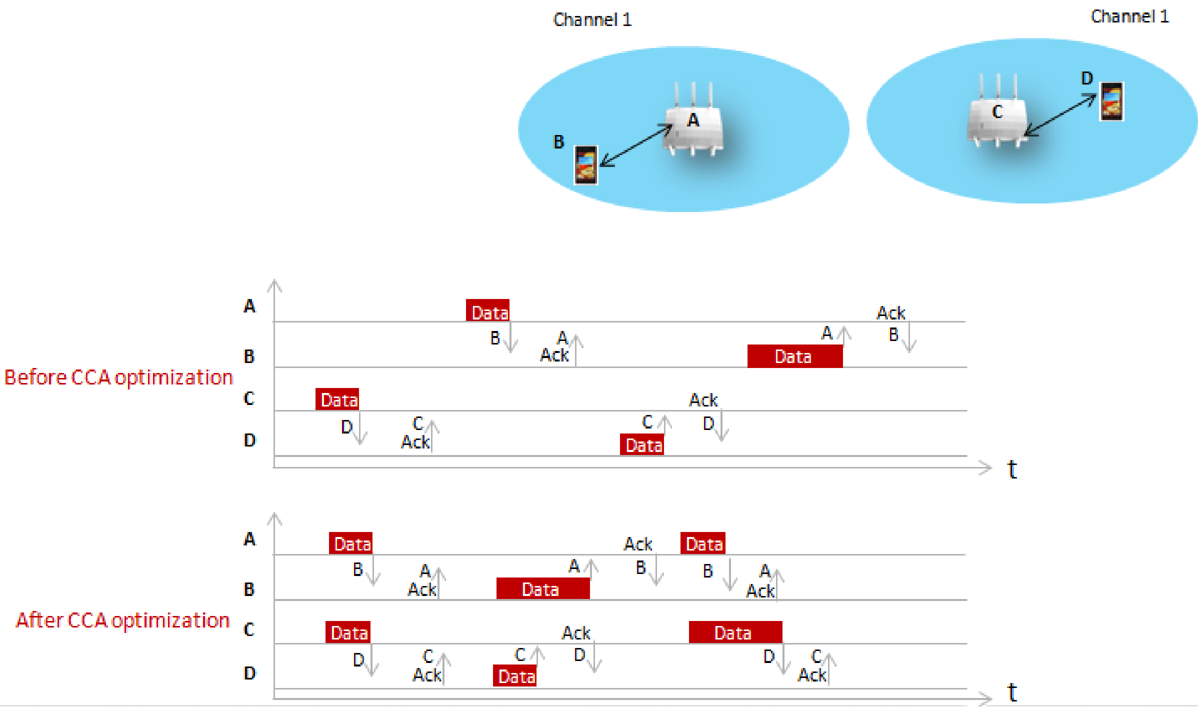
Figure 2-6 CCA principles



1. When the energy of a channel is larger than or equal to the CCA threshold, the channel is considered busy and packets are not sent over this channel.
2. When the energy of a channel is smaller than the CCA threshold, the channel is considered idle and used to send packets.

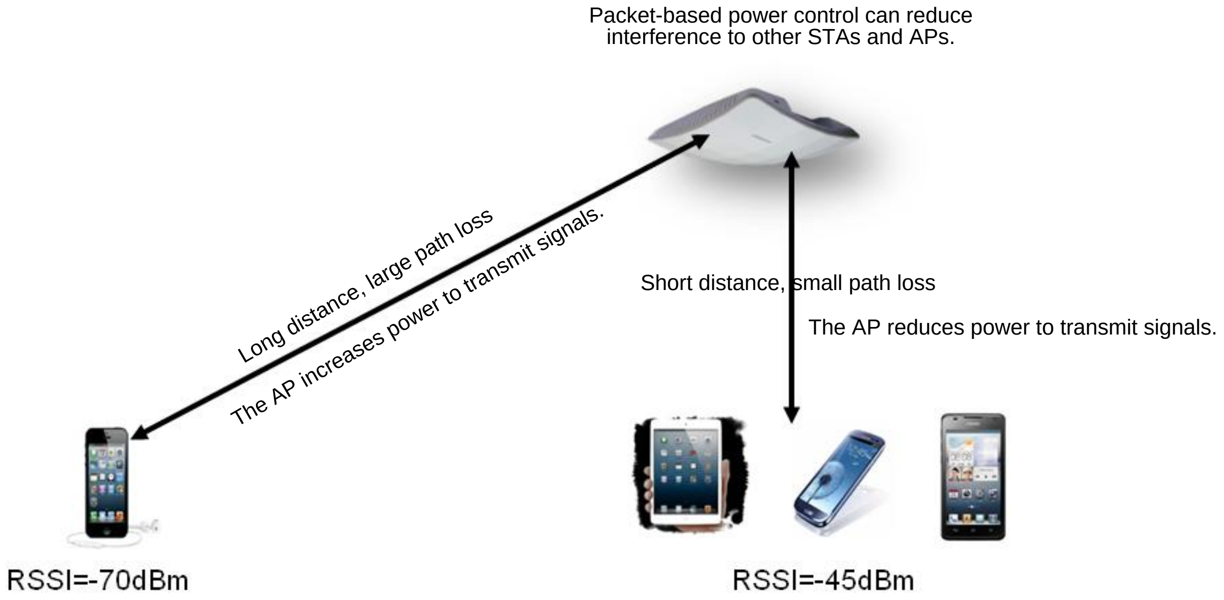
In high density scenarios, many APs and STAs exist and are near to each other. The signal strength is strong, so the detected energy easily exceeds the CCA threshold and two or more devices may share air port resources (in the same collision domain), affecting AP throughput. Huawei CCA optimization reduces the possibility of air port resources shared by multiple devices, allows more user access, and improves the throughput.

Figure 2-7 Data sending before and after CCA optimization



3. **Packet-based Power Control (PPC)**

Figure 2-8 Packet-based power control

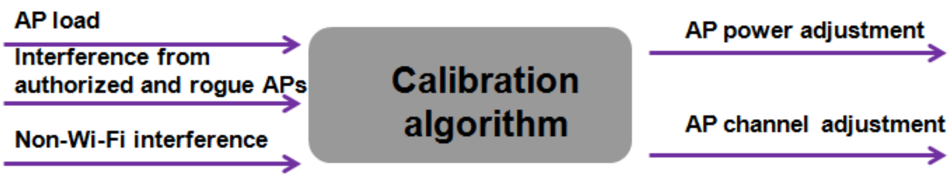


PPC enables an AP to detect the signal strength of a STA in real time. If the AP detects that the signal strength of the STA is strong (the STA is near the AP), the AP reduces its transmit power when sending packets. If the AP detects that the signal strength of the STA is weak (the STA is far from the AP), the AP increases its transmit power to send packets. By adjusting AP transmit power, PPC effectively reduces internal interference and improves the throughput.

4. **Automatic radio calibration**

   Automatic radio calibration allows an AP to collect signal strength and channel parameters of surrounding APs and generate AP topology according to the collected data. Based on interference from authorized APs, rogue APs, and non-Wi-Fi interference sources, each AP automatically adjusts its transmit power and working channel to make the network operate at the optimal performance. In this way, network reliability and user experience are improved.

Figure 2-9 Automatic radio calibration



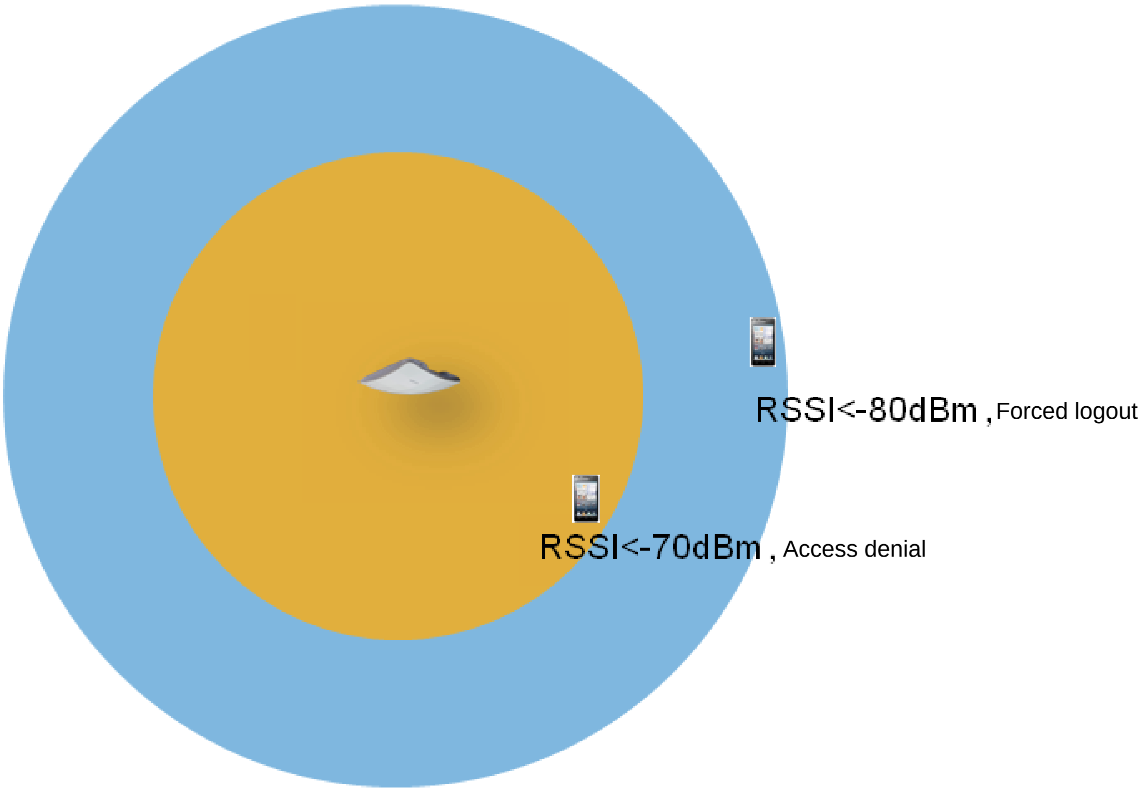
NOTE

1. The AP transmit power obtained through automatic radio calibration determines the upper power limit. PPC adjusts AP transmit power per packet within the upper limit.
2. Automatic radio calibration can reduce network maintenance workload and keep the AP operating at the optimal performance. However, radio calibration may affect services. Exercise caution when using it in high-density scenarios where the traffic volume is large.
3. Radio calibration is implemented based on ACs. Each AC implements radio calibration independently, forming the minimum radio calibration range in each radio calibration region. This reduces the calculation work of each AC and ensures a good calibration effect.

2.4 Air Port Usage Efficiency

Access of low-rate STAs seriously reduces efficiency of the air port and degrades user experience, especially in high-density scenarios where many users access the network. Increased number of low-rate STAs consumes more resources on the air port, reduces the AP capacity, and lowers user experience. Controlling access and resource usage of low-rate STAs can reduce the impact.

Figure 2-10 Air port efficiency improvement



1. Restrict access from low-rate STAs.

   An AP checks the access rate of STAs and rejects access from low-rate STAs.

2. Restrict access from weak-signal STAs.

   An AP checks the signal strength of STAs and rejects access from weak-signal STAs.

3. Force logout of low-rate STAs.

   An AP monitors the rate of online STAs in real time and forces low-rate STAs to log out so that the STAs can reassociate with APs with strong signals.

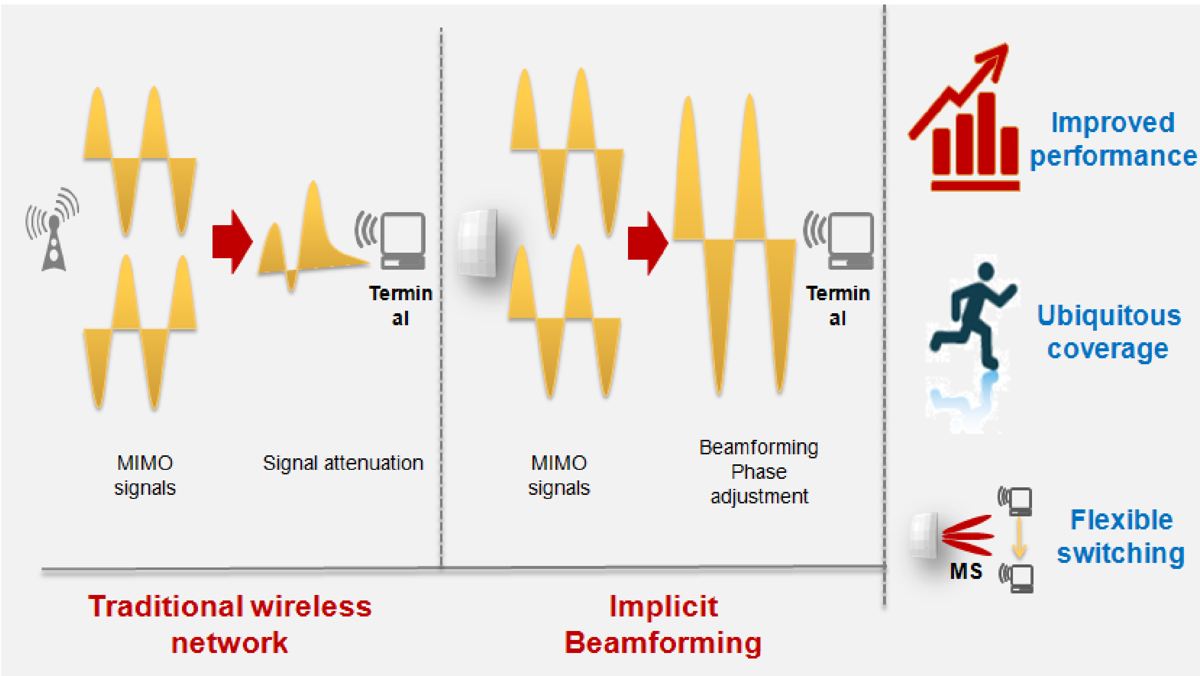
4. Force logout of weak-signal STAs.

   An AP monitors the signal strength of online STAs in real time and forces weak-signal STAs to log out so that the STAs can reassociate with APs with strong signals.

5. Beamforming

   Beamforming allows the transmitter to adjust transmitting parameters based on the obtained channel information to achieve energy concentration on the receiving end. This enhances signal coverage and increases AP capacity. Huawei stadium solution supports implicit and explicit Beamforming, which can improve link performance of all terminals and the air port usage efficiency.

Figure 2-11 Beamforming

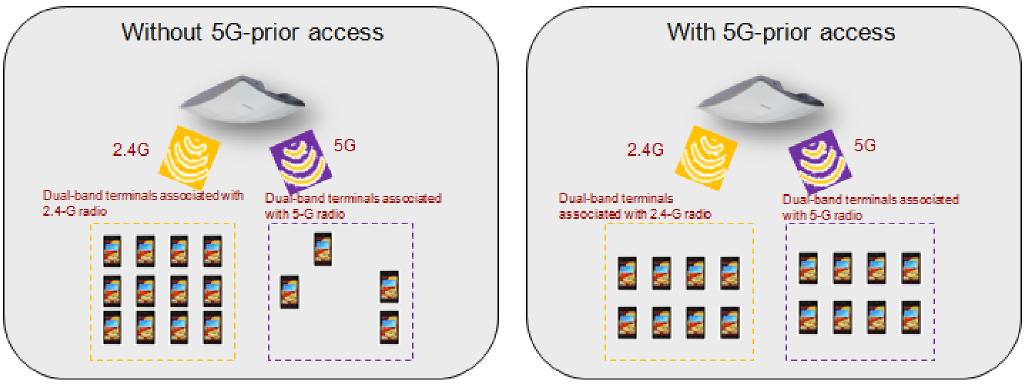


2.5 Load Balancing

1. **Load balancing between radios**

   STAs often connect to the WLAN through the 2.4 GHz radio. As a result, the 2.4 GHz frequency band with fewer channels is congested, heavily-loaded, and has severe interference. The 5 GHz frequency band with more channels and less interference is not well used. When an AP and STA support both 5 GHz and 2.4 GHz frequency bands, the AP can request the STA to associate with the 5 GHz radio first. 5G-prior access reduces traffic load and interference on the 2.4 GHz radio and improves user experience.

Figure 2-12 Load balancing between radios

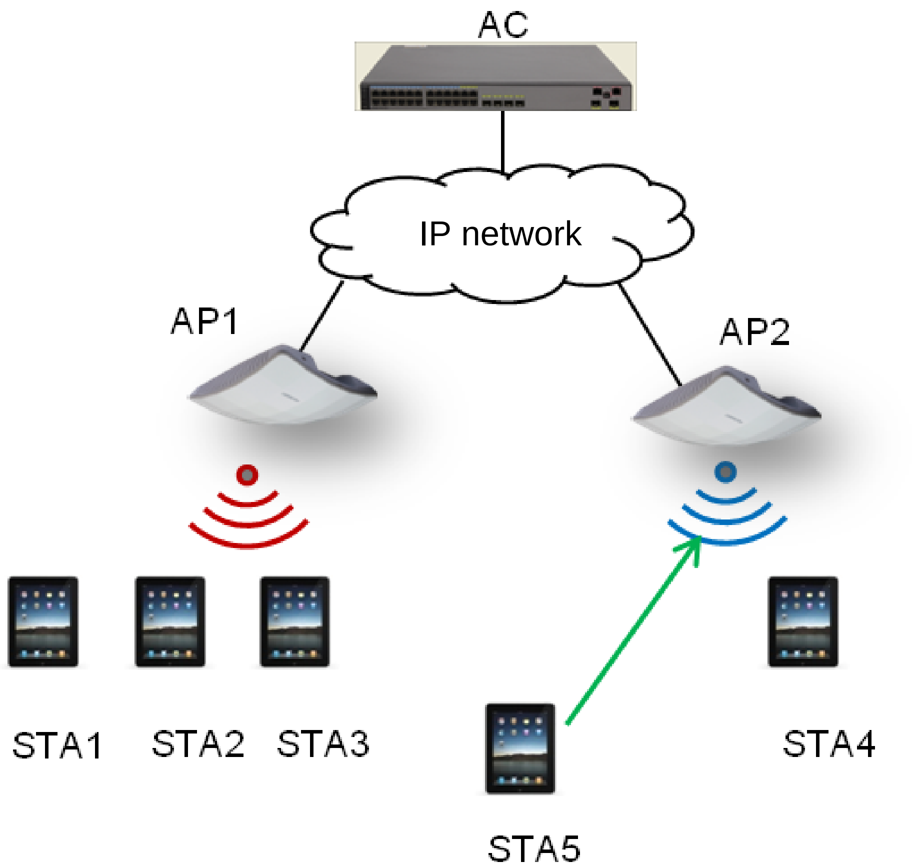


The implementation of this feature is restricted by the percentage of dual-band terminals on the live network. Some chip vendors predict that the number of delivered dual-band terminals will account for more than 50% of the total delivery by the end of 2014. In fact, according to statistics on mainstream smart terminals on the market, the percentage of dual-band terminals has already exceeded 50%.

2. **Load balancing between APs**

   Due to difference in terminal use habits, one of the two neighboring APs may be heavily loaded while the other may have a light load. Load balancing distributes users evenly to APs based on user quantity and traffic volume. In this way, traffic load is balanced among APs to prevent an AP from being heavily loaded.

Figure 2-13 Load balancing between APs



2.6 Air Port Scheduling

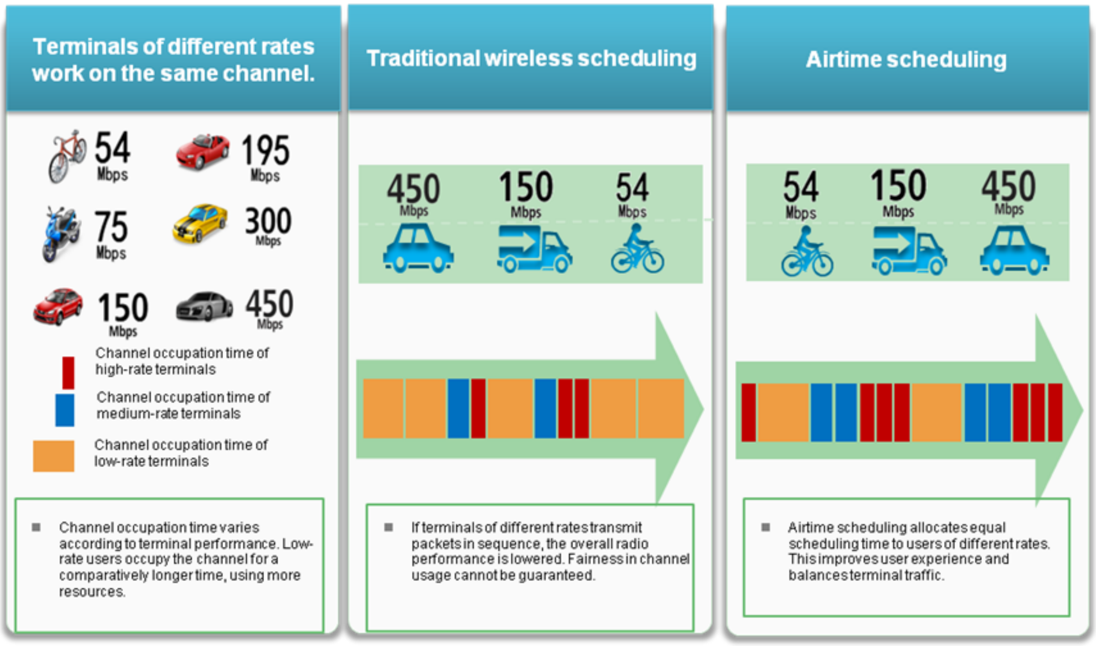
1. **Dynamic EDCA**

   WLAN provides competition-based multi-address access services. If a large number of users exist, the possibility of collisions increases. When an increasing number of users connect to an AP, AP throughput decreases sharply. This may lower the quality of user experience. Enhanced Distributed Channel Access (EDCA) defined by 802.11e allocates different priorities to services of different types by setting different access parameters. Different settings of access parameters affect the possibility of collisions. Huawei dynamic EDCA can detect the user quantity on each AP and flexibly adjust EDCA parameters, which reduces the possibility of collisions, improves AP capacity, and enhances user experience. Dynamic EDCA is supported by all Huawei indoor and outdoor APs used in high-density scenarios.

2. **Airtime scheduling**

   The same packet transmitted by STAs at different rates requires different time on the air port. A high-rate STA has strong transmission capability and high spectrum efficiency, so less time is taken to send packets on the air port. A low-rate STA has low transmission capability and low spectrum efficiency, so much time is taken to send packets on the air port. This reduces the throughput of each AP and lowers the system efficiency. Airtime scheduling evenly allocates the downlink transmission time and helps high-rate STAs transmit more data, improving the AP throughput and allowing more user to connect to the AP.

Figure 2-14 Airtime scheduling

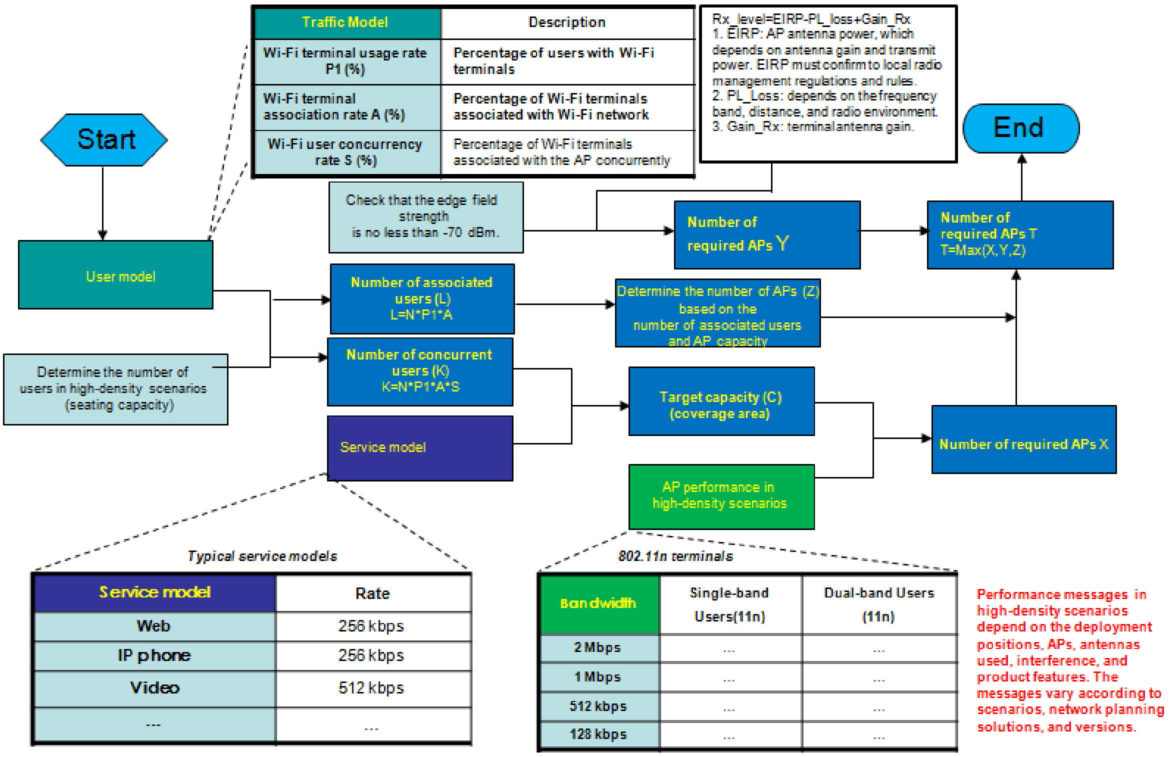


2.7 AP Quantity Calculation

The AP capacity can be determined based on the service model, coverage mode, and usage of software features. In terms of data capacity, the number of APs required depends on the number of concurrent users, service model, and AP performance.

In actual planning, the number of APs is determined by two factors: coverage area and network capacity. A high-density scenario is capacity-limited. Therefore, the AP quantity depends mainly on the network capacity.

Figure 2-15 AP quantity calculation process



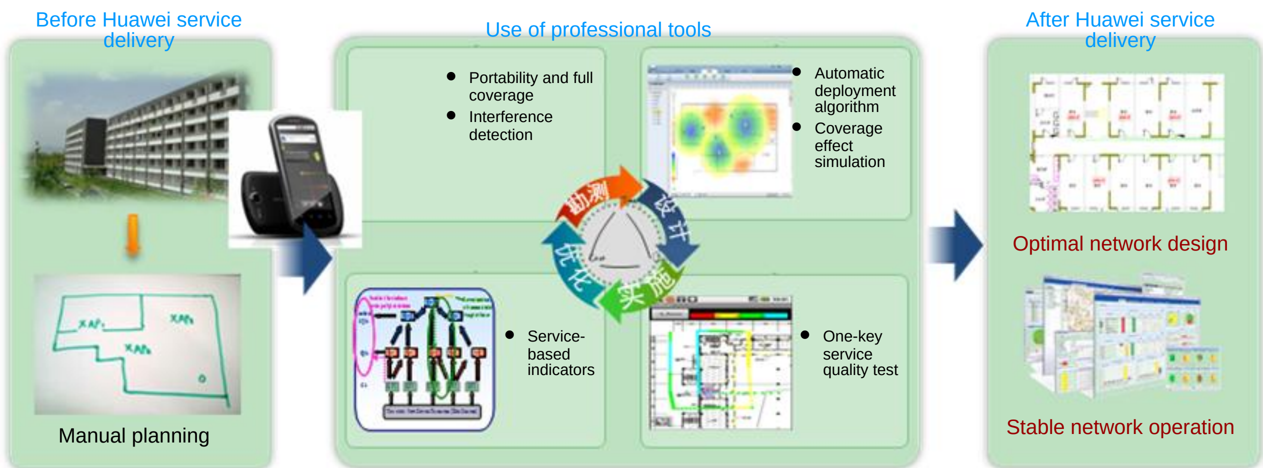
Users need to associate with APs before access to the desired applications. The number of users associated with each AP is limited and is a factor determining the number of APs. Therefore, the AP quantity can be estimated based on the coverage, data capacity, or the number of associated users. The actual AP quantity is the largest of the estimated values.

3 Huawei Advantages

3.1 Professional Network Planning and Optimization

With years of experience in the wireless field and deep expertise in WLAN planning and optimization, Huawei offers customers expert planning and optimization services covering the entire life cycle of WLANs, including planning, deployment, acceptance, O&M, and optimization. At each stage of the life cycle, Huawei services are supported by professional tools and implemented by world-class expert teams.

Figure 3-1 Professional network planning and optimization



3.2 Cutting-edge Software Features

Huawei provides rich software features to manage radio resources and improve high-density access performance. These features include interference suppression, air interface resource scheduling, multi-user scheduling, and load balancing.

Type	Description	Benefit
Interference	CCA optimization	CCA optimization improves the AP's anti-interference

Type	Description	Benefit
suppression		capability.
	Packet-based Power Control (PPC)	Downlink power control of APs reduces internal interference.
	Automatic radio calibration	The AP monitors network environment changes and implements radio calibration periodically or triggers radio calibration by event to remain the optimal network performance.
Air port resource scheduling	Access control on low-rate and weak-signal users	The AP restricts access of low-rate and weak-signal users to improve air port usage efficiency.
	Forced logout of low-rate and weak-signal users	The AP forces low-rate and weak-signal users to log out to improve air port usage efficiency.
	Implicit and explicit Beamforming	Beamforming technology improves air port usage efficiency and ensures user experience.
Multi-user scheduling	Dynamic EDCA parameter adjustment	APs adjust EDCA parameters flexibly to reduce the possibility of collision, improve the throughput, and increase the number of access users.
	Airtime scheduling	Downlink scheduling allocates equal time to users of different rates, helping high-rate users transmit more data and obtain high user experience.
Load balancing	Load balancing between radios	Dual-band terminals preferentially access the 5 GHz radio to make full use of 5 GHz channel resources. This distributes terminals evenly, improving user access experience.
	Load balancing between APs	Terminals are evenly distributed among APs, which improves user access experience.