Analysis based on Signal of 802.11g Wireless Networks

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Abstract. As the rapid development of Wireless Local Area Network, 802.11g has been widely adopted. It plays an important role to the future of wireless communications. Based on the 802.11g, this paper emphatically analyzed orthogonal frequency division multiplexing (OFDM) technology and combined with the author for many years research in the course of teaching experience.

1. Introduction
Wireless Local Area Network (WLAN) develops rapidly and becomes a hot spot of modern mobile communication, with the rapid development of mobile communication technology. There are a variety of WLAN standards applied to indoor environment, such as 802.11b/g working in the 2.4GHz frequency band and 802.11a working in the 5GHz frequency band, etc[1]. Due to different frequencies and technologies, the overall performance of the system is different. The analysis of WLAN protocol standards will produce a great significance to improve the performance of WLAN system. This paper mainly introduces the working principle, structure and key technology analysis of 802.11g standard of WLAN.

2. Overview of wireless network protocols
IEEE802.11a/b/g has been the three most common standards, while IEEE802.11 standard has been developed for more than ten years since its launch[2]. IEEE802.11a standard mainly used in foreign countries, which uses orthogonal frequency division multiplexing (OFDM) technology while in 5GHz frequency band. The IEEE802.11g standard is a new standard proposed widely used by the IEEE working group in recent years, which uses OFDM technology in the 2.4GHz frequency band with two characteristics of high speed and backward compatibility while IEEE802.11b/g all been working in the 2.4GHz frequency band.

Table 1 comparison of IEEE802.11 series standards

| standard  | 802.11  | 802.11b  | 803.11g  | 802.11a  |
|-----------|---------|---------|---------|---------|
| Working band frequency | 2.4G ISM spectrum | 5G. UNII spectrum |
| Communication mechanism | DSSS/FHSS/IR | DSSS/CCK/PBCC | CCK/OFDM/PBCC | OFDM |
| Data rate(Mbps) | 1, 2 | 1,2,5,5,11 | 1,2,…54 | 1,2,…54 |
IEEE802.11 g has become the third generation WLAN standard with its high speed and backward compatibility, officially adopted in 2003. IEEE working group defines four for this standard: the physical DSSS/CCK, OFDM, DSSS/PBCC, DSSS/OFDM, each has its own physical layer convergence process (PLCP) frame structure, the first two is choice mode with the latter two are optional[3].

The input data bit stream from the upper layer which is inserted into pilot frequency for OFDM modulation after perturbation, convolutional coding, interleaving and constellation mapping form eventually WiFi physical layer logic channel signal. After modulation, the signal is added with cyclic prefix and window, and then the leading symbol is inserted to form the signal frame of the physical layer, which is then transmitted through the baseband to the RF transform.

The duration of a frame of signal is uncertain, and the signal length is time-varying due to the burst characteristics of the channel. The signal structure is mainly composed of three parts: the leading symbol, the signal and the data, and the leading part is composed of two parts: the short leading sequence and the long leading sequence.

Short training sequence: it is composed of 10 short training symbols (t1-t10), each symbol is composed of 12 subcarrier modulation, and each symbol period is 16.

Long training sequence: it is composed of two training symbols (T1--T2), each symbol is composed of 52 subcarrier modulation, and each symbol period is 64.

The signal part forms an OFDM symbol separately including the modulation information of the data part, which is transmitted at the BPSK modulation with strong robustness and 1/2 encoding rate. The data part is sent at the data RATE indicated in the RATE field which may consisted of multiple OFDM symbols.

Baseband complex signals can be expressed as:

\[ s(t) = s_{\text{preamble}}(t) + s_{\text{signal}}(t-t_s) + s_{\text{data}}(t-t_d) \]  

While \( t_s = 16 \mu s \) is the duration of the leading training symbol, \( t_d = 20 \mu s \) is the duration of the leading and signal. Subframe signal can be expressed as:

\[ s_{sf}(t) = w_{sf}(t) \sum_{k=-N_{sf}/2}^{N_{sf}/2} d_k \exp[j2\pi k \Delta f(t-T_g)] \]  

While \( N_{sf} = N_d + N_p = 52 \) is generally the subcarrier number, skip the serial number of 0 DC carrier position in order to avoid deviation of the problems of treatment process in d/a or a/d converter, \( w_{sf}(t) \) plays as the window of time domain function, the number of modulation \( d_k \) can be sending data, pilot, or training symbol, is to protect the interval, there are three kinds of different forms as \( T_g \), \( T_g = 0 \mu s \) in short training symbol, in the long training symbol, is the cyclic prefix in OFDM symbol data, can be effective against intersymbol interference (ISI).

The short training sequence is used as the synchronization signal and consists of 10 repeated short symbols. The expression is as follows:

\[ s_{\text{short}}(t) = w_{\Delta t \text{short}}(t) \sum_{k=-N_{sf}/2}^{N_{sf}/2} S_k \exp(j2\pi k \Delta f t) \]  

Sequence \( S_k \) (\( k = -26,\ldots,26 \)), which is defined in[ ], is only non-zero on multiples of 4, and only 12 subcarriers been used, one symbol period \( T_s / 4 = 0.8 \mu s \), \( \Delta T_{\text{short}} = 10 \cdot T_s / 4 = 8 \mu s \).

The long training sequence is used for channel estimation and is composed of two repeated long symbols. The expression is as follows:

\[ s_{\text{long}}(t) = w_{\Delta t \text{long}}(t) \sum_{k=-N_{sf}/2}^{N_{sf}/2} L_k \exp[j2\pi k \Delta f(t-T_g/2)] \]  

Sequence \( L_k \) (\( k = -26,\ldots,26 \)) is defined in [4]. Long training symbols of tow cycles are sented in
order to improve the accuracy of channel estimation.

OFDM symbols of signal and data domain have the same expression, as follows:

\[ s_n(t) = w_{\alpha T_{sym}}(t) \sum_{k=-N_{cp}/2}^{N_{cp}/2} d_{k,n} \exp\left[ j 2\pi k \Delta f \left( t - T_{cp} \right) \right] \]

(5)

Where, \( \Delta T_{sym} = T_{cp} + T_u = 4 \mu s \), the pilot signal is inserted at \((k=-21,-7,7,21)\), and the pilot polarity is determined by a 127-bit pseudo-random sequence \( P_n \).

| Parameter                  | Values  |
|----------------------------|---------|
| Data symbol time \( T_u \) | 3.2us   |
| Cycle prefix time \( T_{cp} \) | 0.8us   |
| OFDM symbol time \( T_{sym} \) | 4.0us   |
| Data subcarrier \( N_d \)  | 48      |
| Pilot subcarrier \( N_p \)  | 4       |
| Sub-carrier spacing \( \Delta f \) | 312.5kHz |
| Total subcarrier bandwidth  | \((N_d+N_p)\Delta f = 16.25MHz\) |

### 3. Analysis of OFDM signal

Orthogonal Frequency Division Multiplexing (OFDM) is a transmission technology that is suitable for transmitting high-speed data in multi-path and doppler Frequency shift wireless channels. Traditional frequency division multiplexing (FDM) system, through the whole frequency band is divided into a number of disjoint sub frequency transmission of parallel data stream, using a set of filter in the receiving end to separate each channel, this way make should have protection band between sub-channels, resulting in the band utilization rate is low, but also had difficulty to implement multiple filters. Figure 1 shows the spectrum comparison diagram of FDM and OFDM. It can be seen from the figure that in the OFDM system, each sub-channel can overlap with each other, so the spectral efficiency is significantly improved compared with the FDM system. In FDM systems, in order to prevent interference between channels, there is a protective band between sub-channels, come into being the spectrum utilization rate lowly.

![Figure 1 spectrum comparison of OFDM and FDM systems](image)

Due to these subcarriers are orthogonal to each other, the data can be transmitted without distortion at the receiving end even though the spectrum of each subcarrier overlaps with each other. Considering that the serial data sequence with a transmission rate of \( 1/T \) is mapped to parallel transmission on \( N \) subcarriers, then the symbol rate will be reduced to:

\[ \frac{1}{T_s} = \frac{1}{NT} \]

(6)

Where, the frequency interval of each subcarrier is \( \Delta f = \frac{1}{T_s} \), and the equivalent low communication signal of OFDM can be expressed as a group of carrier signals transmitted in parallel.
\[
s(t) = \sum_{n=-\infty}^{+\infty} \sum_{k=0}^{N-1} c_{nk} g_k(t-nT_s)
\]

Among them,
\[
g_k(t) = \begin{cases} \left\{ e^{j2\pi f_k t} \right\} & \text{in } [0,T_s] \\ 0 & \text{other} \end{cases}
\]

\((7)\)

\(c_{nk}\) is the symbol transmitted on the \(k\) subcarrier of the \(n\) OFDM symbol interval, \(N\) is the number of subcarriers of the OFDM system, \(T_s\) is the OFDM symbol interval also the symbol interval transmitted on each subcarrier, \(f_k\) is the frequency of the \(k\) subcarrier, \(f_0 = \frac{k}{T_s}\), \(k = 0, \ldots, N-1\) and \(f_0\) is the lowest use frequency. The setting of subcarrier frequency ensures the orthogonality between carriers:

\[
\int_{0}^{T_s} g_k(t) \cdot g^*_l(t) dt = \int_{0}^{T_s} e^{j2\pi f_k t} \cdot e^{-j2\pi f_l t} dt = \int_{0}^{T_s} e^{j2\pi \frac{k-l}{T_s}} dt = T_s \delta(k-l)
\]

\((8)\)

\((9)\)

System model is shown in the figure below:

Figure 2 baseband model of OFDM system

In the early OFDM systems, sinusoidal wave generator and coherent demodulator are used to realize modulation and demodulation. However, when the number of subcarriers is very large, the complexity of the system is too high and the cost is too expensive to receive. In recent years, with the development of lsi technology and digital signal processing technology, it is relatively simple to use IFFT and FFT.

In a subchannel, \(T_s\) is the symbol duration, and is modulated by the carrier frequency \(f_k\), so in the frequency domain, each subcarrier is a function \(\text{sinc}(x)\) of the central frequency \(f_n\), as shown in figure 3 below.

Figure 3 (a) symbol waveform and (b) spectrum of a subcarrier

As the OFDM symbol is the superposition of a series of rectangular code elements in the time domain, it also corresponds to the superposition of a series of functions in the frequency domain. The adjacent subcarriers overlap half of the spectrum, and the central peak of each subcarrier appears at the zero frequency of other carriers, which also reflects the strict orthogonality of each subcarrier.

The processing process of OFDM baseband modulation system is as follows: baseband modulation is carried out on the input bit stream, and the \(n\)-channel parallel symbol stream is formed after the serialization and conversion module[5]. The \(N\) - channel symbol is multi - carrier modulation, that is, \(N\) - point IFFT transform. The data is transformed into A serial data stream of long \(N\) after parallel string transformation, and the cyclic extension of these \(N\) data is carried out, that is, the cyclic prefix CP of \(L\) sample values is added to form A basic OFDM symbol, which is converted by D/A. Into the channel after the filter in the receiving end, the A/D converter, the output of the timing synchronization, data flow estimation deviation, synchronous data flow after delete cyclic prefix CP, parallel data according to OFDM symbols into N road, multicarrier demodulation and FFT transform, after FFT processor and
trace data deviation, and realize the channel estimation, thus demodulation data channel equalization. The received bit stream is obtained after parallel string conversion and baseband demodulation.

OFDM technology is widely concerned because it has the following advantages:

1) High frequency spectrum utilization. In previous transmission methods, the frequency band is generally divided into several disjoint sub-frequencies to transmit data, and enough transition bands are left between the sub-channels, so that the frequency spectrum utilization is not high. However, the OFDM system makes full use of the orthogonality of each subcarrier and allows the spectrum of the subchannels to overlap with each other.

2) High-speed information data flow through the string and transform, convert to a relatively low rate of sub-channel transmission. The symbol period is increased, which can reduce the inter-symbol crosstalk caused by multi-path delay propagation. In addition, general OFDM signals are added with guard intervals. Under the condition that the guard interval length is greater than the maximum path delay, the system can largely eliminate the inter-symbol interference caused by multipath.

3) Effectively counter frequency selective fading and improve system error performance. In the traditional single carrier transmission system, the fading will lead to the failure of the whole communication line. In a multicarrier transmission system, only the subcarriers that fall into the band fading are affected when frequency selective fading occurs in the channel due to multipath transmission.

4) Easy realization of modulation and demodulation. For n-channel subcarriers, the orthogonal modulation and demodulation of each subcarrier can be realized by IFFT/FFT. With the development of large-scale integrated circuit technology and DSP technology, the implementation of IFFT and FFT is relatively simple.

5) Good resistance to multipath effect. Due to its unique signal structure, OFDM is particularly suitable for transmission in urban areas with dense buildings and residential buildings.

6) Wireless data business generally exists asymmetry, namely than uplink data transmission in downlink of data transmission, it is hope that the physical support asymmetric high rate data transmission, OFDM systems can be done by using different number of sub-channels uplink and downlink of different transmission rate requirements.

OFDM technology has become a new generation (4 g) mobile communication and the mainstream of broadband wireless LAN technology, it is because of good properties of OFDM structure in anti-interference, also began to more and more in the field of passive radar signal as the source of the use of this system, the processing of the signal at the receiving end, make full use of the advantages of the system signal.

Although OFDM has the above advantages. However, it is not perfect, and its signal modulation mechanism also makes OFDM signal have some disadvantages in the transmission process:

1) It is very sensitive to the carrier frequency offset and phase noise of the system. When OFDM uses IFFT to realize modulation, each subcarrier is formed by rectangular pulse, which will cause: a) when the frequency interval increases, spectrum sidelobe attenuation of the subcarrier system is slow, and out-of-band interference will be generated; b) if the frequency synchronization error cannot be ignored, each subcarrier will cause interference on other subcarriers. OFDM system requires each subcarrier to maintain strict orthogonality.

2) PAP: peak-to-average Power is too large. OFDM signals are composed of multiple subcarrier signals, which are independently modulated by different modulation symbols. The transmitted data and amplitude are both a random process. OFDM signals are composed of multiple subcarrier signals, which are independently modulated by different modulation symbols. If the signals are in the same phase, the superposition will produce a large instantaneous peak amplitude. Excessive peak-mean ratio will not only increase the complexity of A/D and D/A, but also reduce the efficiency of RF power amplifier.

3) Wide linear range required. Due to higher peak average power ratio (PAPR) and more sensitive to nonlinear amplification, the OFDM modulation system requires a higher linear range of the amplifier than the single-carrier system.

4. Conclusion
Firstly, key technologies of IEEE 802.11g wireless network protocol standard are analyzed and studied in this paper, focusing on OFDM technology and its advantages and disadvantages. Through the analysis and research in this paper, it is able to understand and master IEEE 802.11g network protocol and provide certain technical support for wireless product development.

References
[1] Zhaopin Yuan. On Wireless LAN technology[J], Science and Technology innovation Herald, 2009,NO.21.
[2] Xin Zhou, On the current situation and development of wlan technology [J], Journal of Henan Science and Technology, 2013, NO.08.
[3] Zhendong Luo. Development Trends of WLAN Technology and Standards [J], Focus on Innovation, 2012.04.20
[4] Paul T K, Ogunfunmi T. Wireless LAN comes of age: Understanding the IEEE 802.11 n amendment [J], Circuits and Systems Magazine, IEEE, 2008, 8(1): 28-54
[5] Halperin D, Hu W, Sheth A, et al. 802.11 with multiple antennas for dummies [J]. ACM SIGCOMM Computer Communication Review, 2010, 40(1): 19-25