ESP8266 Wi-Fi Channel Selection Guidelines

1.   Introduction

ESP8266 can be used as a wireless network interface card (NIC) in embedded systems that require internet connectivity or device-to-device communication. It is also capable of executing application code in standalone modes of operation.

This application note focuses on the networking operation of ESP8266 in general and Wi-Fi standards compliance in particular. As ESP8266 implements the network stack internally and also integrates the entire RF circuitry, the actual operation of the transmitter is hidden from the developer. The network hardware is controlled through a set of APIs or commands that do not distinguish between channels based on device location. Because of this, the channel specifications are often overlooked by application developers. However, it is important that the channel allocation be done properly for compliance with laws as well as to observe good design practices.

The IEEE 802.11 (2012) defines standards and requirements for WLAN implementation. Specifically, it contains Physical Layer (PHY) and Medium Access Control (MAC) specifications. In this application note, the 802.11 channels and worldwide allocation schemes are discussed. Terms WLAN/Wi-Fi/802.11 have been used interchangeably throughout the note.

IEEE 802.11 specifies 14 channels for low power Wi-Fi communication in the ISM (unlicensed) band, as shown in Table 1. These channels are spaced 5MHz apart, except ch.14, which is spaced 12 MHz away from ch.13. In 802.11 b/g/n modes, the typical bandwidth requirement per channel is 20 MHz and a guard band of 2 MHz is added to that. Thus, there is potential overlap in operating frequency range when two transmitters operate in the same airspace.

Table 1. IEEE 802.11 channels

Channel No.	Frequency (MHz)	Channel No.	Frequency (MHz)
1	2412	8	2447
2	2417	9	2452
3	2422	10	2457
4	2427	11	2462
5	2432	12	2467
6	2437	13	2472
7	2442	14	2484

2. Channel Selection Considerations

In a Wi-Fi network, each wireless connected device must be set to a particular configuration before it can communicate with other devices. Care must be taken when setting attributes that affect the physical layer operation, such as channel selection. While the APIs provided by Espressif let developers set the channel to their choice, it is the their responsibility as the developer to make sure that the chosen channel is legal in their locality. Do note that the 802.11 b/g/n modes implemented in ESP8266 operate within an unlicensed frequency range of 2400 ~ 2484 MHz. However, this does not mean that the use of all channels is acceptable. Here are some factors that should be taken into account by a developer when programming channel selection behavior of wireless products:

- Interference concerns

- Legal considerations

- FCC rules and transmit power

2.1. Interference Concerns

Wi-Fi channels are spaced 5 MHz apart. However, a channel typically requires up to 20 MHz bandwidth for operation. This results in interference when devices operate in adjacent channels in the same airspace. Therefore, when two transmitters are operating in the same airspace with a possibility of interference, it is good design practice to space the operational channels by at least 20 MHz (or 25 MHz for best results). For example, when one 802.11 transmitter is using channel 1, the other may use channel 5 or 6. Using channel 2 or 3 is not recommended.

2.2. Legal Considerations

While spacing channels widely is better from a system design point of view — there are legal considerations that must be given priority. It is important that the transmitter falls well within the allowed limits in the country of operation. In most countries, the initial channels are usually allowed. For example, channels 1 through 11 may be used safely in most of the countries in the world.

Care must be taken when using the last channels of the spectrum. Using channel 13 and 14 may be prohibited by local authorities in most countries. Also, using channel 13 and 14 must be done carefully as there are chances of interference with the adjacent licensed/restricted bands should the transmitter drift away from the specified channel frequency for some reason.

Also, note that the last few channels are generally used in low power, low range applications and spread spectrum applications (subject to limitations). Please consult the FCC rules for such applications.

Table 2. Legal 802.11 channels

Channel No.	Channel Center Frequency (MHz)	Regulatory Domain	Channel No.	Channel Center Frequency (MHz)	Regulatory Domain
1	2412	FCC/WORLD/TELEC[1]	8	2447	FCC/WORLD/TELEC
2	2417	FCC/WORLD/TELEC	9	2452	FCC/WORLD/TELEC
3	2422	FCC/WORLD/TELEC	10	2457	FCC/WORLD/TELEC
4	2427	FCC/WORLD/TELEC	11	2462	FCC/WORLD/TELEC
5	2432	FCC/WORLD/TELEC	12	2467	WORLD/TELEC
6	2437	FCC/WORLD/TELEC	13	2472	WORLD/TELEC
7	2442	FCC/WORLD/TELEC	14	2484	TELEC[2]

1. Regulatory domains are FCC for the United States, TELEC for Japan, and WORLD for all other countries.
2. Channel 14 for 802.11g is not supported in Japan.

Note that this is general information and developers should consult specifications by regulatory authorities in their area before implementation.

2.3. FCC Rules and Transmit Power

The last few channels have transmit power restrictions. Also, all bands in the unlicensed region have transmit power restrictions in general.

FCC rules state that the maximum permissible power radiation from a transmitter operating in ISM bands is 30 dBm (with 6 dBi antenna gain). As the ESP8266 transmitters available typically provide a smaller output power (~20 dBm maximum, consult the ESP8266 Datasheet for more information) and antenna gain of typically 2 dBi (such as the ESP-WROOM-02), this is not a concern in most applications.

For higher antenna gain in general, for each 3 dBi increase in antenna gain (over 6 dBi), the corresponding transmit power must be reduced by 1 dBm to be FCC compliant.

3. Conclusion

Following the above guidelines will ensure interference free operation with decreased frequency of timeout events and higher effective transmission rates in some cases.