Wireless LANs (WLANs)

When speaking of data networks, it's most common to think of a cable as the network medium. However, there have been wireless data networking technologies available for several years. WLANs are typically used in specific situations that require them, such as when users must be able to roam around a site with a portable computer while remaining connected to the LAN or when network access is required in places where it is impractical or impossible to install LAN cables.

The Wireless Local Area Network (WLAN) technology is defined by the IEEE 802.11 family of specifications. These include: 802.11 (legacy), 802.11a, 802.11b, 802.11g and 802.11n.

Physical Layer Specifications

Topology

Wireless LANs support two topologies; ad-hoc topology and an infrastructure topology.

- Ad-hoc : The ad- hoc topology is one in which computers equipped with wireless network interface adapters communicate directly with each other;. This type of network is designed to support only a limited number of computers, such as those in a home or small business.
- Infrastructure: it is designed to extend the range and flexibility of a normal cabled network by enabling wireless-equipped computers to connect to it using a specialized module called an access point.

WLAN NIC

Access Point (AP)

To extend the range of the wireless part of the network and provide support for more clients, you can use multiple access points in different locations, or you can use an extension point. An extension point is essentially a wireless signal repeater that functions as a way station between wireless clients and an access point.

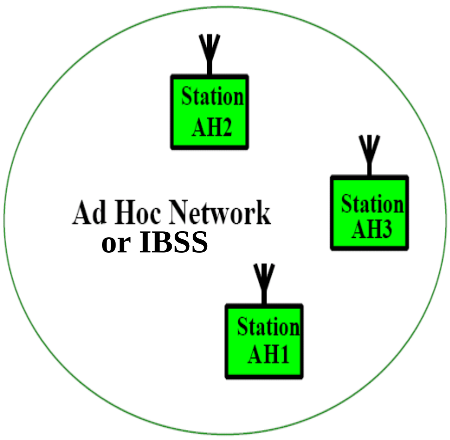
Note: Intervening walls and interference can diminish WLAN performance substantially.

Architecture

a- Basic Service Set (BSS)

Basic Service Set (BSS) consists of two or more wireless nodes, or stations (STAs), which have recognized each other and have established communications. BSS can be considered as the fundamental building block of the IEEE 802.11 standards architecture.

In the basic form, stations communicate directly with each other on a peer-to-peer level sharing a given cell coverage area. This type of network is commonly referred to as Independent Basic Service Set (IBSS) which is the formal name of an ad-hoc network in the IEEE 802.11 family of standards. In most instances BSS operates in the infrastructure topology so the stations are controlled by an access point.



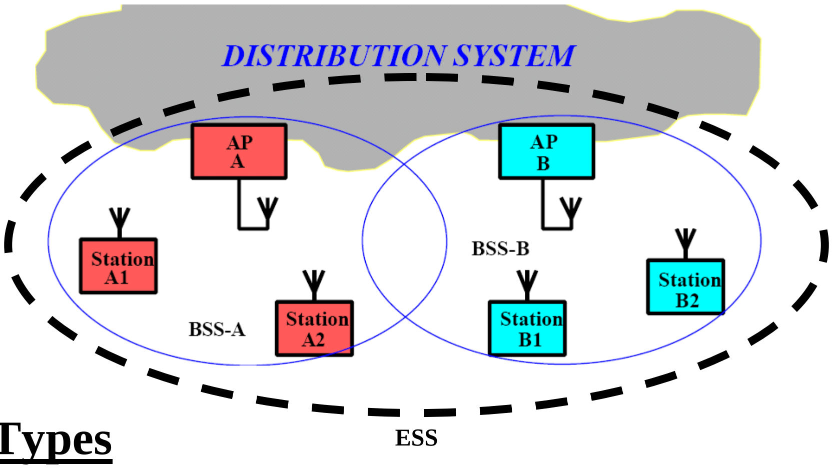
The geographical area covered by the BSS is known as the Basic Service Area (BSA), which is analogous to a cell in a cellular communications network.

b- Extended Service Set (ESS)

Infrastructure networks in IEEE 802.11 family are established using APs. The AP is analogous to the base station in a cellular communications network. Each AP covers A BSS. AP also supports range extension by providing connectivity between multiple BSSs, thus forming what is known as Extended Service Set (ESS). The ESS consists of a series of overlapping BSSs (each containing an AP) connected together by means of a Distribution System (DS).

c- Distribution System (DS)

The DS can be thought of as a backbone network. The DS, as specified by IEEE 802.11, is implementation independent. Therefore, the DS could be a wired IEEE 802.3 Ethernet LAN, IEEE 802.5 token ring LAN, fiber distributed data interface (FDDI), or another IEEE 802.11 wireless medium.



Stations Types

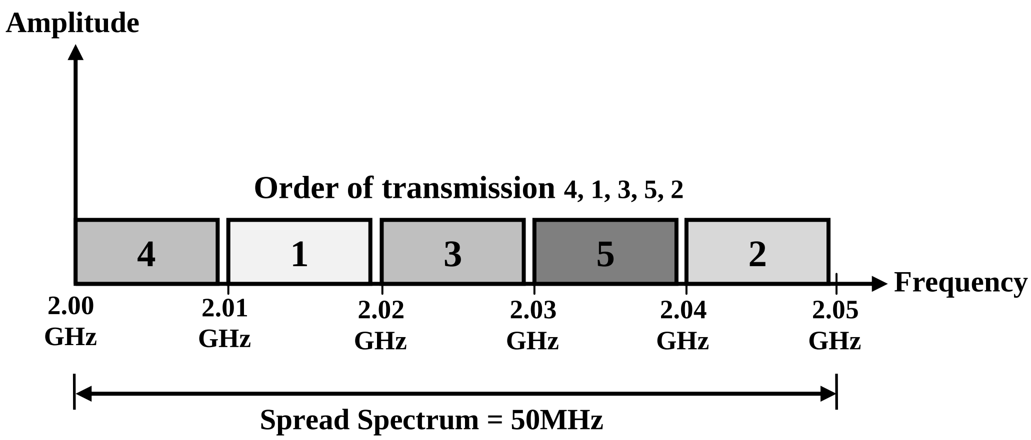
Based on their mobility, IEEE define three types of stations:-

1- No Transition Mobility: here the station is fixed or mobile only in inside the BSS.
2- BSS-Transition Mobility: the station here can move from a BSS to another, the movement is confined inside one ESS.
3- ESS-Transition Mobility: the satiation in this type can move form one ESS to another.

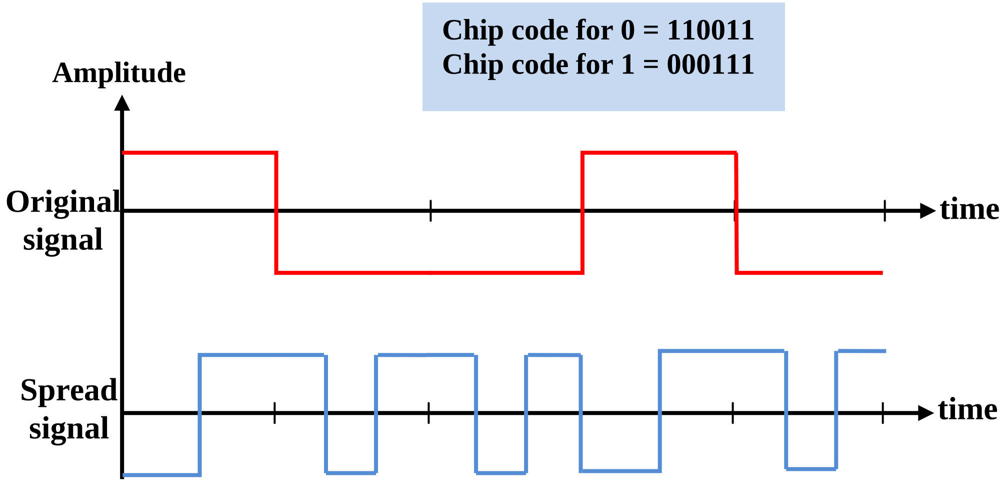
Signaling Scheme

The IEEE 802.11 family of standards uses one or more of the following signaling schemes at each of the IEEE 802.11, IEEE 802.11a, IEEE 802.11b,and IEEE 802.11g standards:

- **Frequency Hopping Spread Spectrum (FHSS):** A radio transmission method in which the transmitter continuously performs rapid frequency shifts or hops according to a preset algorithm. The transmitter sends on a carrier frequency for a short period then hops to another carrier for another period and so on. Hopping periods are equal and for N hopping periods the cycle is repeated. So if the bandwidth of the original signal is B, the bandwidth of the new signal is spread to N× B. The receiver performs the exact same shifts to read the incoming signals.

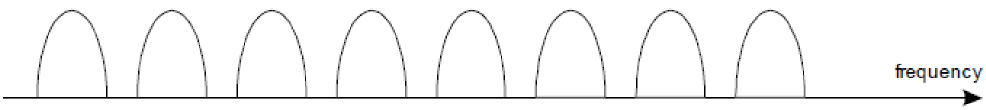


- **Direct Sequence Spread Spectrum (DSSS)**: A radio transmission method in which the outgoing signals are modulated using a digital code called "chip code". The time taken by a bit in the original signal equals the time of the whole chip code. So, if N-bit chip code is used to spread a signal of bandwidth B the new bandwidth needed is N× B. an example of DSSS is illustrated in the figure below.

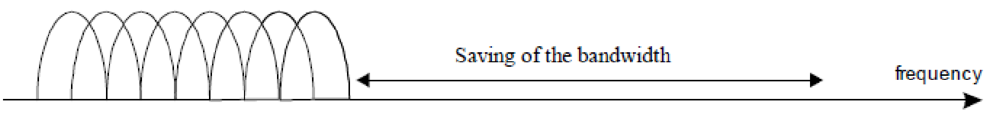


Note: WLANs use an 11-bit chipping code called "Barker Sequence".

- **<u>Orthogonal Frequency Division Multiplexing (OFDM):</u>** This method effectively squeezes multiple modulated carriers tightly together, reducing the required bandwidth but keeping the modulated signals orthogonal so they do not interfere with each other.



Conventional Frequency Division Multiplex (FDM) multicarrier modulation technique



Orthogonal Frequency Division Multiplex (OFDM) multicarrier modulation technique

- **<u>Infrared (IR):</u>** Infrared communications use high frequencies, just below the visible light spectrum. Infrared is a "line of sight" technology, meaning that the signals cannot penetrate through opaque walls and objects.

Antenna Types:

Three types of antennas are usually used in WLANs:-

1- Omni-directional antenna:

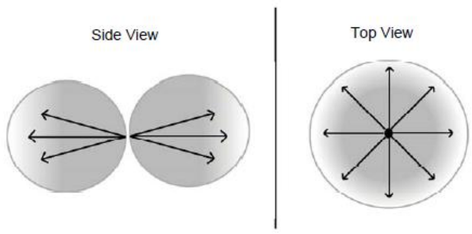
The most common wireless LAN antenna is the omni-directional antenna which is standard equipment on most access points. Omni-directional antenna, radiates its energy in all directions around its axis. As the gain of vertical omni-directional antennas increases , it offers more horizontal coverage area, but the vertical coverage area is reduced.


Outdoor omni-directional antenna


Omni Ceiling Mount Antenna

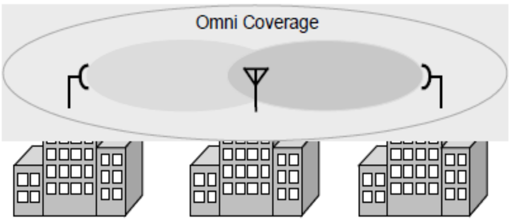

Indoor NIC Omni –directional antenna

Coverage area of an omni-directional antenna



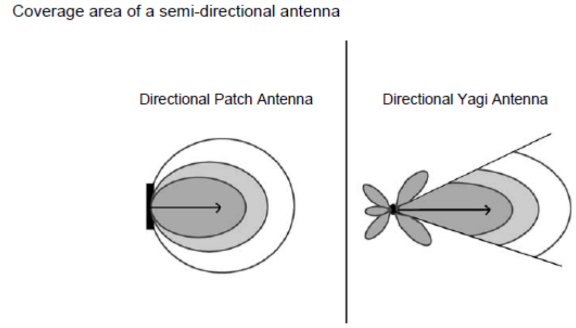
If an omni-directional antenna is placed indoor in the center of a single floor of a multistory building, most of its energy will be radiated along the length of that floor, with some significant fraction sent to the floors above and below the access point. Omni-directional antennas are also commonly used for point-to-multipoint outdoor implementations with an omni-directional antenna being placed on top of a structure (such as a building) in the middle of the coverage area.

Point-to-multipoint link

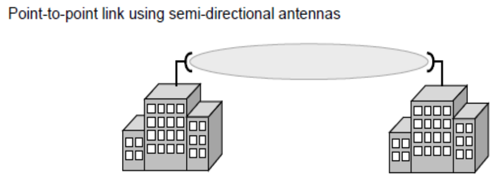


2- Semi-directional Antennas

Semi-directional antennas come in many different styles and shapes. Common semi-directional antennas types frequently used with wireless LANs are Patch, Panel, and Yagi antennas. These antennas direct the energy from the transmitter significantly more in one particular direction.

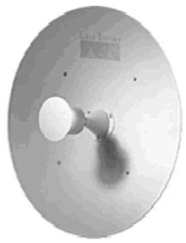


In a large indoor space, if the transmitter must be located in the corner or at the end of a building, a corridor, or a large room, a semi-directional antenna would be a good choice to provide the proper coverage. semi-directional antennas are commonly used outdoor as a point-to-point link between two sites.



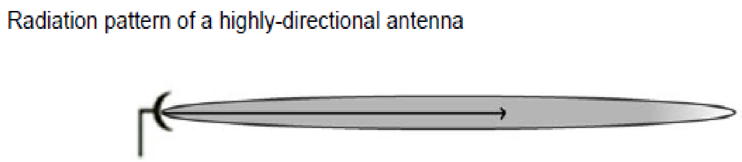
3- Highly-directional Antennas

Highly-directional antennas emit the most narrow signal beam of any antenna type and have the greatest gain of these three groups of antennas. Highly-directional antennas are typically concave devices. Some are parabolic dishes while others are grid antennas to reduce resistance to wind loading. These antennas are ideal for long distance, point-to-point wireless links.



Highly-directional Parabolic dish antenna

Highly-directional Grid antenna

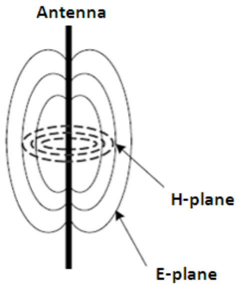


Antennas Concepts

There are several concepts that are essential knowledge when implementing solutions that require antennas. Among those are:

- **Polarization:**

A radio wave is actually made of up two fields. These two fields-the electric and the magnetic- are on planes (E-plane and H-plane) perpendicular to each other. E-plane which is parallel to the axis of the antenna decides the polarization of the antenna. So, if the antenna is vertically mounted, then the polarization is vertical. Antennas that are not polarized in the same way are not able to communicate with each other effectively.

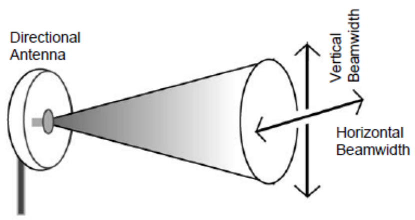


- **Gain:**

Antenna gain is specified in dBi, which means decibels referenced to an isotropic radiator. The higher the antenna gain, the farther the wave will travel, concentrating its output wave more tightly so that more of the power is delivered to the destination (the receiving antenna) at long distances.

- **Beamwidth:**

It is the "width" of the RF signal beam in degrees that the antenna transmits. There are two vectors to consider when discussing an antenna's beamwidths: the vertical and the horizontal. The table below can be used as a quick reference guide for beamwidths.



Antenna Type	Horizontal Beamwidth (in degrees)	Vertical Beamwidth (in degrees)
Omni-directional	360	Ranges from 7-80
Patch/Panel	Ranges from 30-180	Ranges from 6-90
Yagi	Ranges from 30-78	Ranges from 14-64
Parabolic Dish	Ranges from 4-25	Ranges from 4-21

- **Antenna diversity**

It is a simple technique that is used to deal with multipath. It is based on adding a second antenna to the radio. If there are two antennas, at least one of them should be able to receive a usable signal, even if the other is receiving a distorted one. In commercial devices, antenna switching diversity is used, so the signal is received through only one antenna at a time. When transmitting, the radio uses the antenna last used for reception.

Link budget

A link budget is the accounting of all of the gains and losses from the transmitter, through the medium to the receiver in a telecommunication system. A simple link budget equation looks like this:

Received Power (dBm) = Transmitted Power (dBm) + Gains (dBi) − Losses (dB)

Where **Gains = Transmitter Gain + Receiver Gain**
Losses =Transmitter Cable losses +Receiver cable losses + Path Loss

- **Path Loss:**

Path Loss represents the single greatest source of loss in a wireless system. Path loss in wireless systems can be mainly returned to three sources:

❖ Free Space Path Loss:

Signal power is diminished by geometric spreading of the wavefront, commonly known as free space loss. Ignoring everything else, the further away the two radios, the smaller the received signal is due to free space loss. This is independent from the environment, depending only on the distance. The formula for Free Space Path Loss L_{FS} (in dB) is:

$$L_{FS} = 20LOG_{10}\left[\frac{4\Pi d}{\lambda}\right]$$

❖ Attenuation

The second contribution to the path loss is given by attenuation. This takes place as some of the signal power is absorbed when the wave passes through solid objects such as trees, walls, windows and floors of buildings. Attenuation can vary greatly depending upon the structure of the object the signal is

passing through, and it is very difficult to quantify. The most convenient way to express its contribution to the total loss is by adding an "allowed loss" to the free space. Typical attenuations through the different obstacles are presented in the following table.

Obstacle	Attenuation [dB]
Tree	10-20
Wall	2-15
Floor	20 -30

❖ Scattering:

A simple way of applying the effects of scattering in the calculation of the path loss is to change the exponent of the distance factor of the free space loss formula. The exponent tends to increase with the range in an environment with a lot of scattering. Practically, an exponent of 1.5 can be used in an outdoor environment with trees, while one of 2 can be used for an indoor environment.

NOTE: For a rough estimate of the link feasibility, one can evaluate just the free space loss. The environment can bring further signal loss, and should be considered for an exact evaluation of the link.

- **Minimum Received Signal Level**

The minimum RSL, or simply, the sensitivity of the receiver is always expressed as a negative dBm and is the lowest power of signal the radio can distinguish. The minimum RSL is dependent upon rate, and as a general rule the lowest transfer rate has the greatest sensitivity. The minimum RSL will be typically in the range of -75 to -95 dBm.

- **Cable Losses**.

Some of the signal energy is lost in the cables, the connectors and other devices, going from the radios to the antennas. The loss depends on the type of cable used and on its length. Signal loss for short coaxial cables including connectors is quite low, in the range of 2-3 dB. It is better to have cables as short as possible.

- **Fade Margin**

To give some space for attenuation and multipath in the received radio signal, a margin of 15- 20 dB usually being safe enough. This space called fade margin is the amount of signal above the sensitivity of radio that should be received in order to ensure a stable, high quality radio link during bad weather and other atmospheric disturbances. So, If the resulting signal level is greater than the minimum RSL by at least magnitude of the fade margin , then the link is feasible.

NOTE: A link is said to be feasible if it is feasible in both directions.

Example:

A 5km IEEE 802.11g link operates at 2.45 GHz frequency with one access point and one client radio. The access point is connected to an omnidirectional antenna with 10dBi gain, while the client is connected to a sectorial antenna with 14dBi gain. The transmitting power of the AP is 100mW and its sensitivity is -89dBm. The transmitting power of the client is 30mW and its sensitivity is -82dBm. The cables are short, with a loss of 2dB at each side. Estimate the feasibility of this link considering a fade margin of 15 dB.

Solution:

1- AP to client:

- **Gains = Transmitter Gain + Receiver Gain = 10 dBi + 14 dBi = 24 dBi**
- **Losses =Transmitter Cable losses +Receiver cable losses + Path Loss**
  Path loss is roughly estimated by the free path loss = 114 dB
  So the Losses = 2 dB +2 dB + 114 dB= 118 dB
- **Transmitted power = 20 dBm**
- **Received Power = Transmitted Power + Gains − Losses**
  =20+24-118= -74 dB
- **Since the received signal is greater than the receiver sensitivity of the client radio by only 8dB (-74dB - (- 82dB)) which is lowest than the value of the fade margin (15 dB). So, this link may work in fair weather, but it is not feasible in extreme weather conditions.**

2- Client to AP:

- **Transmitted power = 15 dBm**
- **Received Power = Transmitted Power + Gains − Losses**
  =15+24-118= -79 dB

- **The Received signal is greater than the receiver sensitivity of the client radio by 10 dB (-79dB – (- 89dB)). Again this link is not feasible in this direction.**

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