Wi-Fi RANGE DYNAMICS DEMYSTIFIED

Wi-Fi™ REFERENCE SERIES

XIRRUS®

RANGE AND COVERAGE

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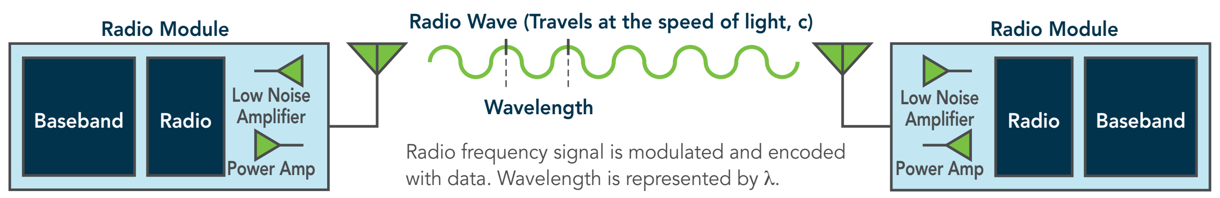
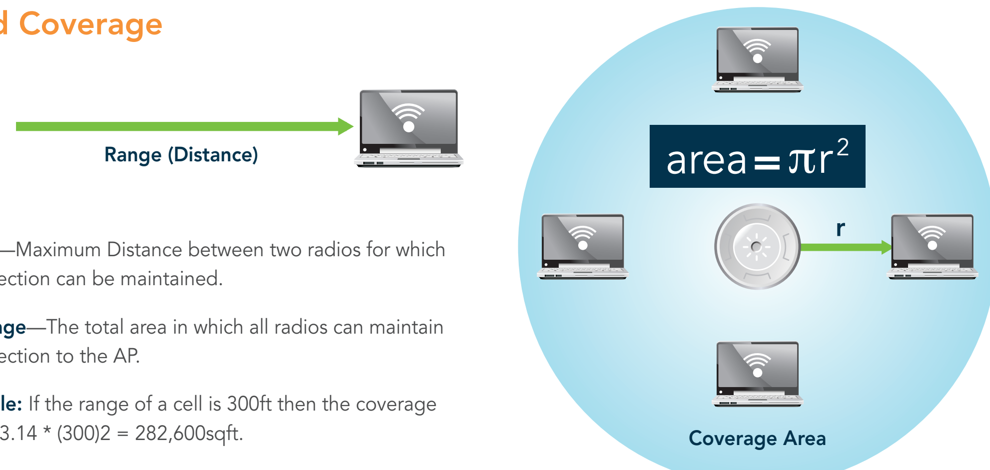
Basic Wi-Fi Radio Link



Radio frequency signal is modulated and encoded with data. Wavelength is represented by λ.

Range and Coverage



Range—Maximum Distance between two radios for which a connection can be maintained.

Coverage—The total area in which all radios can maintain a connection to the AP.

Example: If the range of a cell is 300ft then the coverage area = 3.14 * (300)2 = 282,600sqft.

LINK FORMULAS

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RF Power Dissipation

$$P_R \approx \left(\frac{P_T}{d^2}\right)$$

In Free Space, Power varies inversely with the square of the distance between two points.

Signal Strength (RSSI)

$$P_R = P_T G_T G_R \left(\frac{\lambda}{4\pi d}\right)^2$$

Expected Free Space Signal Strength at the Receiver taking Transmit Power, Antenna Gain, Receiver Gain, Distance, and Frequency into account.

Path Loss

$$PathLoss_{dB} = 20\log\left(\frac{4\pi}{\lambda}\right) + 10n\log d$$

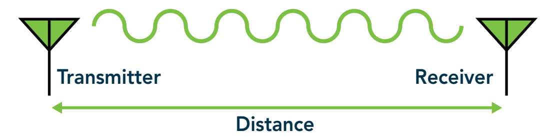
Expected Signal Loss between a Transmitter and a Receiver using an appropriate Path Loss Exponent, n, for the environment. (See Path Loss Exponent chart).

Link Budget

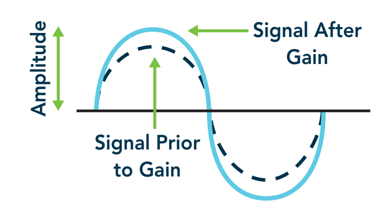
$$P_R = P_T + G_T - PathLoss + G_R - L_R$$

Expected Signal available in an interference-free environment for a given Transmit Power, Antenna Gain, Path Loss, and Receiver Loss. (See SNR).

Gain and Transmit Power



The stronger the Transmit Power, the higher the signal Amplitude. Antenna Gain also increases signal Amplitude.



- P_R—Power at the Receiver
- P_T—Power at the Transmitter
- G_T—Antenna Gain of the Transmitter
- G_R—Antenna Gain of the Receiver
- λ—Wavelength (speed of light/frequency)
- π—Ratio of a Circle's Circumference to its Diameter, approximately 3.14
- d—Distance in Meters
- L_R—Receiver Loss including Insertion Loss, Noise Figure, etc.

SIGNAL TO NOICE RADIO (SNR)

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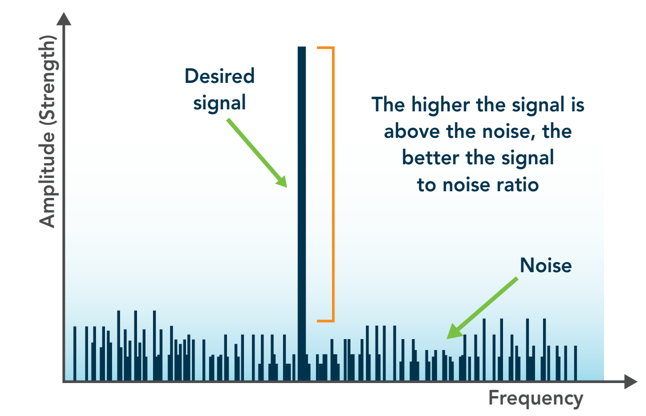
Signal to Noise Ratio (SNR) is the ratio of the desired signal to that of all other noise and interference as seen by a receiver. SNR is important as it determines which data rates can be correctly decoded in a wireless link.

The chart on the right shows the required SNR for 802.11a (5GHz) data rates.



$$SNR = \frac{Signal}{Noise}$$

$$SNR(db) = Signal(dBm) - Noise(dBm)$$

Modulation and Encoding 802.11a	Wireless Data Rate (Mbps)	Minimum Required SNR (dB)
BPSK 1/2	6	8
BPSK 3/4	9	9
QPSK 1/2	12	11
QPSK 3/4	18	13
16-QAM 1/2	24	16
16-QAM 3/4	36	20
64-QAM 2/3	48	24
64-QAM 3/4	54	25

Note: Higher data rates cannot be transmitted at the same Power as the less-complicated encoding of lower data rates.

RANGE LIMITING FACTORS

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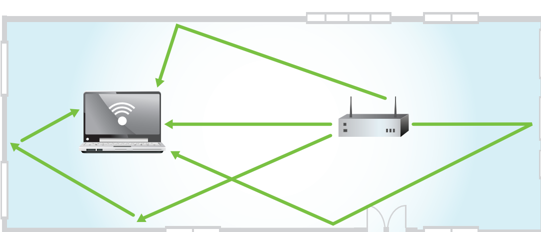
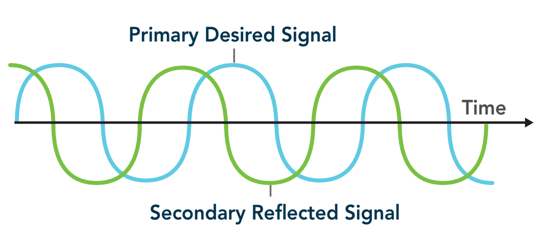
Multipath

Multipath occurs when the intended signal is reflected back

Can be Additive or Destructive

Can completely cancel primary signal (Null)

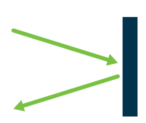




Interference

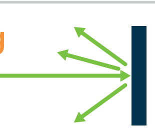
Interference distorts the intended signal.

Reflection



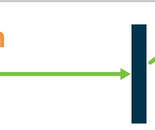
The signal is reflected back.

Scattering



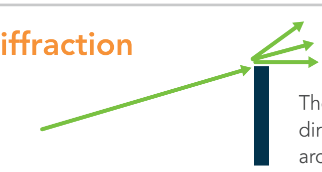
The signal is scattered back into multiple new signals.

Refraction



The signal is bent as it passes through an object.

Diffraction



The signal changes direction as it passes around an object.

Attenuation

The signal strength is reduced as it passes through an object.

ANTENNA BASICS

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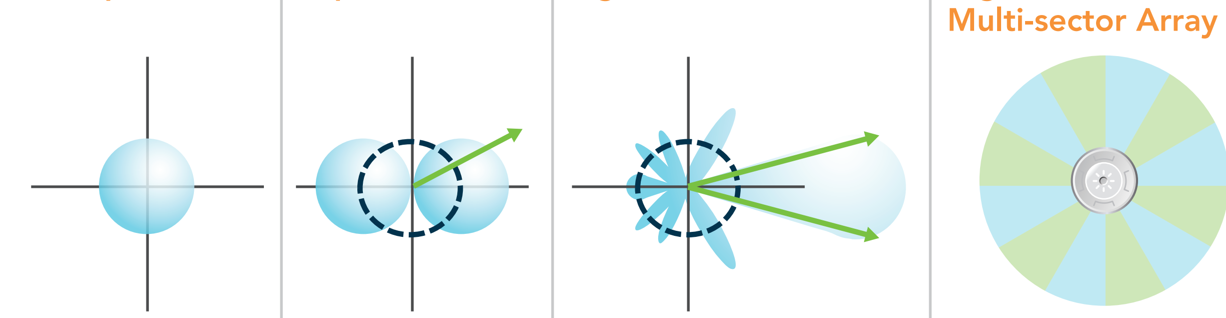
Isotropic

Dipole

High Gain, Directional

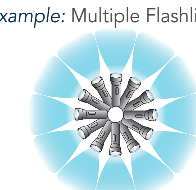
High Gain, Directional Multi-sector Array



Example: Light Bulb

Example: Flashlight

Example: Multiple Flashlights



$$Gain = \frac{\text{Power Density (directional Antenna)}}{\text{Power Density of Isotropic Antenna}}$$

$$G_I = \frac{P_{directional}}{P_{isotropic}}$$

RANGE VERSUS CAPACITY

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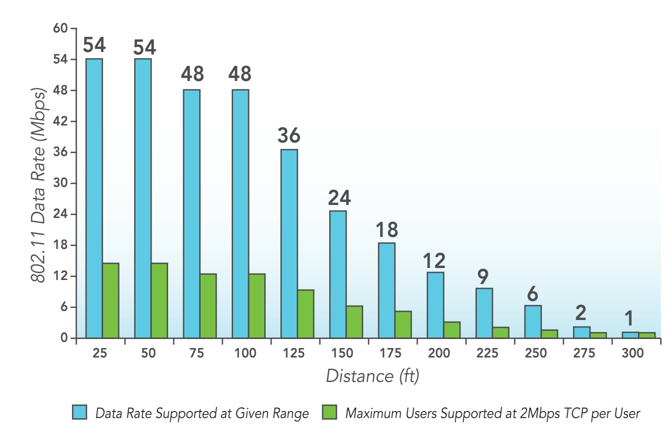
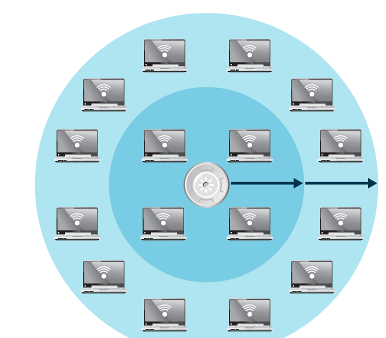
Range versus Capacity

- As omni-directional coverage increases, the number of potential covered users increases
- As the number of users increases, the available capacity per user decreases
- Larger cells create the Hidden Node problem
- A multi-sector approach can help provide both range and capacity and can also help mitigate hidden nodes



The larger the coverage area of a single radio the more potential users will have to be supported and the effective bandwidth per user will decrease.



The larger the cell, the more users covered, the more capacity is required.

Hidden Node Problem

The larger the cell size, the greater the chance that Station 1 and Station 2 cannot hear each other's transmissions. Therefore, both may attempt to transmit at the same time leading to collisions.

PATH LOSS

Typical Environment	Path Loss Exponent, n
Free Space	2
Outdoor Urban Area	2.7 to 3.5
Outdoor Shadowed Urban Area	3 to 5
In-Building, Line-of-sight	1.6 to 1.8
In-Building, Soft Cubicle Partitions	3 to 3.5
Obstructed in Building	4 to 6
Obstructed in Factories	2 to 3

The Path Loss Exponent (n) is a component of the Path Loss Formula that indicates the degree of loss as normally encountered in that environment.

ATTENUATION

Material	Typical Attenuation (Loss) @ 5GHz
Cubical Wall	2dB
Drywall or Sheetrock	3dB
Brick Concrete or Block Wall	15dB
Elevator Shaft	10dB
Glass or Window	3dB
Concrete Floor	11dB

Attenuation of various materials are shown. RF Signal strength is reduced as it passes through various materials.

CHANNEL RE-USE

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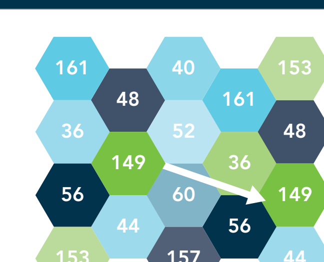
2.4GHz

2.4GHz (802.11b/g) Inter-cell interference from other cells on the same channel

- Number of non-overlapping 2.4GHz 802.11b/g channels = 3
- Distance to cell with same channel is less than a single cell
- Interference from cells on the same channel is large

5GHz



- 802.11a has 24 available channels and the separation between cells on the same channel is at least two cells
- Inter-cell interference from other cells on the same channel will be lower
- Greatly reduces SNR in the local cell
  - The 802.11 "Defer Threshold" setting can help to set cell sizes
  - Defer Threshold is the level below which signals are ignored (treated as interference) and above which a radio will defer transmission until the medium is clear

GLOSSARY

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Antenna Gain—The amplification by a device (usually an antenna) of a wireless signal. It is usually measured in dBi (decibels with respect to an isotropic radiating antenna).

Attenuation—Is the reduction in amplitude and intensity of a signal with respect to distance traveled through a medium.

db—Decibel is a measure of the ratio between two quantities.

dBm—Decibel with respect to milliwatts of power. Power(dBm) = 10 log (Power in milliwatts).

Interference—Distortion of the wireless signal by other sources of electromagnetic waves. Strong enough interference will distort the signal such that it becomes undecipherable by the receiver.

Link Budget—Is an accounting of all of the gains and losses of a signal as it moves from a transmitter to a receiver and takes into account the attenuation of the transmitted signal due to propagation, as well as the loss, or gain, due to the antenna.

MIMO—A technique that uses multiple antennas to simultaneously send and receive data on different antennas. This technique works with multipath and improves the receiver's effective sensitivity.

Multipath—Multiple (delayed) copies of the original transmitted signal that are received at the receiver due to reflections, scattering, etc., that take place in the environment.

Path Loss—The reduction in signal strength (amplitude) that a signal experiences as it travels through the air or through objects from a transmitter to a receiver.

RSSI—Received Signal Strength Indicator: Indicates the strength of a signal as measuredby the receiver. RSSI is normally expressed in dBm or as a numerical percentage.

Wi-Fi Array—Is a multi-radio (4-16) Wi-Fi platform that uses a high gain, multi-sector antenna system for long range, high capacity Wi-Fi networks.

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