Maximizing Your Wireless Link

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ISP Supplies

Topics Covered

- Factors that apply to all wireless links
- Setting realistic expectations
- Common settings that should be scrutinized
- Miscellaneous Tips and Tricks

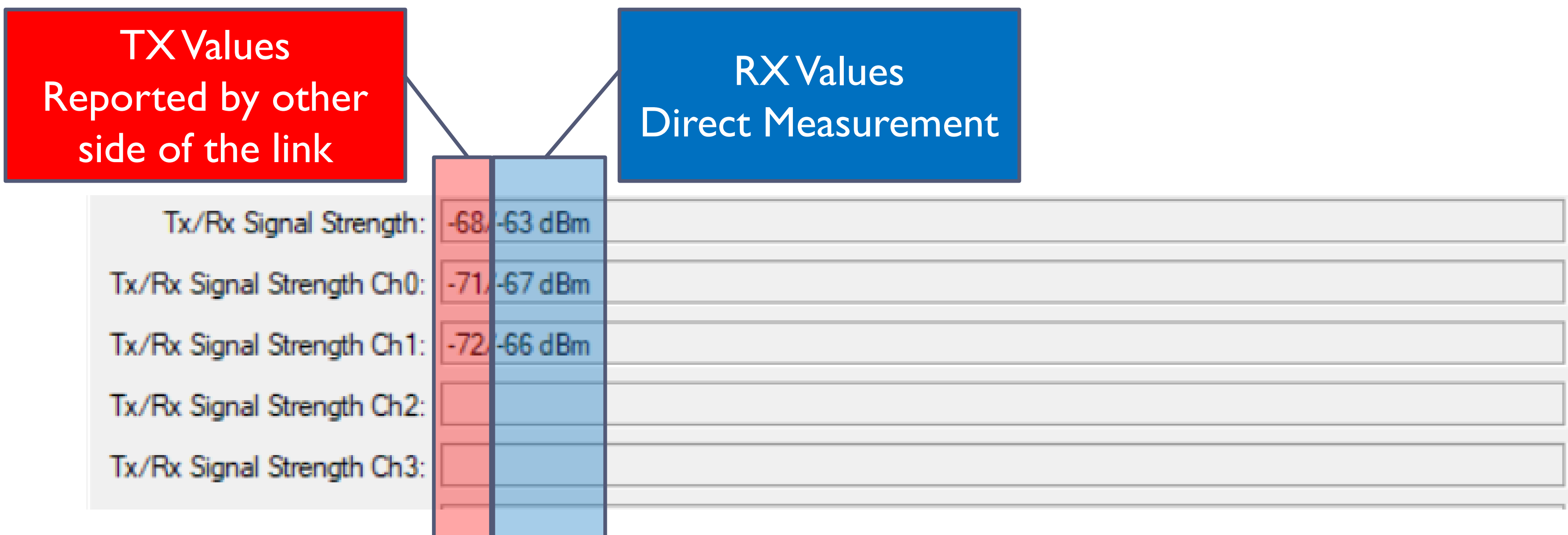
Factors that apply to all wireless links

Factors that apply to all wireless links

- RSSI Levels
- Noise Floor
- Signal to Noise Ratio
- Fresnel Zone Considerations
- Making sure that antennas are in the capture area

RX & TX Signal Strengths

- RX Signal Strengths are direct measurements of the strength of the signal from the perspective of the receiver.
- TX Signal Strengths are transmitted by both the AP and the Station in each wireless frame to the other side.



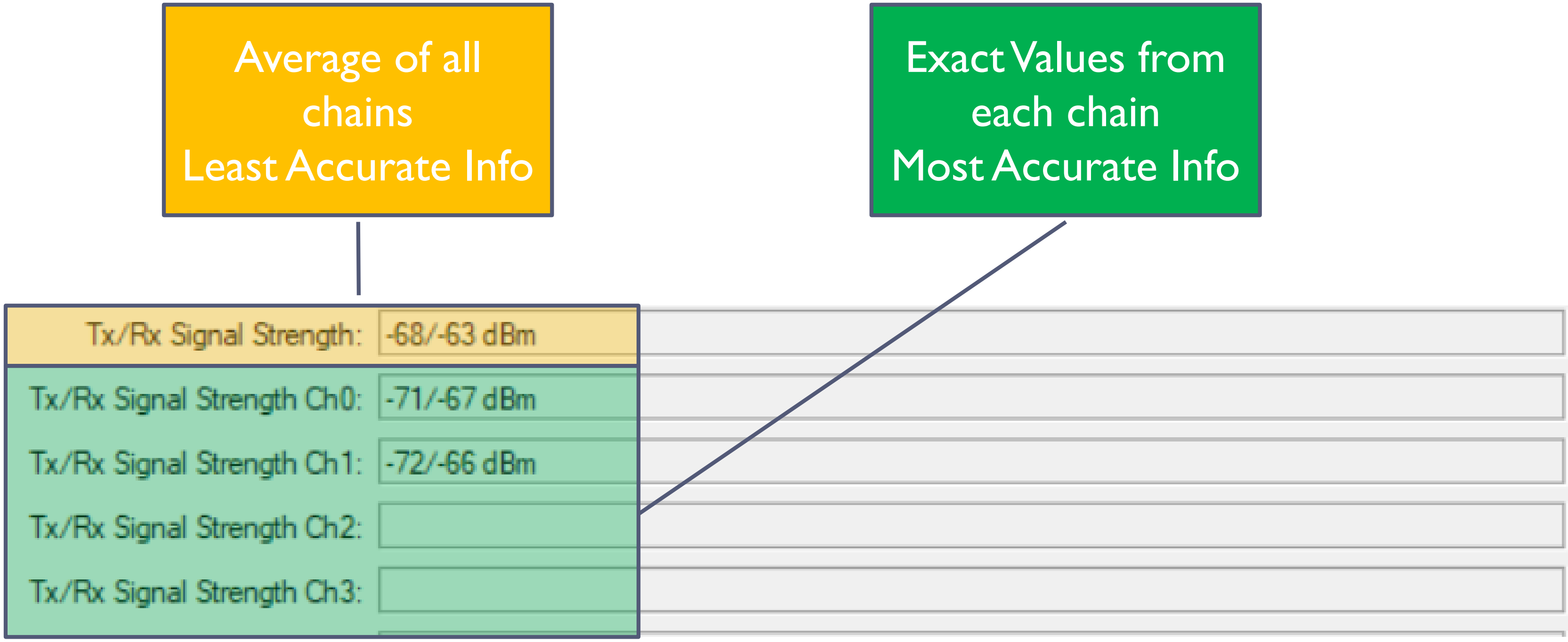
RX & TX Signal Strengths

- TX Signal Strengths are transmitted by both the AP and the Station in each wireless frame.

```
> Frame 29: 110 bytes on wire (880 bits), 110 bytes captured (880 bits)
v Radiotap Header v0, Length 16
    Header revision: 0
    Header pad: 0
    Header length: 16
  > Present flags
    Data Rate: 0.0 Mb/s
    Channel frequency: 2412 [BG 1]
  > Channel flags: 0x00c0, Orthogonal Frequency-Division Multiplexing (OFDM), 2 GHz spectrum
    Antenna signal: -52dBm
v 802.11 radio information
    PHY type: 802.11g (6)
    Proprietary mode: None (0)
    Data rate: 0.0 Mb/s
    Channel: 1
    Frequency: 2412MHz
    Signal strength (dBm): -52dBm
> IEEE 802.11 QoS Data, Flags: ......F.
> Logical-Link Control
> Internet Protocol Version 4, Src: 8.8.8.8, Dst: 172.20.14.91
> Internet Control Message Protocol
```

RX & TX Signal Strengths

- Ideally, TX & RX SS should be equal to each other.
- The difference in SS between chains is also very important!



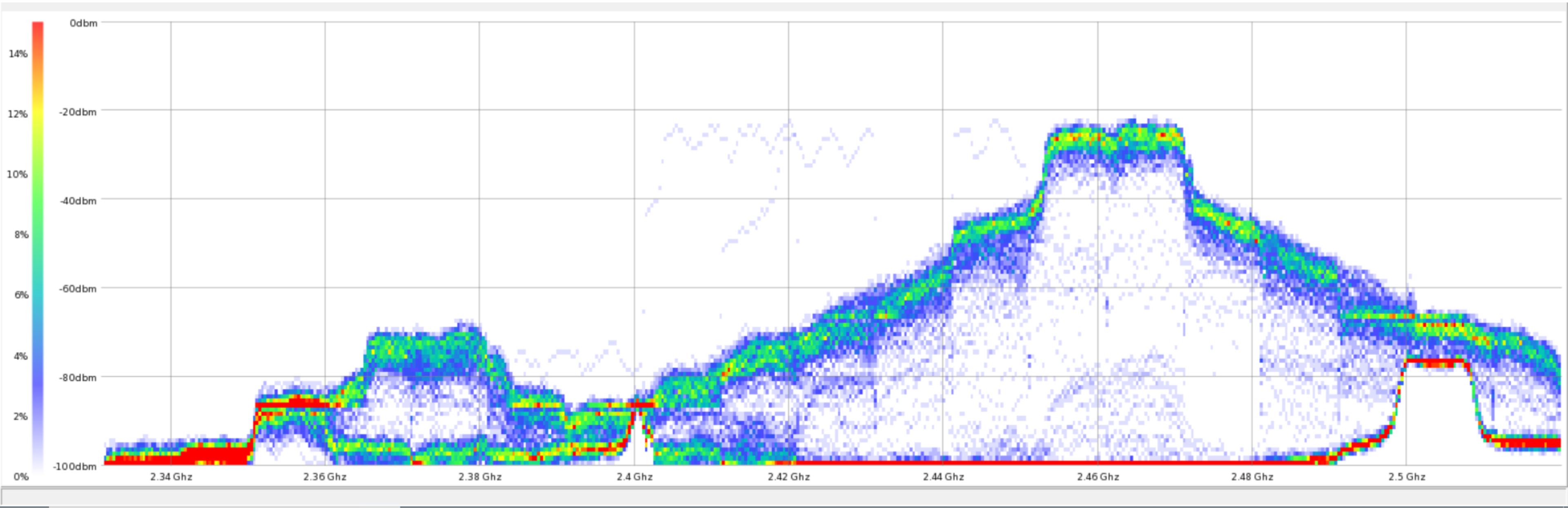
The Decibel

- dB = Decibel (Relative Measurement)
- dBi = Decibel relative to an "Isotropic Radiator in Free Space"
- dBm = Decibel relative to milliwatts
- 3dB change equates to a doubling or halving of power
- 10dB change equates to a 10x increase or decrease
- 20dB change equates to a 100x increase or decrease

This is why every dB counts!

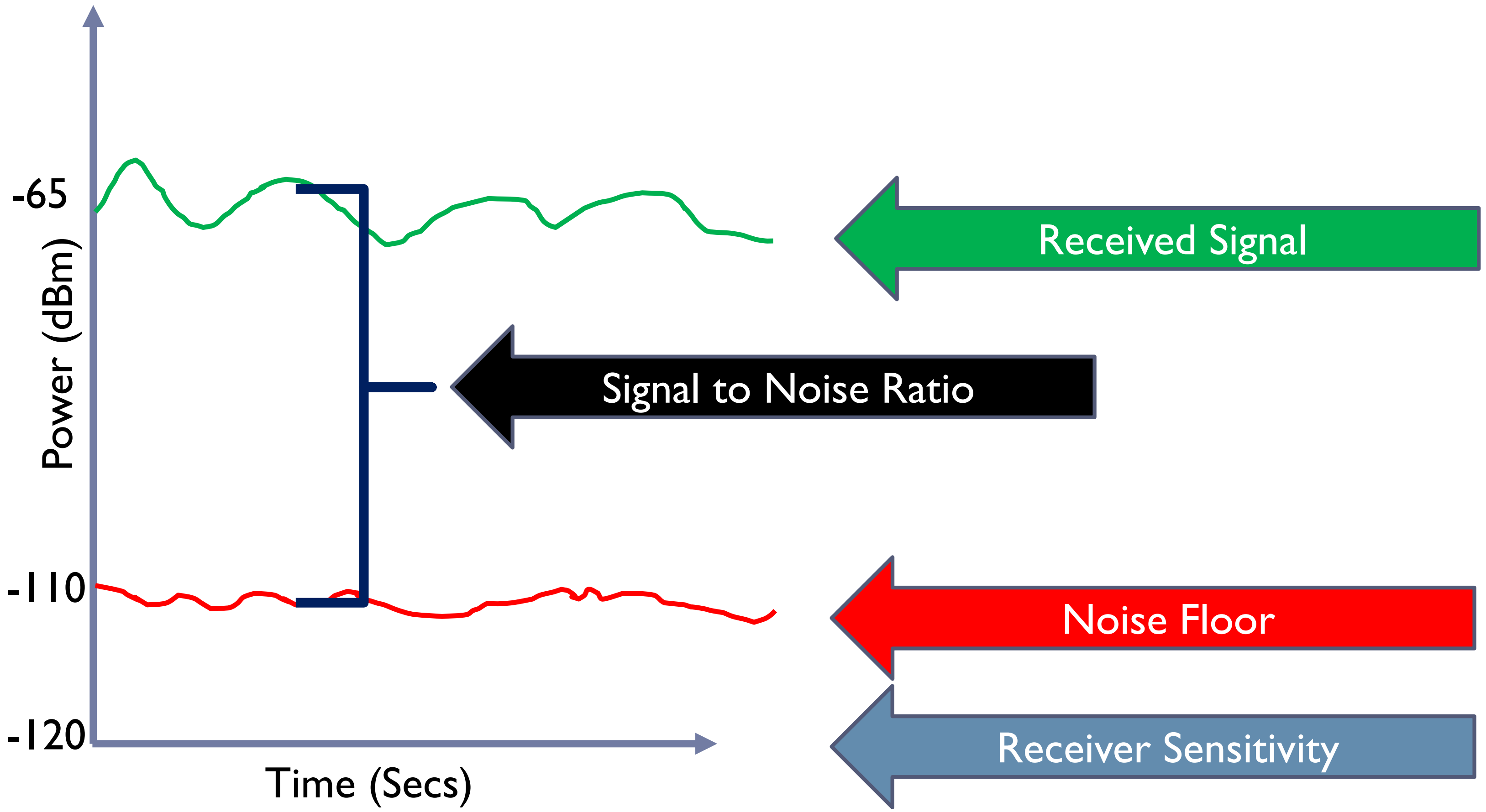
Noise Floor

- The minimum threshold a signal has to surpass in order for our receiver to see it as a discreet signal.



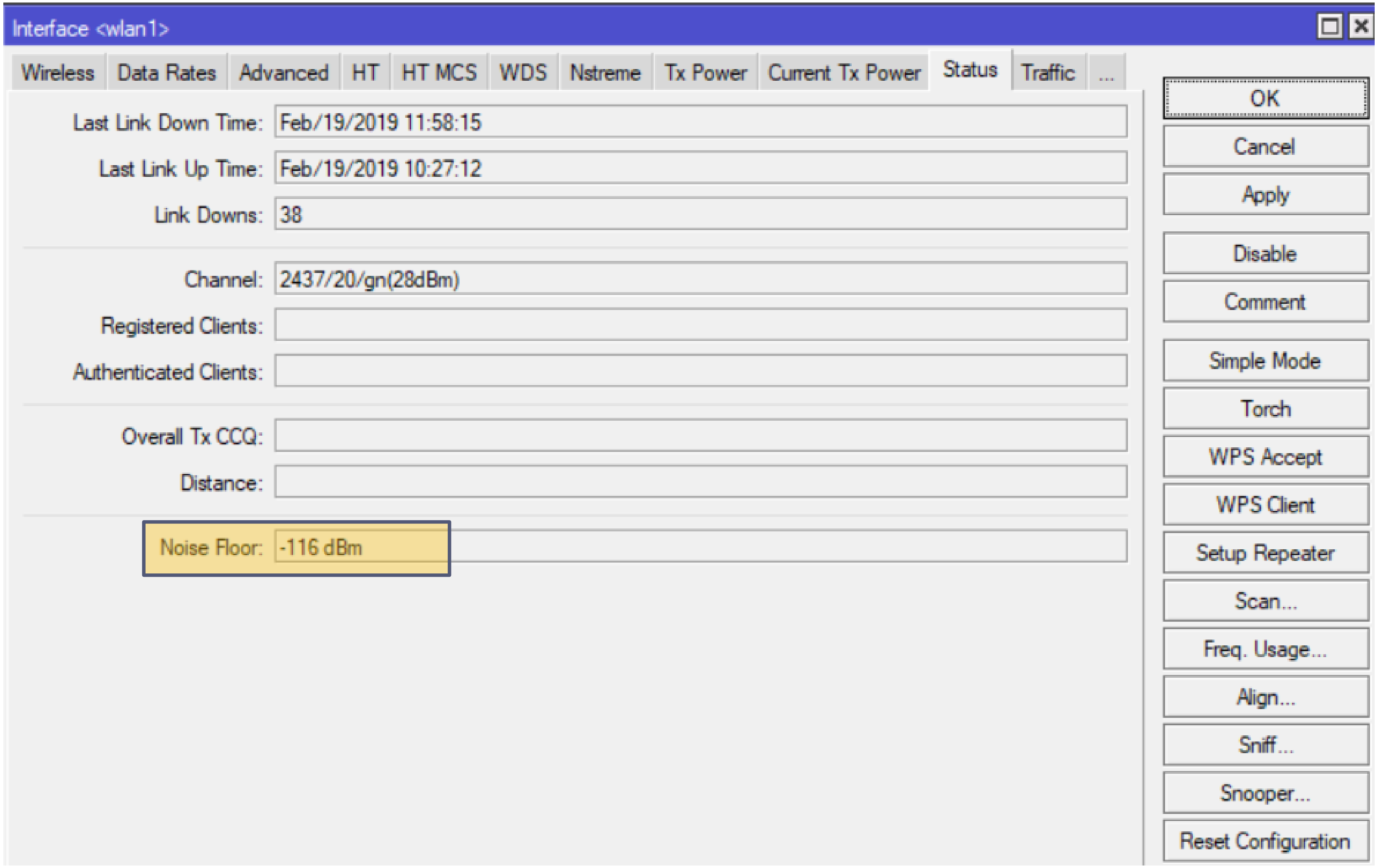
- Represented here as the bottom line (100dBm)
- Actual noise floor was -110dBm

Noise Floor



-65
-110
-120
Power (dBm)
Time (Secs)
Received Signal
Signal to Noise Ratio
Noise Floor
Receiver Sensitivity

Noise Floor


Interface <wlan1>
Wireless
Data Rates
Advanced
HT
HT MCS
WDS
Nstreme
Tx Power
Current Tx Power
Status
Traffic
...
Last Link Down Time: Feb/19/2019 11:58:15
Last Link Up Time: Feb/19/2019 10:27:12
Link Downs: 38
Channel: 2437/20/gn(28dBm)
Registered Clients:
Authenticated Clients:
Overall Tx CCQ:
Distance:
Noise Floor: -116 dBm
OK
Cancel
Apply
Disable
Comment
Simple Mode
Torch
WPS Accept
WPS Client
Setup Repeater
Scan...
Freq. Usage...
Align...
Sniff...
Snooper...
Reset Configuration

Noise Floor

- General Rules of Thumb
  - -128 -- -110 = Life's Great!
  - -109 -- -100 = Good Performance
  - -95 -- -99 = The link can work as long as expectations are realistic
  - -90 -- -94 = Really need to take a look at improving this link
  - -89 and lower = Too problematic for most scenarios

Noise Floor

Tips on improving the Noise Floor…noise rejection.

1. Use RF shielding such as the Sleeve 30
2. Choose metal enclosures over plastic
3. Properly ground your equipment
4. Use antennas that are highly directional; avoid Omnis and wide sectors as much as possible
5. Utilize unusual angles… get out of the transmit plane of other radios
6. Change the elevation of your antennas… get out of the transmit plane of other radios

Signal to Noise Ratio (SNR)

- The difference between the signal strength and the noise floor.
- For RouterOS, a minimum difference of 22dB is need for the link to work properly. Higher modulation rates will require a higher separation.
  - That means if the SS is -65 then the minimum value for noise floor is -87.
  - Or if the noise floor is -110 then the highest signal that can be worked with is a -88.
  - Those values, of course, are a theoretical threshold not to cross. In the real world a signal of -88 or a noise floor at -87 will be very problematic.

Making Sure the Antennas are in the Capture Area

- Always keep in mind where the transmit plane is and what take off angle you are working with.
- For example:
  - A WISP using an omni @200' AGL to talk to CPEs on someone's roof line will usually result in poor performance.
  - Ceiling mounted APs for 802.11/b/g are often less effective than APs mounted on the wall @ 4' where the user's device is. The opposite is true with 802.11n/ac.
  - For ISPs, avoid fringe area connections as much as possible.

Making Sure the Antennas are in the Capture Area

Making Sure the Antennas are in the Capture Area

AS a WISP:

- Make sure that both the AP and the CPE are in the same transmit plane
- Use a down tilt calculator to determine the best angle for the AP. Keep your cells small.
- Tune the CPE in both the horizontal and vertical planes.

Making Sure the Antennas are in the Capture Area

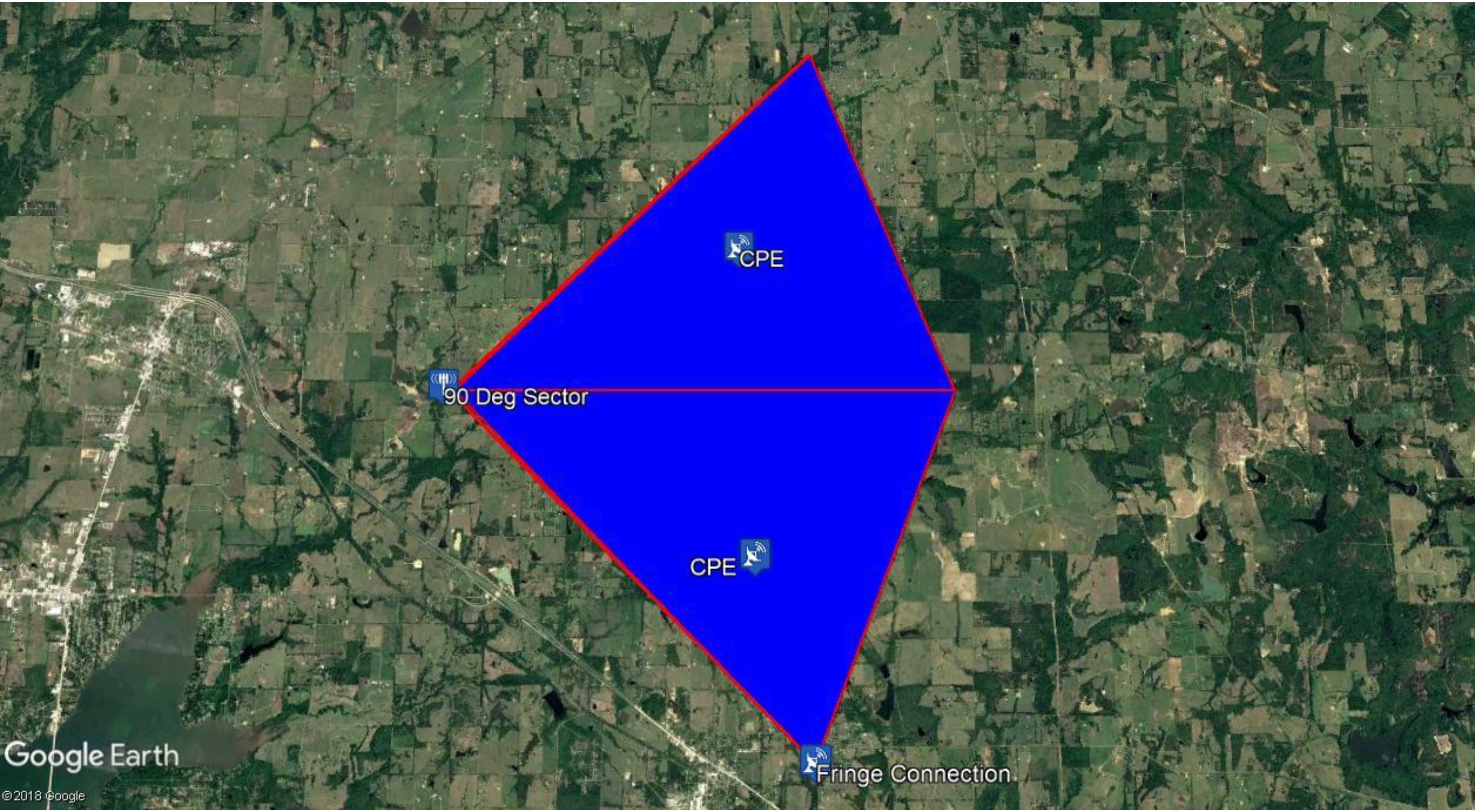
Carefully evaluate your use case for ceiling mounted APs.

- User devices are usually polarized vertically and often held at 45-90 degrees. Ceiling mounted APs are polarized horizontally, which can be helpful for 802.11n/ac, but problematic for 802.11a/b/g
- Placing the ceiling mounted AP on the wall or using a wall mount AP will result in higher signal levels.

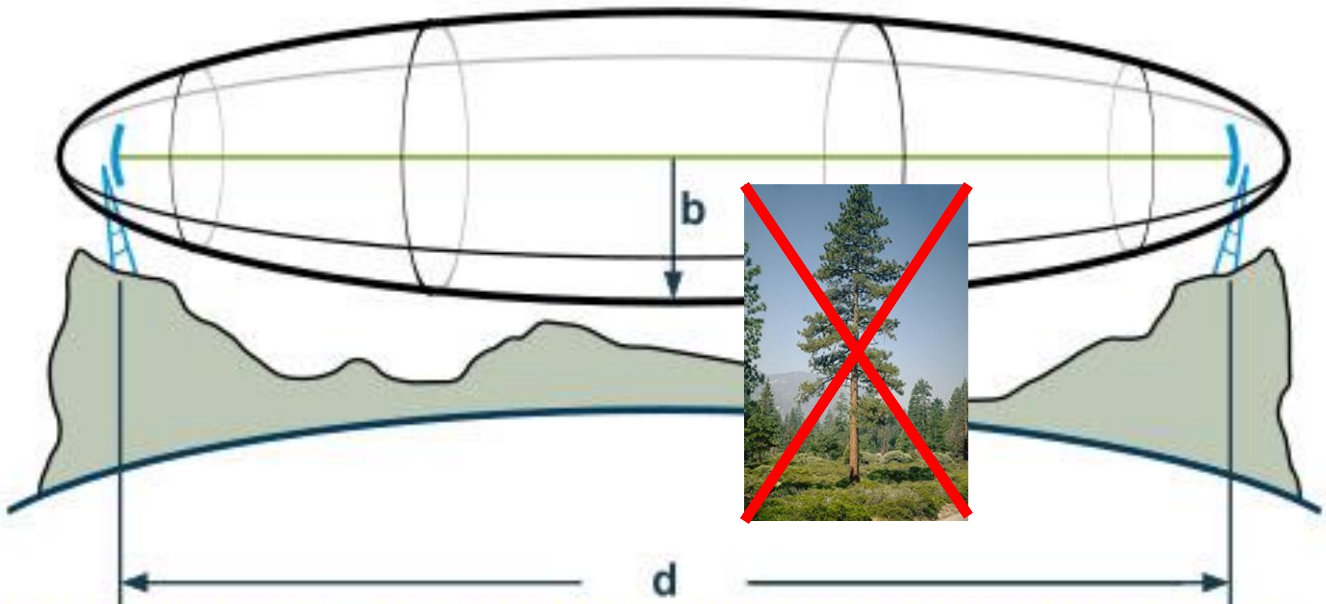
For ISPs -Avoid Fringe Area Connections

- Plot out **ALL** connections and make sure they are connected to the correct AP.
- If connecting to the correct AP does not work, troubleshoot that connection instead of connecting them via some other means.
- Radios on the edge of a coverage area will always struggle, so don't install them there.
- When the opportunity is available, small beam width sectors (30, 60, 90 degrees) are better than "full size sectors" (120 degree). Overlap coverage areas by a few degrees if possible. 3-5 degrees should be enough.
- If you don't need 360 degrees of coverage, don't install the antennas that way.
- You're wireless network is only as good as your worst connection!

Making Sure the Antennas are in the Capture Area



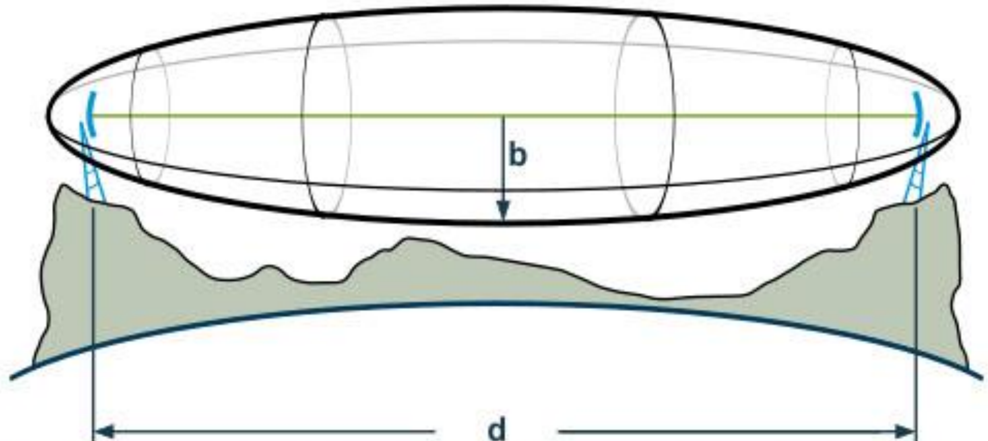
Fresnel Zone



Fresnel zoned is the distance between the transmitter and the receiver, b is the radius of the Fresnel zone.

- LOS is not enough by itself. The entire Fresnel Zone needs to be clear. (At least 80%....but 100% better)

Fresnel Zone



Fresnel zoned is the distance between the transmitter and the receiver, b is the radius of the Fresnel zone.

The max diameter of the Fresnel zone corresponds to the max height and width of the Capture Zone. The Capture Zone is the area the receiving antennas has to be in to receive the signal. Very useful when building arrays or using multiple antennas for MIMO.

Fresnel Zone

900MHz				2.4GHz		
Distance (Miles)	Radius (Feet)	Diamter (Feet)		Distance (Miles)	Radius (Feet)	Diamter (Feet)
1	37.97	75.94		1	23.25	46.5
2	53.7	107.4		2	32.89	65.78
3	65.77	131.54		3	40.28	80.56
4	75.95	151.9		4	46.51	93.02
5	84.91	169.82		5	52	104
10	120.08	240.16		10	73.54	147.08
15	147.07	294.14		15	90.06	180.12
20	169.82	339.64		20	104	208
25	189.87	379.74		25	116.27	232.54
30	207.99	415.98		30	127.37	254.74

Fresnel Zone

5.8GHz				60GHz		
Distance (Miles)	Radius (Feet)	Diamter (Feet)		Distance (Miles)	Radius (Feet)	Diamter (Feet)
1	14.96	29.92		.1	1.47	2.94
2	21.15	42.3		.25	2.33	4.66
3	25.91	51.82		.5	3.29	6.58
4	29.92	59.84		1	4.65	9.3
5	33.45	66.9				
10	47.3	94.6				
15	57.93	115.86				
20	66.9	133.8				
25	74.79	149.58				
30	81.93	163.86				

Setting Realistic Expectations

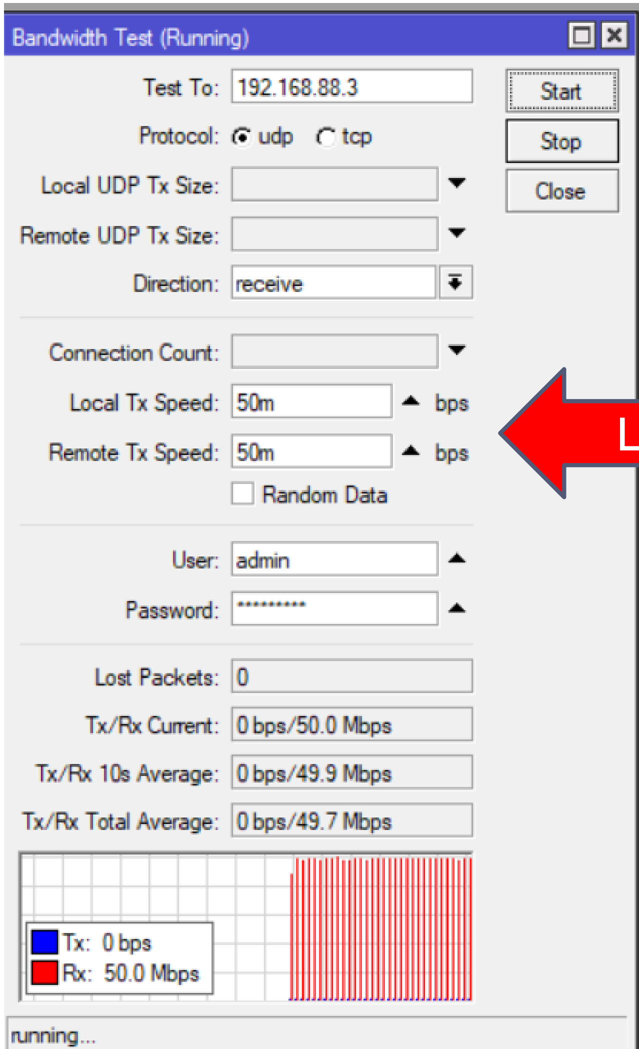
- In any wireless link, Step 1, is determining what we really need:
  - How many users do we need to support?
  - How much throughput do they need?
  - What is our expected duty cycle? Will they be using it occasionally or constantly?
  - What is our physical environment like (indoors, outdoors, metal buildings, lots of small spaces, ectara)?
  - Do we control both ends of the link or only one end?

How many users can we support

- This is one of the most commonly misunderstood concepts.
  - There is, of course, a limit to how many users a single AP can support. Those factor include:
    - Anticipated throughput to each end user
    - The capabilities of the client device
    - The duty cycle of each client device
    - The wireless mode be used (802.11, Nstreme, NV2)

- Here's how you know for sure:
  - Instead of bandwidth testing one client device to the AP, bandwidth test all clients devices to the AP at the same time. That is the only way to get a realistic view of how much bandwidth you can deliver VS the number of clients.
  - That number is smaller than most would expect and ISPs rarely are able to add more than about 25 subs per AP.

How many users can we support



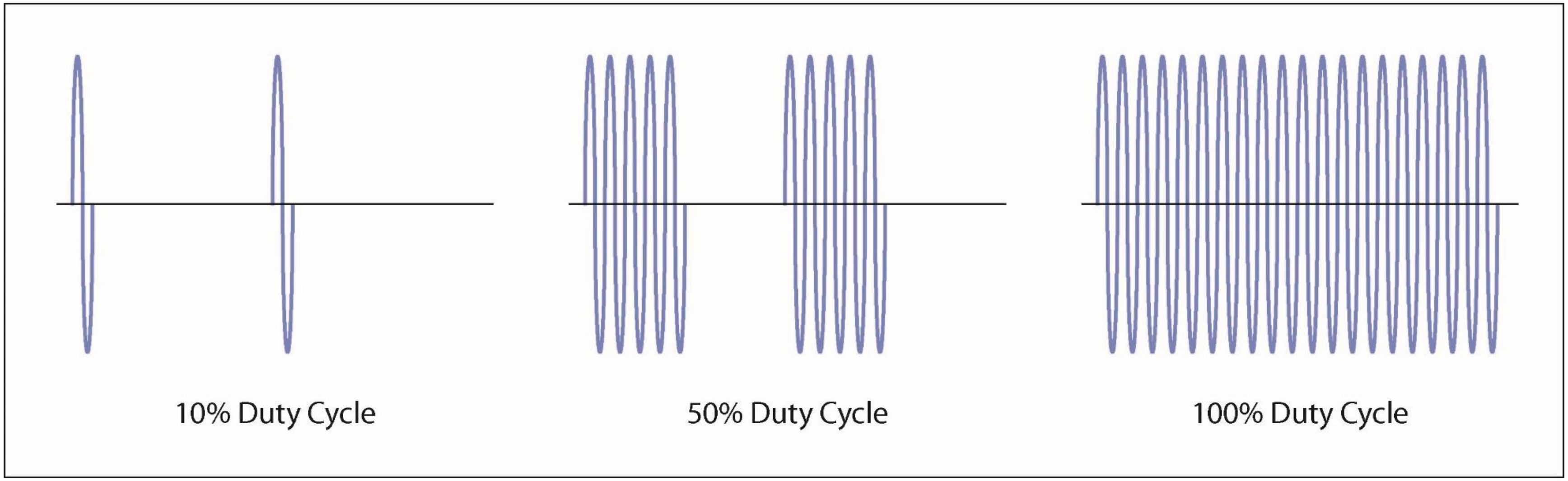
- Allows you to test to a specified limit such as the max speed package you are offering your customers.

- This will allow for a more accurate picture of what your network would look like if your customers were maxing out their queues.

How much throughput do we need?

- Setting realistic expectations for end user needs is critical for growth!!!
- For example, utilizing 802.11ac on a 80MHz channel because its new and should be "better" when all we need a is a few megs for "machine to machine" traffic in an environment such as an industrial setting means when we achieve the AP density needed for the physical coverage area, we're already out of clean spectrum. We've become our own worst problem.
- Don't be greedy!

Duty Cycle



Duty Cycle

- Any transmitter, obviously, can only achieve a maximum of 100% duty cycle.
- In 802.11, the AP needs to communicate with the station and the station needs to transmit as well. Some of the communication is needed to keep the link alive or acknowledge delivery of frames and that does not translate into deliverable bandwidth.
- As more clients needs to transmit, that means their duty cycle and every other transceiver's duty cycle has to get smaller.

Duty Cycle

Let's say in Theory the AP is capable of 100Mb and that is spends ½ of time TX and RX

50% of 100Mb = 50Mb deliverable

Let's argue that each CPE needs an equal amount of time to talk to the AP

10Mb

10Mb

10Mb

10Mb

10Mb

There are several factors this slide does not take into account, but hopefully it conveys that PTMP performance will understandably be much lower than PTP performance.

What is our physical environment?

- Indoor VS Outdoor
- 802.11 standard in use
  - Multipath reflections are destructive to a/b/g
  - Multipath reflections are needed for n/ac
- What other sources of RF are there?
  - Commercial radio stations
  - Home/ office automation products
  - Electrical noise
- Small cells are always better

Multipath Indoors

- Many rooms that we are trying to deliver WIFI to, absorb RF instead of reflecting it.
- We need the reflections/ refractions/ diffractions to take place in order to use the higher modulations rates of 802.11n/ac.
- Force the reflections:
  - Use decorative mirrors to bounce the signal where it needs to go.
  - Add aluminum foil between pictures and frame backings.
  - Place objects in front of the router, so that there is no direct path to the user.
  - Use metal blinds
  - Pick paints that go nuts in a microwave oven ;-)

Multipath Outdoors

- On longer links, multipath is often achieved naturally.
- On shorter links, antennas may have to be skewed slightly so that their time of arrivals are not identical.
- In the real world there are real world factors that affect our antenna selection like space available, weight, and wind loading. However, from a radio perspective, multiple single chain antennas will always out perform an equivalent multi-chain antenna.

Do we control both ends of the link?

- The fastest way to complicate a wireless network is to bring your device (BYOD).
- In a BYOD environment, clients will:
  - Have various supported modes
  - Have various supported capabilities
  - Have various numbers of antennas
  - Have various types of antennas
  - May have problems to result from not being correctly configured or updated.
  - Some devices may simply be partially broken or performing poorly due to age.

BYOD – How do deal with it

- Stop using backwards compatibility modes! This is one of biggest performance killing habits we have.
  - 802.11 – 1997 (22 years ago) (Now obsolete)
  - 802.11b – 1999 (20 years ago)
  - 802.11a – 1999 (20 years ago)
  - 802.11g – 2003 (16 years ago)
  - 802.11n – 2009 (10 years ago)
  - 802.11ad – 2012 (7 years ago) (60GHz band)
  - 802.11ac – 2013 (6 years ago)

BYOD – How do deal with it

- Don't expect perfect performance in such a dynamic environment.
- Set the modulation rates – don't let users get greedy
- If using 802.11n – lock the GI to long
- Stop supporting older wireless encryption standards that use the CPU instead of the encryption co-processor
- Use QoS mechanisms as much as possible
- Physically separate "Guest Networks" from "work networks"
- Avoid VAPs if at all possible

Common settings that should be scrutinized

Common settings that should be scrutinized

- Desired MIMO mode
- Use of guard interval
- Use of RTS/ CTS in high noise environments
- Adjusting power levels

MIMO Roles

- Always evaluated from the AP while it is in a transmit role
- Works independently of channel width
- Up to 3x3 is possible with off the shelf MikroTik products
- Support for 4x4 is in the works
- MU-MIMO is not currently available (at least as far as I know)
- Active beamforming is only available on 802.11ad products and does not relate to the 802.11a/b/g/n/ac portion of this presentation

HT MCS Index	VHT MCS Index	Spatial Streams	Modulation	Coding	LGI	SGI	LGI	SGI	LGI	SGI
0	0	1	BPSK	1/2	6.5	7.2	13.5	15	29.3	32.5
1	1	1	QPSK	1/2	13	14.4	27	30	58.5	65
2	2	1	QPSK	3/4	19.5	21.7	40.5	45	87.8	97.5
3	3	1	16-QAM	1/2	26	28.9	54	60	117	130
4	4	1	16-QAM	3/4	39	43.3	81	90	175.5	195
5	5	1	64-QAM	2/3	52	57.8	108	120	234	260
6	6	1	64-QAM	3/4	58.5	65	121.5	135	263.3	292.5
7	7	1	64-QAM	5/6	65	**72.2**	135	**150**	292.5	325
	8	1	256-QAM	3/4	78	**86.7**	162	180	351	390
	9	1	256-QAM	5/6	N/A	N/A	180	**200**	390	**433.3**
8	0	2	BPSK	1/2	13	14.4	27	30	58.5	65
9	1	2	QPSK	1/2	26	28.9	54	60	117	130
10	2	2	QPSK	3/4	39	43.3	81	90	175.5	195
11	3	2	16-QAM	1/2	52	57.8	108	120	234	260
12	4	2	16-QAM	3/4	78	86.7	162	180	351	390
13	5	2	64-QAM	2/3	104	115.6	216	240	468	520
14	6	2	64-QAM	3/4	117	130.3	243	270	526.5	585
15	7	2	64-QAM	5/6	130	**144.4**	270	**300**	585	650
	8	2	256-QAM	3/4	156	**173.3**	324	360	702	780
	9	2	256-QAM	5/6	N/A	N/A	360	**400**	780	**866.7**
16	0	3	BPSK	1/2	19.5	21.7	40.5	45	87.8	97.5
17	1	3	QPSK	1/2	39	43.3	81	90	175.5	195
18	2	3	QPSK	3/4	58.5	65	121.5	135	263.3	292.5
19	3	3	16-QAM	1/2	78	86.7	162	180	351	390
20	4	3	16-QAM	3/4	117	130	243	270	526.5	585
21	5	3	64-QAM	2/3	156	173.3	324	360	702	780
22	6	3	64-QAM	3/4	175.5	195	364.5	405	N/A	N/A
23	7	3	64-QAM	5/6	195	**216.7**	405	**450**	877.5	975
	8	3	256-QAM	3/4	234	260	486	540	1053	1170
	9	3	256-QAM	5/6	260	**288.9**	540	**600**	1170	**1300**

SISO – Single In Single Out

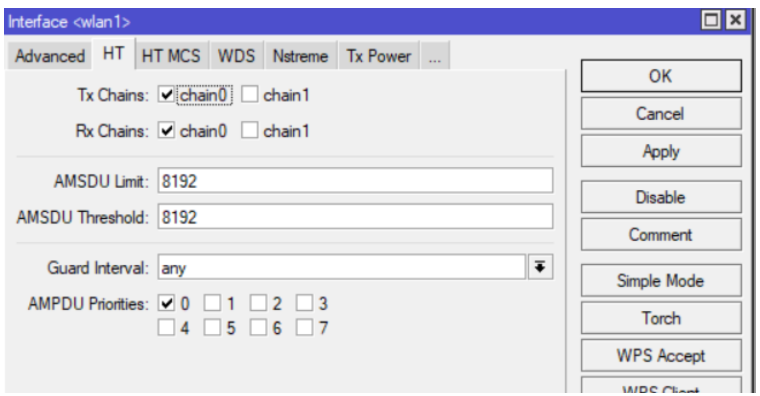
TX

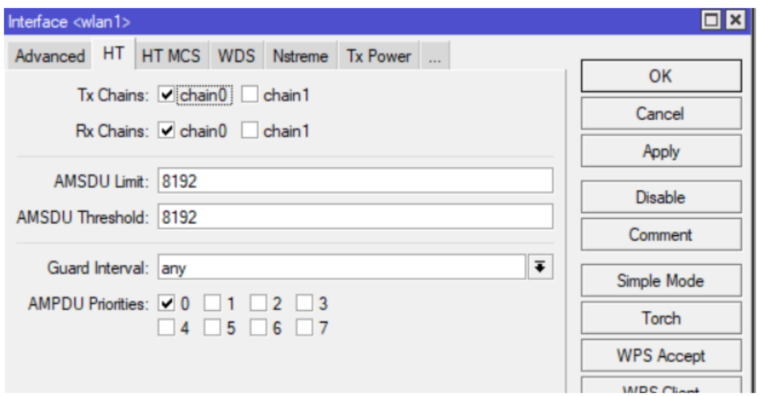
1 TX Chain to 1 RX Chain

1 Block of Data (Applies to 802.11a/b/g/n/ac)

RX

- Considered the performance benchmark for distance and throughput in each standard
- 802.11a/b/g are always SISO
- 802.11n/ac use TX/RX chains to determine role





SIMO – Single In Multiple Out

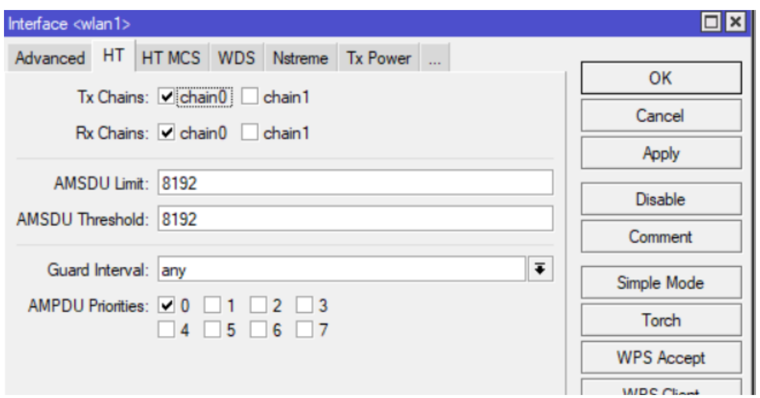
TX

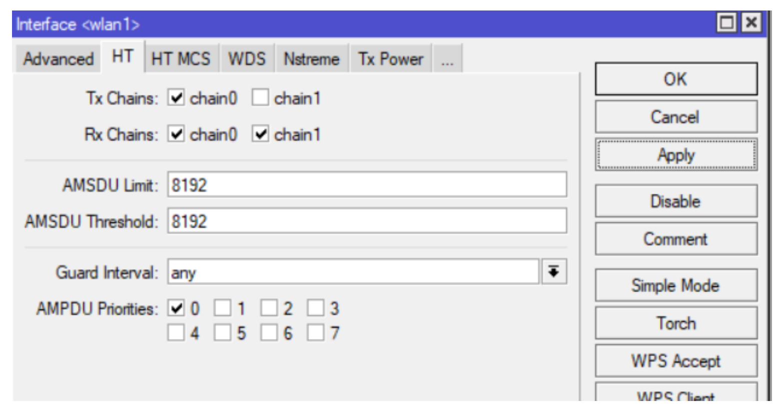
1 TX Chain to 2 or more RX Chains

1 Block of Data (Applies to 802.11n/ac)

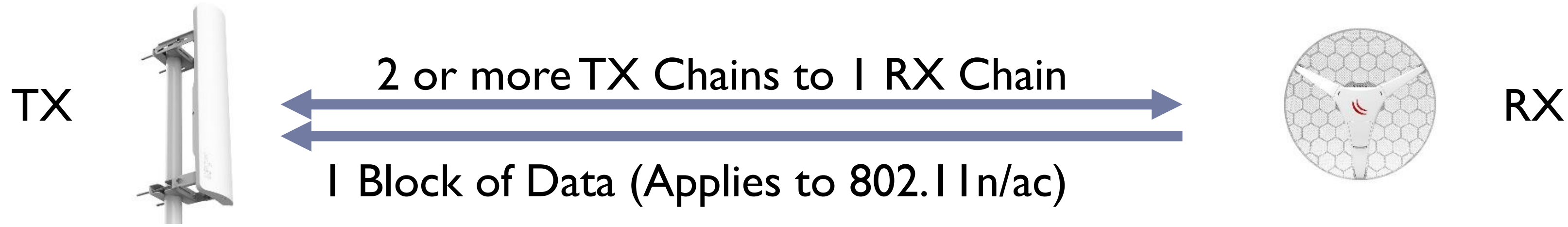
RX

- Allows for higher modulations rates in 802.11n/ac over 802.11a/b/g
- Potentially could result in longer links at a comparable data rate to older standards
- Each additional chain improves Reception and Transmission from the station

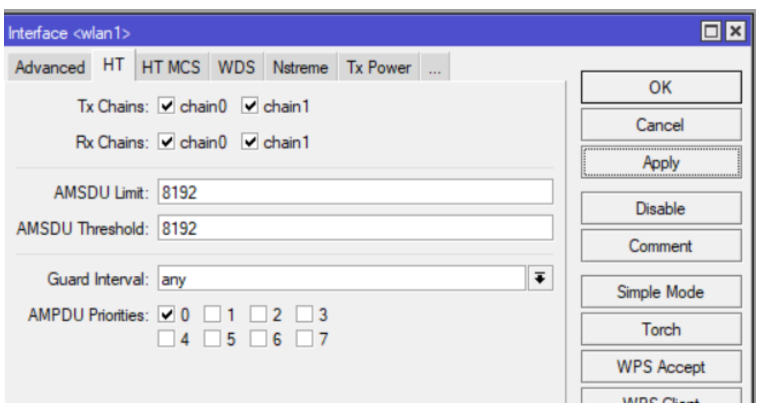


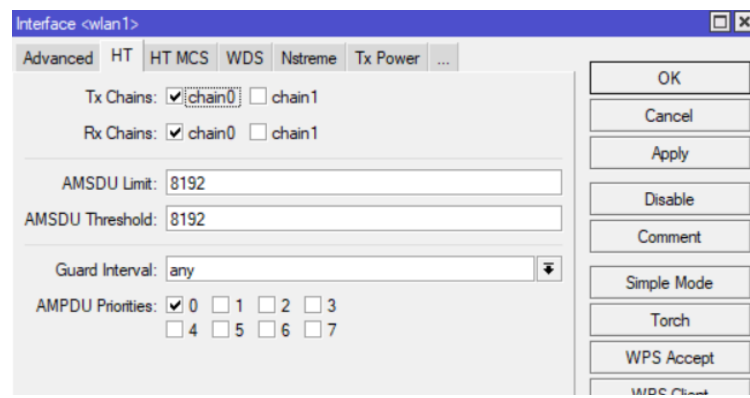


MISO – Multiple In Single Out



- Allows for higher modulations rates in 802.11n/ac over 802.11a/b/g
- Potentially could result in longer links at a comparable data rate to older standards
- Each additional chain improves Reception and Transmission from the AP





MIMO – Multiple In Multiple Out

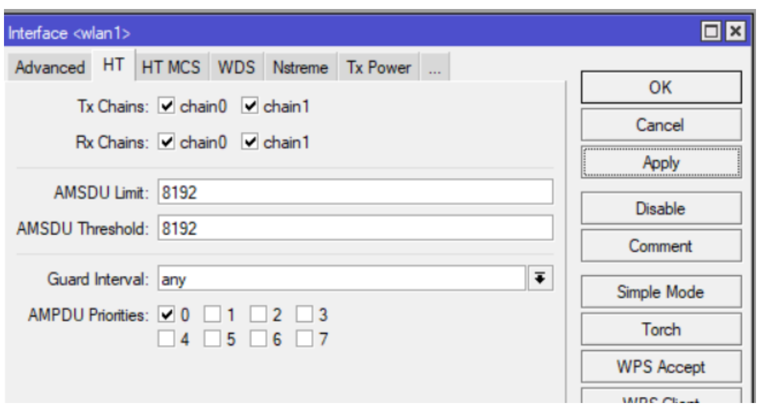
TX 

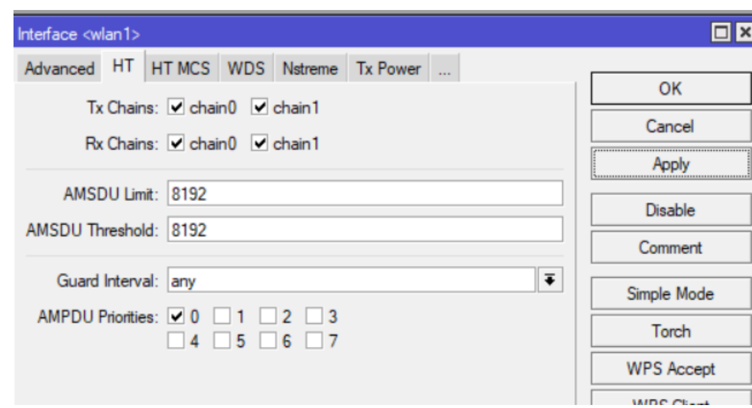
2 or more TX Chains to 2 or more RX Chains

2 or more Blocks of Data (Applies to 802.11n/ac)

 RX

- Allows for higher modulations rates in 802.11n/ac over 802.11a/b/g
- Distances will be comparable to SISO ranges





802.11ac Data Rates

HT MCS Index	VHT MCS Index	Spatial Streams	Modulation	Coding	LGI					
0	0	1	BPSK	1/2	6.5					
1	1	1	QPSK	1/2	13					
2	2	1	QPSK	3/4	19.5					
3	3	1	16-QAM	1/2	[illegible]					
4	4	1	16-QAM	3/4	39					
5	5	1	64-QAM	2/3	52					
6	6	1	64-QAM	3/4	58.5					
7	7	1	64-QAM	5/6	65					
	8	1	256-QAM	3/4	[illegible]					
	9	1	256-QAM	5/6	N/A					
8	0	2	BPSK	1/2	13					
9	1	2	QPSK	1/2	26					
10	2	2	QPSK	3/4	39					
11	3	2	16-QAM	1/2	52	57.8	108	120	234	260
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16	0	3	BPSK	1/2	19.5	21.7	40.5	45	87.8	97.5
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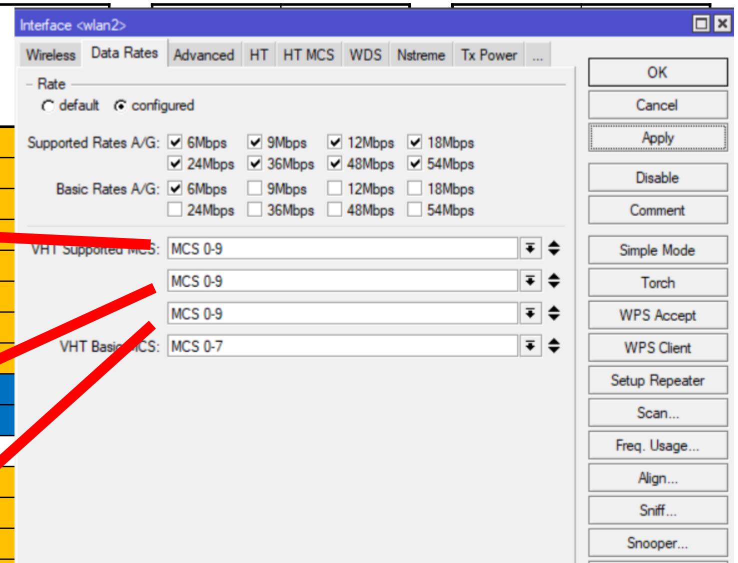
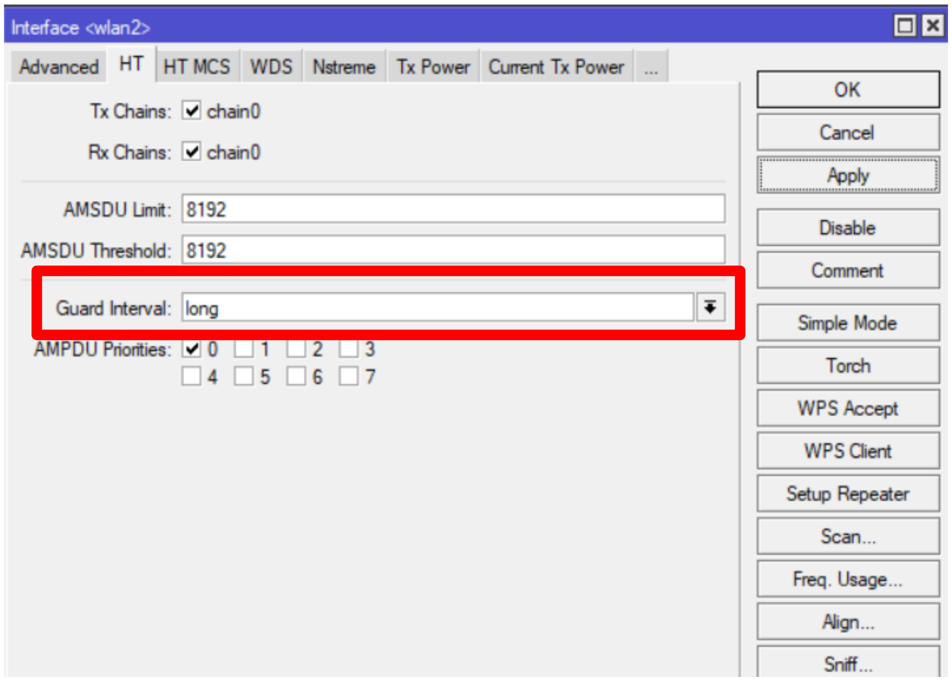
22	6	3	64-QAM	3/4	175.5	195	364.5	405	N/A	N/A
23	7	3	64-QAM	5/6	195	**216.7**	405	**450**	877.5	975
	8	3	256-QAM	3/4	234	260	486	540	1053	1170
	9	3	256-QAM	5/6	260	**288.9**	540	**600**	1170	**1300**

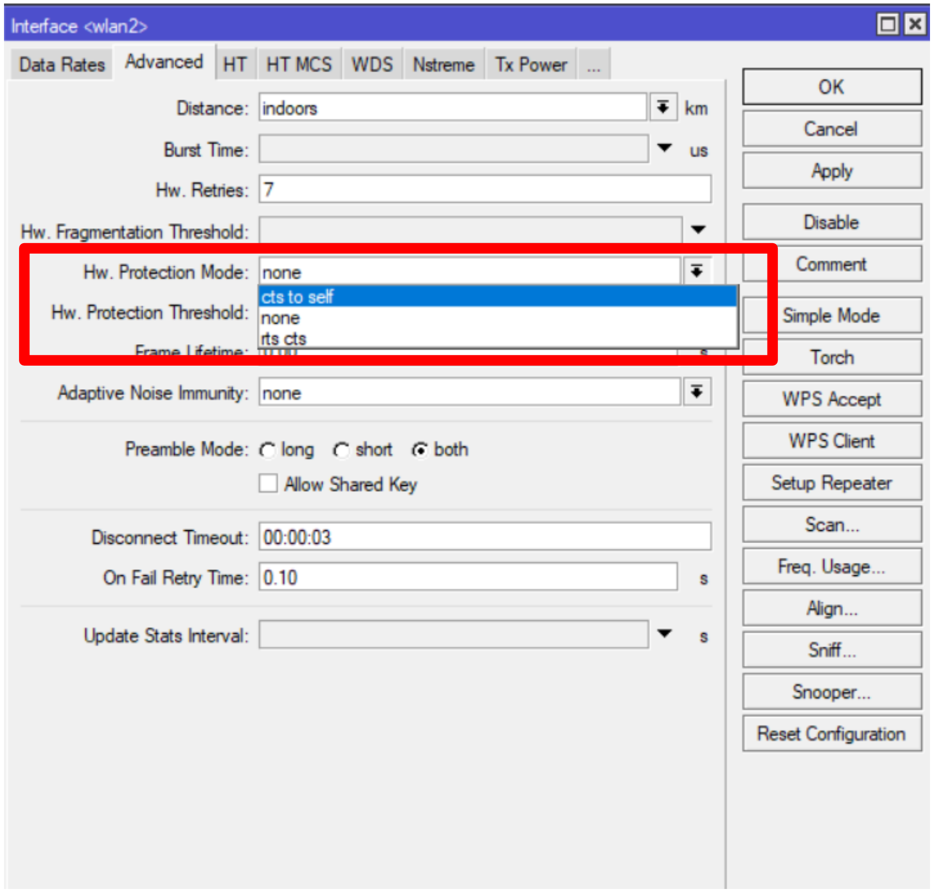


Guard Interval



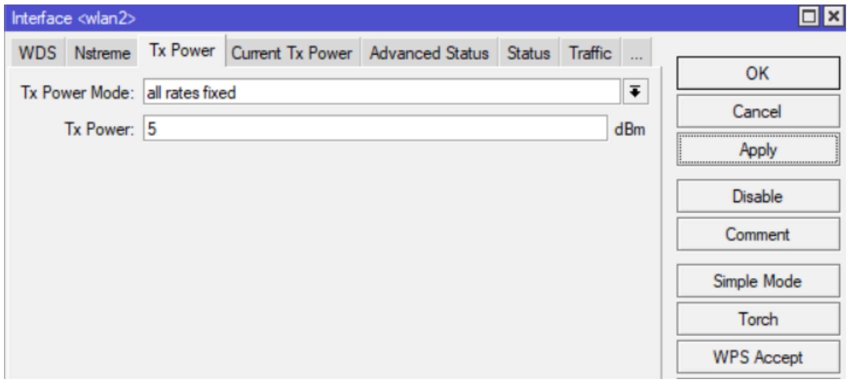
Setting the guard interval to long can result in fewer DFS choices for the radios and ultimately improve long term performance. This applies to both indoor and outdoor links. Don't be greedy!

RTS/ CTS



- Ready to Send/ Clear to Send are 802.11 mechanisms used to mitigate the hidden node problem. The really do work and should be used anytime we have the opportunity for the hidden node problem to exist.
- HW. Protection mode
  - RTS/CTS when you can set it on all devices
  - CTS to self when you can set on only one side

Power Levels



Its better to finesse a link than to muscle a link!

- Power levels are usually ignored and we often use way more than we need.
- This results in the self imposed need to use more power on other radios.
- Carefully, elevate your situation and try to lower the power levels every time you can.

Tips and Tricks

- The auto frequency feature has its place is probably used way too often…
- When your testing your wireless link, do so in a 20MHz channels first.
- 802.11n/ac links with 40MHz and 80MHz channels needs good RSSI and noise floor values on all of the channels.
- A good RSSI for 802.11a/b/g was -65, but good 802.11n/ac links needs better RSSI values.
- Use the scan list! It helps with reconnect times for all wireless links.

Tips and Tricks

- The auto frequency feature has its place is probably used way too often…
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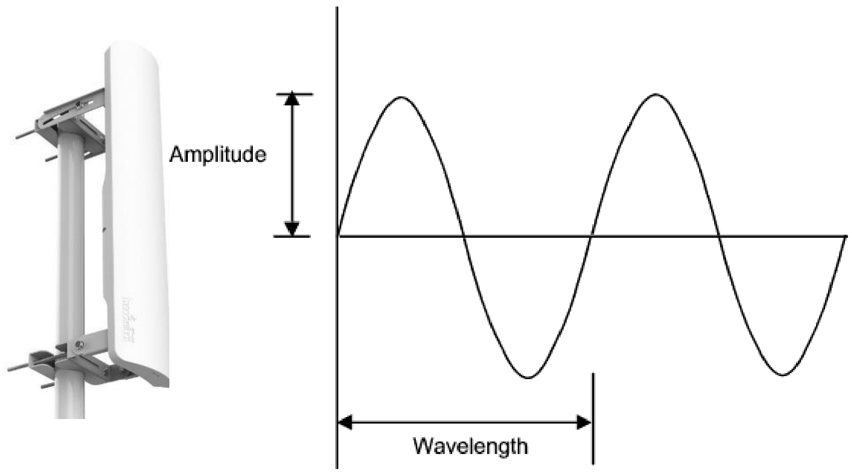
Near field and Far field



The near field is 1 wavelength away from the antenna
The transition zone is the 2nd wavelength
The 3rd wavelength and farther is the far field

When using multiple antennas try to keep them out of the near field and transition zone.

Questions?