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2.4GHz Wireless Local Area Network Optimization in University Dormitory Buildings

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Abstract: *This article describes the wireless network problems met in University dormitory buildings, especially under 2.4GHz spectrum. Through wireless network optimization such as channel re-allocation and transmission power adjustment manually, the performance of the wireless LAN could be improved a lot even for real-time services such as video and live broadcast.*

Keywords: *WLAN (Wireless Local Area Network), Wireless Network Optimization, 802.11, Interference*

1. Introduction

Wireless LAN (WLAN) replaces the old stranded copper wire (Coaxial) with wireless media by using radio frequency (RF) technology in the local area network, making it possible for users to achieve the ideal state of "information portability, and convenience to the world" through the simple access architecture. With the rapid development of Internet applications and the growing number of mobile intelligent terminals, the demand for WLAN has also increased sharply.

Table 1: 802.11 Protocol Family [1]

Protocol	802.11	802.11b	802.11a	802.11g	802.11n	802.11ac Wave1	802.11ac Wave2	802.11ax
					WiFi 4	WiFi 5		WiFi 6
Proposal Time	1997	1999	1999	2003	2009	2013	2015	Officially released in 2019, Release 2 in 2022
Frequency	2.4GHz	2.4GHz	5GHz	2.4GHz	2.4/5GHz	5GHz	5GHz	2.4/5/6GHz
Bandwidth Supported	NA	20MHz	20MHz	20MHz	20/40MHz	20/40/80 MHz	20/40/80/160MHz, 80+80MHz	20/40/80/160MHz, 80+80MHz
Channels (20MHz)	NA	14	14	14	14/24	24	24	24
Highest Order Coding	NA	DBPSK/ DQPSK	64QAM	QPSK	64QAM	256QAM	256QAM	1024QAM
Maximum Physical Layer Rate	2Mbps	11Mbps	54Mbps	54Mbps	600Mbps	3.4Gbps	6.9Gbps	9.6Gbps
Key Technology		DSSS	DSSS/ OFDM	DSSS/ OFDM	OFDM, 64QAM, 4*4MIMO	OFDM, 256QAM, DL MU-MIMO Beamforming		UL/DL OFDMA, 8*8 MU-MIMO, 1024QAM, Spatial Reuse, BSS-Coloring, TWT (Target Wakeup Time)

From 1990s last century, WLAN standards develops fast. From 802.11b, 802.11a, 802.11g, 802.11n, 802.11ac, to today's 802.11ax, it covers from 2.4GHz or 5.8GHz or both, even 6GHz, and provides bandwidth from former 1Mbps to today's 9.6Gbps. Currently, wireless terminals of 2.4/5GHz dual bands are dominant, and the number of 2.4 GHz wireless terminals is decreasing gradually.

For wireless terminals, generally speaking, single band wireless terminals on 2.4GHz accounts for about 10%-20% of total terminals on campus in China today. For Access Points (APs), although the

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new wireless APs on campus almost support dual bands, even supporting 802.11ax, there are still some buildings only installed single band AP of 2.4GHz many years ago. So in the building, all wireless terminals have to operate on 2.4GHz and the wireless performance is limited.

For daily operation in such buildings, many wireless access problems occurred, which have to be solved through wireless network optimization. In this article we only focus on 2.4GHz wireless network optimization.

2. 2.4GHz Wireless Network Communication Problems

Generally, the wireless Access Point Controller (AC) will dynamically adjust the channels and transmission power of the APs according to their neighbor relationships. This makes the initial system configuration easy to implement. However, this may cause the network problems such as co-frequency interference in 2.4GHz to deteriorate the wireless communication quality [2].

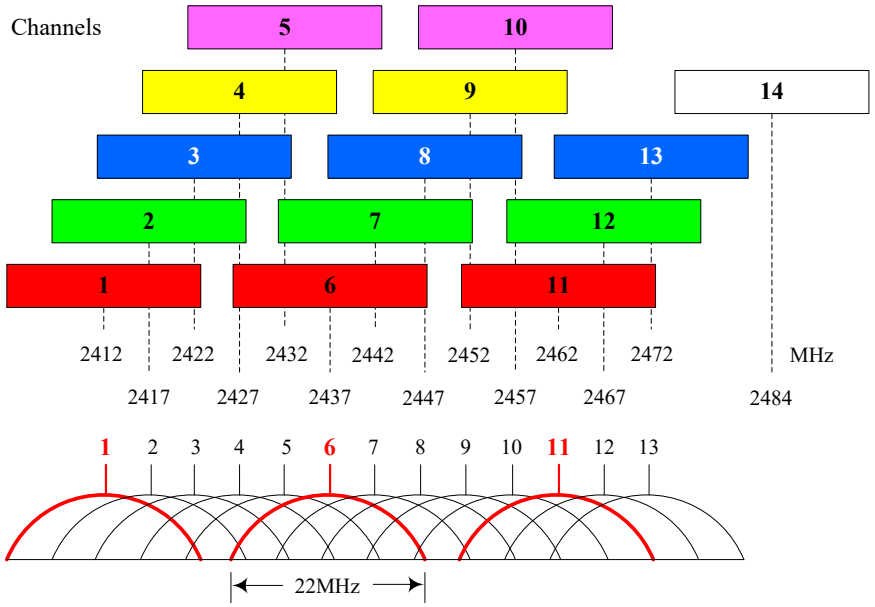

Figure 1: Channel planning of 2.4GHz spectrum

2.1. Frequency Conflict in 2.4GHz

IEEE 802.11 protocol stipulates that the frequency range of 2.4GHz frequency band is 2.4GHz~2.4835GHz, with a total of 14 channels (only the first 13 channels are used in China). The bandwidth of each channel is 22MHz, and the interval between adjacent channels is 5MHz. Among the 13 channels available, the three channels that do not overlap each other have three combinations: 1/6/11, 2/7/12 and 3/8/13. In order to reduce the interference between AP channels, in the real wireless network plan procedure, we will select three completely non-overlapping channels for planning. The most commonly used channels in the world are 1/6/11.

Generally, the wireless network system vendors can support frequency auto allocation on both 2.4GHz and 5.8GHz. However, in dormitory, the rooms are too many and each room installs an AP. Automatic allocation of the frequency may lead unreasonable result in communications. The automatic channel allocation algorithm is complex, and the channel of a room AP may overlap with the channel of the upstairs or next door. Because 2.4GHz only utilizes 3 frequency channels, 1, 6 and 11 with 22MHz bandwidth, so the confliction is much worse than 5.8GHz, because 5.8GHz utilizes more frequency channels. Also, the frequency of Bluetooth and some household appliances around us is also on 2.4GHz, which makes 2.4GHz wireless environment much worse.

2.2. High Transmission Power Problem

The default setting of the transmission power of AP is also set automatically. To maximize the coverage to achieve better performance, AP tends to make the transmission power higher. However,

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because the room density of the dormitory is much higher than in common buildings, higher transmission power makes the wireless Co-frequency interference between rooms very high.

3. 2.4GHz Wireless Network Optimization Solutions

3.1. Re-allocate the Channels of APs According to the Frequency Plan

The signals between APs on the same floor should be isolated as far as possible to reduce interference of the same frequency and adjacent frequency, which means reduce the visibility between the APs. The AP channels can be used are 1, 6 and 11. This optimized channel allocation can effectively increase the access bandwidth of each AP, and also reduce the duty ratio.

Re-allocate the channels in each room according to the plan to ensure that the channels in the upstairs, downstairs, left and right rooms are staggered to reduce co-frequency interference [3].

6F	11	6	1	11	6	1
5F	6	1	11	6	1	11
4F	1	11	6	1	11	6
3F	11	6	1	11	6	1
2F	6	1	11	6	1	11
1F	1	11	6	1	11	6

Figure 2: Channel re-allocation for dormitory buildings rooms

3.2. Manual Adjustment of Ap's Transmission Power

If the AP's transmission power is not adjusted effectively, it will interfere with other APs. We should adjust the AP transmission power reasonably according to the actual application scenario. In the dormitory project implementation, we recommend to adjust the power manually and reduce the AP's transmit power down to about 12dBm, while the automatic adjustment function can be appropriately used in other specific open areas.

3.3. Test the Signal Strength of the Mobile Terminals

The AP's signal parameters are controlled within the following range, and the impact on this floor and downstairs or upstairs AP can be minimized:

a. The signal strength under the antenna shall be controlled at about - 40dBm;

b. The signal strength of the farthest location in the room is controlled at about -60dBm;

c. Whenever the AP signals of the same channel are visible to each other, try to keep the signal strength below - 80dBm. At this time, it can be considered that there is basically no impact on each other.

d. If the signal strength of the connected AP sensing the terminal signal decreases to -80dBm, the AP will force it to go offline, solving the problem of under poor signal terminals not disconnecting from the original AP instead of switching to a better signal AP (because the roaming control is determined by the terminals).

3.4. Enable Speed Limit Function Based on User Air Interface Bandwidth

Due to the sharing feature of wireless network air interface bandwidth, it is recommended to enable the user air interface bandwidth speed limit function to prevent individual user from monopolizing bandwidth [4].

Generally, we adopt static speed limit (specifying the maximum bandwidth per user under the same

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SSID) to limit each user's access speed.

3.5. Enable Layer 2 User Isolation Function

The isolation function between users can reduce the impact of broadcast packets and user-to-user traffic on the network, and can also avoid some ARP attacks, so that the wireless network can be used stably and securely [2].

3.6. Limit the Maximum Number of User Access per AP

Configure the maximum number of user access per AP to 15 terminals to avoid too many users to access to the same AP [2].

3.7. Turn off Low-rate Applications

Turn off low-rate applications reduce the impact of low-rate applications on wireless air interface bandwidth [2].

The prerequisite for the use of this method: good signal coverage must be guaranteed. Use with caution when the terminal signal is weak or the coverage is insufficient.

3.8. Setting of Wireless Terminals' Power Management Properties

Set the power management properties of the wireless terminals to the highest value to enhance the working performance of the wireless terminal and improve the efficiency and stability of data traffic [2].

4. Optimization Results

After wireless network optimization, the wireless packets loss rate drops to below 3% (by Ping), and the delay is reduced to below 10ms. The channel interference is reduced and the channel duty ratio is greatly reduced to ensure the speed of Internet access.

5. Conclusions

By re-allocating 2.4GHz frequency and reduce the transmission power of APs, most of the interference problems could be solve for university dormitory building rooms. In addition, other solutions such as enabling speed limit and Layer 2 user isolation function, turning off low-rate applications could also improve the optimization result. After the wireless network optimization, no students report WLAN problems.

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