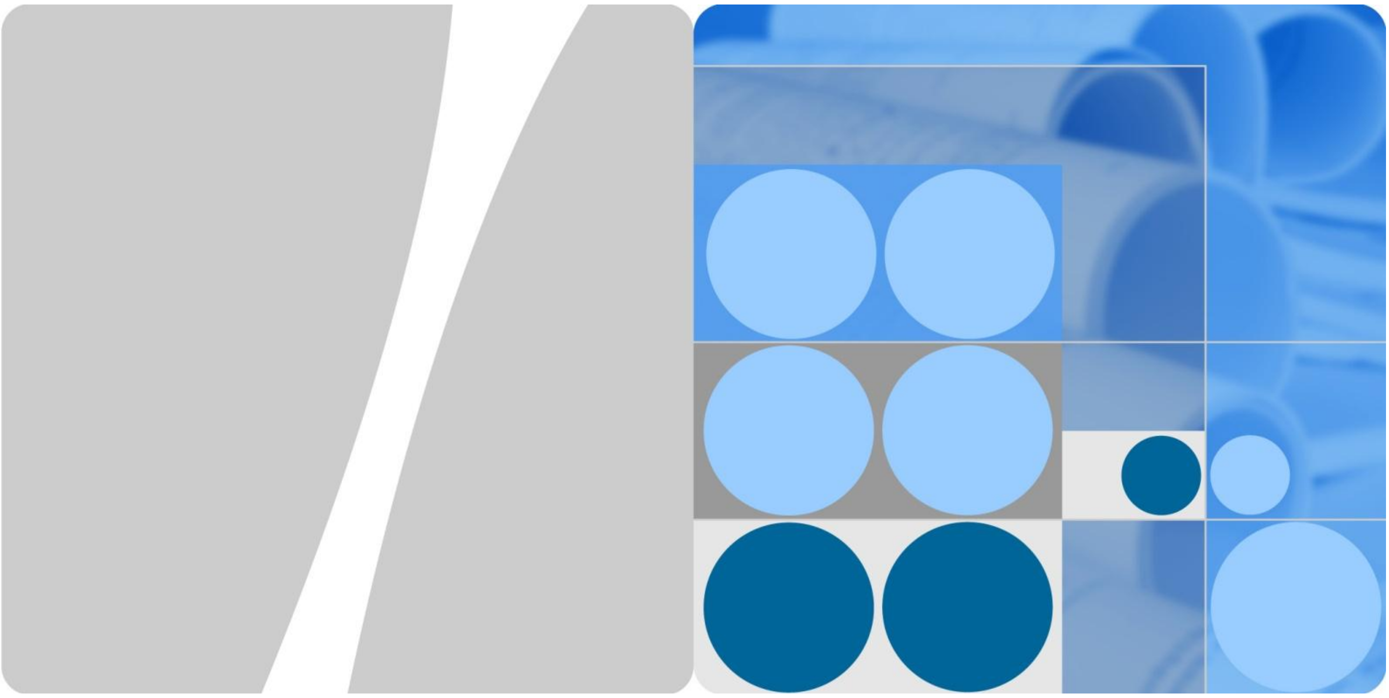

WLAN Radio Calibration Technology White Paper

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About This Document

Keywords

Radio, calibration, neighbor relationship, DCA (Dynamic Channel Assignment), TPC (Transmit Power Control)

Abstract

Radio calibration is a radio resource management solution to enable a wireless network to quickly adapt to changes in the radio environment. It aims to ensure optimal communication quality and make best use of wireless networks.

This document describes the implementation of radio calibration and major applications on networks.

Abbreviations

Abbreviation	Full Name
DCA	Dynamic Channel Assignment
TPC	Transmit Power Control
DFS	Dynamic Frequency Select
AP	Access Point
AC	Access Control

Contents

1 Background

With the explosive growth of mobile terminals, more and more enterprise applications are deployed on mobile terminals and more and more key enterprise applications are transmitted over enterprise WLAN networks. Users benefit from freedom and flexibility of these mobile applications, with their production efficiency, cooperation, and customer response capability improved. Enterprise users expect to obtain better experience in various scenarios. This requirement makes WLAN networks grow in scale. AP topology and radio management also becomes more complicated. If radios are managed manually, technical personnel must have rich experience. Manual check and maintenance will also increase operation and maintenance (O&M) costs.

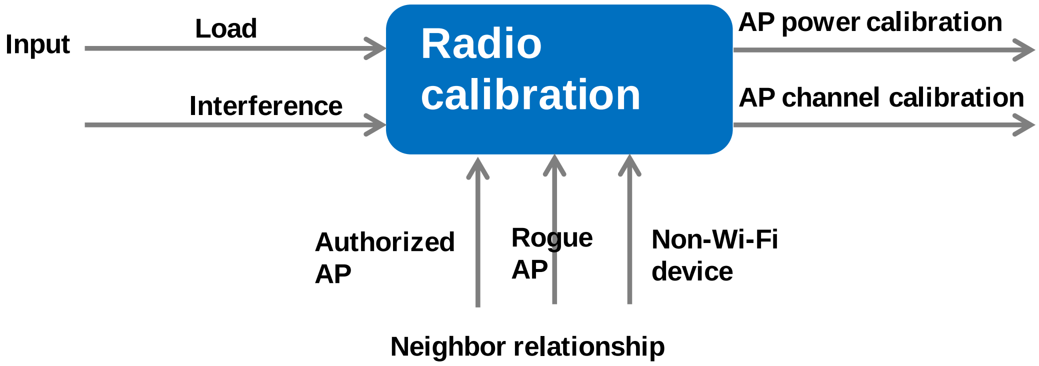
Automatic radio calibration technology can solve the radio management problem and therefore attracts more and more attention. Similar to the self-organizing network (SON) feature of a wireless communication system, automatic radio calibration can automatically allocate channels and power to newly connected APs, adjust power and channels of APs according to the WLAN environment during O&M, and recover the coverage holes when detecting APs out-of-service or offline. These are the self-organizing, self-optimization, and self-repairing functions of radio calibration.

In addition, automatic radio calibration technology also improves WLAN network stability, ensures the network performance when radio performance deteriorates, and recovers coverage holes when APs are out of service.

2 Technology Implementation

During radio calibration, authorized APs collect information about surrounding authorized APs, rogue APs, and non-Wi-Fi devices, and report the information to the AC. The AC generates AP neighbor relationships on the network based on information collected from authorized APs. Then the AC uses Dynamic Channel Assignment (DCA) and Transmit Power Control (TPC) algorithms to calculate the new transmit power and channels based on the neighbor relationships, interference, and load information, and delivers the new transmit power and channel information to the APs. Neighbor relationship, DCA algorithm for channel calibration, and TPC algorithm for power calibration are the key aspects of automatic radio calibration technology and are described in this section.

Figure 2-1 Radio calibration principle



When higher bandwidth is required, 40 MHz or even 80 MHz channels are used on WLANs. Huawei radio calibration can be used in networking scenarios of 20 MHz, 40 MHz or 80 MHz channels.

2.2 Neighbor Relationship

Neighbor relationship is the basis of a calibration algorithm, and neighbor probing is the key to establishment of neighbor relationships. The neighbors include authorized APs, rogue APs, and non-Wi-Fi devices. Limited by frequency resources, 40 MHz and 40 MHz channels prefer the 5G frequency band. Therefore, 40 MHz and 40 MHz channels in the 5G band are used as an example in this document. The process of establishing a neighbor relationship consists of three steps: neighbor probing, neighbor information collection, and neighbor information reporting and neighbor relationship establishment.

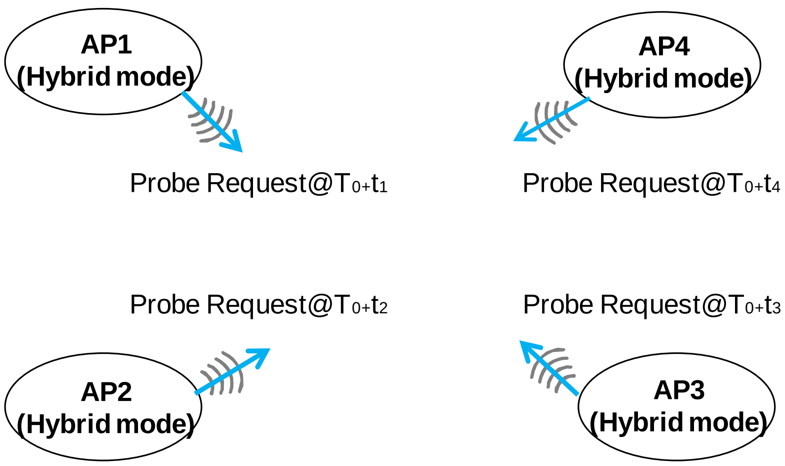
2.2.1 Neighbor Probing

Neighbor probing enables neighboring APs to be aware of a local AP or the local AP to be aware of neighboring APs. Two methods are available for probing neighbors: active probing and passive probing.

2.2.1.1 Active probing

A local AP actively sends Probe Request messages to announce its existence to neighbors. The AP sends Probe Request messages certain times (six times within 60 ms by default) within a period of T_0 (1 minute by default) to different channels. The Probe Request messages carry a specific multicast address. To prevent an AP from missing neighbor information caused by concurrent messages, a random delay *t* is added to T_0 for each AP for the AP to receive neighbor messages. When there are a large number of APs on a network, probe conflict may occur. To prevent this problem, the AC provides a mechanism to add A to the probe result of B if A receives messages from B but B does not receive messages from A.

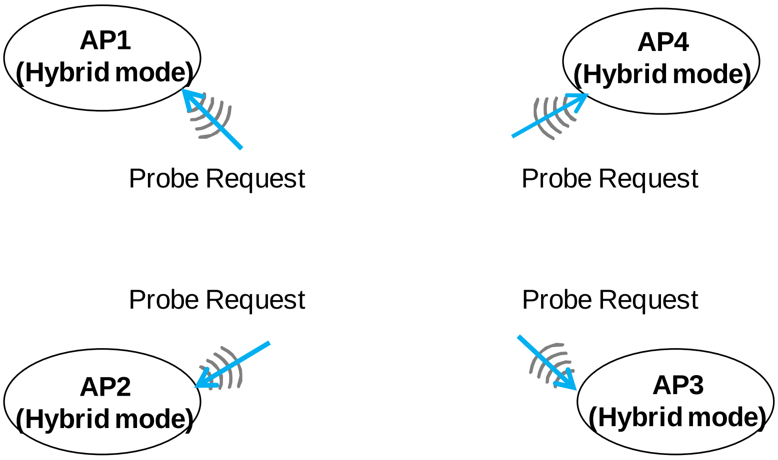
Figure 2-2 Active probing



2.2.1.2 Passive probing

APs passively receive neighbor information to detect surrounding APs. Passive probing is used to collect interference information from neighboring APs, rogue APs, and non-Wi-Fi devices.

Figure 2-3 Passive probing



Is neighbor probing performed to probe all or some of channels on a network? In fact, Huawei radio calibration supports both the methods.

Probing all channels: probes all the channels according to the corresponding country code. This method can collect more comprehensive information about rogue APs, but it takes a longer time to poll all the available channels, which may have a large impact on services.

Probing used channels: probes only channels configured on the network management system (NMS). This method does not affect information collection of authorized APs because authorized APs use the configured channels. This method does not affect rogue AP probing because it can detect rogue APs that work in the same channels as the authorized APs. Obviously, this probe method is recommended.

Neighbor probing on the 20 MHz, 40 MHz, and 80 MHz channels is performed on the channels of the 20 MHz bandwidth, that is, the sub-channels of the 40 MHz and 80 MHz bandwidth are probed. For example, the channel set used by the 40 MHz bandwidth in a 5 GHz HT40 networking is {36, 44}; therefore, its neighbor probing channels are {36, 40, 44, 48}. In active probing mode, an AP sends Probe Request messages to the four sub-channels in turn. In passive probing mode, an AP detects Probe Request message on the four sub-channels in turn.

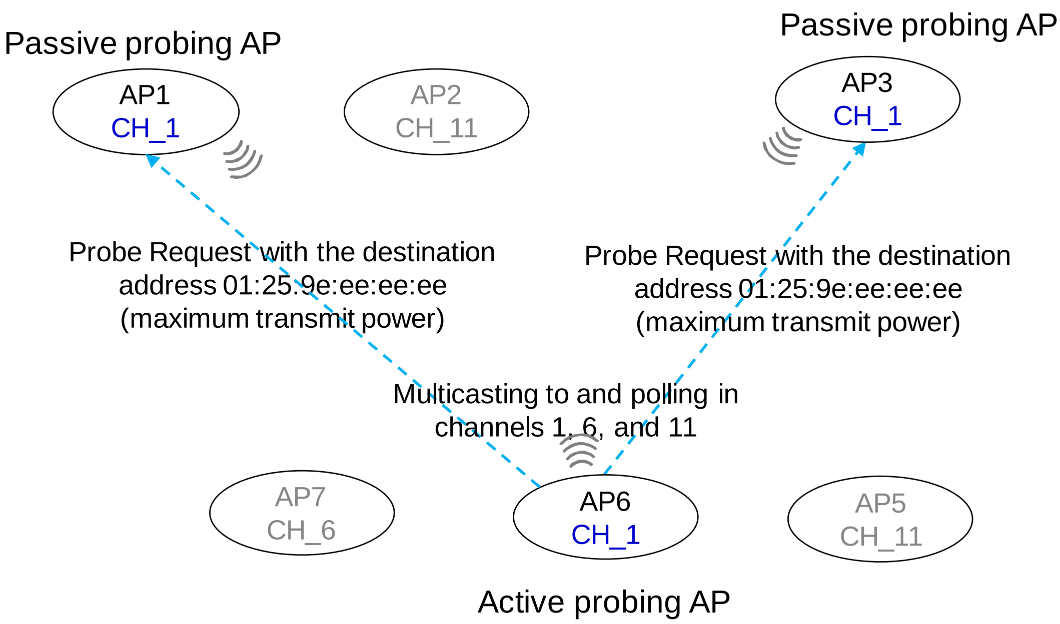
Channel	36	40	44	48
HT20	36	40	44	48
HT40	36		44	

2.2.2 Neighbor Information Collection

Information about an AP's neighbors, load and interference needs to be collected and used as input for radio calibration calculation.

2.2.2.1 Authorized AP

Figure 2-4 Collecting information of authorized AP neighbors



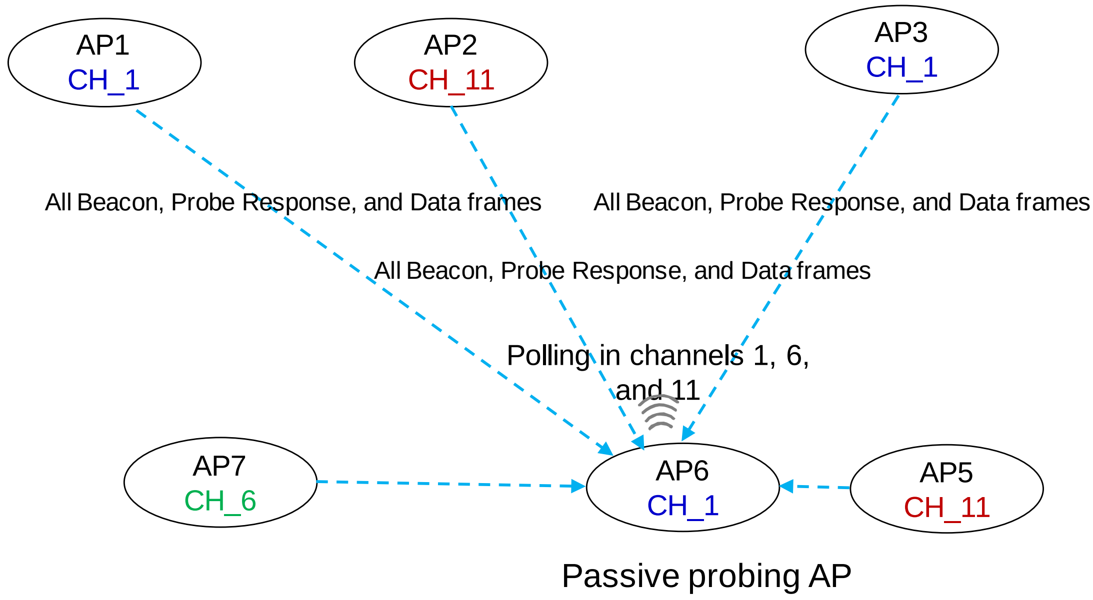
Neighbor relationship:

In active probing, an AP sends Probe Request messages to different channels (such as 1, 6, and 11) in turn using the maximum transmit power. In passive probing, APs on the same channel as the active AP receive Probe Request messages. The messages used for neighbor probing carry the specific multicast address 01:25:9e:ee:ee:ee.

Neighbor interference:

In fact, authorized neighboring APs do not send messages using the maximum transmit power when interference between them is not high. Therefore, you need to collect information about interference between authorized APs. The active AP sends Beacon, Data, Probe Request, and Probe Response messages in different channels in turn to collect the actual interference information. The interference depends on the average value of top 20 signal strengths of these messages.

Figure 2-5 Collecting information of interference to authorized APs



Neighbor load:

In addition to the neighbor relationship and interference, load of each authorized AP is also collected during radio calibration. The load of an authorized AP is determined by its uplink and downlink throughput.

2.2.2.2 Rogue AP

Neighbor relationship:

The WIDS and WIPS module identify rogue APs and the neighbor relationship between a rogue and an authorized AP.

Neighbor interference:

The active authorized AP sends Beacon, Data, Probe Request, and Probe Response messages in different channels in turn to collect interference from rogue APs. The interference depends on the average value of top 20 signal strengths of these messages.

Neighbor load:

The authorized AP collects loads of rogue APs on the same working channel. It collects Data frames received from rogue APs and calculates the uplink and downlink throughput according to the frame size and number of frames.

2.2.2.3 Non-Wi-Fi Device

Neighbor relationship:

Non-Wi-Fi interference derives from non-Wi-Fi devices such as microwave ovens and cordless phones that use the same frequency band as the Wi-Fi system. Non-Wi-Fi interference is collected by spectrum analysis module.

Neighbor interference:

The spectrum analysis module collects the following information: device type, spectrum type (frequency hopping or fixed frequency), signal strength, channel, and interference.

Neighbor load:

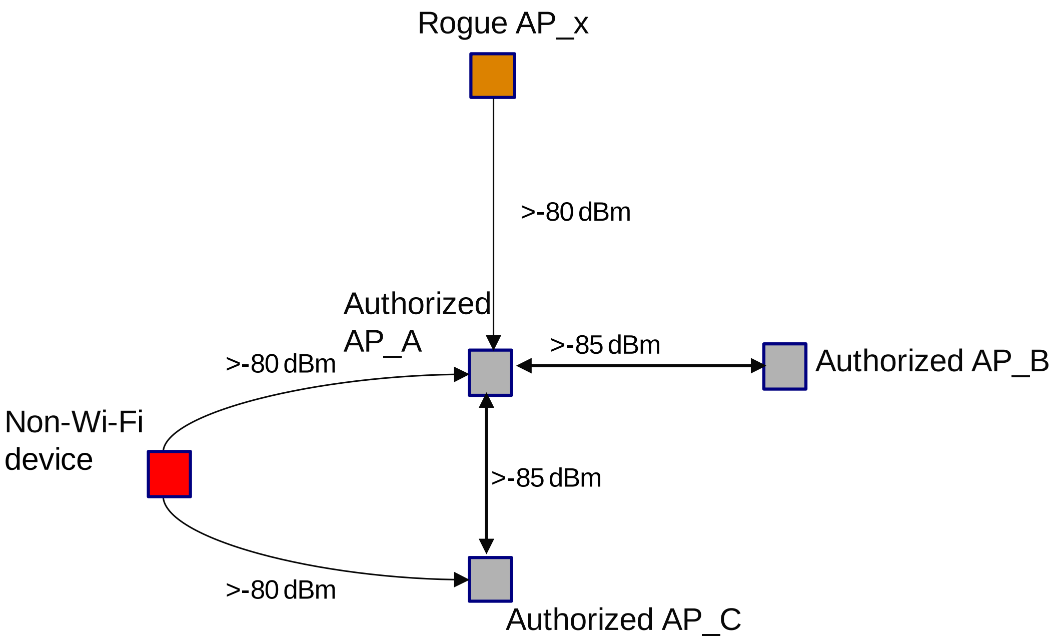
The load of non-Wi-Fi devices is calculated based on the load of interfered authorized APs.

2.2.3 Neighbor Relationship Reporting and Neighbor Relationship Establishment

Based on the probe result reported by APs, the AC can obtain the neighbor relationship between each AP and its neighboring devices, and between all radio devices, including authorized APs, rogue APs, and non-Wi-Fi devices connected to the AC, as shown in Figure 2-6. To avoid huge data reported to the AC, APs only report authorized neighbors of which the signal strength is greater than -85 dBm and unauthorized neighbors of which the signal strength is greater than -80 dBm. The devices and neighbor relationships are described as nodes and edges in the figure.

- Node: includes authorized APs, non-Wi-Fi devices, and rogue APs.
- Edge: indicates the neighbor information between two nodes, including the interference and other auxiliary attributes such as load. In addition, an edge is directional. For example, the edge between the non-Wi-Fi device and authorized AP_A in the following figure indicates the interference of the non-Wi-Fi device to AP_A.

Figure 2-6 Establishing neighbor relationship



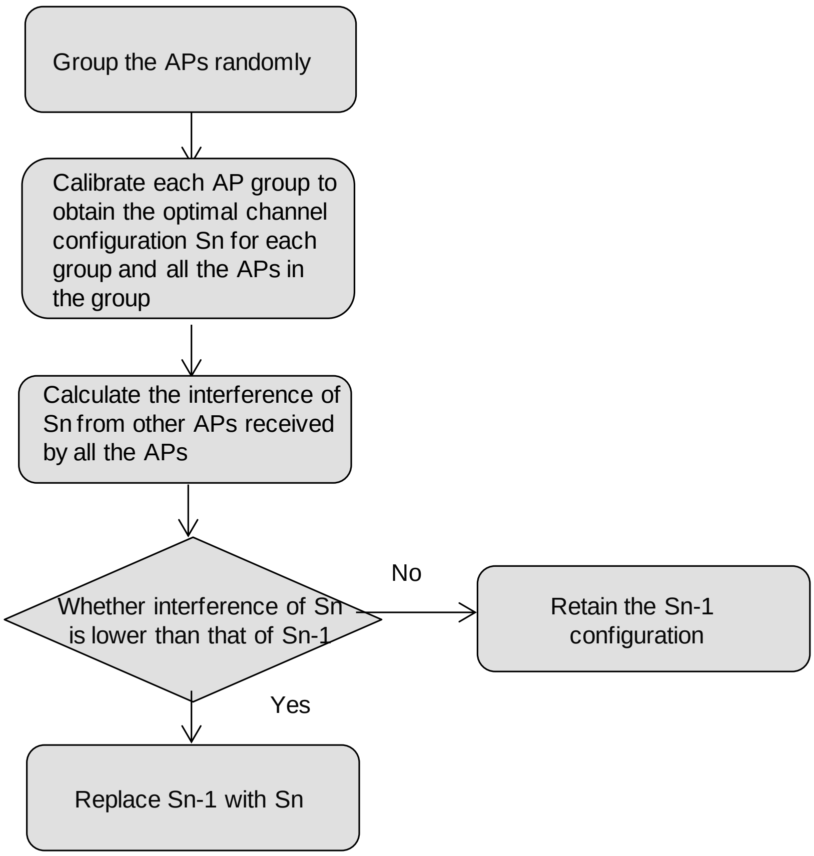
2.3 Channel Calibration

2.3.1 Global Channel Calibration

After obtaining the neighbor relationship topology, interference and load information, the APs use the DCA algorithm to allocate channels. DCA is an iterative algorithm. During each iteration process, DCA allocates channels to APs and formulates AP-Channel combinations. The AP compares each AP-Channel combination with the one used last time. If the new combination results in performance improvement, the AP uses the new combination to replace the one used last time, and continues to compare the new combination with another AP-Channel combination. If the new combination does not lead to performance improvement, the AP compares the one used last time with another AP-Channel combination.

However, the number of AP-Channel combinations increases exponentially as the number of APs increases. If all the combinations are iterated, it may result in low processing efficiency. Huawei uses the DCA algorithm to divide APs into several groups and perform iteration for each AP group to obtain the optimal AP-Channel combination and allocate channels to all the APs in the group. During an iteration process, DCA calculates the sum of interference received by each AP from all other APs, and then the sum of interference of all APs, and uses the value as the result of an iteration process. The DCA algorithm compares the results of multiple iteration processes to obtain the AP-Channel combination with the lowest interference.

Figure 2-7 One iteration process



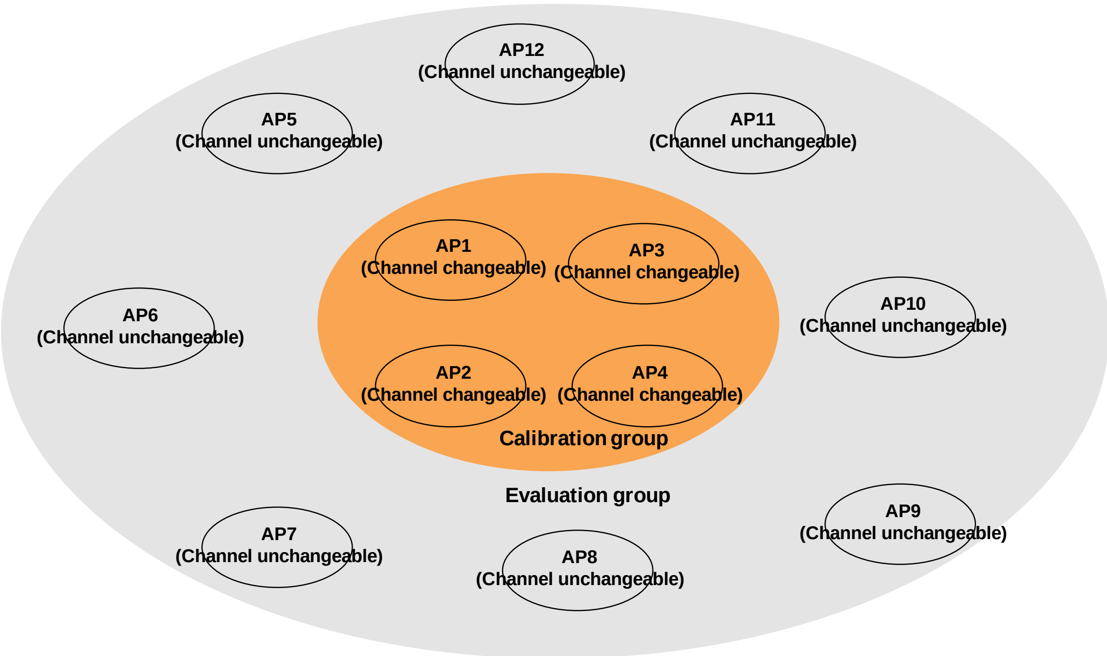
When the channels of all APs need to be calibrated, group the APs at random. When the channels of only some APs need to be calibrated, for example, the APs that are severely interfered by rogue APs, divide these APs in to one group and obtain the optimal AP-Channel combination for the group.

2.3.2 Partial Channel Calibration

An AP needs to traverse all the channels to obtain the optimal AP-Channel combination for the APs in a group. The AP calculates the total value of interference to all APs in the group.

As shown in Figure 2-8, APs are grouped into the calibration group (in orange) for calculating the interference, and the evaluation group (in grey) for calculating the comprehensive interference index. APs in the calibration group are also included in the evaluation group.

Figure 2-8 Calibration group and evaluation group



1. Generate an AP-Channel combination for the calibration group.

   Allocate channels to all the APs in the calibration group. The calibration group in the preceding figure contains four APs. If channels 1, 6, and 11 are used, there will be 81 AP-Channel combinations.

2. Calculate the comprehensive interference index of the AP-Channel combination.

   Calculate the total sum of interference of each AP received from other APs including authorized and rogue APs. The interference refers to strength of interference signals and AP load.

   Calculate the total sum of interference of all APs to obtain the comprehensive interference index for the current AP-Channel combination.

When an AP works at the 20 Mbit/s bandwidth, the interference equals to the AP's signal strength. The following describes how to calculate the interference signal strength at the 40 Mbit/s or 80 Mbit/s bandwidth.

Authorized AP

The signal strength of an AP working at the 40 Mbit/s or 80 Mbit/s bandwidth differs from that working at 20 Mbit/s bandwidth. The interference of a high-bandwidth channel is determined by the maximum signal strength of its sub-channel at the 20 Mbit/s bandwidth. Take the HT40 channel (44 + 40M) as an example. As shown in the following table, an AP has two co-channel neighbors, and the interference of the two neighbors in channel 44 is RSSI0 and RSSI2, in channel 48 is RSSI1 and RSSI3. The neighbor interference to the AP's candidate working channel is calculated as max(RSSI0, RSSI1) + max(RSSI2, RSSI3).

Channel	44	48
Authorized neighbor 1 interference	RSSI0	RSSI1
Authorized neighbor 2 interference	RSSI2	RSSI3
HT40 candidate working channel interference	max (RSSI0, RSSI1) + max (RSSI2, RSSI3)	

Rogue AP and Non-Wi-Fi Devices

The signal strength of an AP working at the 40 Mbit/s or 80 Mbit/s bandwidth differs from that working at 20 Mbit/s bandwidth. Interference of non-Wi-Fi devices is distributed in several consecutive channels. The interference of a high-bandwidth channel is determined by the maximum signal strength of its sub-channel at the 20 Mbit/s bandwidth. Take the HT40 channel (48 + 40M) as an example. As shown in the following table, the interference of a non-Wi-Fi device is calculated as max(RSSI0, RSSI1) + RSSI2. The interference of a rogue AP is determined by the maximum signal strength of its sub-channels at the 20 Mbit/s bandwidth, such as max(RSSI3, RSSI4) in the following table.

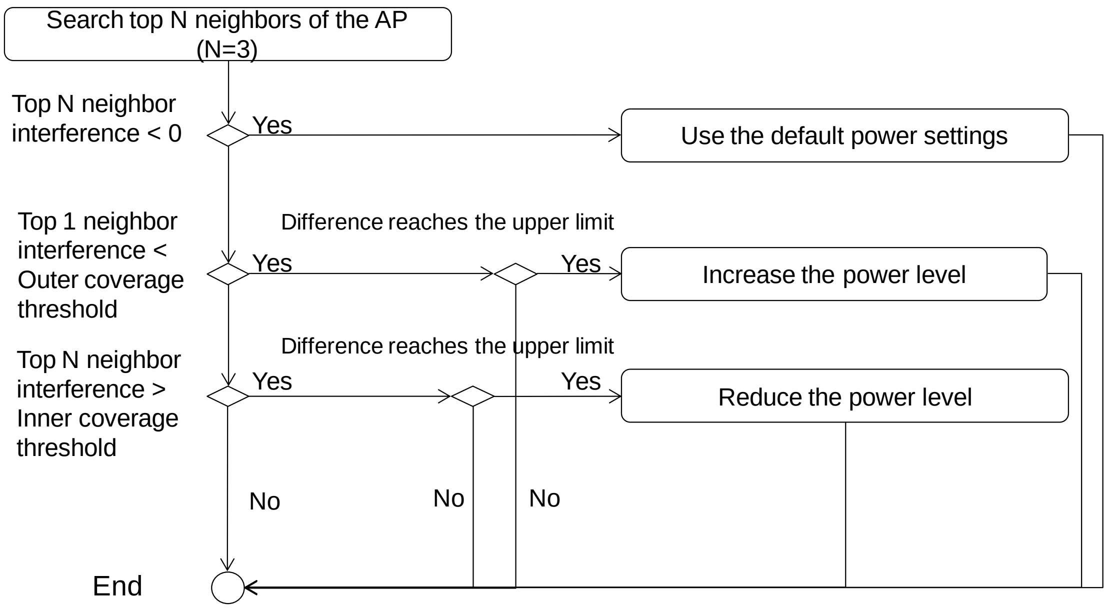
Channel	44	48	52	56
Non-Wi-Fi interference		RSSI0	RSSI1	RSSI2
Rogue AP interference		RSSI3	RSSI4	
HT40 candidate working channel interference (non-Wi-Fi interference)	max(RSSI0, RSSI1)+RSSI2			
HT40 candidate working channel interference (rogue AP interference)	max(RSSI3, RSSI4)			

3. Repeat step 1 and record the comprehensive interference index of all the AP-Channel combinations.
4. Select the optimal AP-Channel combination for the calibration group.

2.4 Power Calibration

TPC is a transmit power control algorithm. Both TPC and DCA are used in automatic radio calibration, but they are independent from each other. Different from DCA, TPC processes the APs in returns at random.

Figure 2-9 Power calibration process



AP power does not need to be adjusted when no interference source exists around the AP. This seldom occurs unless the AP provides signal coverage for an isolated area.

When neighbors exist and the strongest signal strength of a neighbor is lower than the outer coverage threshold, and the difference between them reaches a specified upper limit, the neighboring APs provide poor signal coverage and the AP power must be enlarged.

When neighbors exist and the interference received from Top 3 neighbors is larger than the inner coverage threshold, and the difference between them reaches a specified upper limit, the neighboring APs are overlapping with each other and the signals in the overlapping area are too strong. This indicates that the signal strength of at least three APs has exceeded the inner coverage threshold and the AP transmit power must be reduced.

3 Benefits to Customers

With the wide application of radio calibration on WLAN networks, it shows great advantages in improving network performance and reliability and reducing O&M costs.

1. Remaining the optimal network performance

   The radio environment changes frequently. For example, a rogue AP associates with the network; a cordless phone accesses the network; an AP becomes out-of-service; or two APs interfere each other due to their location changes. All the changes to the radio environment may result in performance deterioration of the WLAN. Radio calibration can intelligently manage radio resources in real time through automatic monitoring, analysis, and adjustment, to quickly adapt to the radio environment changes, remaining the optimal network performance.

2. Reducing deployment and O&M costs

   The traditional O&M mode requires a lot of manual intervention. You need to plan channels in the deployment phase, monitor network performance in the maintenance phase, analyze and locate performance problems, and adjust the channels correspondingly. All these works seem to be simple, but require rich experience and deep understanding of wireless technology. Radio calibration can automatically manage radio resources to reduce manual intervention, requirements of the O&M personnel, and O&M costs.

3. Enhancing WLAN network reliability

   Performance monitoring allows you to quickly detect microwave oven on a WLAN network. Then you need to analyze and locate the microwave oven location, the spectrum used by the microwave oven, the interfered APs, and channels used by the APs. After all the information is collected, you can optimize the channels to avoid interference of the microwave oven. It takes a long time to perform manual analysis and troubleshooting, which brings challenges to WLAN reliability. Radio calibration can reduce the impact caused by performance deterioration in a timely manner through automatic monitoring, analysis, and adjustment. This greatly improves system reliability and provides users with better experience.

   It should be noted that, although automatic radio calibration technology reduces the workload in the deployment and maintenance phases, it cannot substitute the site survey during the WLAN planning phase. You must carry out the site survey to determine the AP deployment position and signal penetration loss to ensure that service APs have strong signals and interfering APs have weak signals.

   In addition, although automatic radio calibration technology maintains network status and network reliability, channel probing and switching during the calibration process may have an impact on services. Therefore, you are advised to exercise caution when using the radio calibration function in a high-density scenario with a large service volume.

4 Application Scenarios

4.1 Deployment

During the deployment stage, a network with automatic radio calibration enabled can adjust and optimize the channel and power of each AP without manually planning. If a large number of APs are deployed in an office, it takes a long time to manually plan the AP channel and power. Radio calibration can allocate channel and power for each AP automatically, reducing the deployment cost and ensuring fine network status. After all APs are deployed and have gone online, the manual trigger mode can be used by running the **calibrate manual startup** command. For details on the other configuration commands, see the product documentation.

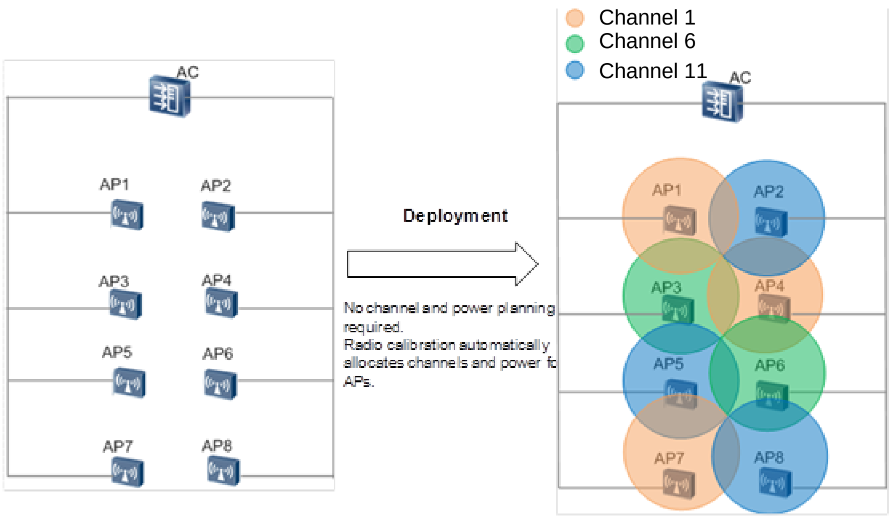
<AC6605> system-view

[AC6605] wlan

[AC6605-wlan-view] calibrate enable manual

[AC6605-wlan-view] calibrate manual startup

Figure 4-1 Radio calibration in the deployment stage



4.2 Routine Maintenance

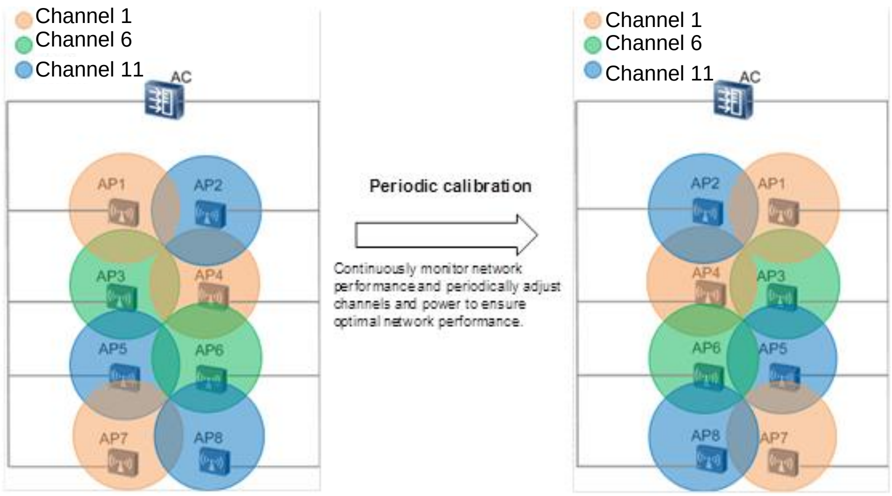
In an office scenario with a large number of APs deployed, the system needs to continuously monitor the network environment changes and periodically perform radio calibration to ensure optimal network performance. As frequent radio calibration may affect user services, the interval for periodical radio calibration should be set to a larger value or radio calibration can be executed at a scheduled time at night. If the scheduled mode is used, the system performs radio calibration at a scheduled time every day. The periodic mode, manual mode, and scheduled mode are mutually exclusive. You need to configure a time for the scheduled mode. For details on the commands, see the product documentation.

<AC6605> system-view

[AC6605] wlan

[AC6605-wlan-view] calibrate enable schedule time 20:30:00

Figure 4-2 Radio calibration in routine maintenance



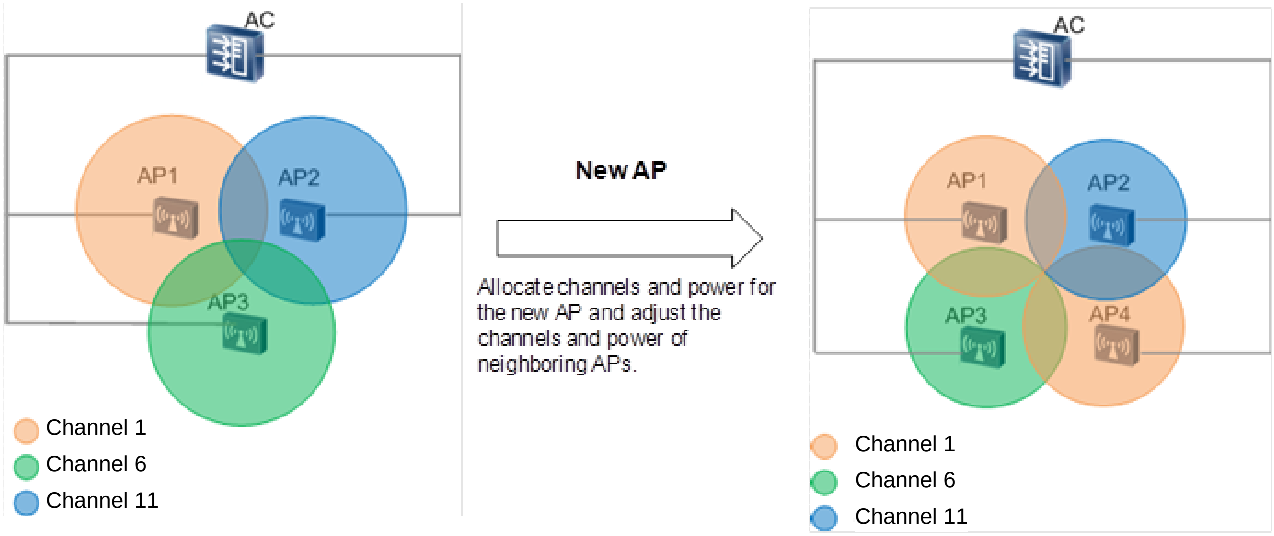
4.3 New AP

A company office has a WLAN network constructed. After the network runs for a period of time, more and more Wi-Fi devices are added to the network; therefore, existing APs cannot meet the capacity and coverage requirements. More APs need to be deployed to ensure sufficient Wi-Fi signal coverage. If radio calibration is enabled, you do not need to plan channels and power for new APs because the WLAN can automatically allocate channels and power for them.

After the AC detects that new APs have gone online, it reserves a period of time for channel and power calibration. The APs detect and collect neighbor information during this period. After the reserved period of time expires, the AC uses the DCA and TPC algorithms to calculate channels and power based on the neighbor information collected and delivers the results to the APs. The APs use the allocated channels and power. During the entire process, you only need to set the new AP's channel-mode and power-mode to **Auto**. For details on the other configuration commands, see the product documentation.

```
<AC6605> system-view
[AC6605] wlan
[AC6605-wlan-view] radio-profile name 80211b
[AC6605-wlan-radio-prof-80211b] channel-mode auto
[AC6605-wlan-radio-prof-80211b] Power-mode auto
```

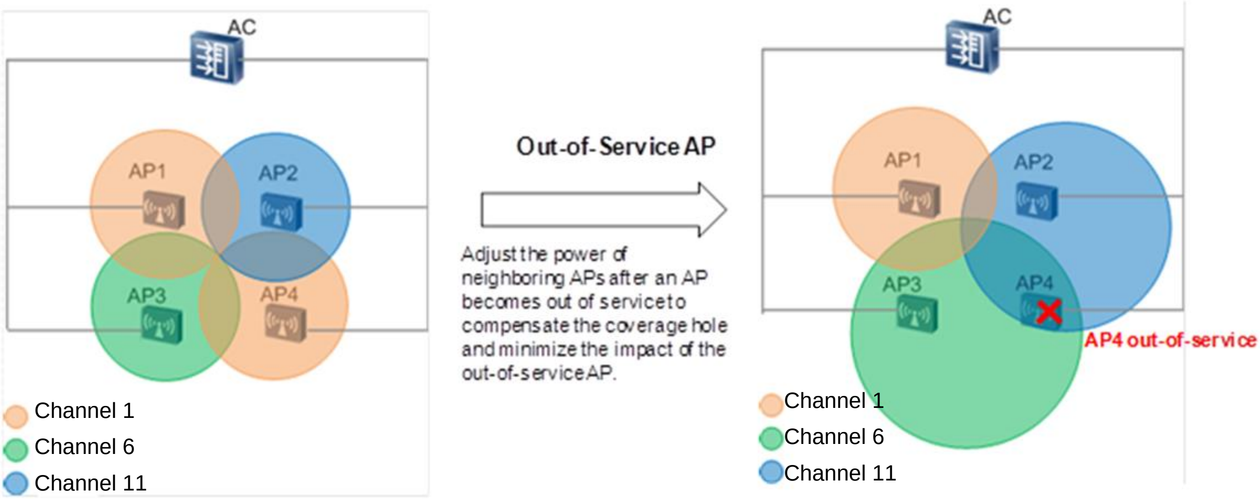
Figure 4-3 Calibrating new APs



4.4 Out-of-Service AP

When a fault occurs during the running of an AP, the AP becomes out of service, and the original coverage area of the AP becomes a coverage hole. The automatic radio calibration can adjust the power of neighboring APs to compensate the coverage hole, ensuring network reliability and minimizing the impact of the out-of-service AP. To enable out-of-service AP compensation, you only need to enable the radio calibration function.

Figure 4-4 Calibrating out-of-service APs



4.5 Rogue AP Interference

Rogue APs exist on a network and use the same frequency band as the authorized APs, resulting in interference to the authorized APs. Automatic radio calibration can be used to avoid or minimize interference of rogue APs to the authorized APs, ensuring network reliability and fine operating status.

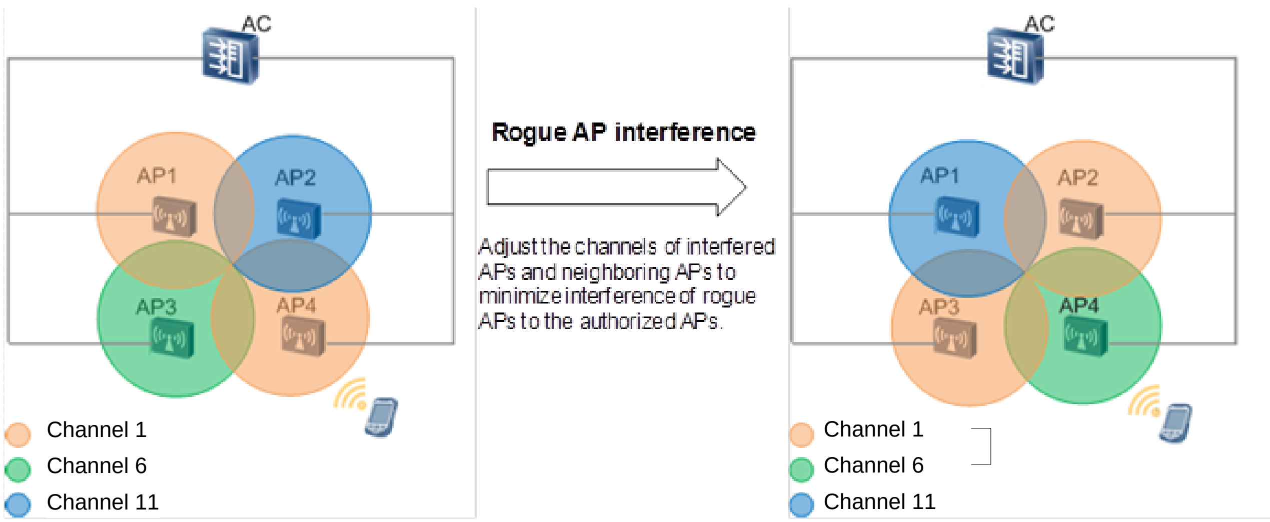
In this scenario, you need to set to calibration policy to **rogue-ap**. For details on the other configuration commands, see the product documentation.

<AC6605> system-view

[AC6605] wlan

[AC6605-wlan-view] calibrate policy rogue-ap

Figure 4-5 Calibrating rogue APs



4.6 Non-Wi-Fi Device Interference

There are microwave ovens in the office. When the microwave ovens are turned on, they produce severe interference to the APs. When detecting interference from the microwave ovens, you can trigger automatic radio calibration in a timely manner to avoid or minimize the interference on APs, ensuring network reliability and fine operating status.

In this scenario, you need to set to calibration policy to **non-wifi**. For details on the other configuration commands, see the product documentation.

<AC6605> system-view

[AC6605] wlan

[AC6605-wlan-view] calibrate policy non-wifi

Figure 4-6 Calibrating non-Wi-Fi devices