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

# 企业典型场景高品质WLAN网络建设白皮书

版本 1.0

White Paper on Building High-Quality WLANs in Typical Enterprise Scenarios version1.0

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# 前言
# Preamble

世界无线局域网应用发展联盟（World WLAN Application Alliance，WAA）是在中国民政部注册成立的、专注于无线局域网产业发展的国际组织。WAA 以“为数字世界提供最佳体验的无线局域网络”为愿景，携手全球产业伙伴共同推动 WLAN 产业蓬勃发展。
WLAN 应用已经深入家庭、办公、教育、生产、物流等多种场景，关乎国计民生，是数字经济的关键基础设施。伴随着 WLAN 技术的进步和业务场景的不断丰富，深入分析不同场景的业务需求、建网标准，以进一步提升网络质量和用户体验成了业界需要解决的问题。
本白皮书分析了 WLAN 在企业各种应用场景中的场景特征、业务需求，以及 WLAN 技术最新的发展趋势，对 WLAN 在企业场景的中建网和使用提供参考。
本文档的目标读者主要是企业应用各场景中 WLAN 网络的使用者、WLAN 网络的建设者和企业应用各场景 WLAN 网络的维护者。

The World WLAN Application Alliance (WAA) is an international organization dedicated to the development of the wireless local area network (WLAN) industry. WAA is registered in the Ministry of Civil Affairs of China. Inspired by the vision of "Building the WLAN that delivers the best experience in the digital world", WAA works with global partners to promote the development of the WLAN industry.
WLAN applications have been widely used in various scenarios, such as home, office, education, production, and logistics. WLAN applications are critical to the national economy and people's livelihood and are the key infrastructure of the digital economy. As WLAN technologies and service scenarios evolve, the industry needs a deeper understanding of service requirements and network construction standards in different scenarios to keep up with the demand for better network quality and user experience.
This white paper analyzes the characteristics and service requirements of WLANs in various enterprise application scenarios, and the latest development trends of WLAN technologies. It serves as reference for WLAN network construction and application in enterprise scenarios.
This document is intended for WLAN users, network builders, and maintainers in enterprise application scenarios.

# 目录
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# 第 1 章

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# WLAN 在企业已广泛使用
# 但业界缺少性能及体验标准

## 1.1 WLAN 承担了 70% 的末端流量，产业规模和经济价值持续增长

伴随着移动互联网的发展， 无线网络给大家的工作、 学习和生活带来了极大的便利， 随时随地的上网成了人们的基本诉求。WLAN 网络成为与水电同等重要的基础设施， 成为人们日常生活的必需品之一， WLAN 技术的应用价值、 商业价值也被广泛认可。根据第三方咨询公司报告， 全球超过 70% 的末端流量是通过 WLAN 技术实现的最后一跳接入， 使之成为最重要的末端接入技术。

WLAN 网络是实现智慧家庭的基本需求。在家庭中，支持 WLAN 的设备数量不断增加，手机、平板电脑、笔记本电脑、摄像头、智能电视、智能家电、扫地机器人等终端均需要连接 WLAN 网络， 使得家庭 WLAN 网络的终端接入密集度不断提高。

WLAN 网络是各种园区和公共场所的基本配置。商场、 机场、 酒店、 地铁等人员流动比较多的地方， 处处可见为消费者提供的免费 WLAN 网络，并通过 WLAN 提供定位、导航、移动支付等业务，增加客户粘度，提升客户满意度。
WLAN 网络也是企业数字化转型的重要基础设施。有了 WLAN 网络， 企业员工可以实现移动协同办公， 或通过移动 APP 随时办公。当前超过 70% 的企业已经实现无线办公， 极大程度的提高工作效率。数字化转型也带动物联网设备的数量呈爆发式增长， 据预测 2025 年全球联接设备数将达 1000 亿， WLAN 作为物联网（IoT）设备的第一个网络连接点，其价值将会更加凸显。

WLAN 是“小”技术， “大”产业， 产业规模和经济价值持续增长。据第三方咨询公司分析，全球 WLAN 市场预计从 2019 年至 2025 年期间持续大幅增长， 设备年出货量将从 2019 年的 31 亿台增加到 2025 年的 45 亿台以上， 年复合增长率超过 10%。

WLAN 已经成为企业和运营商网络的关键技术， 并且是家庭以及个人消费品的重要组成部分， 随着新一代产品在未来几年内的普及，这种价值还会继续上升。

## 1.2 WLAN 产业缺少场景化的性能体验测试标准

在 WLAN 发展的 20 多年时间理，由于在相当长的时间内应用主要是互联网接入和电子邮件等简单业务，对网络性能要求不高。但随着 WLAN 应用场景和业务类型的不断丰富， 在时延、可靠性、抗干扰、漫游切换等性能体验方面的要求也越来多，已经成为当前 WLAN 产业发展面临的新问题和新需求。

| | | 1997 | 1999 | 2007 | 2009 | 2012 | 2019 |
|---|---|---|---|---|---|---|---|
| 技术标准 | IEEE | 802.11 | 802.11b/a | 802.11g | 802.11n | 802.11ac | 802.11ax |
| 互通认证 | WFA | | Wi-Fi 1/2 | Wi-Fi 3 | Wi-Fi 4 | Wi-Fi 5 | Wi-Fi 6 |
| 性能标准 | BBF | | | 缺失 | | | TR-398 家庭网关WLAN接口性能要求和测试方法 |
| 性能认证 | CCSA 无 | | | | | | |

图 1 WLAN 产业界长期缺乏性能标准认证体系

当前 WLAN 产业界的测试认证仅满足互联互通，无 WLAN 网络建网标准、无网络性能＆体验性能测试规范及认证体系，网络运营方无验收标准， 最终客户体验差。产业长期缺乏 WLAN 性能标准认证体系， 已经成为 WLAN 产业发展的明显短板，亟需尽快补齐。

# Chapter 1

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# Despite Widespread Usage of WLANs in Enterprises, the Industry Lacks Standards Regarding Performance and Experience

## 1.1 WLAN Carries 70% of Last-Hop Traffic, with Continuous Growth in Industry Scale and Economic Value

In the mobile Internet era, wireless networks are bringing unprecedented convenience to people's work and life. Internet access that is available anytime, anywhere has become a basic need. WLAN networks have become a daily necessity and key infrastructure, just like water and electricity. The application and commercial value of WLAN technologies are also widely recognized. According to a report from a third-party consulting firm, more than 70% of the world's last-hop traffic is implemented through WLAN technology, making WLAN the most important terminal access technology.

WLANs are the basic requirements for smart homes. In homes, the number and types of devices supporting WLAN are increasing. Terminals such as mobile phones, tablets, laptops, cameras, smart TVs, and smart home appliances need to connect to the WLAN, leading to a higher access density of the home WLAN.

WLANs are a basic facility in campuses and public locations. Places with high foot traffic such as shopping malls, airports, hotels, and subways provide free WLAN access for consumers. The consumers use WLANs for positioning, navigation, and mobile payment. This in turn increases customer loyalty and satisfaction.

WLANs are also important infrastructures for enterprises' digital transformation. With the WLAN network, employees can work and collaborate on mobile networks or use mobile apps to work at any time. Currently, more than 70% of enterprises have implemented wireless offices, greatly improving work efficiency. Digital transformation has also led to explosive growth in the number of Internet of Things (IoT) devices. It is predicted that the number of connected devices worldwide will reach 100 billion by 2025. As the first network connection point for IoT devices, WLAN will demonstrate even more value.

All these examples speak one thing: WLAN is a "small" technology but a "big" industry. Its industry scale and economic value will continue to grow. According to the analysis of a third-party consulting firm, the global WLAN market is expected to continue to grow significantly from 2019 to 2025. The annual shipments of WLAN devices will increase from 3.1 billion units in 2019 to more than 4.5 billion units in 2025, with a compound annual growth rate of more than 10%.

WLAN has become a key technology in enterprise and carrier networks and an important part of consumer products for homes and individuals. This value will continue to grow as next-generation products become popularized in the coming years.

## 1.2 The WLAN Industry Lacks Scenario-based Performance Experience Test Standards

In the more than 20-year development of WLAN, its application used to be basic services, such as Internet access and e-mail. Such services have low requirements for network performance. However, as the application scenarios and service types of WLAN become more diversified, demands arise for experience-critical performance, such as latency, reliability, anti-interference, and roaming handover. This has become a new challenge to the WLAN industry

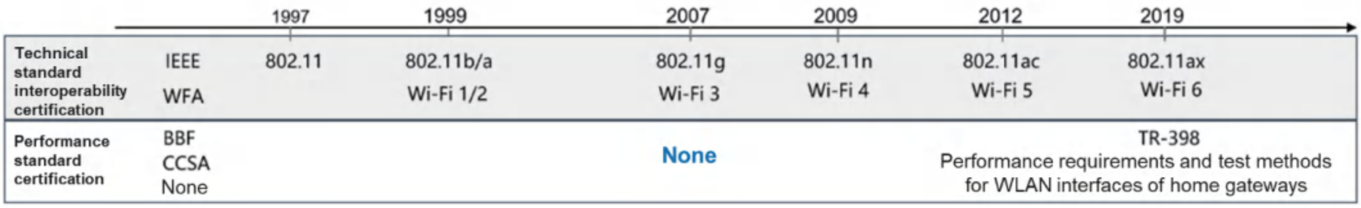


Figure 1-1The WLAN industry has long lacked a performance standard certification system

Currently, the test and certification of the WLAN industry focuses mainly on interoperability. There are no WLAN network construction standards, network performance, experience performance test specifications, or certification systems, and carriers do not have acceptance standards, either, resulting in poor user experience. The industry has long lacked a WLAN performance standard certification system, which has become an obvious weakness in the development of the WLAN industry and needs to be addressed imperatively.

# 第 2 章

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# 企业 WLAN 场景复杂，需求多样亟需高品质 WLAN 建网标准

在教育、医疗、旅游、库管、会展等领域无线网络有着广阔额应用场景，而不同场景对网络的体验要求也各不相同，主流场景分为如下几类：

# 2.1 园区办公

## 2.1.1 场景简介

随着无线网络技术的日趋成熟，越来越多的企业通过搭建无线网络来支撑日常业务需求，无线办公场景空间主要为高密办公区、低密办公区、会议室、休闲区及餐厅等场景，业务聚焦于办公软件、邮件、网页浏览、文件传输、IM 即时通讯、音视频会议等应用，要求可以重点保障音视频会议、IM 即时通信等关键办公业务，用户关注网络传输效率、接入稳定性以及移动办公流畅性，无线部署应能支持高密接入、高并发应用，并且低延时的高效传输。

## 2.1.2 场景业务需求

园区办公业务以办公软件、邮件、网页浏览、文件传输、即时通讯、音视频会议等应用为主，业务带宽需求及占比如下表格：

表 1 园区办公场景业务需求

| 业务类型 | 单业务基线速率（Mbps） | | 各场景区域业务占比 | | | | |
|---|---|---|---|---|---|---|---|
| | Excellent | Good | 高密办公区 | 低密办公区 | 会议室 | 休闲区 | 餐厅 |
| 网页浏览 | 8 | 4 | 20% | 20% | 50% | 25% | 25% |
| 流媒体（1080P） | 16 | 12 | 10% | 5% | 5% | 30% | 30% |
| 流媒体（4K） | 50 | 25 | 10% | 5% | 5% | 20% | 25% |
| VoIP | 3 | 2 | 10% | 20% | 10% | 0% | 0% |
| 电子白板 | 32 | 16 | 5% | 5% | 10% | 0% | 0% |
| 电子邮件 | 32 | 16 | 3% | 3% | 5% | 10% | 10% |
| 文件传输 | 32 | 16 | 2% | 2% | 10% | 0% | 0% |
| 桌面共享 | 3 | 2 | 10% | 10% | 0% | 0% | 0% |
| 游戏 | 2 | 1 | 0% | 0% | 0% | 10% | 5% |
| 即时通讯 | 1 | 0.5 | 30% | 30% | 5% | 5% | 5% |

## 2.1.3 高密与低密办公区场景

### 2.1.3.1 场景示意图

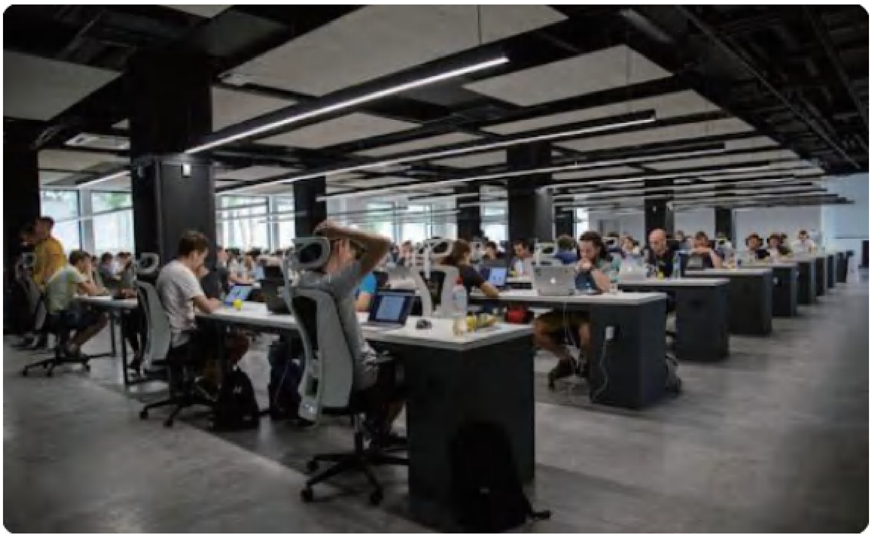

图 2 高密办公区示意图

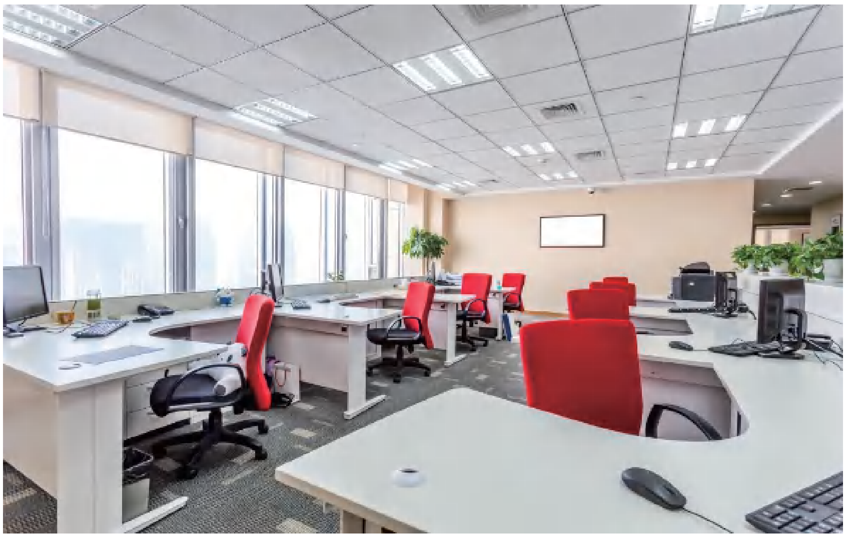

图 3 低密办公区示意图

#### 2.1.3.2 业务类型描述

此场景以无线化办公为主。业务类型分为： 办公业务和非办公业务。办公业务： 视频会议、 网页浏览、 电子邮件、文件下载等。非办公业务： 视频、游戏、语音通信等。

#### 2.1.3.3 环境设定与场景性能要求

· 空间设定： 空间层高 3-5 米，面积几平方米到几百平方米不等
· 密度设定： 高密： 人均 2-3 平方米空间； 低密： 人均 4-5 平方米空间
· 容量要求： 高密： 单 AP 接入 80 终端，并发率 40%； 低密： 单 AP 接 40 终端，并发率 40%
· 覆盖要求： 覆盖范围内 95% 的区域 RSSI ≥ -65dBm
· 此外还需根据实际场景情况规划： AP 部署方式与间距、带宽等因素

#### 2.1.3.4 无线功能需求

· 广覆盖需求： 开放办公场景，一般面积比较大，没有固定的隔断，但是人员比较集中，需要考虑无线信号覆盖。

· 高并发需求： 办公场景下会有大量的无线连接， 会导致无线网络的干扰和拥堵， 在带宽确定的前提下， 需要合理规划网络，配置射频资源，来尽量满足无线用户的并发需求。

· 高带宽需求： 办公场景中存在各种需要传输大量数据流量的情况， 例如音视频会议、 大型文件传输等， 这些应用对于网络带宽的要求非常高。在办公场景下，可以利用资源保证技术保障关键应用或者关键终端的带宽需求。

· 抗干扰需求： 高密场景下往往存在较大的无线干扰， 包含 WLAN 干扰和非 WLAN 干扰。无线网络下的各种干扰往往会对网络的稳定性、 数据传输速度和网络连接质量造成较大影响， 甚至导致网络中断等问题， 故要求设备有一定的干扰抑制能力，在干扰严重的环境中也能保障无线用户的上网体验。

· 无感漫游需求： 移动办公要求在不同 AP 之间快速无缝切换，保障移动办公的连续性和效率，并且需要保证移动办公在不同位置的服务质量和用户体验。服务质量包括移动设备的连接速度、 数据传输速度、 链接时间、 可用性和稳定性。

· 关键用户保障需求： 办公场景需保障关键用户作为 VIP 级用户接入体验。VIP 用户的带宽保障需要是全方位的， 在网络内标记此类用户， VIP 用户具有优先接入、 不受限速、 预留资源等权利。VIP 用户可获得比普通用户更高品质的无线网络体验： 例如更高的无线网络使用优先级、更高的网络带宽、更低的网络延迟等。

## 2.1.4 会议室场景

### 2.1.4.1 场景示意图


图 4 会议室场景示意图

### 2.1.4.2 业务类型描述

此场景以无线化办公为主： 电子白板、网页浏览、电子邮件、文件下载等。

### 2.1.4.3 环境设定与场景性能要求

· 空间设定： 空间层高 3-5 米

· 密度设定： 小型会议室 10 人 /20 平方米； 中型会议室 20 人 /50 平方米； 大型会议室 60 人 /200 平方米

· 容量要求： 单 AP 接入 40 终端，并发率 30%（特定场景建议采用三射频 AP 减少 AP 部署数量）

· 覆盖要求： 会议室范围内 95% 的区域 RSSI ≥ -65dBm

· 此外还需根据实际场景情况规划： AP 部署方式与间距、带宽等因素

### 2.1.4.4 无线功能需求

· 高并发需求： 大型会议室场景下会有大量的无线连接， 会导致无线网络的干扰和拥堵， 在带宽确定的前提下， 需要合理规划网络，配置射频资源，来尽量满足无线用户的并发需求。

· 高带宽需求： 会议室场景中存在各种需要传输大量数据流量的情况， 例如音视频会议、 大型文件传输等， 这些应用对于网络带宽的要求非常高。在办公场景下，可以利用资源保证技术保障关键应用或者关键终端的带宽需求。

· 抗干扰需求： 大型会议室场景下往往存在较大的无线干扰， 包含 WLAN 干扰和非 WLAN 干扰。无线网络下的各种干扰往往会对网络的稳定性、 数据传输速度和网络连接质量造成较大影响， 甚至导致网络中断等问题， 故要求设备有一定的干扰抑制能力，在干扰严重的环境中也能保障无线用户的上网体验。

· 关键用户保障需求： 会议室场景需保障关键用户作为 VIP 级用户接入体验， 如无线投屏用户等。VIP 用户的带宽保障需要是全方位的， 在网络内标记此类用户， VIP 用户具有优先接入、 不受限速、 预留资源等权利。VIP 用户可获得比普通用户更高品质的无线网络体验： 例如更高的无线网络使用优先级、更高的网络带宽、更低的网络延迟等。

## 2.1.5 餐厅场景

### 2.1.5.1 场景示意图

图 5 餐厅示意图

### 2.1.5.2 业务类型描述

此场景以无线化娱乐为主： 网页浏览，音视频业务，电子邮件，游戏等。

### 2.1.5.3 环境设定与场景性能要求

· 空间设定： 空间层高 3-5 米，面积几十平方米到几百平方米不等
· 密度设定： 人均 1-2 平方米空间
· 容量要求： 要求单 AP 接入 60 终端，并发率 30%
· 覆盖要求： 95% 的区域 RSSI ≥ -65dBm
· 此外还需根据实际场景情况规划： AP 部署方式与间距、带宽等因素

### 2.1.5.4 无线功能需求

· 广覆盖需求： 餐厅场景，一般面积比较大，没有固定的隔断，但是人员比较集中，需要考虑无线信号覆盖。

· 高并发需求： 餐厅场景下会有大量的无线连接， 会导致无线网络的干扰和拥堵， 在带宽确定的前提下， 需要合理规划网络，配置射频资源，来尽量满足无线用户的并发需求。

· 无感漫游需求： 移动办公要求在不同 AP 之间快速无缝切换，保障移动办公的连续性和效率，并且需要保证移动办公在不同位置的服务质量和用户体验。服务质量包括移动设备的连接速度、 数据传输速度、 响应时间、 可用性和稳定性。

# 2.2 教育场景

## 2.2.1 场景简介

教室场景的主要特点是用户密度大， 无线上网并发行为集中， 进而对网络体验要求较高。在上课时， 教室中的智慧黑板 / 大屏、 线上教学系统的应用以及老师授课使用的笔记本电脑 / 平板等电子设备在该场景需要优先保障业务正常不中断， 且能分配到足够的带宽进行使用。在自习和课间休息等高峰用网期间， 需要承载学生和老师上网的多种业务并发。

宿舍场景是学校学生用网的主要区域， 每个房间人数在 4 到 8 人， 区域相对较小且封闭。用网的高峰时间段集中在中午午休和晚上下课之后， 用网时间集中， 业务主要以影音播放、游戏、文件下载为主， 对网络带宽和整体网络质量有较高需求。

## 2.2.2 场景业务需求

教育场景的业务以音视频、文件传输、即时通讯、桌面共享、网页浏览等应用为主，业务带宽需求及占比如下表格：

表 2 教育场景业务需求

| 业务类型 | 单业务基线速率（Mbps） | | 各场景区域业务占比 | |
|---|---|---|---|---|
| | Excellent | Good | 宿舍 | 电子教室 |
| 网页浏览 | 8 | 4 | 10% | 20% |
| 流媒体（1080P） | 16 | 12 | 20% | 30% |
| 流媒体（4K） | 50 | 25 | 10% | 20% |
| VoIP | **3** | 2 | 0% | 0% |
| 电子白板 | 32 | 16 | 0% | 0% |
| 电子邮件 | 32 | 16 | 5% | 0% |
| 文件传输 | 32 | 16 | 20% | 0% |
| 桌面共享 | **3** | 2 | 0% | 20% |
| 游戏 | 2 | 1 | 30% | 0% |
| 即时通讯 | 1 | 0.5 | 5% | 10% |

## 2.2.3 宿舍场景

### 2.2.3.1 场景示意图

图 6 宿舍示意图

### 2.2.3.2 业务类型描述

此场景以无线化娱乐为主： 网页浏览，音视频业务，大文件下载，游戏等。

### 2.2.3.3 环境设定与场景性能要求

· 空间设定： 空间层高 3 米左右，面积十多到几十平方米不等
· 密度设定： 4 ~ 8 人每房间
· 容量要求： 单 AP 接入： 8~16 终端，并发率 50%
· 覆盖要求： 覆盖范围内 95% 的区域 RSSI ≥ -65dBm
· 此外还需根据实际场景情况规划： AP 部署方式与间距、带宽等因素

### 2.2.3.4 无线功能需求

· 高带宽需求： 宿舍场景中存在各种需要传输大量数据流量的情况， 例如音视频、 大型文件传输等， 这些应用对于网络带宽的要求非常高。在宿舍场景下，可以利用资源保证技术保障关键应用或者关键终端的带宽需求。

· 抗干扰需求： 宿舍场景下往往存在较大的无线干扰， 包含 WLAN 干扰和非 WLAN 干扰。无线网络下的各种干扰往往会对网络的稳定性、 数据传输速度和网络连接质量造成较大影响， 甚至导致网络中断等问题， 故要求设备有一定的干扰抑制能力，在干扰严重的环境中也能保障无线用户的上网体验。

## 2.2.4 教室场景

### 2.2.4.1 场景示意图

图 7 电子教室示意图

### 2.2.4.2 业务类型描述

此场景以无线化教育为主： 电子白板，多 PAD 音视频业务等。

### 2.2.4.3 环境设定与场景性能要求

· 空间设定： 空间层高 3~5 米，面积几十到几百平方米不等
· 密度设定： 每座位 1 平方米左右
· 容量要求： 单 AP 接入 100 终端，并发率 30%
· 覆盖要求： 覆盖范围内 95% 的区域 RSSI ≥ -65dBm
· 此外还需根据实际场景情况规划： AP 部署方式与间距、带宽等因素

### 2.2.4.4 无线功能需求

· 广覆盖需求： 教室场景，一般面积比较大，没有固定的隔断，但是人员比较集中，需要考虑无线信号覆盖。
高并发需求： 教室场景下会有大量的无线连接，会导致无线

· 高并发需求： 教室场景下会有大量的无线连接， 会导致无线网络的干扰和拥堵， 在带宽确定的前提下， 需要合理规划网络，配置射频资源，来尽量满足无线用户的并发需求。

· 高带宽需求： 教室场景中存在各种需要传输大量数据流量的情况， 例如音视频、大型文件传输、电子白板等， 这些应用对于网络带宽的要求非常高。在教室场景下，可以利用资源保证技术保障关键应用或者关键终端的带宽需求。

· 抗干扰需求： 高密场景下往往存在较大的无线干扰， 包含 WLAN 干扰和非 WLAN 干扰。无线网络下的各种干扰往往会对网络的稳定性、 数据传输速度和网络连接质量造成较大影响， 甚至导致网络中断等问题， 故要求设备有一定的干扰抑制能力，在干扰严重的环境中也能保障无线用户的上网体验。

# 2.3 智能制造场景

## 2.3.1 场景简介

随着工业转型升级， 机器替代人工已经成为重要趋势。AGV(Automated Guidec Vehicle， 自动导引运输车 ) 在仓储、物流、 电力等行业得到了越来越广泛的应用。AGV 小车工作时需要在场所内不停地移动， 所以必须为 AGV 小车提供一个稳定可靠的无线网络。

AGV 仓储场景一般是指企业的自动化仓库区域， 是企业 WLAN 的主要应用场景之一。该场景的业务特征通常为低时延、漫游多、丢包敏感。仓库的层高一般较高，部分高度超过 10 米。无线信号的遮挡也比较普遍，遮挡主要来自于货架以及货架上的货物。AGV 小车工作时需要在场所内不停地移动，业务特征通常为低时延、漫游多、丢包敏感。

## 2.3.2 场景业务需求

智能制造场景的业务以扫码枪、AGV 等业务为主，业务带宽需求及占比如下表格：

**表 3 智能制造场景业务需求**

| 业务类型 | 单业务基线速率（Mbps） | | 各场景区域业务占比 | |
|---|---|---|---|---|
| | Excellent | Good | 货架区 | AGV |
| 扫码枪 | 128 | 64 | 80% | 0% |
| AGV | 256 | 128 | 0% | 90% |
| 其他 | 300 | 128 | 20% | 10% |

## 2.3.3 AGV 及货架场景

### 2.3.3.1 场景示意图


图 8 AGV 及货架场景示意图

### 2.3.3.2 业务类型描述

此场景以 AGV 和扫码枪为主，带宽要求低，但对漫游和时延要求高。

### 2.3.3.3 环境设定与场景性能要求

· 容量要求： 单 AP 接入 ≤ 50 终端，并发率 30%。
· 覆盖要求： 95% 的区域 RSSI ≥ -65dBm。
· 漫游要求： 漫游成功率 > 99%，漫游平均时延和漫游丢包率要求很高。

### 2.3.3.4 无线功能需求

· 广覆盖需求： 仓储和 AGV 场景，一般面积比较大，没有固定的隔断，无线接入需要考虑无线信号覆盖

· 无感漫游需求： AGV 要求在不同 AP 之间快速无缝切换， 保障 AGV 业务的连续性和效率， 要求在漫游时丢包率和时延尽量低，可采用端网协同等技术降低漫游丢包率及时延，同时提升可靠性

# 2.4 医疗场景

## 2.4.1 场景简介

在医院场景， 随着近年来越来越多的医院建立了功能强大的医疗信息管理系统（如 HIS、 PACS 等）， 医护人员通过访问这类管理系统， 实现医生查房、病人监护、药剂师配药和分发、医疗设备管理和实时监控、药品库存管理、病人档案和病例查阅等功能。而无线网络相对传统的有线网络访问方式， 天然具备终端可移动、 接入灵活方便等特点， 因此无线网络在越来越多的医院得到规模部署， 被广泛应用于医院的门诊、办公、病房、住院部、手术室等场景，使医院更加有效地提高管理人员、 医生和护士的工作效率， 协调相关部门有序工作， 更好地满足病患在院期间的无线多样化上网需求。无线业务主要集中在门诊大厅及住院部区域。

## 2.4.2 场景业务需求

医疗场景的业务以医疗 PDA、移动诊疗车等应用为主，业务带宽需求及占比如下表格 ：

表 4 医疗场景业务需求

| 业务类型 | 单业务基线速率（Mbps） | | 各场景区域业务占比 | |
|---|---|---|---|---|
| | Excellent | Good | 门诊大厅 | 住院部 |
| 医疗 PDA | 10 | 5 | 0% | 40% |
| 移动诊疗车 | 500 | 300 | 0% | 30% |
| 网页浏览 | 8 | 4 | 30% | 10% |
| 流媒体（1080P） | 16 | 12 | 20% | 5% |
| 流媒体（4K） | 50 | 25 | 10% | 5% |
| 即时通讯 | 1 | 0.5 | 40% | 10% |

## 2.4.3 门诊大厅

### 2.4.3.1 场景示意图


图 9 门诊大厅场景示意图

### 2.4.3.2 业务类型描述

此场景以网页浏览、音视频等业务为主。

### 2.4.3.3 环境设定与场景性能要求

· 空间设定： 空间层高 3-5 米，面积几百平方米
· 密度设定： 人均 1-2 平方米空间
· 容量要求： 要求单 AP 接入 100 终端，并发率 30%
· 覆盖要求： 95% 的区域 RSSI ≥ -65dBm
· 此外还需根据实际场景情况规划： AP 部署方式与间距、带宽等因素

### 2.4.3.4 无线功能需求

· 广覆盖需求： 门诊大厅场景，一般面积比较大，没有固定的隔断，但是人员比较集中，需要考虑无线信号覆盖。

· 高并发需求： 门诊大厅听场景下会有大量的无线连接， 会导致无线网络的干扰和拥堵， 在带宽确定的前提下， 需合理规划网络，配置射频资源，尽量满足无线用户的并发需求。

· 高带宽需求： 门诊大厅场景中存在各种需要传输大量数据流量的情况， 例如音视频业务等， 这些应用对于网络带宽的要求非常高。在门诊大厅场景下，可以利用资源保证技术保障关键应用或者关键终端的带宽需求。

· 抗干扰需求： 高密场景下往往存在较大的无线干扰， 包含 WLAN 干扰和非 WLAN 干扰。无线网络下的各种干扰往往会对网络的稳定性、 数据传输速度和网络连接质量造成较大影响， 甚至导致网络中断等问题， 故要求设备有一定的干扰抑制能力，在干扰严重的环境中也能保障无线用户的上网体验。

· 无感漫游需求： 门诊大厅业务要求在不同 AP 之间快速无缝切换，保障移动业务的连续性和效率，并且需要保证用户在不同位置的服务质量和用户体验。服务质量包括移动设备的连接速度、 数据传输速度、 响应时间、 可用性和稳定性。

## 2.4.4 住院部

### 2.4.4.1 场景示意图

图 10 住院部场景示意图

### 2.4.4.2 业务类型描述

此场景以医疗 PDA、移动诊疗车为主。

### 2.4.4.3 环境设定与场景性能要求

· 空间设定： 空间层高 3 米左右，面积十几平方米
· 密度设定： 人均 5 平方米左右空间
· 容量要求： 要求单 AP 接入 10 终端，并发率 30%
· 覆盖要求： 95% 的区域 RSSI ≥ -65dBm
· 此外还需根据实际场景情况规划： AP 部署方式与间距、带宽等因素

### 2.4.4.4 无线功能需求

· 广覆盖需求：住院部场景，病房一般面积较小，有固定的隔断，因为医疗 PDA、移动诊疗车等终端移动性要求较高，需要考虑无线信号覆盖。

· 高带宽需求： 随着医疗水平的发展， 医学影响的质量从 MB 级已提升至 GB 级， 甚至是 10GB 以上。以住院部 PACS 影像为例，影像需要秒级显示，故需求 AP 提供高带宽。

· 无感漫游需求： 医疗 PDA 等业务要求在 AP 信号间快速无缝切换， 客户希望业务不中断， 以保障医疗 PDA 等业务的连续性和效率。

# 2.5 小结

由上面分析可知，企业不同场景对 WLAN 的覆盖、并发、漫游、干扰、时延、带宽、安全等诉求各不相同，要实现不同场景的无线高品质覆盖，需要在技术上不断的发展和演进。

# Chapter 2

# Enterprise WLAN Scenarios Are Complex and Diversified, Calling for Standards for Building High-Quality WLANs

Wireless networks are widely used in fields such as education, healthcare, tourism, warehouse management, and exhibition. Different scenarios have different requirements for network experience. Mainstream scenarios are classified into the following:

## 2.1 Campus Office

### 2.1.1 Scenario Overview

As wireless network technologies become increasingly mature, more and more enterprises build wireless networks to meet daily service requirements. Wireless office scenarios include high-density office areas, low-density office areas, conference rooms, recreation areas, and canteens. The applications in these scenarios are mainly office software, e-mail, web browsing, file transfer, instant messaging (IM), and audio and video conferencing. The key demand is to ensure critical office services such as audio and video conferencing and IM. Users' top concerns are network transmission efficiency, access stability, and mobile office smoothness. Wireless deployment is required to support high-density access, high-concurrency applications, and efficient transmission with low latency.

### 2.1.2 Scenario-specific Service Requirements

Campus office services mainly include office software, e-mail, web browsing, file transfer, IM, and audio and video conferencing. The following table lists the bandwidth requirements of services and their proportions by bandwidth consumption.

Table 2-1Service bandwidth requirements in campus offices

| Service Type | Baseline Rate (Mbps) per Service | | Proportion of Bandwidth Consumption in Each Scenario | | | | |
|---|---|---|---|---|---|---|---|
| | Excellent | Good | High-Density Office Area | Low-Density Office Area | Conference Room | Recreation Area | Canteen |
| Web browsing | 8 | 4 | 20% | 20% | 50% | 25% | 25% |
| Streaming media (1080p) | 16 | 12 | 10% | 5% | 5% | 30% | 30% |
| Streaming media (4K) | 50 | 25 | 10% | 5% | 5% | 20% | 25% |
| VoIP | 3 | 2 | 10% | 20% | 10% | 0% | 0% |
| Electronic whiteboard | 32 | 16 | 5% | 5% | 10% | 0% | 0% |
| E-mail | 32 | 16 | 3% | 3% | 5% | 10% | 10% |
| File transfer | 32 | 16 | 2% | 2% | 10% | 0% | 0% |
| Desktop sharing | 3 | 2 | 10% | 10% | 0% | 0% | 0% |
| Gaming | 2 | 1 | 0% | 0% | 0% | 10% | 5% |
| Instant messaging | 1 | 0.5 | 30% | 30% | 5% | 5% | 5% |

## 2.1.3 High-Density and Low-Density Office Areas

### 2.1.3.1 Scenario Examples

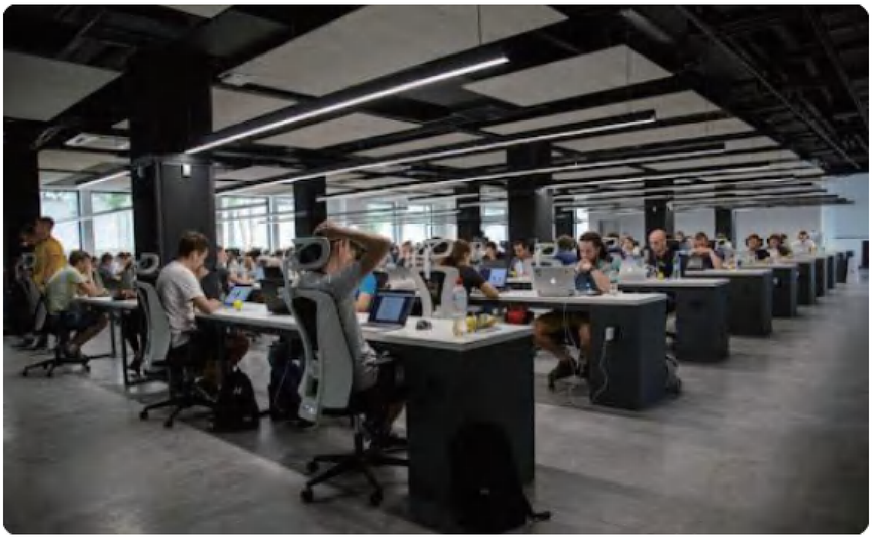

Figure 2-1 High-density office area

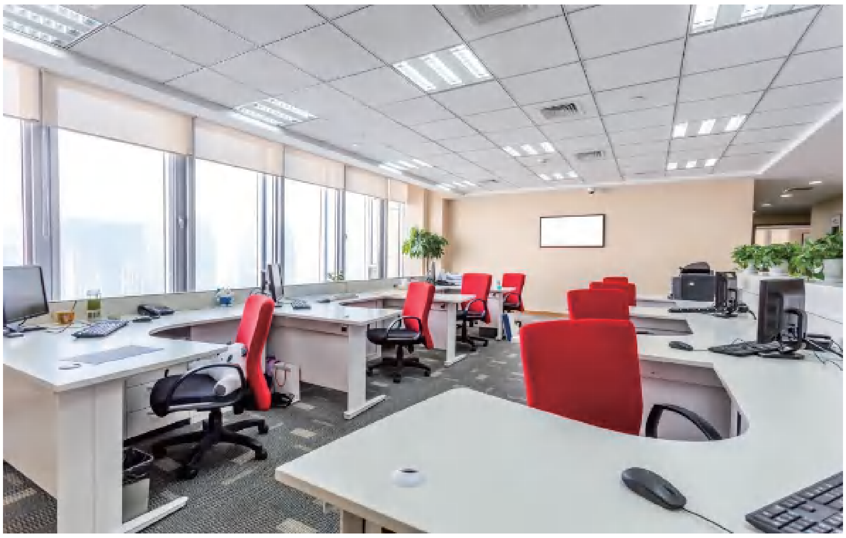

Figure 2-2Low-density office area

#### 2.1.3.2 Service Description

This scenario is mainly wireless offices. Service types include office services and non-office services. Office services include video conferencing, web browsing, e-mail, and file download. Non-office services include video, gaming, and voice communication.

#### 2.1.3.3 Environment Setting and Performance Requirements

·Space: Floor height 3-5 meters, areas ranging from several square meters to several hundred square meters
·Density: High density: 2–3 square meters per person. Low density: 4–5 square meters per person
·Capacity: High density: 80 terminals per access point (AP), 40% concurrency. Low density: 40 terminals per AP, 40% concurrency
·Coverage: Received signal strength indicator (RSSI) ≥ -65 dBm in 95% of the coverage areas
·In addition, the planning needs to take into account factors such as the AP deployment mode, distance between APs, and bandwidth, based on the actual scenario.

#### 2.1.3.4 Wireless Function Requirements

·Wide coverage: In open office scenarios, the area is large and there is no fixed hurdles. However, users are concentrated. Therefore, sufficient wireless signal coverage needs to be considered.
·High concurrency: In office scenarios, a large number of wireless connections may cause interference and congestion on the wireless network. Within the given bandwidth, the network must be properly planned and radio resources must be configured to meet the concurrency requirements of wireless users.
·High bandwidth: In office scenarios, a large amount of data traffic needs to be transmitted, such as in audio and video conferences and large file transfers. These applications have high requirements for network bandwidth. Resource assurance technologies need to be used to meet the bandwidth requirements of key applications or key terminals.
·Interference resistance: In high-density scenarios, there is strong wireless interference, including WLAN interference and non-WLAN interference. Interference on a wireless network affects network stability, data transmission speed, and network connection quality, and can even cause network interruption. Therefore, devices must be capable of resisting interference to ensure the Internet access experience of wireless users even in the case of severe interference.
·Seamless roaming: Mobile office requires fast and seamless handovers between different APs to ensure mobile office continuity and efficiency. In addition, the service quality and user experience of mobile offices in different locations must be ensured. Quality of service includes connection speed, data transmission speed, linking time, availability, and stability of mobile devices.
·Assurance for key users: In office scenarios, key users must access the network as VIP users. The bandwidth guarantee for VIP users must be all-round. Such users are marked on the network so that they have prioritized access to the network, unlimited rate, and reserved resources. VIP users can enjoy a higher-quality wireless network experience than common users. For example, VIP users have higher wireless network priority, higher network bandwidth, and lower network latency.

## 2.1.4 Meeting Rooms

### 2.1.4.1 Scenario Examples

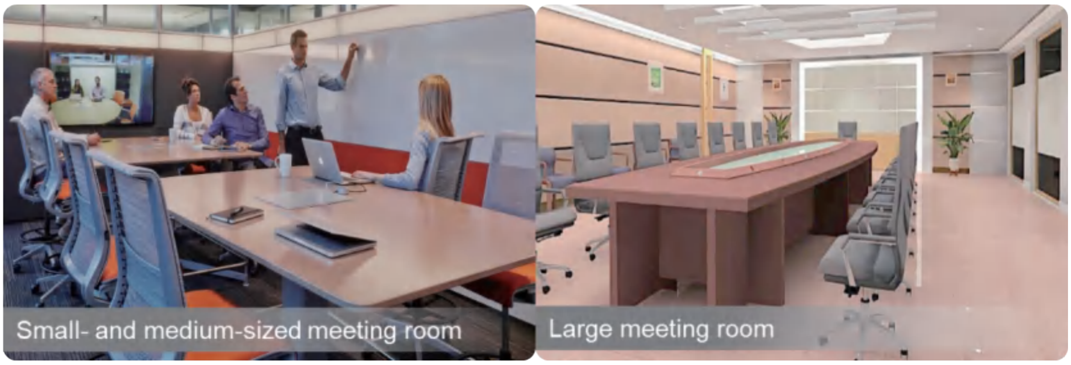


Figure 2-3Meeting rooms

### 2.1.4.2 Service Description

Services in this scenario are mainly wireless office applications, including electronic whiteboards, web browsing, e-mail, and file download.

### 2.1.4.3 Environment Setting and Performance Requirements

·Space: Floor height 3-5 meters

·Density: Small meeting rooms: 20 square meters/10 persons. Medium-sized meeting rooms: 50 square meters/20 persons. Large meeting rooms: 200 square meters/60 persons

·Capacity: 40 terminals per AP, 30% concurrency (Triple-radio APs are recommended in specific scenarios to reduce the number of APs to be deployed.)

·Coverage: RSSI ≥ -65 dBm in 95% of the areas within a conference room

·In addition, the planning needs to take into account factors such as the AP deployment mode, distance between APs, and bandwidth, based on the actual scenario.

### 2.1.4.4 Wireless Function Requirements

·High concurrency: In the case of large meeting rooms, a large number of wireless connections may cause interference and congestion on the wireless network. Within the given bandwidth, the network must be properly planned and RF resources must be configured to meet the concurrency requirements of wireless users.

·High bandwidth: In meeting room scenarios, a large amount of data traffic needs to be transmitted, such as in audio and video conferences and large file transfers. These applications have high requirements for network bandwidth. Resource assurance technologies need to be used to meet the bandwidth requirements of key applications or key terminals.

·Interference resistance: In large meeting rooms, there is strong wireless interference, including WLAN interference and non-WLAN interference. Interference on a wireless network affects network stability, data transmission speed, and network connection quality, and can even cause network interruption. Therefore, devices must be capable of resisting interference to ensure the Internet access experience of wireless users even in the case of severe interference.

Assurance for key users: In meeting room scenarios, key users, such as users using wireless projection, must be able to access the network as VIP users. The bandwidth guarantee for VIP users must be all-round. Such users are marked on the network so that they have prioritized access to the network, unlimited rate, and reserved resources. VIP users can enjoy a higher-quality wireless network experience than common users. For example, VIP users have higher wireless network priority, higher network bandwidth, and lower network latency.

## 2.1.4 Canteens

### 2.1.4.1Scenario Examples

Figure 2-4Canteen

### 2.1.4.2 Service Description

This scenario is mainly wireless entertainment, including web browsing, audio and video services, e-mail, and gaming

#### 2.1.4.3 Environment Setting and Performance Requirements

· Space: Floor height 3–5 meters, areas ranging from dozens of square meters to several hundred square meters
· Density: 1–2 square meters per person
· Capacity: 60 terminals per AP, 30% concurrency
· Coverage: RSSI ≥ -65 dBm in 95% of the coverage areas
· In addition, the planning needs to take into account factors such as the AP deployment mode, distance between APs, and bandwidth, based on the actual scenario.

#### 2.1.4.4 Wireless Function Requirements

· Wide coverage: In canteen scenarios, the area is large and there is no fixed hurdles. However, users are concentrated. Therefore, sufficient wireless signal coverage needs to be considered.
· High concurrency: In canteen scenarios, a large number of wireless connections may cause interference and congestion on the wireless network. Within the given bandwidth, the network must be properly planned and RF resources must be configured to meet the concurrency requirements of wireless users.
· Seamless roaming: Mobile office requires fast and seamless handovers between different APs to ensure mobile office continuity and efficiency. In addition, the service quality and user experience of mobile offices in different locations must be ensured. Quality of service includes connection speed, data transmission speed, response time, availability, and stability of mobile devices.

## 2.2 Education

### 2.2.1 Scenario Overview

Classrooms often have a huge number of wireless users and as a result, many wireless access requests are usually made concurrently, both of which tend to increase expectations of the network experience. During a class, all electronic devices and applications – from smart blackboards and smart displays to online education applications and the teachers' laptops and tablets – require a strong and stable connection and adequate bandwidth. When students study independently in a classroom or take breaks, both students and teachers need the network to support concurrent access requests for multiple types of services.

Dormitories are another place where students intensively use the wireless network. Given that each dormitory room accommodates four to eight students, a significant number of devices connect to the network across the dormitory buildings. Peak usage hours are at lunchtime and in the evening. Major services include video, gaming, and file download, all of which rely on huge network bandwidth and high network quality.

## 2.2.2 Scenario-specific Service Requirements

Education services mainly include audio and video, file transfer, instant messaging, desktop sharing, and web browsing. The following table lists the bandwidth requirements of services and their proportions by bandwidth consumption.

Table 2-2Service bandwidth requirements in education

| Service Type | Baseline Rate (Mbps) per Service | | Proportion of Bandwidth Consumption in Each Scenario | |
|---|---|---|---|---|
| | Excellent | Good | Dormitory Room | Electronic Classroom |
| Web browsing | 8 | 4 | 10% | 20% |
| Streaming media (1080p) | 16 | 12 | 20% | 30% |
| Streaming media (4K) | 50 | 25 | 10% | 20% |
| VoIP (Voice) | 3 | 2 | 0% | 0% |
| Electronic whiteboard | 32 | 16 | 0% | 0% |
| E-mail | 32 | 16 | 5% | 0% |
| File transfer | 32 | 16 | 20% | 0% |
| Desktop sharing | 3 | 2 | 0% | 20% |
| Gaming | 2 | 1 | 30% | 0% |
| Instant messaging | 1 | 0.5 | 5% | 10% |

## 2.2.3 Dormitories

### 2.2.3.1 Scenario Example

Figure 2-5Dormitory

### 2.2.3.2 Service Description

This scenario is mainly wireless entertainment, including web browsing, audio and video services, large file download, and gaming.

### 2.2.3.3 Environment Setting and Performance Requirements

·Space: Floor height 3 meters, areas ranging from ten-plus square meters to several dozen square meters

·Density: 4–8 people per room

·Capacity: 8–16 terminals per AP, 50% concurrency

·Coverage: RSSI ≥ -65 dBm in 95% of the coverage areas

·In addition, the planning needs to take into account factors such as the AP deployment mode, distance between APs, and bandwidth, based on the actual scenario.

### 2.2.3.4 Wireless Function Requirements

·High bandwidth: In the dormitory scenario, a large amount of data traffic needs to be transmitted, such as in audio and video services and large file transfers. These applications have high requirements for network bandwidth. Resource assurance technologies need to be used to meet the bandwidth requirements of key applications or key terminals.

·Interference resistance: In the dormitory scenario, there is strong wireless interference, including WLAN interference and non-WLAN interference. Interference on a wireless network affects network stability, data transmission speed, and network connection quality, and can even cause network interruption. Therefore, devices must be capable of resisting interference to ensure the Internet access experience of wireless users even in the case of severe interference.

## 2.2.4 Classrooms

### 2.2.4.1 Scenario Example

Figure 2-6E-classroom

### 2.2.4.2 Service Description

This scenario is mainly wireless education, including electronic whiteboards and multi-tablet audio and video services.

### 2.2.4.3 Environment Setting and Performance Requirements

·Space: Floor height 3–5 meters, areas ranging from several dozen square meters to several hundred square meters

·Density: 1 square meter per seat

·Capacity: 100 terminals per AP, 30% concurrency

·Coverage: RSSI ≥ -65 dBm in 95% of the coverage areas

·In addition, the planning needs to take into account factors such as the AP deployment mode, distance between APs, and bandwidth, based on the actual scenario.

### 2.2.4.4 Wireless Function Requirements

·Wide coverage: In the classroom scenario, the area is large and there is no fixed hurdles. However, users are concentrated. Therefore, sufficient wireless signal coverage needs to be considered.

·High concurrency: In the classroom scenario, a large number of wireless connections may cause interference and congestion on the wireless network. Within the given bandwidth, the network must be properly planned and RF resources must be configured to meet the concurrency requirements of wireless users.

·High bandwidth: In the classroom scenario, a large amount of data traffic needs to be transmitted, such as in audio and video, large file transfer, and electronic whiteboards. These applications have high requirements on network bandwidth. Resource assurance technologies need to be used to meet the bandwidth requirements of key applications or key terminals.

·Interference resistance: In high-density scenarios, there is strong wireless interference, including WLAN interfer ence and non-WLAN interference. Interference on a wireless network affects network stability, data transmission speed, and network connection quality, and can even cause network interruption. Therefore, devices must be capable of resisting interference to ensure the Internet access experience of wireless users even in the case of severe interference.

# 2.3 Smart Manufacturing

## 2.3.1 Scenario Overview

As industries continue to transform and upgrade, the trend of automating previously manual work is gaining momentum. Automated guided vehicles (AGVs) are increasingly being used in sectors such as warehousing, logistics, and electricity. An AGV in operation is always on the move, and this requires a stable wireless connection.

The AGV-based warehousing scenario, otherwise known as automated warehouses, is one of the major application scenarios of enterprise WLANs. In this scenario, services (such as AGVs) require low latency and frequent roaming, and are highly sensitive to packet loss. Warehouses are usually tall buildings, and some are even more than 10 meters tall. Inside a warehouse, there are often spots where the wireless signal is weak or even unavailable, and this is often due to shelving and the storage of goods.

## 2.3.2 Scenario-specific Service Requirements

Smart manufacturing services mainly include barcode scanners and AGVs. The following table lists the bandwidth requirements of services and their proportions by bandwidth consumption.

Table 2-3Service bandwidth requirements in smart manufacturing

| Service Type | Baseline Rate (Mbps) per Service |
|---|---|
| | Excellent |
| Barcode scanner | 128 |
| AGV | 256 |
| Other | 300 |

## 2.3.3 AGVs and Shelves

### 2.3.3.1 Scenario Examples

Figure 2-7Shelves and AGVs

### 2.3.3.2 Service Description

This scenario mainly involves AGVs and barcode scanners, which have high requirements on roaming and latency and low requirements on bandwidth.

### 2.3.3.3 Environment Setting and Performance Requirements

·Capacity: 50 or fewer terminals per AP, 30% concurrency

·Coverage: RSSI ≥ -65 dBm in 95% of the coverage areas

·Roaming: Roaming success rate > 99%; high requirements on average latency and packet loss rate

### 2.3.3.4Wireless Function Requirements

·Wide coverage: In the warehousing and AGV scenarios, the area is large and there are no fixed hurdles. Therefore, sufficient wireless signal coverage needs to be considered.

·Seamless roaming: AGVs require fast and seamless handovers between different APs to ensure their continuity and efficiency. The packet loss rate and latency during roaming must be as low as possible. Technologies such as network-terminal synergy can help reduce the packet loss rate and latency during roaming and improve network reliability.

# 2.4 Healthcare

## 2.4.1 Scenario Overview

More and more hospitals are deploying powerful medical information management systems, such as hospital information systems (HISs) and picture archiving and communication systems (PACSs). Medical workers can use these systems when inspecting wards, monitoring patients, prescribing and dispensing medicine, managing and monitoring medical equipment in real-time, managing medical inventories, or querying patient files and cases. Unlike fixed networks, wireless networks support portable terminals and provide flexible and easy access. As a result, more hospitals are using wireless networks in areas such as outpatient centers, offices, wards, inpatient buildings, and operating rooms. With wireless networks, managers, doctors, and nurses can work more efficiently, tasks can be more easily coordinated between departments and inpatients' needs for wireless connectivity can be met. Wireless services are in huge demand in both outpatient centers and inpatient buildings.

## 2.4.2 Scenario-specific Service Requirements

Healthcare services mainly include medical personal digital assistants (PDAs) and mobile diagnosis and treatment vehicles. The following table lists the bandwidth requirements of services and their proportions by bandwidth consumption.

Table 2-4Service bandwidth requirements in healthcare

| Service Type | Baseline Rate (Mbps) per Service | | Proportion of Bandwidth Consumption in Each Scenario |
|---|---|---|---|
| | Excellent | Good | Outpatient Center |
| Medical PDA | 10 | 5 | 0% |
| Mobile diagnosis and treatment vehicle | 500 | 300 | 0% |
| Web browsing | 8 | 4 | 30% |
| Streaming media (1080P) | 16 | 12 | 20% |
| Streaming media (4K) | 50 | 25 | 10% |
| Instant messaging | 1 | 0.5 | 40% |

## 2.4.3 Outpatient Centers

### 2.4.3.1 Scenario Example

Figure 2-8Outpatient center

### 2.4.3.2 Service Description

This scenario mainly involves web browsing and audio and video services.

### 2.4.3.3 Environment Setting and Performance Requirements

·Space: Floor height 3–5 meters, areas covering several hundred square meters

·Density: 1–2 square meters per person

·Capacity: 100 terminals per AP, 30% concurrency

·Coverage: RSSI ≥ -65 dBm in 95% of the coverage areas

·In addition, the planning needs to take into account factors such as the AP deployment mode, distance between APs, and bandwidth, based on the actual scenario.

### 2.4.3.4 Wireless Function Requirements

·Wide coverage: In the outpatient center scenario, the area is large and there is no fixed hurdles. However, users are concentrated. Therefore, sufficient wireless signal coverage needs to be considered.

·High concurrency: In the outpatient center scenario, a large number of wireless connections may cause interference and congestion on the wireless network. Within the given bandwidth, the network must be properly planned and RF resources must be configured to meet the concurrency requirements of wireless users.

·High bandwidth: In the outpatient center scenario, a large amount of data traffic needs to be transmitted, such as in audio and video services. These applications have high requirements on network bandwidth. Resource assurance technologies need to be used to meet the bandwidth requirements of key applications or key terminals.

·Interference resistance: In high-density scenarios, there is strong wireless interference, including WLAN interference and non-WLAN interference. Interference on a wireless network affects network stability, data transmission speed, and network connection quality, and can even cause network interruption. Therefore, devices must be capable of resisting interference to ensure the Internet access experience of wireless users even in the case of severe interference.

·Seamless roaming: Services in outpatient centers require fast and seamless handovers between different APs to ensure mobile service continuity and efficiency. In addition, the service quality and user experience of outpatient centers in different locations must be ensured. Quality of service includes connection speed, data transmission speed, response time, availability, and stability of mobile devices.

## 2.4.4 Inpatient Buildings

### 2.4.4.1 Scenario Examples

Figure 2-9Inpatient buildings

### 2.4.4.2Service Description

This scenario mainly involves medical PDAs and mobile diagnosis and treatment vehicles.

### 2.4.4.3Environment Setting and Performance Requirements

·Space: Floor height: about 3 meters; area: over 10 square meters
·Density: About 5 square meters per person
·Capacity: 10 terminals per AP, 30% concurrency
·Coverage: RSSI ≥ -65 dBm in 95% of the coverage areas
·In addition, the planning needs to take into account factors such as the AP deployment mode, distance between APs, and bandwidth, based on the actual scenario.

### 2.4.4.4Wireless Function Requirements

·Wide coverage: In inpatient buildings, wards are relatively small and have fixed partitions. Terminals such as PDAs and mobile diagnosis and treatment vehicles have high requirements on mobility. Therefore, sufficient wireless signal coverage needs to be considered.

·High bandwidth: With the development of medical technologies, the required bandwidth of medical images has changed from megabyte level to gigabyte level, or even over 10 gigabytes. For example, the PACS used by inpatient departments displays images in seconds, which requires APs to provide high bandwidth.

·Seamless roaming: PDAs and other services require fast and seamless handovers between APs. Customers expect to have uninterrupted networks to ensure the continuity and efficiency of PDAs and other services.

## 2.5 Summary

The preceding analyses show that enterprises have different requirements on WLAN coverage, concurrency, roaming, interference, latency, bandwidth, and security based on scenarios. Continuous technical development and evolution are essential to achieving high-quality wireless coverage in different scenarios.

# 第 3 章

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# 高品质企业 WLAN 网络关键技术现状和发展趋势

# 3.1 覆盖优化技术

## 3.1.1 产生背景

WLAN 技术起源于以家庭为代表的小范围使用场景，在家用环境通常只需要考虑单个 AP 的信道，功率，抗干扰能力，而 WLAN 在进入企业园区使用后，为了让用户随时随地地可以接入网络，就需要保证用户使用网络的点位都要无盲区的覆盖， 但 WLAN 本身的空口资源是共享的， 在保证有效覆盖的同时还需要避免 AP 间信号的相互干扰， 以提升整网的性能和使用体验。在当前企业级 WLAN 建网当中用户通常会考虑以下因素：

· 信号的覆盖情况
· 合理的信道，功率和频宽以提升整网性能
· 按需动态调整网络资源以适应用户和流量的变化
· 当设备故障或者突发干扰时可以动态调整，降低异常事件对网络的影响
· 复杂环境下的抗干扰和更好的覆盖能力

WLAN 设备厂商目前都在研究多种覆盖优化技术，以满足用户在企业 WLAN 建网当中的上述覆盖需求。

## 3.1.2 射频资源优化技术

RRM（Radio Resource Management， 射频资源管理）是一种射频资源优化解决方案， 通过系统化的实时智能射频管理使无线网络能够快速适应无线环境变化，保持最优的射频资源状态。RRM 技术包含三个关键因素： 信道调整、功率调整和频宽调整。RRM 技术按照数据来源和分析计算的载体分为本地 RRM 和云 RRM 两大类。

· 本地 RRM 技术利用无线设备存储的本地数据进行分析计算。
· 云 RRM 技术利用云平台丰富的数据，借助大数据分析能够进行多维度的计算。

当本地 RRM 和云 RRM 同时开启时，由云 RRM 负责统一调度和调整，提供更优质的无线服务。

### 3.1.2.1 本地 RRM

WLAN 频段的频谱资源是有限的，每个射频工作在数量有限的信道上，邻居 AP 工作在同频信道会产生干扰，并且周围环境可能会存在雷达、微波炉等干扰。自动信道调整为射频分配最优信道，使 AP 避免工作在存在干扰严重的信道上，保证可靠传输。

传统功率控制方法单纯追求信号的最大覆盖范围， 将射频的发射功率设置为最大值， 虽然保证了信号的覆盖范围， 但是会对其它无线设备造成不必要的干扰； 并且容易导致终端无法进行漫游， 导致终端粘滞， 降低无线网络的体验。自动功率调整在保证射频信号覆盖的前提下，会同时考虑降低 AP 间干扰，兼顾终端的漫游体验，为射频分配合理的发射功率。

为了追求最大速率和吞吐，一般会将射频的频宽设置为最大频宽，虽然能够提高 AP 和终端的协商速率，理论上提升 AP 和终端的吞吐量， 但是受可用信道数量的限制， 相邻 AP 使用相同的信道会产生严重干扰， 降低系统的整体容量，无法满足用户对高吞吐的需求。因此，在选择频宽时，需要同时考虑 AP 的部署密度、终端的数量和流量、还有干扰的情况，在保障无线服务的质量的前提下提升整网吞吐量。

### 3.1.2.2 云 RRM

云 RRM 收集历史网络统计信息，根据 AP 统计数据、邻居信息、终端统计数据和时间维度进行四维 RRM 分析和预测，能够适应不同的场景， 调整方案更精确； 根据流量模型准确区分网络闲时和忙时， 提前局部优化 AP 的信道， 调整结果更符合网络实际状况和业务需要； 在凌晨对射频参数进行变更，减少对终端的影响，提升用户体验。

根据长时间的历史数据， 在食堂等存在明显潮汐式人流的开放场所中， AP 部署密集； 高峰期， 人流量、 终端数量、业务流量明显增大，AP 间干扰严重，无线网络无法正常使用，此时可降低频宽使 AP 可用信道组合变多，AP 间干扰控制在允许范围内，提升用户体验； 高峰期过后，人流量和终端数量快速减少，业务流量明显减小，此时增大频宽，并配合进行信道调整，提升终端速率，提升用户体验。

## 3.1.3 覆盖增强技术

无线网络的流量模型是实时动态的， 终端会陆续不断的接入、离线、移动， 漫游， 如何保障终端在不同的位置， 尤其是边缘都能具有良好的体验是个关键的话题。根据香农公式， 在空间流， 频宽不变的情况下， 进一步提升传输速率与体验， 就需要从信噪比上入手。AP 与终端位置固定的场景下， 能够提升接收信噪比的措施主要有增大发射功率， 接收增强技术、预编码技术和智能天线等技术。

### 3.1.3.1 接收增强：

当接收天线射频流数大于数据流数时， 接收端可以根据信号情况选择效果好的天线进行接收（天线可选（ASEL）），或者将多个天线上的数据进行合并（最大比接收（MRC）技术），达到增强接收信噪比的效果。

### 3.1.3.2 预编码：

预编码（Precoding) 技术伴随 MIMO(Multi-Input Multi-Output 多输入多输出 ) 技术一并开始进行广泛运用， 发射端通过上下行信道的互易性或终端协议报文的直接反馈， 获得信道状态信息 (Channel State Information, CSI)。预编码系统根据获取到的 CSI，调整发射天线信号的幅度与相位，将有限的发射功率合理分配，使得终端的接收信号最优。

TXBF 技术： 常说的 TXBF(Transmit beamforming/ 发送波束成形 ) 技术主要是针对单用户系统， 即 AP 与 STA 间进行点对点传输。发射机通过信道状态信息 CSI（Channel State Information）对传输信号进行加权， 提升接收端信噪比，来提升通信吞吐，降低丢包率。

MU-MIMO 技术： MU-MIMO 技术的波束赋形在单终端波束赋形上进行升级， 对多个终端进行联合波速赋形。不仅仅实现使得每个终端接收信号好，还实现不同终端之间尽可能的干扰小，提升了并行传输数据流的能力。
此外，除点对点（TXBF），点对多点（MU-MIMO）的波束赋形预编码技术外，多点对多点的联合预编码技术的部分研究也在进行中，将进一步提升终端的传输性能与边缘吞吐速率。

### 3.1.3.3 智能天线

智能天线可称为“自适应波束切换技术”， 该技术利用具有多个硬件天线的天线阵列， 智能的从中选择多个天线阵子进行信号的发射和接收， 不同天线的组合可以形成不同的信号辐射方向， 从而可以为处于不同位置的 STA 选择最佳的发送或接收天线，提高信号接收质量，最终提升系统的吞吐量。
智能天线技术主要包括 2 个方面：一方面是智能天线阵列，即天线阵列硬件设计；另一方面是智能天线波束选择算法，即如何选择天线阵列里的天线。

· 智能天线阵列

天线阵列是由一系列的小天线组合而形成一个阵列。每个小天线可以是全向天线， 也可以是定向天线。其排列方式与小天线本身的增益， 极化方式， 方向图等都有关。小天线的数目决定了最终形成的波束的数目， 与此同时小天线上的振子数量越多， 天线组合就越多， 则波束发射的方向性越精确， 使信号更加集中， 提高信号接收质量， 最终提升系统的吞吐量。

· 智能天线波束选择

智能天线选择算法其基本原理是在当前天线配置下，通过发送训练包，根据该天线层反馈的 PER 和 RSSI 选择当前用户最合适的天线配置。天线配置主要包括天线组合、发送速率。

智能天线选择算法是智能天线特性的重要组成部分。通过发送数据报文， 根据终端的位置， 从天线阵列中选择合适的天线组合提升网络性能。利用定向波束替代原来的全向波束，使能量集中，提高信号接收质量，提升系统的吞吐量。

# 3.2 资源调度保障

## 3.2.1 产生背景

在办公、教育等组网场景，随着全无线的普及，新的使用习惯和流量模型的变化趋势也随之出现：

· 人均终端数从单一终端转变为多终端。

· 应用类型从单一数据业务为主转变成数据、音视频多种业务混合。

· 并发的数据量大幅度提升。

数据流量的大幅增加， 以及不同业务对于时延， 丢包， 抖动等参数的敏感性不同， 就要求无线设备对无线空口资源进行合理的分配、调度，以保证不同业务的差异化服务

## 3.2.2 资源保障技术

在 WLAN 网络中， QoS 主要通过 WMM 技术来完成优先级业务的保障， 但在多用户多业务场景下， 随机退避的机制暴露出来一些缺点， 很难满足新场景的需求。基于此类场景需要， 主要从如下技术方向探讨资源保障： VIP 用户， 带宽智能分配，业务识别及差异化调度。

· VIP 用户保障， VIP 是指在网络中， 存在的高优先级类别客户端， 需要对该类用户进行带宽保障， 不区分此类客户端的业务类型，而是客户端属性，这类客户端的流量需要优先保障与调度。

· 带宽分配，资源保障最主要的目的，是实现客户端的良好体验，在前文提到无线资源是有限的，如果设备能够评估出一个可使用资源门限， 一方面减少多设备间资源竞争带来的空口浪费， 另外设备下的客户端能够在有限资源下， 得到一个合理到资源分配， 保障客户端的网络体验， 带宽分配主要包含两部分资源评估算法， 带宽分配算法， 终端调度算法。

· 资源评估算法，在网络使用过程中， 通过检测网络运行参数，如底噪， 信道使用率， 终端数目等， 来大致评估出可使用的网络带宽，网络带宽随网络运行状态实时动态更新，为后续带宽分配所使用。

· 带宽分配算法，在多客户端场景下， 通过检测各个终端的流量大小与类型， 可以评估出终端属性， 带宽分配算法则跟踪采集到的数据信息， 为终端分配合理的带宽使用门限， 在保障业务的前提下， 终端不能超过该门限值， 如果判定存在空闲带宽情况下，则大流量终端可以抢占空闲带宽，达到一个资源合理分配使用，多客户端差异化调度。

· 终端调度算法，结合应用识别技术， 报文携带优先级标签， 高优先级类报文可以获得优先转发调度， 而多客户端各自所获得的有效使用带宽门限是确定的， 在完成高优先级类别调度时， 保障了业务优先， 同时多客户端带宽确定下， 又完成了多客户端的资源保障。

· 应用识别与调度保障，在 AP 或者无线控制器上通过 DPI、DFI 等技术，设备可以将终端用户使用的应用，进行精准细致的分类，通过配置策略设定，将给不同类别的应用进行标记，进行关键业务的优先调度和保障，例如，办公场景中音视频会议为重要业务，可以通过该技术进行识别并优先调度和保障，从而提升该业务使用体验。

· 动态速率调整，WLAN 网络使用中，存在多类型终端，如 Wi-Fi4，Wi-Fi5，Wi-Fi6 等终端可能同时使用无线网络的情况，不同类型终端在标准协议上，约定的最大传输速率是确定的，如果网络存在干扰或低 RSSI 情况下，重传和丢包较高，则会进行降速，如果系统能够检测空口环境并统计选速信息，将终端的选速进行一个区间调整，这样减少高速率出现的丢包与重传，减少空口竞争，从而提升空口使用效率。

· 链路优化（OFDMA（正交频分多址）），该项技术主要是可以通过在频域上想多个客户端并发，提升多用户通信时的效率，具体实现是将频段子载波分配给不同的客户端进行并发通信，可根据客户端需求划分资源单元（RU），灵活的 RU 分配可为多个客户端提供高效的体验速度。

· 增强型 MU-MIMO，多用户场景下，不同用户的业务报文达到 AP 时间不一致，报文量也不一样，导致 AP 在转发业务报文时不能满足 MU 配对的要求，通过增强型 MU-MIMO 技术，AP 进行报文预处理，增加 MU 配对的成功率，使用 MU-MIMO 来同时发送多用户的业务报文，以此减少空口发送的频次，提升空口资源的利用率，以此来提升整网的带宽

· 空口资源联合调度，目前网络上的数据流量，基于 TCP 协议的数据流量的比例达到了 90% 以上。多用户并发场景下，上行的 TCP ACK 与下行 MU-PPDU 数据报文存在较大冲突碰撞概率，会导致错包丢包。针对该场景，通过空口资源联合调度，多用户上行业务报文可同一时刻发包，降低了空口上下行碰撞的概率，提升了多用户的并发能力。

## 3.3 无感漫游

### 3.3.1 产生背景

在传统无线局域网络中，无线客户端漫游时机由无线客户端控制，是无线客户端的自主行为。漫游检测、漫游决策等漫游环节没与 AP 进行协同交互，存在一定局限性，导致漫游效果不理。常见的问题有：漫游粘滞，漫游不及时，乒乓漫游，运维问题。要想做到漫游效果，需要从终端，无线设备，云端运维平台一起协同来形成一套漫游体系来保证漫游过程对用户的业务无感

### 3.3.2 协同漫游技术体系

AP 与无线客户端多维度互相感知网络，AC（Access Controller，接入控制器）全视角综合计算与无线客户端协商进行精准漫游，提升用户的使用体验。

AP 通过 802.11k 协议，提供给无线客户端，邻居 AP 所在信道及对应无线服务信息，避免无线客户端信道逐一扫描，缩短无线客户端发现服务时间。

AP 实时监测链路质量，进行精准漫游。监测链路质量，选择合适时机触发准备漫游目标 AP。目标 AP 主要通过接入历史路径结合 802.11k 测量终端发现的邻居 AP、终端漫游特征等因素综合选择。监测链路质量，选择合适的时机通过 802.11v 协议把终端引导到目标 AP，确保整个过程链路质量抖动小，对业务无感。

网络可部署 802.11r 进行快速漫游切换。
AC 对漫游后的链路质量继续监测校准。若引导出现偏差，链路质量与之前出现明显下降，则进行校准，引导到合适的 AP，确保链路质量能在合理的预期内。
云端会对终端的漫游行为进行数据分析，优化终端漫游特征库。

### 3.3.3 链路质量检测增强技术

无线 AP 实时监测终端的链路质量变化，主要包括：上行信号变化，上下行速率变化，休眠变化情况，流量使用情况，对于支持 802.11k 终端使用 802.11k 测量获取终端视角下行信号变化，对于支持辅助射频，获取周围 AP 视角终端信号的变化。综合各因素变化，判断终端当前可能的行为，如静止、静止信号抖动、快速移动、慢速移动。针对不同的行为，选择不同的时机进行漫游目标 AP 的准备及不同时机进行漫游切换。

### 3.3.4 漫游校准技术

由于 AP 布局、配置阈值及终端所处位置等因素，终端有部分不符合预期的漫游切换效果，AC 需要自动识别多次漫游现象并能自动修复校准，让终端最终上线到最好的服务上停止漫游。

### 3.3.5 终端漫游特征库辅助漫游技术

终端漫游特征库辅助漫游技术，核心是将终端“千端一面”变为“终端特征”，基于终端生成个性化漫游参数，最大程度消除协议兼容性和终端实现差异带来的负面影响。

学习大量漫游数据样本，在此基础上，对不同终端的漫游引导行为进行分析，尝试大量参数进行训练，最终学习出了适合不同终端的终端漫游特征库。终端漫游特征库有两类特征。静态特征，终端本身系统的一些能力或行为，如引导协议能力、测量协议能力、频段能力。动态特征，在具体网络覆盖下终端的业务特征，如漫游信号阈值，源 / 目标的信号强度值。

基于上述终端漫游参数，通过协同测量引导技术对终端进行持续的信号感知，判断终端的运动趋势（靠近或者远离关联 AP），在该类终端最佳的位置、最佳的时机主动牵引终端漫游到质量最好的 AP 上，使终端漫游更为及时，成功率更高。

## 3.4 干扰抑制

### 3.4.1 产生背景

随着 WLAN（无线局域网）技术的普及和应用，特别是 WLAN 网络在企业园区的规模使用，WLAN 网络干扰问题也日益凸显。WLAN 网络干扰往往会影响网络的稳定性、数据传输速度和网络连接质量，甚至导致网络中断等问题。WLAN 网络的干扰可能是因为微波炉、射频识别设备、蓝牙设备等设备产生的电磁波信号与 WLAN 网络信号产生冲突，也可能是因为两个 WLAN 网络的信道重叠或接近，它们的信号就会产生干扰。

### 3.4.2 立体射频调优

传统射频调优基于 AP 间互相测量得到的信号强度， 形成 AP 间邻居关系的二维拓扑。调优的基本原则是避免近距离邻居分配相同信道，在保障信号覆盖的前提下，功率也要适当的降低，尽量降低干扰和保证及时漫游。由于 AP 安装环境复杂， 二维网络拓扑不能完全反映 AP 间的准确关系， 因此传统射频调优对复杂点位 AP 的调优结果不理想。有代表性的是 AP 间遮挡及 AP 高挂场景。

AP 间遮挡场景： AP 之间因为遮挡导致互相感知非常弱， 在网络拓扑上认为距离远； 被分配相同信道， 终端侧造成强同频干扰。

AP 高挂场景： AP 之间无遮挡导致互相感知非常强，会降低发射功率； 由于高挂，导致终端接收 AP 信号弱，用户体验下降。

借助终端对 AP 的测量，构建三维立体的拓扑关系，更好地适应复杂多变的空间环境，实现了立体射频调优，对 AP 间遮挡和 AP 高挂场景进行了优化，提升用户体验。

### 3.4.3 多 AP 间的协同

· Bss color， 在 Wi-Fi 6 标准提出了 bss 着色技术， 用于解决同频率下 BSS 重叠， 提升空间重用率的方法， 减少因为 BSS 重叠导致的空口竞争开销。Bss color 信息同时被添加在 WLAN 报文的 PHY 层和 MAC 层， 设备在竞争时， 根据检测到 PHY 层头部的 bss color 字段来分配 MAC 层的竞争行为， 主要分为相同 BSS （intra-bss） 和重叠 BSS （inter-bss）。引入的自适应 CCA 机制， 通过提高 inter-bss 信号检测阈值， 同时保持 intra-bss 较低检测阈值， 来减少 MAC 层竞争，提升 MAC 层效率。

· 多 AP 间发射功率协同， 在高密办公场景中， AP 部署比较密集， 存在一定的同频干扰， 当某 AP 发送数据时， 会影响周围的同频 AP 正常发送数据。通过 AP 间协同， 控制 AP 发送数据的发射功率来消除对周围同频 AP 的干扰，使周围同频 AP 可同时发送数据，从而提升整网的容量。

### 3.4.4 动态 EDCA

在网络使用过程中， 终端个数会动态变化， 业务大小也是动态变化， 通过检测终端数目和整机业务大小， 对 EDCA 参数进行动态调整。在终端数目少， 业务单一情况下适当调小 EDCA 窗口， 减少不必要的退避， 提高空口使用效率， 而在终端数目多， 业务多样时， 差异化调整不同优先级业务的 EDCA 参数， 一方面对高优先级业务进行一个空口保障，另外减少空口的冲突竞争。

### 3.4.5 动态 CCA

802.11 协议定义了 CCA 机制以实现信道闲 / 忙的状态监测。当信道空闲时，WLAN 设备才开始进行信道竞争抢占动作。通过 CCA 机制可以避免在有干扰时发送信号， 避免信号与干扰发生冲突， 从而减少干扰对 WLAN 性能的影响。CCA 机制可以实现信道闲 / 忙的状态监测，当监测到信道空闲时再发送报文，减少因为信道状态未知而发送报文导致的冲突。通过 CCA 门限检测， 可以比较准确判断信道的闲 / 忙状态， 从而控制数据报文在信道空闲时发送， 有效地减少空口冲突，提升传输效率。然而在不同场景下，使用相同的默认 CCA 门限值， 取得的实际效果存在差异。动态 CCA 机制能够根据场景差异，动态调整 AP 设备的 CCA 门限，来减少冲突概率、提升 AP 并发率，从而提升整网的用户体验。

# 3.5 网端协同

## 3.5.1 产生背景

WLAN 技术源自局域网， 相比 3GPP 网络在移动性管理、 QoS 管控方面存在天然不足， 导致终端在普遍存在漫游不及时、链路不稳定等缺点；

目前网络厂商、 终端厂商各自都在尝试解决或优化这些问题， 诸如扫描效率提升、 应用 11k/v/r 协议、 调整漫游灵敏度、 有线无线 QoS 映射等， 但是终端侧和网络侧的措施没有形成统一策略， 在一些细节逻辑上经常存在兼容类问题， 还有一些稳定性问题仍难以解决； 这些问题严重影响了用户在语音、高清视频等业务上的体验连续性， 以及 WLAN 技术向工业互联网等新兴领域的快速拓展；

为了应对 WLAN 用户体验稳定性不足的缺点， WAA 联盟从协同终端侧与网络侧联合优化的思路出发， 通过定义 WLAN 网络侧设备与终端设备之间的协同控制相关的补充协议， 针对性解决现有问题， 让更多的终端在更多的网络中有着更好的体验，满足客户不断提高的业务场景需求，支持 WLAN 产业的健康发展。

## 3.5.2 网端协同技术方向

1) 网络侧和终端优化服务发现机制，从而保证用户在移动过程中快速发现的服务保障接入速度。

2) 网络侧和终端可以共同决定何时发起漫游或切换， 并选择最佳漫游或切换的目标， 从而保证用户在移动过程中的服务连续性和稳定性。

3) 网络侧和终端可以共同判断出网络延迟的情况， 并采取针对性的措施， 如优先分配网络资源给正在进行关键操作的用户，以减少关键业务延迟和丢包。

4) 通过共同跟踪网络资源使用情况， 网络侧和终端可以协作完成网络资源分配和调度， 从而实现网络容量最大化， 提高用户体验。

5) 网络侧和终端在感知网络变化或出现问题时，互相通知对方，共同配合快速解决突发网络问题。

6) 网络侧和终端建立两个空口链接，以此增强空口链路的可靠性

# 3.6 超大容量

## 3.6.1 产生背景

随着 WLAN 技术的发展， 家庭、 企业等越来越依赖 WLAN 作为移动接入的主要手段。近年来不断出现的新型应用对吞吐率要求也更高，比如 4K 和 8K 视频、VR/AR、游戏、远程办公、在线视频会议和云计算等。虽然 Wi-Fi 6 已经重点关注了高密场景下的用户体验， 然而面对上述更高要求的吞吐率依旧无法完全满足需求。而 IEEE 目前正在制定当中的 802.11be 标准（Wi-Fi 7）采用了诸多技术可以提升网络容量和设备吞吐率

## 3.6.2 Wi-Fi 7

Wi-Fi 7 的设计目标是将 WLAN 网络的吞吐率提升到至少 30Gbps， 并且提供低时延的接入保障。为了满足这个目标，整个协议在 PHY 层和 MAC 层都做了相应的改变。相对于 Wi-Fi 6 协议，Wi-Fi 7 协议带来的主要技术变革点如下

1) 更快的速度

可以提供更快的网络速度。根据 Wi-Fi7 标准， 无线设备可以在更宽的频谱范围内运行， 从而提供更高的峰值速度。这意味着您可以更快地下载文件，播放视频和游戏。

2) 更高的容量

Wi-Fi7 还具有更高的容量。通过使用更大的频谱范围和更高的 QAM， Wi-Fi7 可以支持更多的设备同时连接到同一个无线设备，而不会导致网络拥塞或卡顿。

3) 更快的响应时间

通过采用 Multi-Link 多链路机制、OFDMA 增强在内的多种技术，Wi-Fi7 可以提供更快的响应时间。

# 3.7 趋势展望

根据 OVUM 报告显示，未来两年内企业的智能终端数量将成倍增长， 音视频流量以每年 30% 增长， 2025 年 80% 的应用上云，企业园区网络正在向超宽、极简、高品质体验和智能运维发展。随着 Wi-Fi7 已经商业化， 可以说高品质万兆园区时代已经到来！

# Chapter 3

# Key Technologies of High-Quality Enterprise WLAN: —Status Quo and Development Trends

# 3.1 Coverage Optimization Technologies

## 3.1.1 Background

WLAN technology originates from small-scale application scenarios such as homes. In residential environments, the channel, power, and anti-interference capabilities of only a single AP need to be considered. When a WLAN is deployed for an enterprise campus, however, network access anytime, anywhere is needed. To achieve this, the WLAN needs to ensure network coverage without coverage holes at all network access positions of users. Additionally, the air interface resources of a WLAN are shared. As such, the WLAN needs to minimize signal interference between APs to improve network-wide performance and user experience. The following lists typical factors to be considered during enterprise WLAN construction:

- Signal coverage
- Channel, power, and frequency bandwidth for better network-wide performance
- On-demand dynamic network resource adjustment for adapting to user and traffic changes
- Dynamic adjustment when a device is faulty or interference suddenly occurs, reducing the impact of abnormal events on the network
- Anti-interference and better coverage capabilities in complex environments

WLAN device vendors are doing research on coverage optimization technologies, aiming at meeting the coverage requirements raised during enterprise WLAN construction.

## 3.1.2 Radio Resource Optimization Technologies

Radio Resource Management (RRM) is a radio resource optimization solution. It uses systematic real-time intelligent radio management to enable a WLAN to quickly adapt to changes in the environment and maintain the optimal radio resource status. RRM technology involves three key factors: channel adjustment, power adjustment, and frequency bandwidth adjustment. RRM technology can be classified as local RRM or cloud RRM based on data sources and the carriers for analysis and computing.

- Local RRM uses local data stored on wireless devices for analysis and computing.
- Cloud RRM uses rich data on the cloud platform and big data analysis to perform multi-dimensional computing.

When both local RRM and cloud RRM are enabled, cloud RRM is used for unified scheduling and adjustment to provide better wireless services.

### 3.1.2.1 Local RRM

The spectrum resources of WLAN frequency bands are limited. Each radio operates on a limited number of channels. If neighboring APs operate on the same channel, interference is generated. In addition, interference from radar signals and microwave ovens may exist in the surrounding environment. Automatic channel adjustment allocates optimal channels to radios. This prevents APs from operating on channels with severe interference, thereby ensuring reliable transmission.

Conventional power control methods only pursue the maximum signal coverage range and therefore set the transmit power of the radio to the maximum value. This ensures the signal coverage range; however, interference is caused to other wireless devices. In addition, such methods may hinder STAs from roaming, causing STA stickiness and degrading the wireless network experience. In comparison, automatic power adjustment reduces interference between APs while ensuring radio signal coverage for a better roaming experience of STAs and allocates proper transmit power to radios.

Typically, the frequency bandwidth of radios can be set to the maximum value to achieve the maximum rate and throughput. This can increase the negotiated rates between APs and STAs and also increase the theoretical throughput of them can be improved theoretically. However, severe interference may occur when neighboring APs use the same channel because the number of available channels is limited. As a result, the overall capacity of the system is reduced, failing to meet the high throughput requirements of users. Therefore, when selecting the frequency bandwidth, you need to consider the deployment density of APs, the number and traffic of STAs, and interference for better network-wide throughput while ensuring the quality of wireless services.

#### 3.1.2.2 Cloud RRM

Cloud RRM collects historical network statistics and performs RRM analysis and prediction based on AP statistics, neighbor information, STA statistics, and time. Such technology is applicable to different scenarios and supports more accurate solution adjustment. For example, it can accurately distinguish off-peak hours from peak hours based on the traffic model and optimize AP channels in advance to better meet service requirements according to actual network conditions. Besides, it can modify radio parameters in the early morning to reduce the impact on STAs and improve user experience.

According to long-term historical data, APs are densely deployed in open places with obvious tidal crowds, such as canteens. During peak hours, the crowd flow, number of STAs, and service traffic increase significantly. As such, the interference between APs is severe, and the WLAN service cannot work properly. In this case, cloud RRM can lower the frequency bandwidth to increase the number of available AP channel combinations and limit inter-AP interference within an acceptable range for improved user experience. After peak hours, the number of users and that of STAs decrease rapidly, and so does the service traffic volume. In this case, cloud RRM can increase the frequency bandwidth and adjust channels to increase the STA rates for improved user experience.

### 3.1.3 Coverage Enhancement Technologies

The traffic model of a wireless network is dynamic in real time because STAs continuously access, go offline, move, and roam. As such, it has become a hot topic that how to ensure good user experience at different locations, especially at the coverage edge. According to the Shannon formula, the signal-to-noise ratio (SNR) plays a key role in further improving the transmission rate and user experience with the spatial stream and frequency bandwidth remaining unchanged. In scenarios where the locations of APs and STAs are fixed, the received SNR can be improved by increasing the transmit power through receive enhancement technology, precoding technology, and smart antennas.

#### 3.1.3.1 Receive Signal Enhancement

TWhen the number of spatial streams supported by receive antennas is greater than the number of data streams, the receive end can perform antenna selection (ASEL) to select an antenna with optimal signal quality or leverage maximum ratio combining (MRC) to combine data from multiple antennas for a higher received signal to noise indicator (RSNI).

#### 3.1.3.2 Precoding

Precoding technology is widely used together with multiple-input multiple-output (MIMO) technology. The transmit end obtains channel state information (CSI) through the reciprocity between uplink and downlink channels or direct feedback of STA protocol packets. The precoding system adjusts the amplitude and phase of signals from the transmit antenna according to the obtained CSI, and properly allocates the limited transmit power. In this way, STAs can receive the optimal signal.

· TXBF technology: Transmit beamforming (TXBF) technology is mainly used for single-user systems, that is, point-to-point transmission is performed between an AP and a single STA. The transmit end weights transmitted signals based on the CSI to increase the SNR at the receive end, thereby increasing the communication throughput and reducing the packet loss rate.

· MU-MIMO technology: Multi-user MIMO (MU-MIMO) technology upgrades the single-STA beamforming to joint beamforming for multiple STAs. This not only ensures that each STA can receive good signals, but also minimizes the interference between different STAs, thereby improving the capability of concurrently transmitting data streams.

In addition to precoding technologies such as point-to-point beamforming (TXBF) and point-to-multipoint beamforming (MU-MIMO), research have been conducted on multipoint-to-multipoint joint precoding technologies, which will further improve the transmission performance and edge throughput of STAs.

#### 3.1.3.3 Smart Antenna

Smart antenna technology can be referred to as adaptive beam switching technology. It uses an antenna array that has multiple hardware antennas and intelligently selects multiple antenna elements to transmit and receive radio signals. Combining different antennas can form different signal transmission directions, allowing STAs at different locations to use the optimal transmit or receive antenna for signal transmission, improving received signal quality and system throughput.

Smart antenna technology mainly includes the smart antenna array (antenna array hardware design) and the smart antenna beam selection algorithm (how to select an antenna in the antenna array).

· Smart antenna array

An antenna array is made up of a series of small antennas. Each small antenna can be an omnidirectional antenna or a directional antenna. The antenna arrangement depends on the gain, polarization mode, and radiation pattern of small antennas. The number of small antennas determines the number of beams that are finally formed. In addition, the more the elements on the small antennas are, the more the antenna combinations will be, and the more accurate the directivity of beam transmission will be. This makes signals more concentrated, thereby improving the received signal quality and the system throughput.

· Smart antenna beam selection

The basic principle of the smart antenna selection algorithm is to select the most appropriate antenna configuration for the current user based on the packet error rate (PER) and received signal strength indicator (RSSI) fed back by the antenna layer by sending training packets under the current antenna configuration. The antenna configuration mainly includes the antenna combination and transmit rate.

The smart antenna selection algorithm is an important feature of small antennas. By sending data packets to STAs, STA locations can be determined. The smart antenna selection algorithm can then select appropriate antenna combinations from an antenna array to improve network performance. Directional beams are used to replace original omnidirectional beams to concentrate the energy, improving received signal quality and system throughput.

## 3.2 Resource Scheduling Assurance

### 3.2.1 Background

In networking scenarios such as office and education, new preferences and traffic models emerge accompanying the popularization of fully wireless networks. For example, users have more than one terminal, and application types are becoming diversified, including data, audio, and video services. Additionally, the amount of concurrent data increases significantly.

As the data traffic increases greatly and different services are sensitive to parameters such as delay, packet loss, and jitter, wireless devices must properly allocate and schedule air interface resources to ensure differentiated services.

### 3.2.2 Resource Assurance Technology

In a WLAN quality of service (QoS) policy, Wi-Fi Multimedia (WMM) is used to guarantee priority services. However, in multi-user and multi-service scenarios, the random backoff mechanism adopted in WMM can no longer meet the requirements of new scenarios. As such, resource assurance is raised in the aspects of VIP user assurance, intelligent bandwidth allocation, service identification, and differentiated scheduling.

· VIP user assurance: Bandwidth needs to be guaranteed for high-priority users on the network. These users are VIP users, who are identified by user attributes but not by service types. The traffic of the VIP users needs to be preferentially guaranteed and scheduled.

· Intelligent bandwidth allocation: The main purpose of bandwidth allocation and resource assurance is to achieve a good user experience. As radio resources are limited, an available resource threshold evaluated by a device can reduce air interface waste caused by resource contention between multiple devices. Additionally, this ensures that STAs connected to the device are allocated proper resources and enjoy a good network experience. Bandwidth allocation involves the resource evaluation algorithm, bandwidth allocation algorithm, and STA scheduling algorithm.

–Resource evaluation algorithm: roughly evaluates the available network bandwidth by detecting network running parameters, such as the noise floor, channel utilization, and number of STAs. The network bandwidth is dynamically updated in real time based on the network running status and is used for subsequent bandwidth allocation.
–Bandwidth allocation algorithm: evaluates the STA attributes by detecting the traffic volume and type of each STA in a multi-STA scenario. This algorithm traces the collected data and allocates a proper bandwidth usage threshold to the STAs. The bandwidth for a STA cannot exceed the threshold while services are guaranteed. If there is idle bandwidth, STAs with heavy traffic are allowed to preempt the idle bandwidth. In this way, resources can be properly allocated, achieving differentiated scheduling for multiple STAs.

–STA scheduling algorithm: works with application identification technology and tags packets with priority. High-priority packets can be preferentially forwarded and scheduled. The effective bandwidth threshold obtained by multiple STAs is fixed. When high-priority packets are scheduled, services are preferentially processed. The bandwidth of multiple clients is determined, in addition, the resources of multiple clients are guaranteed.

· Application identification and scheduling assurance: APs or ACs use technologies such as Deep Packet Inspection (DPI) and Deep Flow Inspection (DFI) to accurately categorize applications of end users. Different policies can be configured to mark different types of applications, allowing for preferential scheduling and assurance for key services. For example, audio and video conferences are important services in office scenarios. Application identification technologies can be used to identify, preferentially schedule, and guarantee service traffic of audio and video conferences, improving user experience.

· Dynamic rate adjustment: On a WLAN, multiple types of STAs, such as Wi-Fi 4, Wi-Fi 5, and Wi-Fi 6, may use the WLAN service simultaneously. The maximum transmission rates supported by different types of terminals are fixed based on standard protocols. If interference exists on the network or the RSSI is low, the retransmission rate and packet loss rate are high. In this case, the transmission rate is reduced. To prevent this, the system can detect the air interface environment, collect statistics on rate selection information, and adjust the selectable STA rates in a range. Such adjustment helps reduce the packet loss rate, retransmission rate, and finally, the contention over the air interface, improving air interface efficiency.

· Link optimization based on orthogonal frequency division multiple access (OFDMA): OFDMA technology improves multi-user communication efficiency by allocating subcarriers of a frequency band to different STAs for concurrent communication. This technology divides resource units (RUs) based on STA requirements and flexibly allocates RUs to multiple STAs, providing efficient experience rates.

· Enhanced MU-MIMO: In multi-STA scenarios, service packets of different STAs arrive at an AP at different times, and the number of packets is different. As a result, the AP cannot meet MU pairing requirements when forwarding service packets. Enhanced MU-MIMO enables the AP to preprocess packets, increasing the MU pairing success rate. MU-MIMO is used to send service packets of multiple STAs at the same time. This reduces the frequency of sending service packets over the air interface, improves the use efficiency of air interface resources, and increases network-wide bandwidth.

· Joint resource scheduling on the air interface: The proportion of TCP-based data traffic on the current network is more than 90%. When multiple STAs coexist, there is a high probability that uplinks TCP ACK packets conflict with downlink MU-PPDUs, which may cause error packets. PPDU is short for physical layer convergence procedure Protocol Data Unit. In this scenario, air interface resources can be jointly scheduled, and uplink service packets of multiple STAs can be sent at the same time. This reduces the probability of uplink and downlink transmission collisions on the air interface and improves the concurrent capability of multiple STAs.

## 3.3 Seamless Roaming

### 3.3.1 Background

On a conventional WLAN, roaming is initiated proactively by STAs, and the roaming time is controlled by the STAs. During this process, STAs do not coordinate with APs about roaming detection and roaming decision-making, which cannot ensure a satisfactory roaming effect. Common issues that may occur include roaming stickiness, delayed roaming, repeated roaming, and O&M issues. Therefore, roaming coordination is needed among the STAs, wireless devices, and cloud O&M platform to form a roaming system to ensure that user services are not affected by the roaming process.

### 3.3.2 Coordinated Roaming Technology System

IIn this coordinated roaming technology system, APs and STAs detect the network from multiple dimensions, and an access controller (AC) performs comprehensive computing and negotiates with STAs to implement precise roaming, improving user experience.

An AP uses the 802.11k protocol to provide STAs with the channels and wireless service information about neighboring APs. In this manner, STAs are free of scanning channels one by one and require shorter service discovery times.

APs monitor link quality in real time and perform precise roaming. By monitoring link quality, an AP selects a proper time to trigger roaming to a target AP. The target AP is selected based on the historical access path, neighboring APs discovered by 802.11k measurement STAs, and STA roaming characteristics. Then the local AP steers STAs to the target AP at a proper time based on the 802.11v protocol. This ensures that the link quality jitter is small and services are not affected.

802.11r can be deployed on the network for fast roaming.

The AC continues to monitor and calibrate the link quality after a STA roams. If the link quality deteriorates significantly, the AC calibrates roaming and steers the STA to a proper AP to ensure that the link quality is within the expected range.

The cloud O&M platform analyzes STA roaming behavior data and optimizes the STA roaming profile library.

### 3.3.3 Link Quality Detection Enhancement Technology

APs monitor link quality changes of STAs in real time, including uplink signal changes, uplink and downlink rate changes, sleep changes, and traffic usage. For 802.11k-capable STAs, 802.11k measurement is used to obtain downlink signal changes of STAs. Auxiliary radios can obtain signal changes of surrounding APs. Based on the changes of various factors, an AP can determine the possible behaviors of a STA, such as stationary, stationary signal jitter, fast movement, and slow movement. Based on different behaviors, the AP gets prepared for roaming to the target APs at different times and performs roaming handovers accordingly at different times.

### 3.3.4 Roaming Calibration Technology

Due to factors such as AP layout, configured thresholds, and STA positions, some STAs cannot achieve the expected roaming handover effect. In this case, the AC needs to automatically identify multiple roaming events and rectify the calibration so that the STAs can go online on the optimal service and stop roaming.

### 3.3.5 Assisted Roaming-Assisted STA Profile Library

The STA profile library changes the "one profile for all" to "personalized STA profiles", generates the roaming parameter settings for each type of STAs, and minimizes the adverse impact of protocol compatibility and STA implementation differences.

Huawei analyzes the roaming steering behavior of different STAs based on a large number of roaming data samples, trains a large number of parameters, and finally learns roaming profiles suitable for different STAs. The roaming profile content in the STA profile library is categorized as follows:

· Static characteristics: include capabilities supported by STAs or the STA behavior, including the steering protocol capability, measurement protocol capability, and frequency band capability.

· Dynamic characteristics: include service characteristics of STAs under specific network coverage, such as the roaming signal threshold and source/target signal strengths.

Based on the preceding STA roaming parameters, coordinated measurement steering technology is used to continuously detect signals of STAs, determine the movement trend of STAs (close to or far away from associated APs), and proactively steer STAs to the AP with the optimal quality at the most appropriate location and time. In this way, STAs can roam in a timely manner and the roaming success rate is higher.

## 3.3 Seamless Roaming

### 3.4.1 Background

With the popularization and application of WLAN technologies, especially the large-scale use of WLANs in enterprise campuses, WLAN interference becomes increasingly prominent, which affects network stability, data transmission speed, and network connection quality, and even causes network interruption.

WLAN interference may be caused by conflicts between WLAN signals and electromagnetic wave signals generated by devices such as microwave ovens, radio frequency identification (RFID) devices, or Bluetooth devices. Besides, WLAN interference may also be caused by overlapping or closed channels of two WLANs.

### 3.4.2 3D Radio Calibration

Traditional radio calibration forms a two-dimensional (2D) topology of neighbor relationships between APs based on the signal strength measured by APs. The basic calibration principle is to prevent adjacent APs from being allocated the same channel and lower the allocated power to minimize mutual interference and ensure timely roaming. However, due to complex AP installation environments, and the 2D network topology cannot fully reflect the accurate relationships between APs. Therefore, the traditional radio calibration result is unsatisfactory for APs at complex positions. Typical scenarios include:

· Blocking between APs: APs are blocked from each other and can hardly or cannot detect each other. In this case, no neighbor relationship or weak neighbor relationship is displayed on the logical network topology. As a result, APs are allocated the same channel, causing strong co-channel interference on the STA side.

· AP installation at high positions: APs detect strong signals between each other and lower the transmit power. However, the signal strength of APs detected by STAs is weak, degrading user experience.

3D radio calibration leverages downlink measurement on STAs to form a 3D topology, which reflects the actual propagation of radio signals in the space and the impact of signals on STAs and APs. Radio calibration based on the 3D topology can better adapt to the complex and variable space environment and improve the environment generalization of the algorithm.

### 3.4.3 Multi-AP Coordination

· Basic service set (BSS) coloring technology is proposed in the Wi-Fi 6 standard to address BSS overlapping on the same frequency, improve the spatial reuse rate, and reduce the air interface contention overhead caused by BSS overlapping. BSS color information is added to both the PHY and MAC layers of WLAN packets. During contention, the device allocates contention behavior at the MAC layer based on the BSS color field in the PHY header. The contention behavior is classified as intra-BSS or inter-BSS (also known as OBSS: overlapping BSS). The adaptive clear channel assessment (CCA) mechanism is introduced to increase the OBSS signal detection (SD) threshold and keep the intra-BSS SD threshold low to reduce contention and improve the efficiency at the MAC layer.

· Transmit power coordination among multiple APs is supported. In high-density office scenarios, APs are densely deployed, causing co-channel interference. When an AP sends data, surrounding co-channel APs are affected. Through coordination between APs, the transmit power of the AP is controlled to eliminate interference to neighboring co-channel APs. In this manner, neighboring co-channel APs can send data at the same time, improving the capacity of the entire network.

### 3.4.4 Dynamic EDCA

When the network is in use, the number of STAs and the service volume both change dynamically. The enhanced distributed channel access (EDCA) parameters can be dynamically adjusted based on the number of STAs and the service volume of the entire system. When the number of STAs is small and services are simple, the EDCA window size is decreased to reduce unnecessary backoff and improve air interface efficiency. When the number of STAs is large and services are diversified, EDCA parameters are adjusted for services with different priorities to guarantee air interface quality for high-priority services and to reduce collisions over the air interface.

### 3.4.5 Dynamic CCA

The 802.11 protocol defines the CCA mechanism to monitor the idle/busy status of channels. A WLAN device starts to preempt a channel only when the channel is idle. By using the CCA mechanism, signals are not sent when interference exists on a channel, thereby avoiding conflicts on the channel and reducing the impact of interference on WLAN performance.

The CCA mechanism can monitor the idle/busy status of a channel, and send a packet only when the channel is idle. This reduces conflicts caused by sending packets at an unknown channel state. CCA threshold-based detection can accurately determine whether a channel is idle or busy. In this manner, data packets can be sent when the channel is idle, effectively reducing air interface conflicts and improving transmission efficiency.

However, when the same default CCA threshold is used in different scenarios, actual effects vary. As such, the dynamic CCA mechanism is introduced to dynamically adjust the CCA threshold of APs based on scenarios to reduce the conflict probability and increase the AP concurrency rate, improving user experience on the entire network.

## 3.5 Network-Terminal Synergy

### 3.5.1 Background

WLAN technology originates from the local area network (LAN). Compared with the 3rd Generation Partnership Project (3GPP) network, WLAN technology has disadvantages in mobility management and QoS control, such as untimely roaming and unstable links.

Currently, network vendors and terminal vendors are trying to solve or optimize these issues, for example, by improving scanning efficiency, applying the 802.11k/v/r protocol, adjusting roaming sensitivity, and mapping between wired and wireless QoS. However, no unified policy is formed on the terminal side and the network side, compatibility issues are common in some detailed logic, and some stability issues are still difficult to solve. These severely affect the continuity of user experience in audio and HD video services and the rapid expansion of WLAN technologies to emerging fields such as the industrial Internet.

To cope with the poor WLAN user experience stability, the WAA defines supplementary protocols related to coordinated control between WLAN network-side devices and terminal-side devices to address existing problems. This feature enables more terminals to provide a better user experience on more networks, meets customers' increasing service requirements, and supports the healthy development of the WLAN industry.

### 3.5.2 Technical Direction of Network-Terminal Synergy

1.The service discovery mechanism is optimized on the network side and terminals to ensure that services can be quickly discovered during terminal movement, ensuring the access speed of terminals.

2.The network side and terminals can jointly determine when to initiate roaming or handover and select the optimal roaming or handover target. This ensures service continuity and stability during terminal movement.

3.The network side and terminals can jointly determine the network delay and take specific measures. For example, the network side preferentially allocates network resources to terminals that are performing key operations to reduce the delay and packet loss of key services.

4.By jointly tracking network resource usage, the network side and terminals can coordinate to complete network resource allocation and scheduling, thereby maximizing network capacity and improving user experience.

5.When detecting network changes or issues, the network side and terminals notify each other of the changes or issues. In this way, the network side and terminals can cooperate with each other to quickly solve network exceptions.

6.Two air interface links are established between the network side and a terminal to enhance link reliability.

## 3.6 Ultra-Large Capacity

### 3.6.1 Background

With the development of WLAN technologies, homes, and enterprises increasingly rely on WLANs as the main means of mobile access. In recent years, new applications, such as 4K and 8K videos, VR/AR, games, remote offices, online video conferencing, and cloud computing, have higher requirements on throughput. Wi-Fi 6, in spite of its focus on user experience in high-density scenarios, cannot fully meet the preceding higher throughput requirements. As such, the 802.11be standard (Wi-Fi 7) being formulated by IEEE leverages various technologies to improve network capacity and device throughput.

### 3.6.2 Wi-Fi 7

Wi-Fi 7 is designed to increase the WLAN throughput to at least 30 Gbps and provide low-latency access assurance. To meet this goal, this new standard involves changes in both the PHY and MAC layers. Compared with Wi-Fi 6, Wi-Fi 7 brings the following technical changes:

1.Higher speed

Wi-Fi 7 provides faster network speeds. With Wi-Fi 7, wireless devices can operate in a wider spectrum range, providing higher peak speeds. This allows users to download files and play videos or games much faster.

2.Higher capacity

Wi-Fi 7 supports a higher capacity. By using a larger spectrum range and higher-order quadrature amplitude modulation (QAM), Wi-Fi 7 allows more terminals to connect to the same wireless device at the same time without causing network congestion or frame freezing.

3.Faster response time

By using multiple technologies such as multi-link operation (MLO) and OFDMA enhancement, Wi-Fi 7 can provide faster response time.

## 3.7 Trend Prospect

According to a report of Ovum, the number of smart terminals in enterprises will multiply in the next two years, audio and video traffic will increase by 30% every year, and 80% of applications will be migrated to the cloud by 2025. Enterprise campus networks are developing towards ultra-broadband, simplified, high-quality experience, and intelligent O&M. With the commercialization of Wi-Fi 7, we can embrace the era of high-quality 10 Gbps campus.

# 第 4 章

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# WAA 将通过标准和认证
# 推动企业场景高品质体验网络建设

## 4.1 WAA 联盟定位： 高品质 WLAN 国际标准及产业平台

WLAN 产业规模大， 各种应用发展迫切需要 WLAN 性能标准的推出， 而当前产业界还没有相应的组织覆盖这一业务，是产业发展亟需补齐的短板，在这样的背景下，建立健全 WLAN 性能标准认证体系，是非常必要和及时的。

WAA 联盟是一个在自愿、互利、合作的基础上，由 WLAN 产业相关的企业、社会团体、高等院校、科研院所等组成的非营利性的社会团体，围绕着推动建立健全 WLAN 性能标准体系，开展 WLAN 性能测试认证等主要目标开展工作。WAA 联盟的定位是建设产业平台和国际标准平台的双平台定位， 即定位于产业需求、 产业规划、 产业协作到产业落地推动的产业平台，和定位于新业务、新技术开发标准平台。WAA 将在如下方面开展工作。

· 开展 WLAN 网络应用场景的需求分析， 孵化 WLAN 创新方案， 开展 WLAN 网络标准规范前期的研究工作， 推动相关技术、体验、性能等的标准化和国际化；
· 组织 WLAN 网络性能体验有关的测试用例交流、测试认证规范制定，对外开展测试认证，推动新技术、新标准的规模商用及应用创新，保障应用的体验，促进 WLAN 应用的不断成熟和发展；
· 开展 WLAN 产业营销和市场推广工作， 促进产业界针对 WLAN 标准和应用创新展开深度交流合作， 保持产业活力，繁荣产业生态，促进产业发展；
· 开展 WLAN 产业相关标准、技术、 应用、 市场等多维度的产业洞察和分析， 形成 WLAN 产业发展报告， 并对联盟会员及产业界伙伴开展培训；
· 开展全 WLAN 网络国际交流与合作，促进联盟与国外相关组织与机构进行产业合作。

## 4.2 WAA 将持续推动企业场景高品质 WLAN 体验建网标准

目前 WAA 围绕企业典型场景已经开展了两个维度的项目， 一个是《园区办公场景测试认证项目》， 另一个是《工业 WLAN 通信》工作组。

办公园区场景测试认证项目对办公场景的业务特征和场景特征等进行充分分析， 识别出园区办公场景 KQI 指标体系和性能指标体系 ( 如下图所示 )， 根据具体的场景给出具体的性能指标和相应的测试方法， 制定出《办公园区场景测试认证标准》， 为办公场景客户提供建网标准依据。

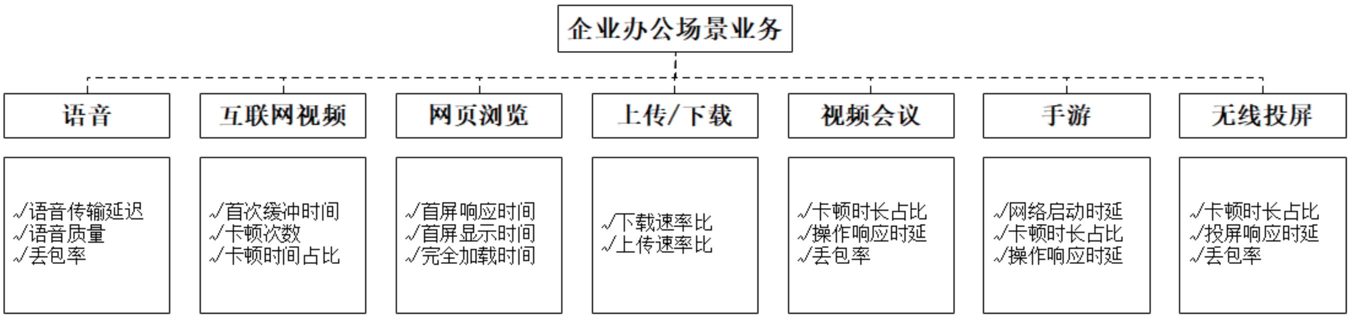



图 11 园区场景业务 KQI 指标体系

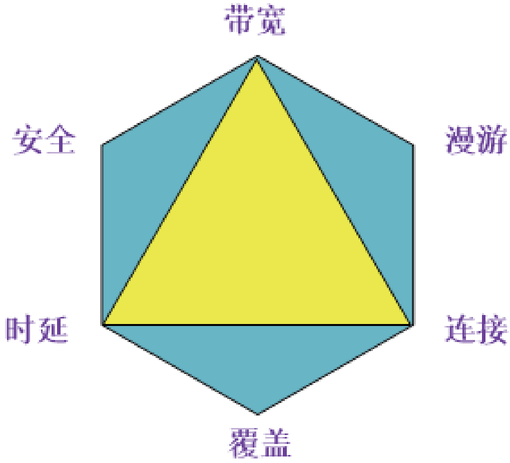



图 12 园区办公场景单设备 WLAN 性能指标

对于智能制造领域，目前 WAA 成立一个《工业 WLAN 通信工作推进组》正在定义智能制造领域下业务需求、场景特征等，在不久的将来相应的测试认证标准。

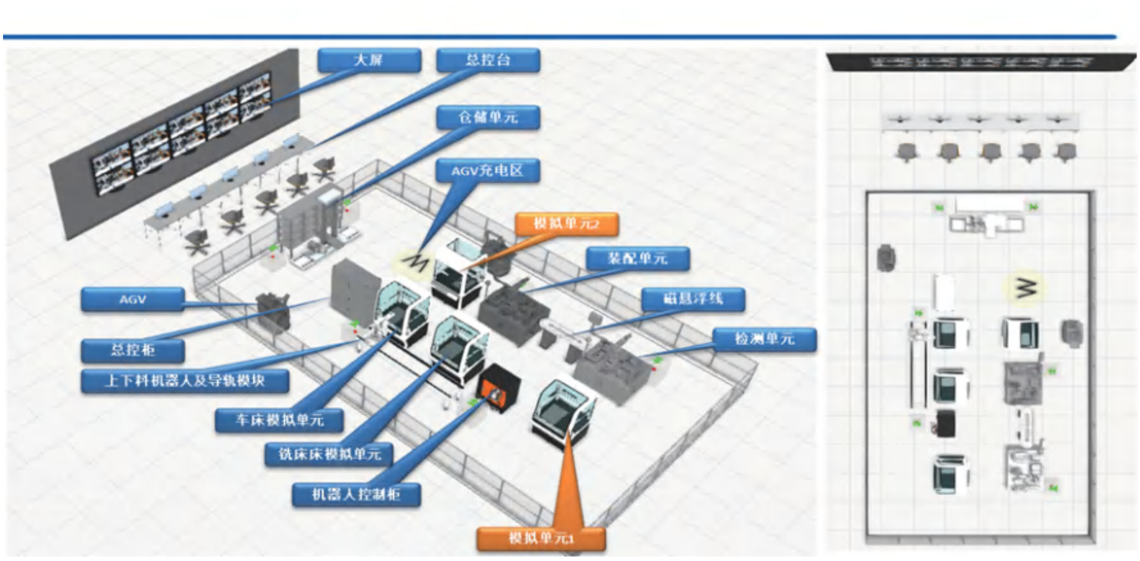



图 13　智能制造典型场景和业务需求

## 4.3 WAA 联盟持续支撑 WLAN 产业发展

统一 WLAN 性能标准，建设认证平台，增强企业创新动力，激励企业加大研发投入，补齐短板、锻造长板
建设产业公共服务平台，完善产业标准体系，牵引产业做大做强，加快发展现代产业体系： WLAN 性能体验相关的标准基本处于“标准空白区”， WLAN 应用发展联盟希望抓住 WLAN 应用性能标准薄弱的机遇； 汇聚产业力量建设统一的性能标准和认证的产业公共服务平台，帮助产业发展和技术进步。

支持产业共性基础技术研发，加强产业基础能力建设： WLAN 技术广泛应用在智能交通、智慧物流、智慧能源、智慧医疗、智慧农业等领域，以 WAA 联盟为基础平台，集中产业力量识别关键需求与技术方案，支持行业龙头企业联合高等院校、科研院所和行业上下游企业共建产业创新，整合提升 WLAN 这一关键共性技术的应用和使用体验。

建立健全 WLAN 产业人才培养机制， 培养造就高水平人才队伍： WAA 联盟将以开展 WLAN 人员培训， 技术研讨、 产业峰会等方式， 夯实人才技术能力， 激发人才创新活力， 全方位培养产业人才激发人才创新活力， 充分发挥人才第一资源的作用，为产业赋能。

加快推动数字产业化，推进产业数字化转型： WAA 联盟将致力于激活产业链上下游各环节的新场景需求研究，技术创新以及服务推广 WLAN 技术在千行百业的应用创新， 与蜂窝技术携手进入数字转型深水区。建设覆盖面积广、 运行效率高的通信基础设施体系，催生新产业新业态新模式，打造数字经济新优势。

畅通国内大循环， 建设数字中国， 加快形成“双循环”新发展格局： 借助 WAA 联盟平台， 依托强大的国内市场， 贯通全产业的研发、 应用、 生产、 分配、 流通、 消费等各环节， 形成需求牵引供给、 供给创造需求的更高水平动态平衡， 促进国民经济良性循环， 加快我国数字化发展。同时团结国际 WLAN 产业链伙伴， 促进国内国际产业链与创新链深度融合，加快形成“双循环”新发展格局。

# Chapter 4

# WAA Promotes the Construction of Networks that Offers High-Quality Experience in Enterprise Scenarios Through Standards and Certifications

## 4.1 WAA: An International Standards and Industry Platform for High-Quality WLAN

The WLAN industry is large in scale. The Development of diverse applications is in urgent need of WLAN performance standards, which no industry organization is currently working on. This is a gap that must be filled to promote industry development. In this context, it is necessary to promptly establish and improve a WLAN performance standards certification system.

WAA is a non-profit social organization composed of enterprises, social organizations, higher education institutions, and scientific research institutes related to the WLAN industry on the basis of voluntary participation, mutual benefit, and cooperation. The goal of WAA is to establish and improve the WLAN performance standard system and conduct WLAN performance tests and certifications.

WAA is positioned as both an industry platform and an international standards platform. That means it is an industry platform for driving the implementation of industry requirements, industry planning, and industry collaboration, and also a platform for developing standards for new services and new technologies. To this end, WAA will work on the following aspects:

· Analyzing requirements of WLAN application scenarios, incubating innovative WLAN solutions, and conducting early-stage research on WLAN standards and specifications to promote standardization and internationalization of related technologies, experience, and performance.

· Organizing the communication of test cases related to WLAN network performance experience, formulating test and certification specifications, and conducting tests and certifications for external parties. This is to promote the large-scale commercial deployment and application innovation of new technologies and standards, ensure application experience, and promote the maturity and development of WLAN applications.

· Carrying out marketing and promotion for the WLAN industry, and promoting in-depth communication and cooperation on WLAN standards and application innovation across the industry to maintain industry vitality, make the industry ecosystem thrive, and promote industry development.

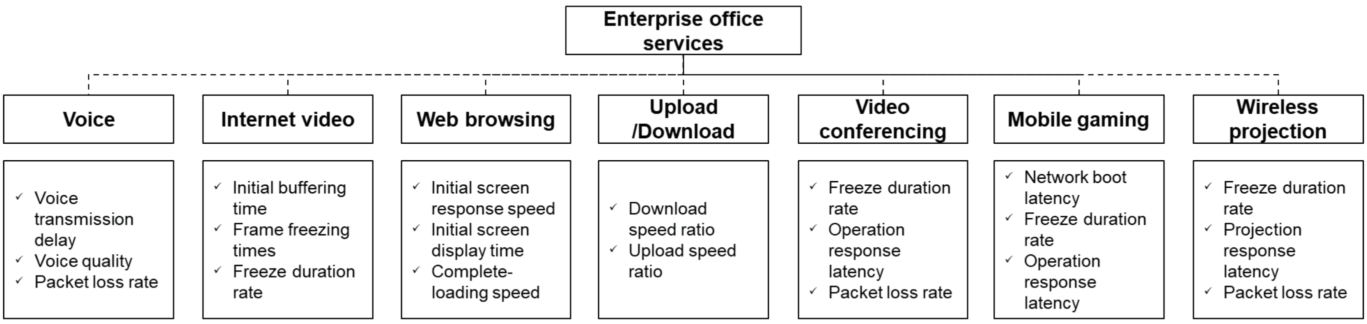
· Developing industry insights and analyses on WLAN standards, technologies, applications, and markets to formulate WLAN industry development reports, and providing training for Alliance members and industry partners.

· Conducting international exchanges and cooperation on WLAN, and promoting industry cooperation between WAA and relevant organizations and institutions outside China.

# 4.2 WAA Keeps Promoting Standards for Constructing High-Quality WLAN in Enterprise Scenarios

WAA has been implementing two projects based on typical enterprise scenarios. One is the Campus Office Scenario Test and Certification Project, and the other is the Industrial WLAN Communications Promotion Group.

The Campus Office Scenario Test and Certification Project has fully analyzed the service and scenario characteristics of office scenarios, identified the KQI system and PI system for these scenarios (as shown in the following figure), and provided specific performance indicators and test methods based on the scenarios. The Office Campus Scenario Test and Certification Standards have been formulated to provide network construction standards for customers in office scenarios.



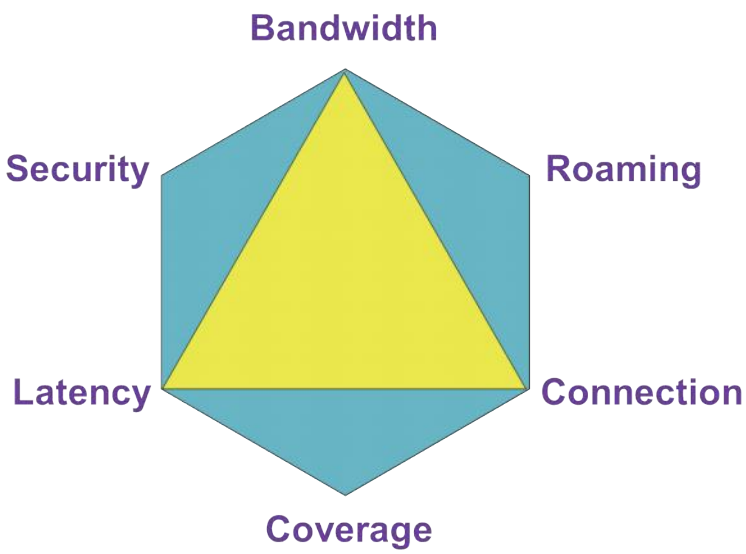




Figure 4-2WLAN PIs for single devices on campuses

WAA has set up an Industrial WLAN Communications Promotion Group to define service requirements and scenario characteristics of smart manufacturing, and will develop related test and certification standards soon.

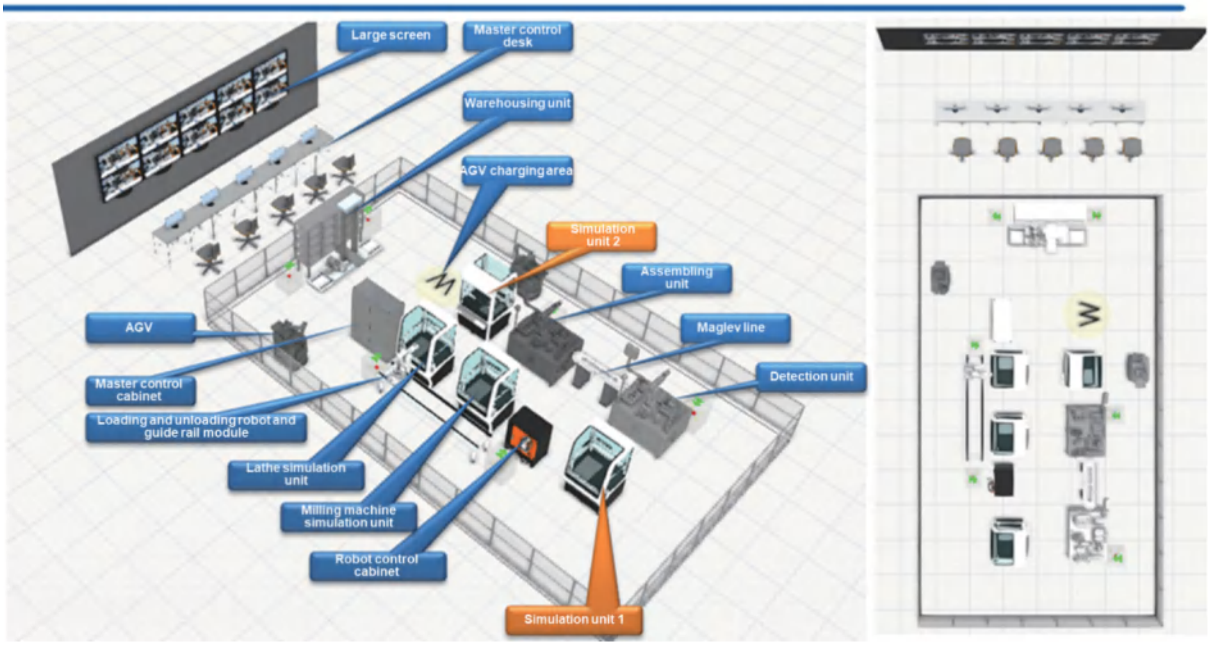



Figure 4-3Typical scenarios and service requirements of smart manufacturing

To improve user experience with technologies, WAA is currently working on the Network-Terminal Synergy Technology Standards Project. This project aims to improve user experience by enhancing collaboration between network-side devices and terminal-side devices from the following two perspectives:

· Roaming optimization: When a device moves between multiple APs, conflicts might occur due to different roaming decision-making logics. This will result in slow roaming handovers or sticky clients.

· QoS assurance: Services carried out by Wi-Fi protocols are becoming more diversified and complex, including latency-sensitive services like interactive gaming, XR, and VR. Whether the latency meets service requirements directly affects user experience. However, APs and STAs do not have a unified negotiation mechanism. When global network information on the terminal side is missing, users may experience problems such as frame freezing and disconnection.

Based on the preceding discussion, the Network-Terminal Synergy Technology Standards Project aims to use protocols to promote collaboration between APs and STAs to improve user experience and achieve cellular-like air interface performance.

In addition to the preceding ongoing projects and workgroup, WAA plans to develop a wide range of test and certification projects for typical enterprise scenarios such as education and healthcare. These projects will provide a standard basis for network construction and device selection. WAA will keep driving high-quality WLAN technology standard projects and leading the development of the WLAN industry.

## 4.3 WAA Continuously Supports the Development of the WLAN Industry

WAA is committed to unifying WLAN performance standards, building a certification platform, and stimulating enterprise innovation and R&D investment by bridging gaps and cultivating strengths.

WAA works hard to build a public service platform for the industry to improve the industry standard system, drive the industry to expand and grow, and accelerate the development of a modern industry system. Specifically, as there is basically no WLAN performance and experience standard, WAA is ready to fill this gap by building unified performance standards and a certified industry public service platform alongside other industry players with the aim to support industry development and technological progress.

WAA supports the R&D of basic technologies and strengthens the cultivation of basic capabilities in the industry. WLAN technologies are widely used in fields such as intelligent transportation, smart logistics, smart energy, smart healthcare, and smart agriculture. WAA serves as a platform where industry players work together to identify key requirements and technical solutions in these fields. WAA also supports innovation resulting from collaboration between industry leaders and universities, scientific research institutes, and upstream and downstream enterprises, aiming to improve the application and user experience of WLAN, a key universally-used technology.

WAA works on establishing and improving the talent cultivation mechanism for the WLAN industry to build a high-level talent team. WAA also organizes training, technical seminars, and industry summits to consolidate talent's technical capabilities and stimulate innovation. In a nutshell, WAA cultivates industry talent in an all-round way to stimulate innovation, so as to give full play to the role of talent as the key resource to enable the industry.

WAA also helps accelerate digital industrialization and industry digital transformation. WAA focuses on stimulating the research on new scenarios throughout the industry value chain, innovating technology, and promoting the application of WLAN technologies across industries. In this way, both the WLAN technologies and cellular technologies will advance to even more critical areas of application in digital transformation. WAA promotes the building of a communications infrastructure system with extensive coverage and efficient operations. This will create new industries, business forms, and models, which will become new advantages of the digital economy.

In addition, WAA supports China's efforts in streamlining the internal cycle, building a digital China, and accelerating the formation of a new dual circulation development pattern. With the help of WAA, based on the strong market in China, the R&D, application, production, distribution, circulation, and consumption across the industry will be integrated to form a higher-level dynamic balance where demand leads supply and supply creates demand. This will promote a virtuous circle of the national economy, and accelerate China's digital development. WAA will work with international WLAN partners to promote the in-depth integration of the domestic and international industry value chains and innovation chains, and accelerate the formation of the new dual circulation development pattern.

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