

Implementing IEEE 802.11b/g wireless Local Area Networks: Planning and Operations

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Abstract

This paper outlines wireless network infrastructure establishment in an outdoor environment and provides experimental methodology and planning test site for an infrastructure mode of IEEE 802.11b/g wireless LAN, using a various types of wireless devices. The paper is also giving in-depth data for real implementation of wireless network. This paper focuses on various benefits of the wireless outdoor network, access point and its use. The paper also gives proper attention for new wireless network establisher to calculate link budget and Fresnel Zone for implanting outdoor IEEE 802.11b/g wireless outdoor network.

Key Words: Wireless network, access point, Fresnel Zone, link budget, Fade Margin, IEEE 802

1. Introduction

Wireless LANs, a term that was formerly known only to a few, has in a short period of a couple of years become a layperson's term. The market penetration has been as unexpected as the growth of mobile communications and the Internet in the boom era. This growth has obviously been due to the benefits of wireless local area networks (WLANs), e.g., ease of deployment, low cost, and flexibility. However, WLANs have also brought with them several issues while opening the door to a new future of data communications. This paper gives an introduction to WLANs and their installation requirements, and issues [1–2].

2. Basic Concepts of WLANs

Two types or modes of WLANs exist; the technology that provides connectivity to the infrastructure network and the technology that provides the connectivity of one device to another or an adhoc network. This is also depicted in Figure 1.1 [3-5]. IEEE 802.11-based WLANs work in both modes. WLANs do not replace wired solutions but complement them; the same can be said about WLANs and wireless wide area networks (WWANs) and wireless personal area networks (WPANs).

WLANs provide network connectivity in difficult wiring areas; they provide flexibility to move and extend networks or make changes. WLANs allow mobile users to work with traditional wired applications. In fact WLANs are the only LAN devices that allow true mobility and connectivity. WLANs provide connectivity for slow mobility (walking speed) with high throughput for both indoor and outdoor environments. Figure 1.2 shows the place of WLANs among the different wireless communications systems.

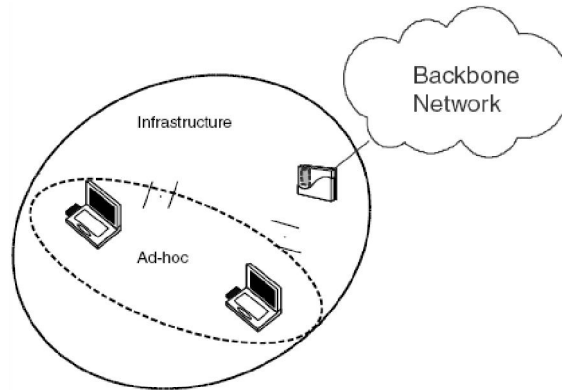


Figure 1.1 what is a WLAN?

Although WLANs came into the market almost a decade ago, standardized WLANs have been available since the late 1990s when IEEE 802.11 was born. Meanwhile several other WLAN standards came into being, for example, High Performance Radio Local Area Network-Type 2 (HIPERLAN/2) and HomeRF but none of them have been successful.

In 1999 the Wireless Ethernet Compatibility Alliance (WECA) was started. The purpose of WECA was to bring interoperability amongst IEEE 802.11 products of various vendors. The alliance developed a Wireless-Fidelity (Wi-Fi) interoperability test and provided logos for products that had passed the test. Today Wi-Fi has become a synonym of IEEE 802.11 and the alliance is now named as the Wi-Fi Alliance

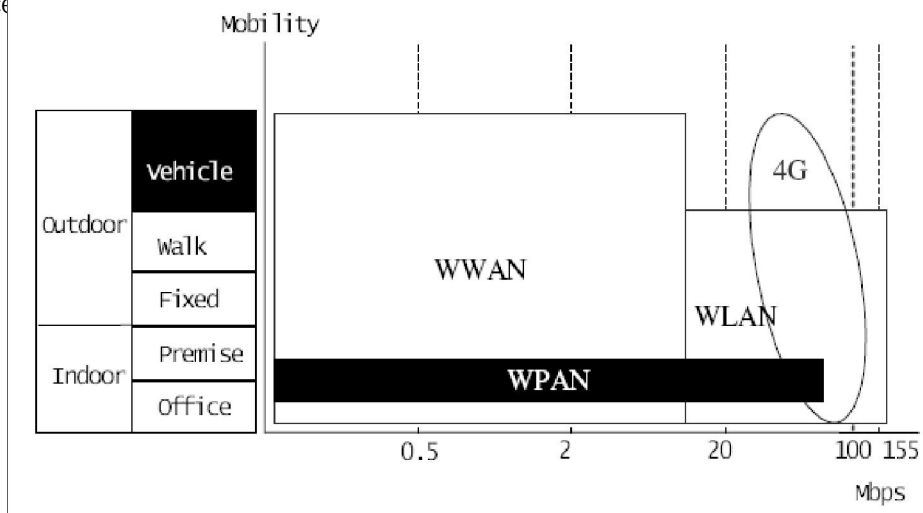


Figure 1.2 Placing Wireless LANs among wireless communications technologies.

The Wi-Fi Alliance also provides interoperability for IEEE 802.11a, 802.11b, and 802.11g [6]. The alliance has developed a wireless Internet service provider (WISP) roaming (WISPr) recommendation too. The WISPr recommendation was developed to allow WLAN users connectivity at any other WISP's hotspot while being charged at one account (i.e., a single billing solution) [7]. IEEE 802.11b works in the 2.4 GHz band, like .11g, while the IEEE 802.11a solution works in the 5 GHz frequency band. These spectrums are license free. In Table 1.1 the frequency bands in which various IEEE 802.11 standards work and the regulatory requirements on output power are given. A detailed overview of the IEEE 802.11 standards and a comparison with WPANs are given in Table 1.1 [1, 2].

- ◆ IEEE 802.11: Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) Medium Access Control (MAC), and 1 and 2 Mbps for DSSS, FHSS in 2.4 GHz band, and Infrared, ratified in 1997;
- ◆ IEEE 802.11a: Works at 6, 9, 12, 18, 24, 36, 48 and 54 Mbps in 5GHz band, ratified in 1999;
- ◆ IEEE 802.11b: Works at 5.5 and 11 Mbps in 2.4 GHz band, ratified in 1999;
- ◆ IEEE 802.11e: MAC enhancements for Quality of Service (QoS), work ongoing;
- ◆ IEEE 802.11f: Inter Access Point Protocol (IAPP), ratified in 2003;
- ◆ IEEE 802.11g: Works at same data rates as IEEE 802.11a and other optional modes; meant for 2.4 GHz band and is backward compatible to IEEE 802.11b, ratified in 2003;
- ◆ IEEE 802.11h: Spectrum managed IEEE 802.11a; addresses European Radio Communications Committee requirements at 5GHz addition of TPC (transmit power control) and DCS (dynamic channel selection);
- ◆ IEEE 802.11i: MAC enhancements for security, work ongoing;
- ◆ IEEE 802.11j: The purpose of Task Group J is to enhance the 802.11 standard and amendments, to add channel selection for 4.9 GHz and 5 GHz in Japan and to conform to the Japanese rules on operational mode, operational rate, radiated power, spurious emissions, and channel sense;
- ◆ IEEE 802.11k: This Task Group will define Radio Resource Measurement enhancements to provide mechanisms to higher layers for radio and network measurements;
- ◆ IEEE 802.11m: The goal of the task group is to complete this review of other documents and to determine a final list of work items;
- ◆ IEEE 802.11n: Possibility to improve 802.11 to provide high throughput (100 Mbps+);

- ◆ IEEE 802.11r: The group is looking at fast roaming mainly for voice over IP service;
- ◆ IEEE 802.11s: This group is working on AP-based mesh network;

Location	Regulatory Range (MHz)	Maximum Output Power (mW)	Standard
Europe	2,400-2,483.5	10 /MHz (max 100 mW)	IEEE 802.11b,g
	5,150-5,350	200	IEEE 802.11a
	5,470-5,725	1,000	
North America	2,400-2,483.5	1,000	IEEE 802.11b,g
	5,150-5,250	2.5 /MHz (max. 50 mW)	
	5,250-5,350	12.5 /MHz (max 250 mW)	IEEE 802.11a
	5,725-5,825	50 /MHz (max 1000 mW)	
Japan	2,400-2,497	10 /MHz (max 100 mW)	IEEE 802.11b,g
	5,150-5,250		
	4,900-5,000 (until 2007)	Indoor 200	IEEE 802.11a
	5,030-5,091 (from 2007)		

Table 1.1 : IEEE 802.11 Standard and Worldwide Frequency Bands

There are also several other study groups (SGs) like the access point functionality (APF) SG, wireless internetwork and external network (WIEN) SG, wireless network management (WNG) SG, and wireless access for the vehicular environment (WAVE) SG. There are other activities on publicity, and the wireless next generation study committee is looking at globalization and harmonization. There are also thoughts on creating an advanced security SG.

3. BENEFITS OF WLANs

Wireless LANs are usually designed to operate in license-free bands making their operation and maintenance costs less than contemporary cellular and PCS networks (for details on cellular and PCS networks see [8]). The use of license-free spectrum, however, increases the risk of network security and in-band interference. The key advantages of wireless networks as opposed to wired networks are mobility, flexibility, ease of installation and maintenance, and reduced costs (for details on wireless networks, see [9], and for wired networks, see [10]). Some of them are discussed below [1, 2].

3.1 Mobility

The most significant advantage of wireless networks is mobility and portability. They allow wireless network users to connect to existing networks and roam freely. A wired network user, in contrast, cannot roam freely or move while connected to the network [11].

3.2 Flexibility

Flexibility is an important feature of wireless networks and has been very attractive for wireless service providers. The wireless service providers can add new users only by authorizing their usage provided the network infrastructure is already built. The same infrastructure can be used to spread network coverage over a larger area than wired networks and the service providers do not need to run any cables or install network ports in order to increase the coverage. Thus this kind of flexibility is convenient to both the service provider and the end-user.

3.3 Ease of Installation

Wireless networks offer substantial ease of installation and cost savings as compared to wired networks. The required network infrastructure including base station equipment (routers, bridges etc) and antennas can be installed at any convenient place even at those places where wired networks are impossible to install or cost too much such as rivers, freeways etc.

3.4 Cost Savings

Wireless networks lead to both deployment and operational cost savings. The substitute for cabling allows companies to spend less on installation and maintenance of the network. In addition, compared to wired networks, flexibility allows them to scale their networks easily.

3.5 Scalability

Wireless LAN systems can be configured in a variety of topologies to meet the needs of specific applications and installations. Configurations are easily changed and range from independent networks suitable for a small number of users to full infrastructure networks of thousands of users that allow roaming over a broad area. Such opportunities are not possible with wired networks [12].

4. Wireless Data Network Implementation

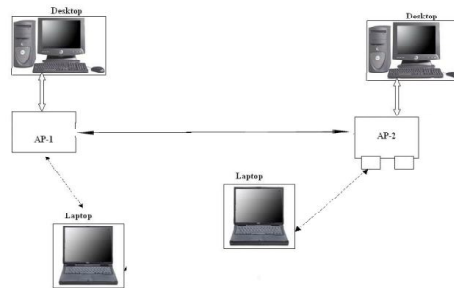
We designed and deployed an 802.11b/g compliant experimental wireless network on Saurashtra University Campus Road. This part discusses the experimental network design and architecture, and describes site details including link budget calculations and network components.

4.1 Network Architecture

Our designed network features a wireless backbone with a linear topology, and two different nodes stretched over the road length (approximately 2KM). While Aerial distance measured through GPS System from Computer department to opponent site is 0.6204Km. The department GPS Position is

Latitude N 22° 17.563 Longitude E 070° 44.654 and opponent site GPS Position is Latitude N 22° 16.960 and Longitude E 070° 44.677. The network is based on IEEE 802.11b/g wireless LAN standard, and is equipped with two Wireless Access Points (WAPs).

The designed network is built on two distinct nodes. The nodes are numbered as 1, and 2 starting from the Department of c access point which has 1 along the road provide an uth. Each node consists of an access point which has 1 aneously. The access points



4.2 Network Equipment

The network interfaces one access point along the road. The access points are connected to Desktop nodes via straight Ethernet cables. Each access point is equipped with D-Link access point DWL-3200 AP, 24 dBi 120° sector antennas and 360° Omni directional antennas. All backbone antennas are

installed at an approximate height of 40 feet (12.2 meters), whereas most of the access network antennas are installed at an approximate height of 30 feet (9.1 meters) from ground level. A computer is connected to first access point using cross over Ethernet cable. One and sometimes two laptops are used for collecting network performance measurements. AMG W developed by researcher and NetIQ Chariot software tools are used f

4.3 Wireless Access Points

I have been using D-Link access point DWL-3200 AP in our network. Similar to network router it is also equipped with 10/100 Base-T Ethernet (IEEE 802.3) interface with power over Ethernet.



4.4 WiFi Client

I have been using D-Link USB PC Cards as wireless client in our laptops and network infrastructure including backbone desktop. The same card can be used as WiFi wireless client for access point applications and delivers data rates up to 54 Mbps.



4.5 Antennas

Gain Antennas

We are using following 2.4 GHz, 3 dBi Magnetic Vehicle Mount Omni directional antenna from D-link.



2.4 GHz omnidirectional antennas were used for access network. 2.4 GHz omnidirectional antennas were used



4.6 Fixed Computer

We have a computer with an Intel P-IV with 2.4GHz processor to the first network using approximately 100 feet crossover Ethernet cable. The computer is equipped with 1 GB RAM and Microsoft Windows XP-Sp3 operating system.

4.7 Laptops

We are in need of two laptops for our network performance measurement purposes. Currently I have only one laptop. The Dell latitude 830 laptop is equipped with Intel Pentium core 2 Due Processor 2.0 GHz CPU, 4 GB RAM and Microsoft Windows Vista operating system. This laptop is installed with NetIQ Chariot and AMG Wifi Manager Software tools, which were used to measure network performance. This laptop is used throughout to measure network performance.

5. Fresnel Zone calculation

The concept of the Fresnel zone (pronounced "frA-nel"; the "s" is silent) provides a method of calculating the amount of clearance that a wireless wave (from transmitter to receiver) needs to pass over an obstacle to ensure that the obstacle does not attenuate the signal. To calculate the Fresnel zone.

The amount of Fresnel zone clearance is determined by the wavelength of the signal, the total path length, and the distance to the obstacle. The Fresnel zone is always widest in the middle of the path, between the two antennas. At least 60 percent of the calculated Fresnel zone must be clear to avoid significant signal attenuation. In above Figure, the top of the hill extends so far into the Fresnel zone that 60 percent of the Fresnel zone is not clear; therefore, part of the signal will be attenuated.

The following Figure shows the calculation of Fresnel ; same two-mile path.

When we are working with wireless, "Seeing is not believing." In other words, just because we can see to the other end of a wireless path, do not believe that we have a clear LOS wireless path.

The clear, visual LOS path does not mean that we have an attenuation-free wireless path. We must calculate the size of the Fresnel zone and confirm that the clearance above any obstacle(s) is at least equal to one-half of 60 percent of the Fresnel zone diameter.

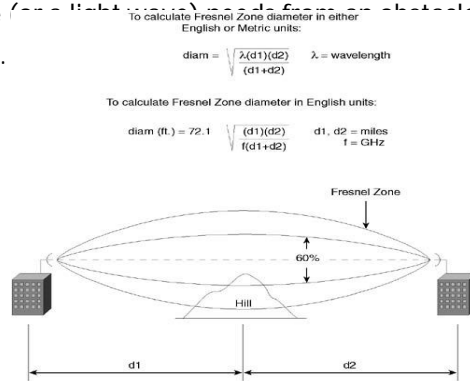


Figure Fresnel Zone Calculation

Fresnel Zone Diameter in Feet
 $d1, d2 = 1 \text{ mile}$
 $f = 2.4 \text{ GHz}$

$$\begin{aligned} \text{diam.} &= 72.1 \sqrt{\frac{(d1)(d2)}{f(d1+d2)}} \\ &= 72.1 \sqrt{\frac{(1)(1)}{2.4(1+1)}} = 72.1 \sqrt{\frac{1}{4.8}} \\ &= 72.1 \sqrt{.208} = 72.1 (.456) \\ &= 32.9 \text{ ft.} \end{aligned}$$

60% of FZ = $0.6(32.9) \text{ ft.} = 19.7 \text{ ft. (6m)}$

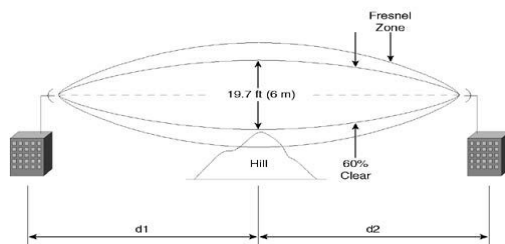


Figure Fresnel Zone Clearance for 2.4 GHz

6. Wireless Link Budget

A wireless link budget calculation totals the signal gains, subtracts the signal losses over the length of a wireless link, and predicts whether the signal level that arrives at the receiver will be high enough for the link to work reliably. If the link budget predicts that the link will not work reliably, you can examine the gain of each link budget element to see which elements to change and by how much to get the link to work.

The individual link budget elements are as follows:

- ◆ Transmitter power output
- ◆ Transmitter antenna system coaxial cable (transmission line) loss
- ◆ Transmitting antenna gain
- ◆ Free-space path loss
- ◆ Receiving antenna gain
- ◆ Receiver antenna system transmission line loss
- ◆ Receiver sensitivity threshold

6.1 Transmitter Output Power

The transmitter generates power and delivers it to the transmitter output connector. This power level is specified in dBm—decibels referenced to 1 mW. Typical transmitter output powers range from 10 mW (+10 dBm) to 1W (+30 dBm). Transmitter output power adds to the link budget.

6.2 Transmitter Antenna System Transmission Line Loss

The transmitter antenna system coaxial cable or transmission line carries power from the transmitter output connector to the transmitting antenna. Some power is lost in the cable (and in the cable connectors and lightning arrestor) during this process. The smaller the diameter of the cable and the shorter the wireless wavelength (the higher the frequency), the more power that is lost. Typical power losses at 2.4 GHz are 7 dB for each 100-ft length of 3/8-in. diameter cable. The total transmission line loss is subtracted from the link budget.

6.3 Transmitting Antenna Gain

The transmitting antenna receives power from the transmission line. The antenna focuses and concentrates this power and radiates it toward the distant receiver. This focusing ability results in an effective power gain in the direction of the antenna's main lobe. For 2.4-GHz antennas, gains typically range from +6 dBi to +24 dBi. The transmitting antenna gain adds to the link budget.

6.4 Free-Space Path Loss

We must pay a price to use the magic of wireless. That price is that most of the wireless energy that leaves your transmitting antenna is lost—gone forever. Only a tiny fraction of the transmitted energy ever arrives at the receiving antenna. How much of the energy actually arrives? If we have a 2.4-

GHz signal that travels 1 mile, our receiving antenna catches less than 1 ten billionth of the energy that we radiated from our transmitting antenna. All the energy that is lost (remember that there is no wire present) is called the free-space path loss. The longer the wireless path and the shorter the wavelength of the wireless signal, the higher the free-space path loss. The free-space path loss can be calculated using the following formula:

$$PL = 96.6 + 10 \log(d^2) + 10 \log(f^2) \text{ dB}$$

Where f is the frequency in GHz and d is the distance in miles.

If we prefer to use metric units to compute the free-space path loss, here is the formula:

$$PL = 92.4 + 20 \log(f) + 20 \log(d) \text{ dB}$$

Where f is the frequency in GHz and d is the distance in km.

The following Table shows several examples of free-space path loss for the 2.4-GHz and 5.7-GHz frequency bands.

Table Examples of Free-Space Path Loss		
	Free-Space Path Loss at 1 Mile (1.6km)	Free-Space Path Loss at 2 km
2.4GHz	104 dB	106dB
5.7GHz	112 dB	113.53dB

6.5 Receiving Antenna Gain

The receiving antenna works like the transmitting antenna to concentrate energy, but in reverse. The receiving antenna gathers and concentrates the small amount of power that reaches it at the far end of a wireless link. Think for a moment about the catcher in a game of baseball. The receiving antenna works a lot like the catcher's glove. The larger the glove, the easier it is for the catcher to grab the ball that the pitcher throws. The larger the receiving antenna, it is easier for the antenna to grab the incoming signal—and the more signal that the antenna grabs. The more signal the antenna receives, the more gain that is added to the link budget.

6.6 Receiver Antenna System Transmission Line Loss

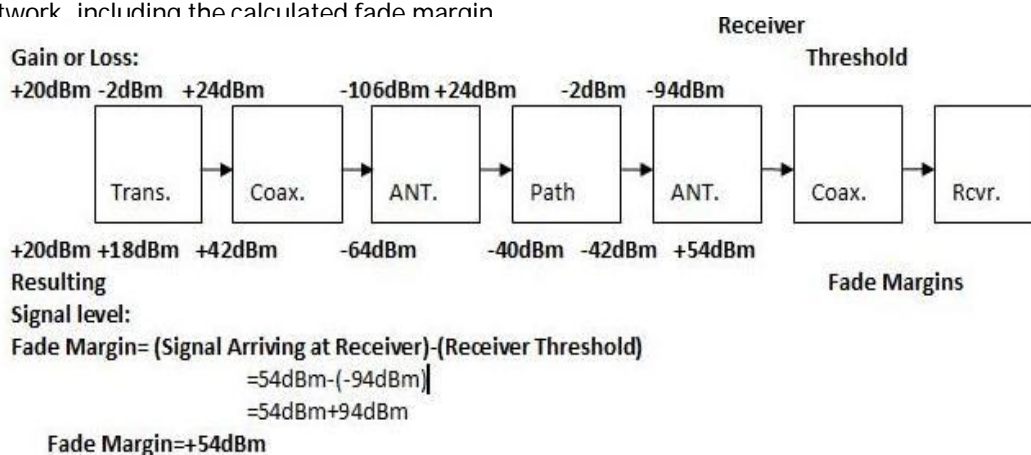
The receiving antenna system transmission line carries power from the receiving antenna to the receiver input. Just like with the transmitter antenna system transmission line, some power is lost in the cable during this process. This cable loss subtracts from the link budget.

6.7 Receiver Sensitivity Threshold

Each receiver has a threshold level—a minimum level of signal where the receiver just starts to operate. The receiver cannot detect signals below this threshold. The receiver antenna system (receiving antenna plus transmission line) must deliver a signal that is at or above this threshold for the wireless link to begin to operate. A typical threshold for an 11-Mbps 2.4-GHz wireless link receiver is around -85dBm while for 54 Mbps 2.4 GHz wireless link receiver is around -72dBm . The smaller (the more negative) this number is, the more sensitive the receiver is. For example, a receiver that has a threshold of -90dBm is more sensitive than a receiver that has a threshold of -85dBm .

6.8 Fade Margin

The reason for calculating a wireless link budget is to design and build a reliable wireless link. Microwave signals normally interact with many objects in their environment. Therefore, fading is a normal condition for all microwave links. To overcome the effects of this fading and to provide reliable service, every microwave link needs a certain amount of extra signal, over and above the minimum receiver threshold level. This extra signal is called the fade margin. Another term sometimes used for this extra signal is system operating margin (SOM). Most wireless equipment manufacturers recommend a minimum fade margin of at least $+10\text{ dB}$ to ensure reliable link performance. In general, the longer the link, the more fluctuation in signal levels and the greater the fade margin needs to be. The following figure shows a link budget calculation for the designed experimental network including the calculated fade margin



By calculating the fade margin, we can predict the reliability of a wireless link. The 2-Km long link shown in above Figure has a fade margin of $+54\text{ dB}$. $+54\text{ dB}$ is 44 dB more than the 10 dB fade

margin needed to make this link perform reliably; therefore, we can conclude that this link is going to deliver excellent reliability.

7. Conclusions

The paper discussed the implementation of wireless network in outdoor environment. It clarifies that wireless coverage and end-user data rate depends on site details in addition to location of the antenna and the type used. The implementation also depends on the use of hardware's and Fresnel Zone Clearance as well as link budget calculation. An RSSI value of -85 or more may guarantee 11 Mbps data rate between end-users. An RSSI of -94 or less may cause data loss along the road.

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