WiFi Overview

02.13.17

WiFi Fundamentals

Some Common WiFi Terms and Definitions

- Access Point – or AP; equipment which connects wireless devices to a wired network (in general)
- Client – device which connects to an access point. May also be referred to as a station or device.
- SSID – **S**ervice **S**et **ID**entifier is the network name associated with the access point or a group of access points;
  - For example: “2WIRE479” or “StayOffMyWiFi”
- BSSID – **B**asic **S**ervice **S**et **ID**entifier is essentially the MAC address of an access point.
- PHY – the physical layer transmission rate selected by the radios on a per-packet basis. Determined by equipment standard, number of streams and SNR.
- MIMO – multiple input, multiple output – uses multiple transmitters, receivers and antennas to move more data simultaneously

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The 802.11 Family View

- 802.11 is the “parent” of a family of Institute of Electronics and Electronic Engineering (IEEE) specifications for **Wireless LAN, or WLAN**
- The base standard was released in 1997 and has undergone several revisions since then:

Protocol	Main Frequency Band (GHz)	Single Stream Max Data Rate (Mbps)	BW (MHz)	Modulation	MIMO Support?
802.11a	5	54	20	OFDM	No
802.11b	2.4	11	22	DSSS/CCK	No
802.11g	2.4	54	20	OFDM/CCK	No
802.11n	2.4/5	72/150	20/40	OFDM	4
802.11ac	5	87/200/433/867	20/40/80/160*	OFDM	8

* 160MHz channel support is optional in 802.11ac

OFDM = Orthogonal Frequency Division Multiplexing
CCK = Complimentary Code Keying
DSSS = Digital Sequence Spread Spectrum

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Channel Utilization and the Distribution Control Function

- WiFi is *half duplex* and a channel may be shared by many AP's
- All devices associated with an AP also use the same channel
- All AP's / devices on a given channel share air time, but only one AP or device can "talk" at a time.
- WiFi uses Carrier Sense Multiple Access with Collision Avoidance, or *CSMA/CA* to control access to the medium.
- An AP or device will listen on the channel before trying to transmit, and will start transmission only if no one else is transmitting (sounds familiar, right?)
- BUT, a radio can't hear while it's transmitting. Therefore if a packet is not acknowledged at L2, then a *collision is assumed* to have occurred.
- If a collision is assumed, the *radio retries after a random delay*.
- Number of collisions will increase as traffic on the channel (or utilization) increases.

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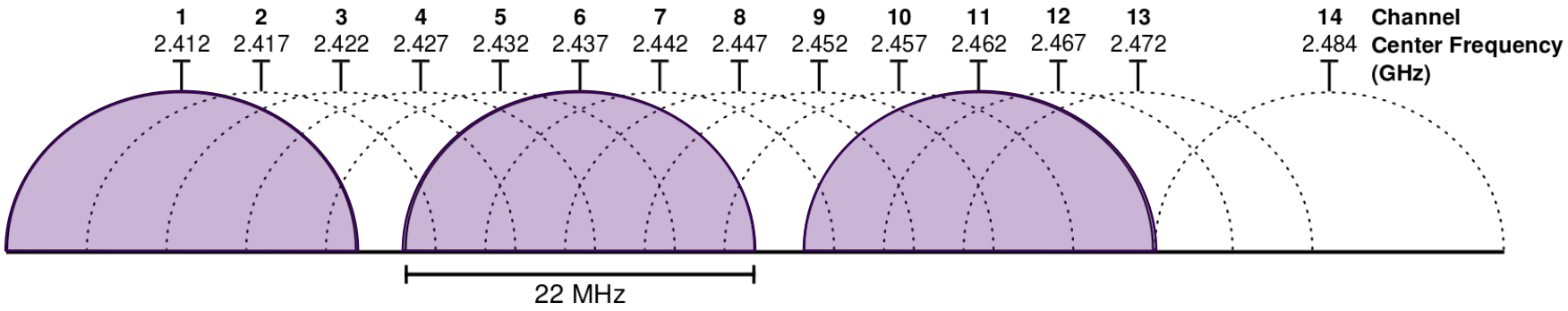
2.4 GHz WiFi Channels



Michael Gauthier, Wireless Networking in the Developing World (http://creativecommons.org/licenses/by-sa/3.0)

- Channels are 22 MHz wide for 802.11b and 20MHz wide for 802.11g / n
- Channels are spaced 5 MHz apart
- Channels 1, 6 and 11 are non-overlapping
- 3 - 5 MHz guard band between non-overlapping channels

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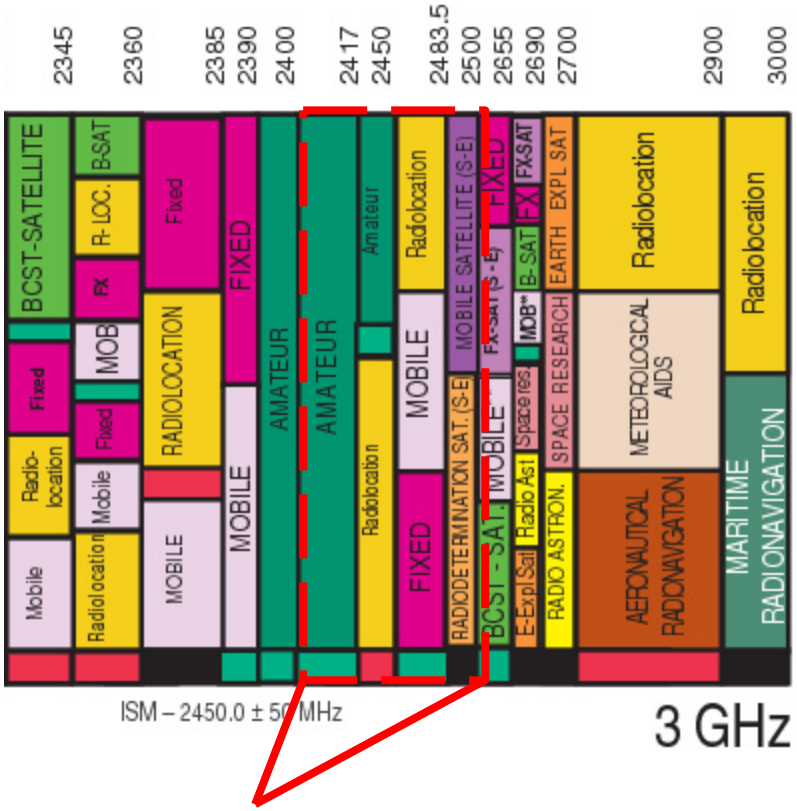
2.4 GHz Spectrum Allocation



ISM (aka 2.4G) Band

- "Amateur" applies to both terrestrial and satellite.
- ISM stands for "Industrial, Science and Mechanical"; the band can be used by anything that gets a FCC Part 15 approval, like:
  - Bluetooth devices
  - cordless telephones
  - baby monitors
  - **microwave ovens**
  - Many, many others...

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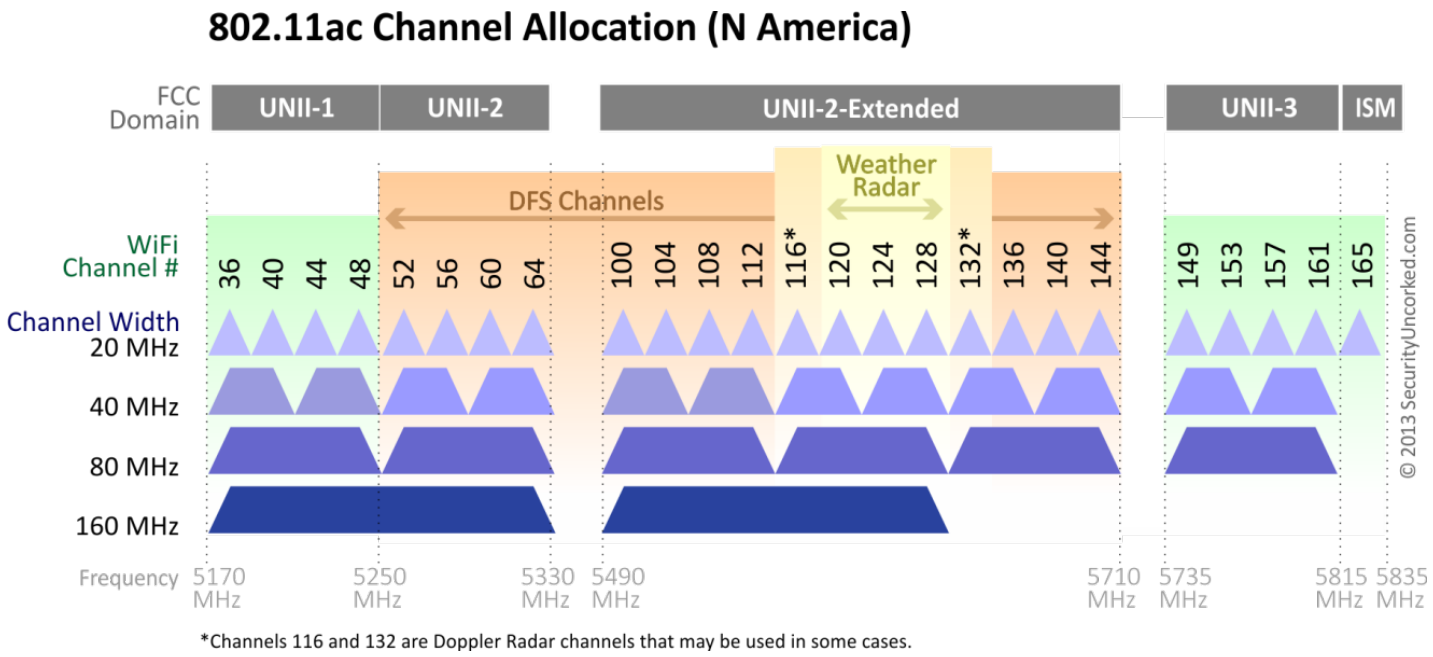
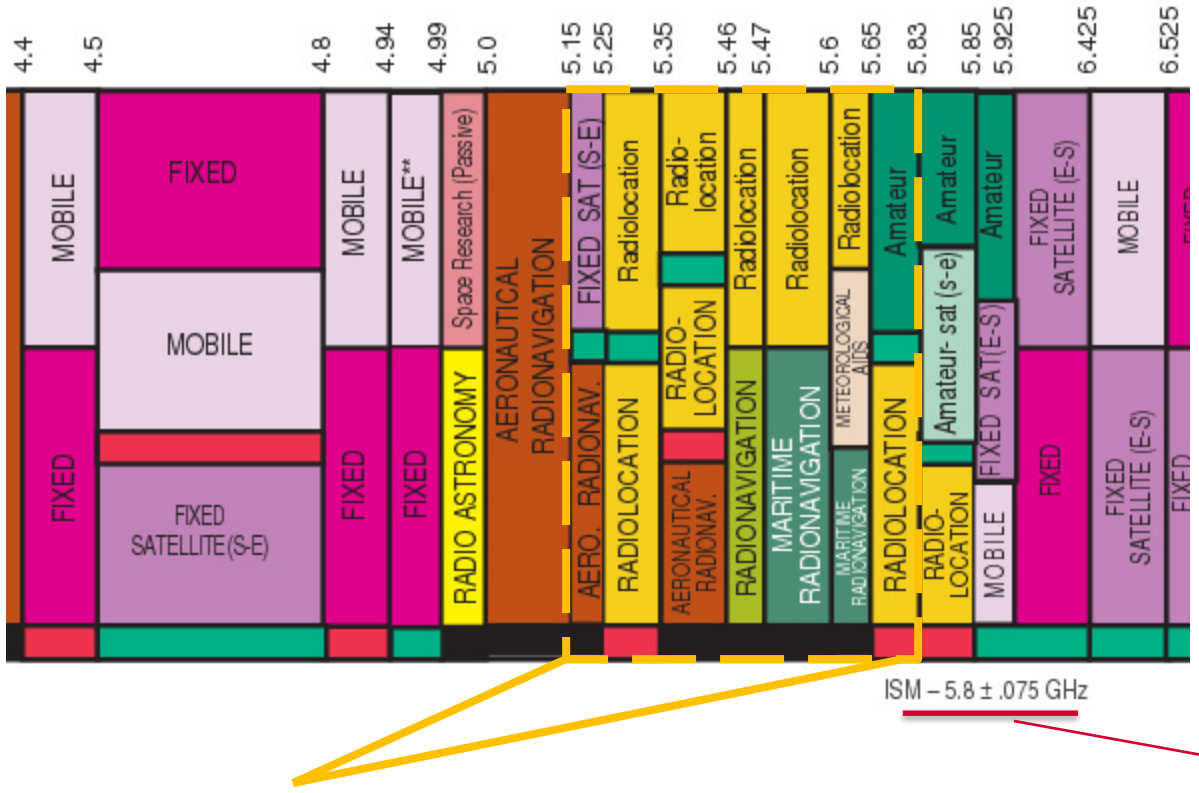
5 GHz WiFi Channels



J. Jabbusch, Information Week Network Computing

- Channels are 20 MHz wide
- Channels are non-overlapping by design
- UNII stands for Unlicensed National Information Infrastructure

5 GHz Spectrum Allocation



"5G" Band
(Worldwide except Japan)

- Most of the world uses the spectrum from 5.18 – 5.835 GHz.
- Many of these frequencies are used for low power satcomm:
  - To them, WiFi is the interferer.
- Note that another ISM band exists here
  - cordless phones
  - point-to-point radios
  - baby monitors
  - etc.

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802.11ac Advancements

- More channel bonding, increased from the maximum of 40 MHz in 802.11n, and now up to 80 or even 160 MHz
- Denser modulation, now using 256 quadrature amplitude modulation (QAM), up from 802.11n's 64QAM
- More MIMO 8-stream max vs. 4-stream
- MU-MIMO enabling frames to be transmitted to multiple clients at the same time over the same channel
- Standardized Beamforming
- VHT (Very High Throughput) additions to frame processing, etc. Draft 4.0

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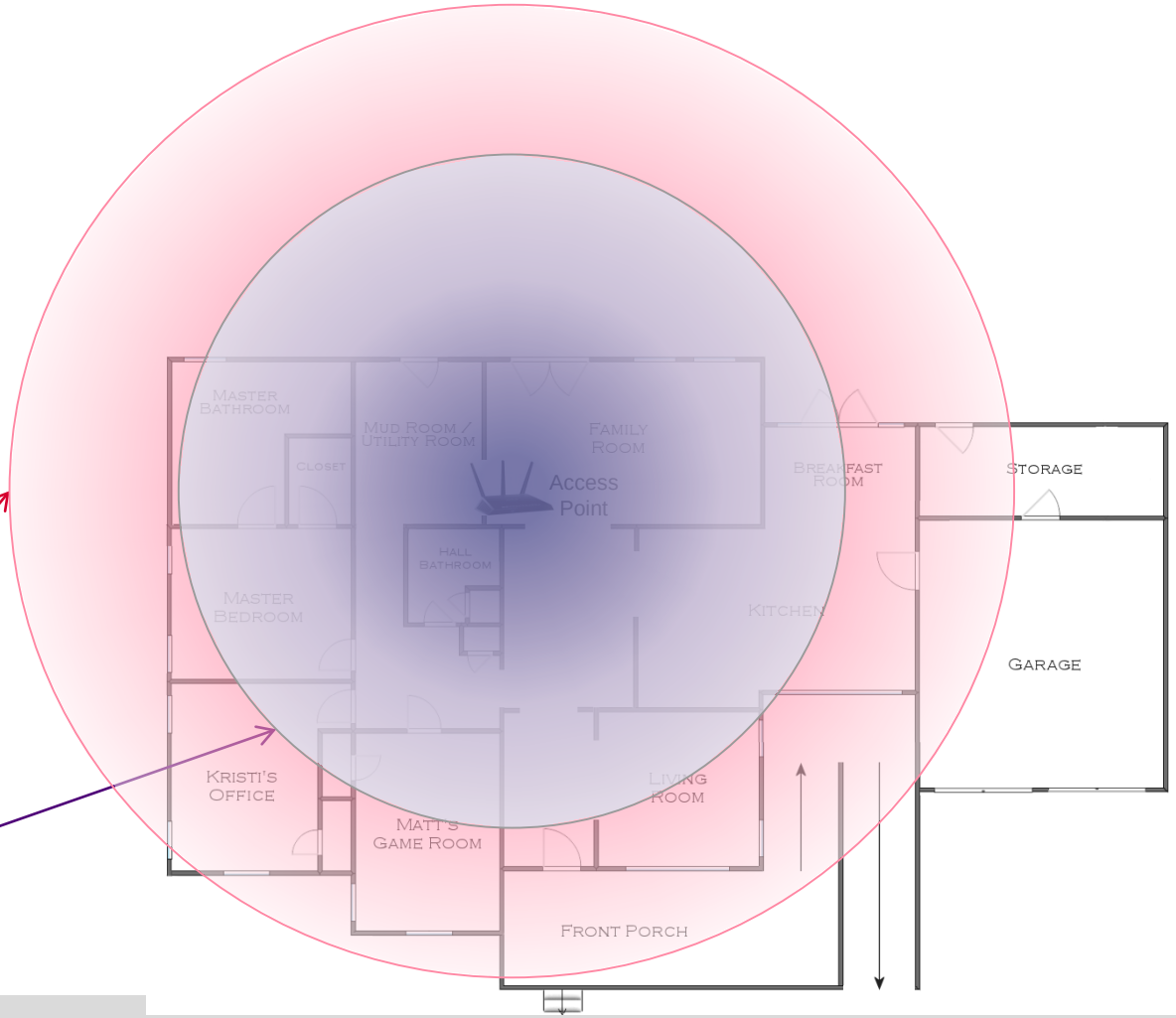
5 GHz Reach vs. 2.4 GHz Reach

- 5G has shorter reach than 2.4G. Compare:
  - 802.11g
    - 2.4 GHz band
    - PHY data rates:
      - 6Mbps to 54Mbps
  - 802.11a
    - 5 GHz band
    - PHY data rates:
      - 6Mbps to 54Mbps

802.11g 6 Mbps limit

802.11a 6 Mbps limit



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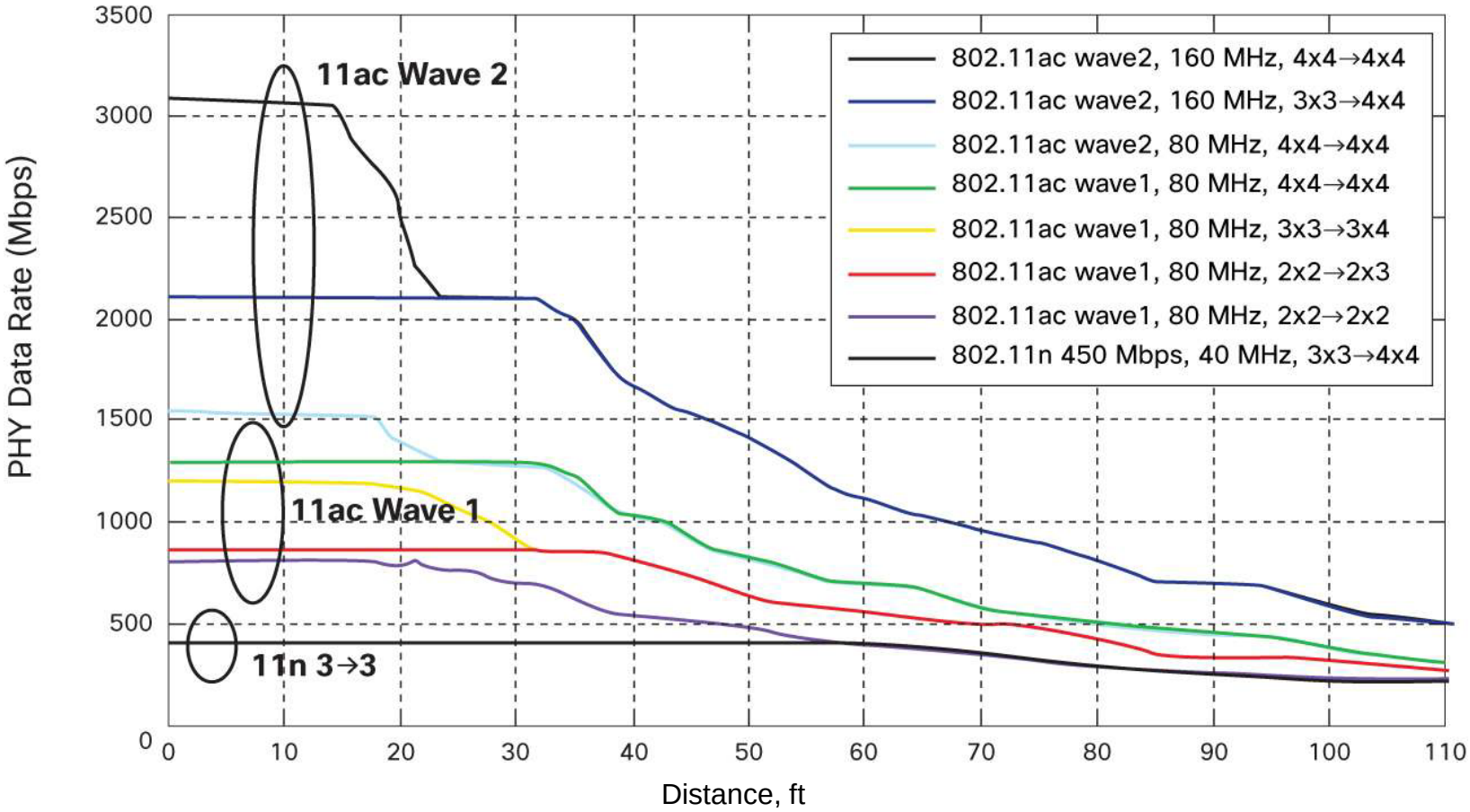
802.11ac Summary Rate & Reach



Source: CISCO

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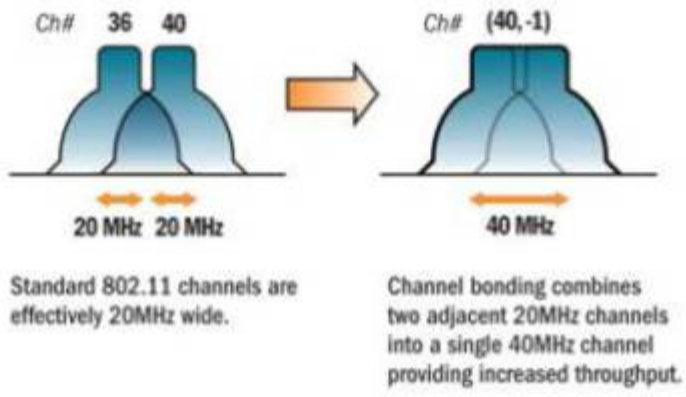
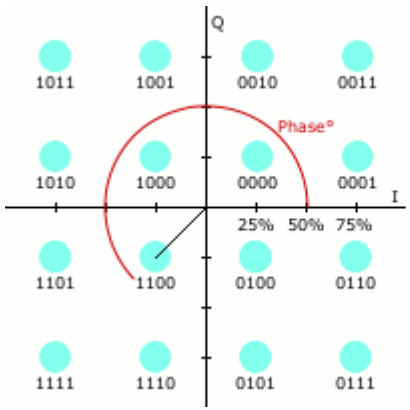
Techno-Nuggets

Channel Bonding



Source: http://wifijedi.com/2009/01/25/how-stuff-works-channel-bonding/



16 QAM

256 QAM

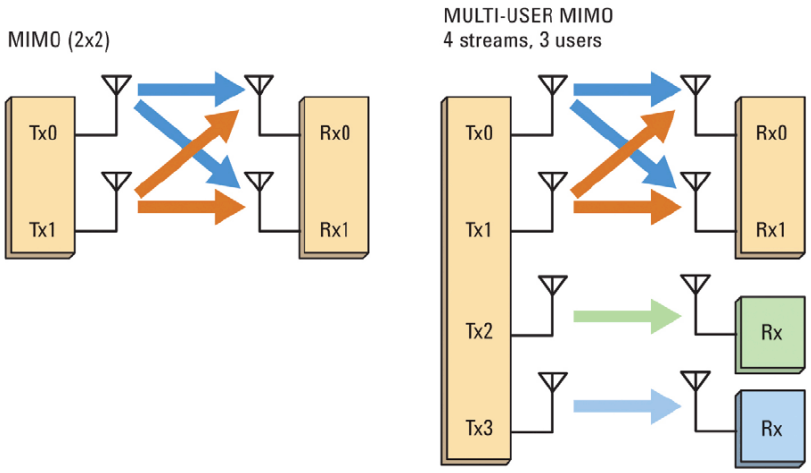
Summation of 2 carriers conveys both phase and amplitude of a constellation point.

Sources: Wikipedia and Cisco

MIMO vs. Multiple Spatial Streams

- MIMO actually means parallel RX processing of the *same data* from multiple TX sources, increasing the reliability of the transmission using antenna diversity.
- Multiple Spatial Streams means that *multiple data streams* are transmitted at the same time, and recombined by the receivers using MIMO techniques
- *M* x *N* x *Y* nomenclature:
  - *M* TX antennas
  - *N* RX antennas
  - *Y* spatial streams

MU-MIMO



Source: http://www.embedded.com/print/4230487

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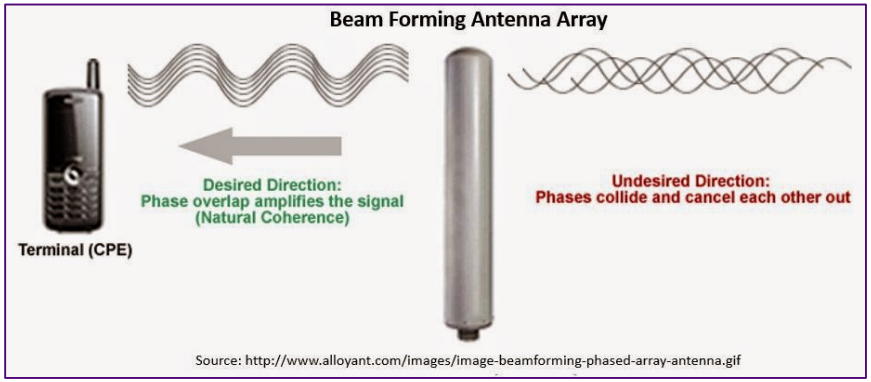
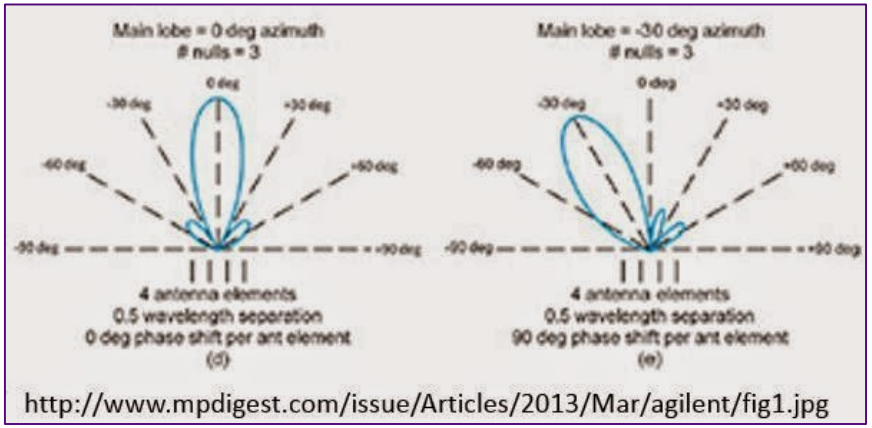
Transmit Beamforming

- Tx Beamforming using multiple omnidirectional antennas is most common technique used in commercial AP's.
- Requires a phased antenna array – multiple antennas of the same type, with known separation so as to be deliberately out of phase.
  - Other techniques such as switched antenna arrays and adaptive antenna arrays exist, but are less common
- Two key requirements:
  - The number of transmit radios must be greater than the number of spatial streams
  - The transmitter needs to know where the receiver is located relative to the AP. (Handshake)
- The transmitter adjusts the phase offsets for each antenna so that the signals propagating toward the receiver all *constructively interfere*.
  - Can achieve a + 3dB improvement for each antenna in the array
  - Downside – signals in other directions will *destructively interfere*.





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PHY Rates for 802.11ac

- *Available* PHY data rates are determined by a combination of radio supported:
  - Channel width (20, 40, 80, 160 MHz)
  - Modulation (BPSK, QPSK, 16/64/256-QAM)
  - Coding rate (1/2, 2/3, 3/4 or 5/6) *format = # user data bits / total transmitted data bits*
  - Guard interval (time between symbols; normal = 800ns or short = 400ns; drives symbol rate)
  - Number of spatial streams (1 to 8 spatial streams)
- *Actual* PHY rate used is related to the SNR between communicating radios.

Theoretical throughput for single spatial stream (in Mbit/s)[8][a]										
MCS index[b]	Modulation type	Coding rate	20 MHz channels		40 MHz channels		80 MHz channels		160 MHz channels	
			800 ns GI[c]	400 ns GI	800 ns GI	400 ns GI	800 ns GI	400 ns GI	800 ns GI	400 ns GI
0	BPSK	1/2	6.5	7.2	13.5	15	29.3	32.5	58.5	65
1	QPSK	1/2	13	14.4	27	30	58.5	65	117	130
2	QPSK	3/4	19.5	21.7	40.5	45	87.8	97.5	175.5	195
3	16-QAM	1/2	26	28.9	54	60	117	130	234	260
4	16-QAM	3/4	39	43.3	81	90	175.5	195	351	390
5	64-QAM	2/3	52	57.8	108	120	234	260	468	520
6	64-QAM	3/4	58.5	65	121.5	135	263.3	292.5	526.5	585
7	64-QAM	5/6	65	72.2	135	150	292.5	325	585	650
8	256-QAM	3/4	78	86.7	162	180	351	390	702	780
9	256-QAM	5/6	N/A	N/A	180	200	390	433.3	780	866.7
10	1024-QAM[9]	3/4	97.5	108.4	202.5	225	438.75	487.5	877.5	975
11	1024-QAM	5/6	N/A	N/A	225	250	487.5	541.6	975	1083.4

PHY Rate for 256-QAM, 80 MHz wide, SGI and **1** spatial stream = 433.33Mbps

PHY Rate for 256-QAM, 80 MHz wide, SGI and **3** spatial streams = 433.33 x 3 = 1300 Mbps

Resource: http://chimera.labs.oreilly.com/books/1234000001739/ch02.html#the_transmission_and_reception_process

Table Source: https://en.wikipedia.org/wiki/IEEE_802.11ac

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Coverage Problems

Typical WiFi Related Problems

Problem	Action
▪ Signal Strength and Coverage Problems ▫ Attenuation with distance and materials in the home ▫ 5GHz has shorter reach than 2.4 GHz	Look for -35 to -70 dBm RSSI; ≥ 20 dB SNR
▪ 802.11 Interference Sources ▫ Co-Channel interference (forces your AP to share the channel) ▫ Adjacent Channel interference (looks like noise to your AP)	Look for ≤ 4 co-channel and ≤ 3 adjacent channel
▪ Non-802.11 Interference Sources ▫ Microwaves, AV transmitters, cordless phones, baby monitors, etc.	Observe spectrum for interferers in ch. of interest
▪ High Channel Utilization: ▫ The more AP's in a channel the higher the *potential* utilization ▫ High utilization, low noise = high 802.11 traffic on the channel ▫ High utilization, high noise = potential non-802.11 interferer	Look for < 35% utilization + low noise
▪ 802.11a/b/g devices in your network ▫ Slow a/b/g PHY rates occupy the channel longer than modern PHY rates for the same amount of information transfer ▫ Old security types (WEP / WPA1) limit connection to lower 802.11 rates	Detect & advise replacement of old gear
▪ Understanding *real* WiFi Throughput is critical to reliable install ▫ Physical and Link layer results provide *indications* of actual WiFi throughput performance, but… ▫ WiFi is adaptive. *Actual* performance is dependent on many environmental factors and under-the-hood design complexities	Determine real packet throughput and service margin

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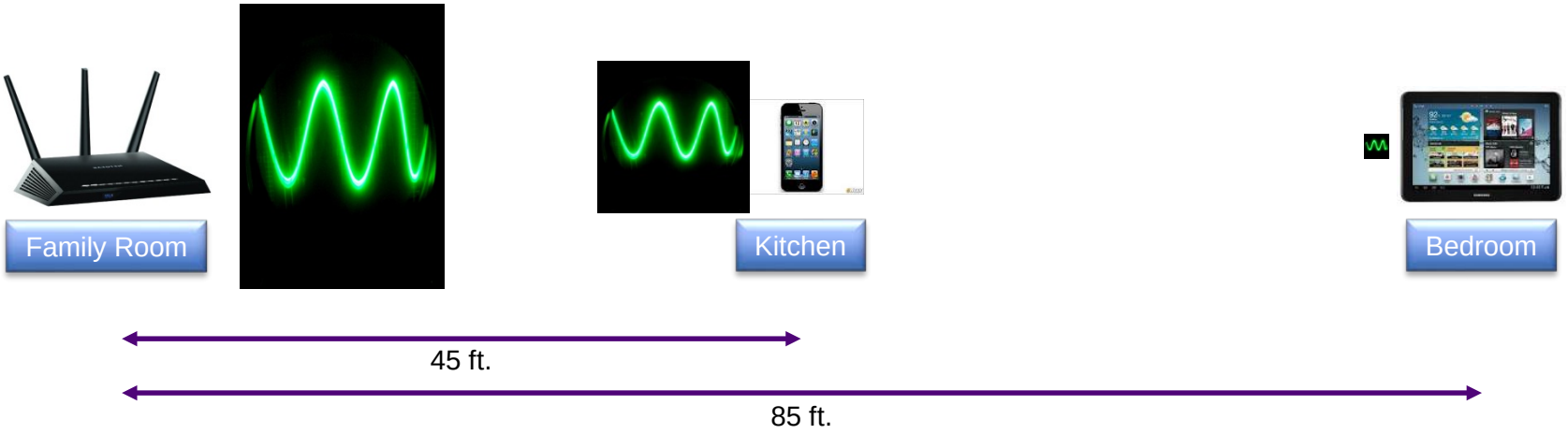
WiFi Signal Loss

- WiFi Signal strength is attenuated by (the square of the) distance …



  - … and by passing through intervening structures and materials

(Turn animation on!)

5 GHz Reach vs. 2.4 GHz Reach

- 5G has shorter reach than 2.4G. Compare:
  - 802.11g
    - 2.4 GHz band
    - PHY rates:
      - 6Mbps to 54Mbps
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    - 5 GHz band
    - PHY rates:
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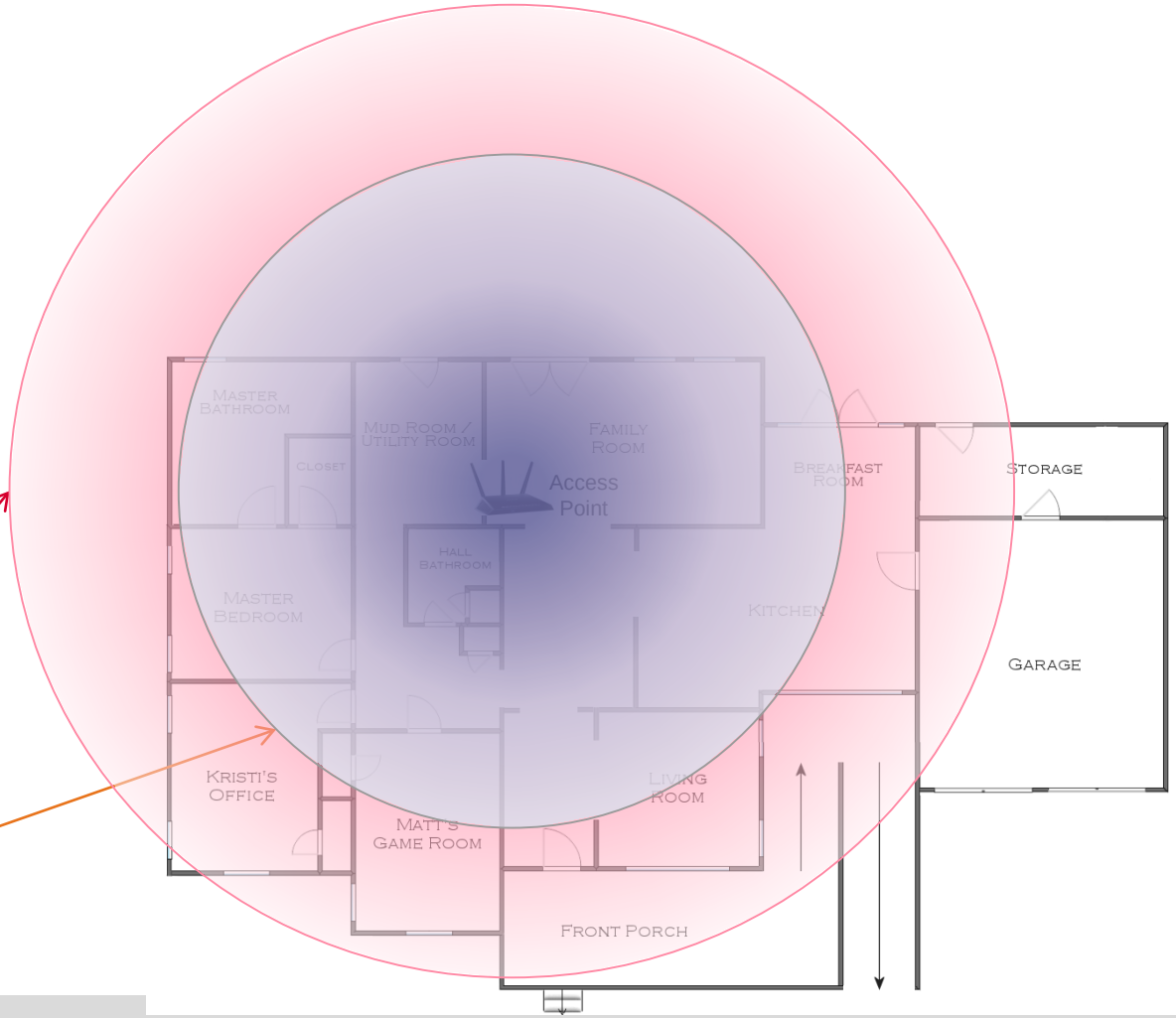
802.11g 6 Mbps limit

802.11a 6 Mbps limit



How to Improve Signal Strength / Coverage

What have *you* seen in the field?

- Symptom: Can't connect, slow speed, buffering / pixelating video
- Problem: Low signal strength, or RSSI (Noise level seems to be OK!)
- Actions:
  - Move or reposition AP to a closer / more centralized location
    - Improving signal strength in one location frequently comes at the expense of signal strength elsewhere. Be careful to keep all locations where WiFi service is desired in mind as you move the Access Point.
    - Avoid corners of the house (and walls, if possible)
    - Try not to place the Access Point on the floor. Higher elevation is generally better.
    - Experiment with antenna orientation if the Access Point permits. Vertical orientation frequently yields best response.
  - Remove / circumvent typical signal path obstructions:
    - Metal objects like file cabinets, shelving, appliances, duct work or large mirrors
    - Dense building materials like brick, stucco, stone, concrete, concrete with re-bar, fireproof concrete, walls with metal studs, wire mesh in plaster walls, bullet proof glass
    - Items with high water content like fish tanks, radiators, flower pots and water coolers, and people
  - Update the wireless equipment, if applicable
    - MIMO + beamforming can help greatly
  - Install a wireless bridge, repeater or extender *(Careful of possible utilization impact!)*
  - Change band: 5GHz -> 2.4GHz *(Changing channels in the same band won't help!)*
  - Install CAT 5/6 Ethernet, MoCA, HPNA or PLT connection

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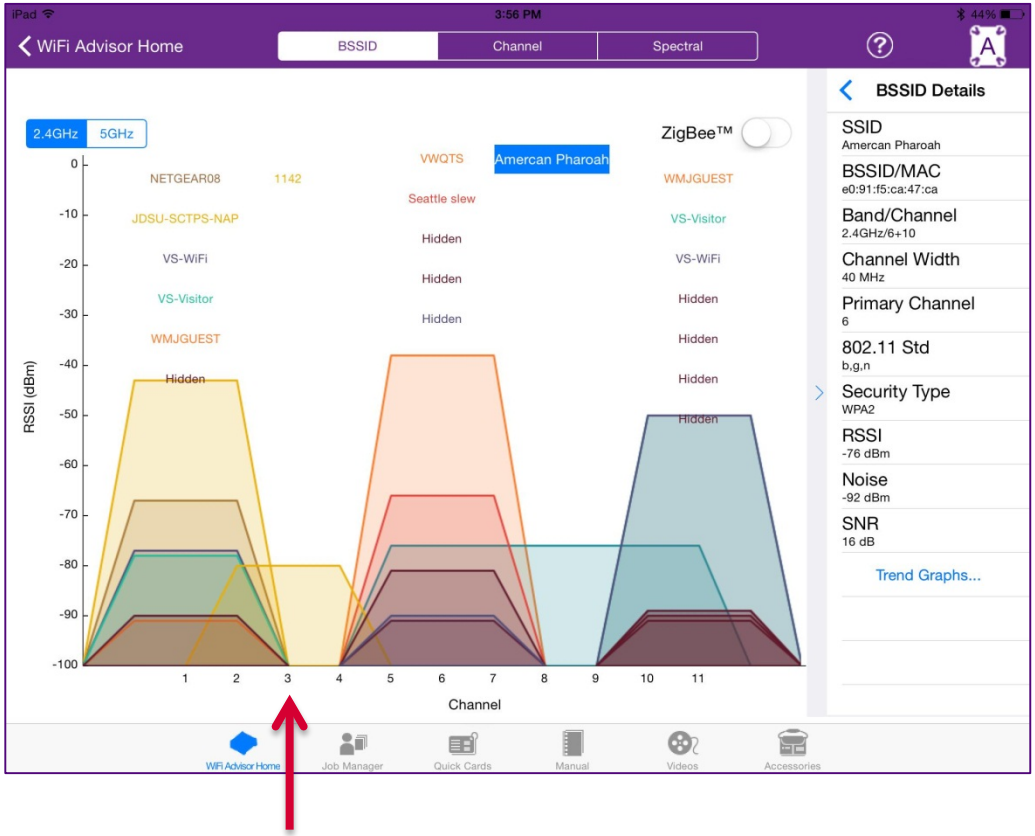
Interference Problems

- WiFi Interference
- Non-WiFi Interference

The BSSID View – *How do I Avoid the Crowd?*

- BSSID View
  - Number of Access Points
  - Signal Strength / SNR
  - Channel Position / Width
  - Security Type

- Understand occupancies relative to customer AP
- Optimize placement of a new AP into the band



Adjacent Channel Interference on Channels 1 and 3

Co-Channel Interference present on Channels 1, 6 and 11

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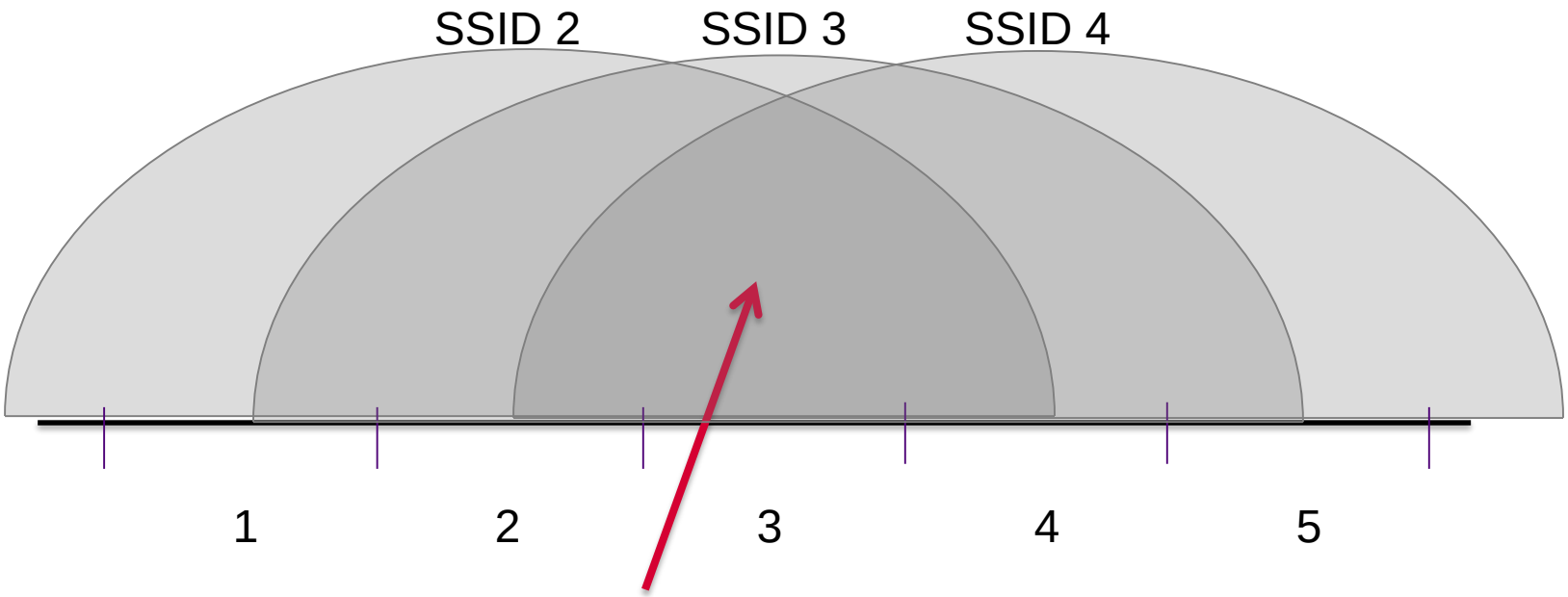
Adjacent Channel Interference

Checkpoint for understanding

- 2.4GHz WiFi channels “bleed over” into neighboring channels due to width and spacing of the channel plan.
- Adjacent channel energy from Ch. 2 and 4 can’t be managed by the 802.11 protocol for a transmitter in Ch. 3 and is treated as noise.
- In-channel WiFi transmissions can be decoded to predict how long the channel will be occupied. But, the radio must sample continuously to discover when the channel is clear for non-WiFi or out-of-channel WiFi transmissions.



SSID 3 experiences interference from SSID 2 and SSID 4

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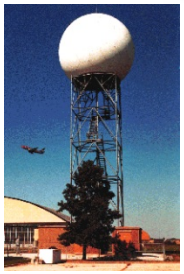
Non-802.11 Interference

- Non-802.11 RF emitters that overlap in the 2.4GHz and 5GHz bands can greatly affect WiFi performance.
- If an interferer can't be removed, its impact can be mitigated by increasing the distance between it and your WiFi equipment.
- Common interference sources that can affect WiFi include:

2.4 GHz Band	5 GHz Band
Microwaves	Wireless Cameras (fixed frequency video)
Bluetooth Devices	Alarm Systems
Digital and Analog Baby Monitors	Digital Baby Monitors
Non-DECT Cordless Phones	Wireless audio or audio / video devices
Wireless Cameras (fixed frequency video)	Radar
Zigbee devices	Perimeter Sensors
Wireless audio or audio / video devices	
Alarm Systems	
Harmonics from LCD displays	
X10 cameras	
Municipal wireless networks	
Wireless gamepads	
2.4 GHz HAM radios	
Non-802.11 Wireless Internet Services (like WiMax)	
Home RF spread spectrum based network (non-802.11)	
Outdoor microwave links	
Fluorescent lights / bad ballasts	
Bad electrical connections or AC/DC power supplies	
Treadmills	
Wireless ceiling fan controllers	
Garage Door openers	



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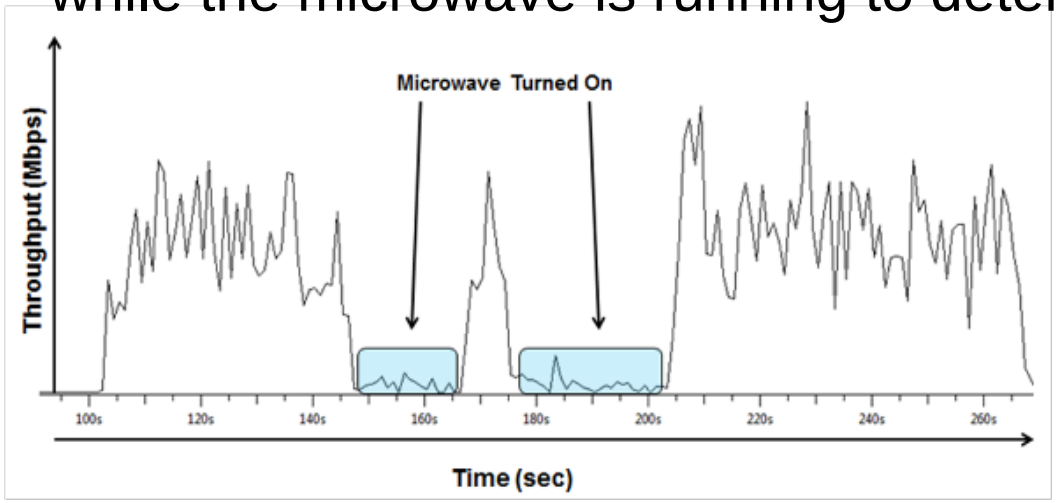
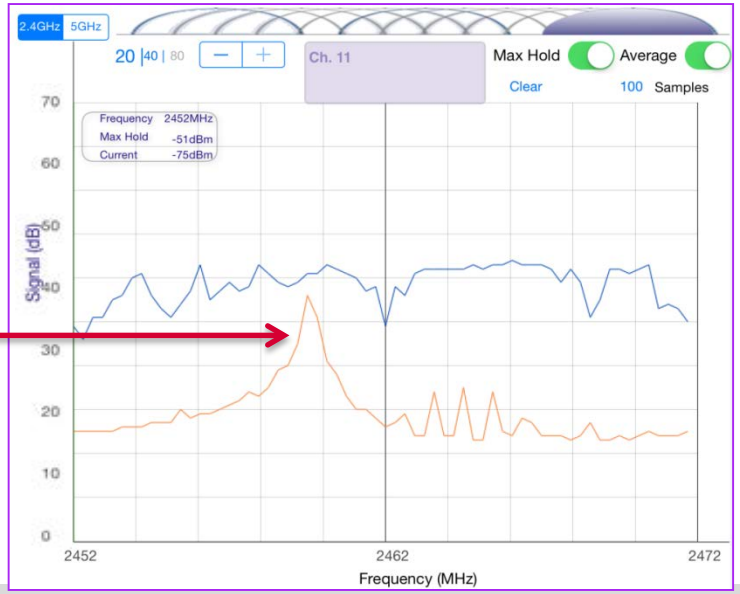
Non-802.11 Interferers - Microwave

- Microwave ovens can cause havoc with an 802.11 signal. They are most prevalent in channels 10 and 11.
- If possible, it is a good idea to look at the spectral response while the microwave is running to determine it's impact.



Spectral signature of microwave in Ch. 11



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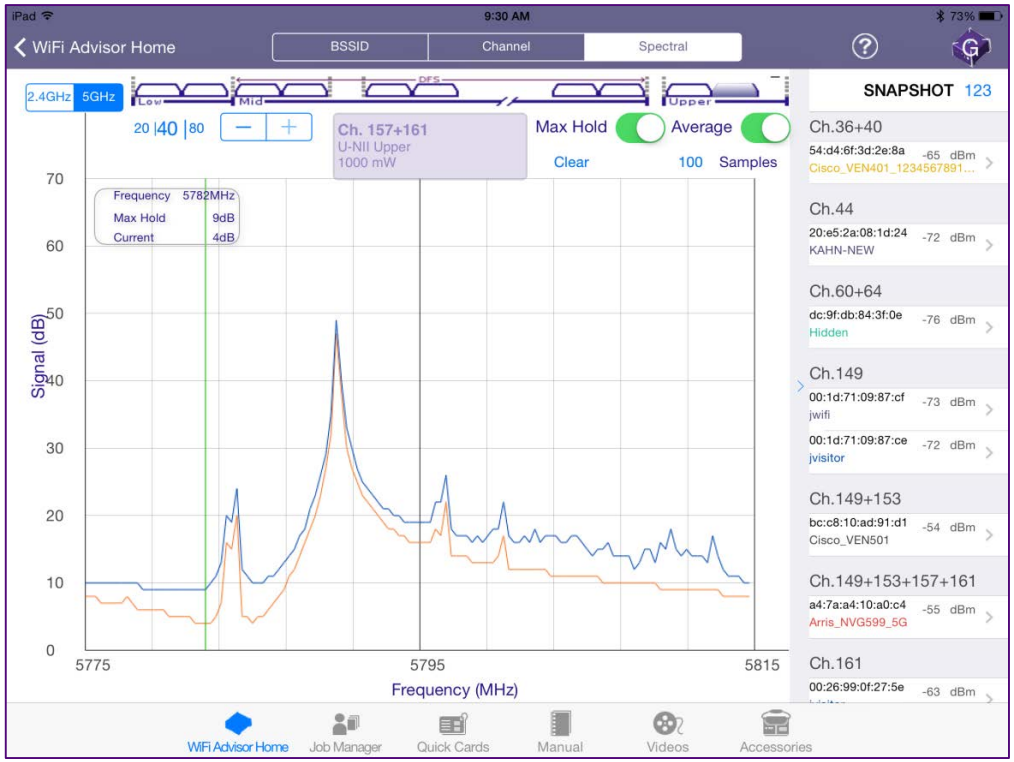
Non 802.11 Interferers – Wireless A/V Transceivers



- Many proprietary, non-802.11 A/V transmitters use the 5GHz band and have the potential to obliterate 5G WiFi channels that overlap with them.

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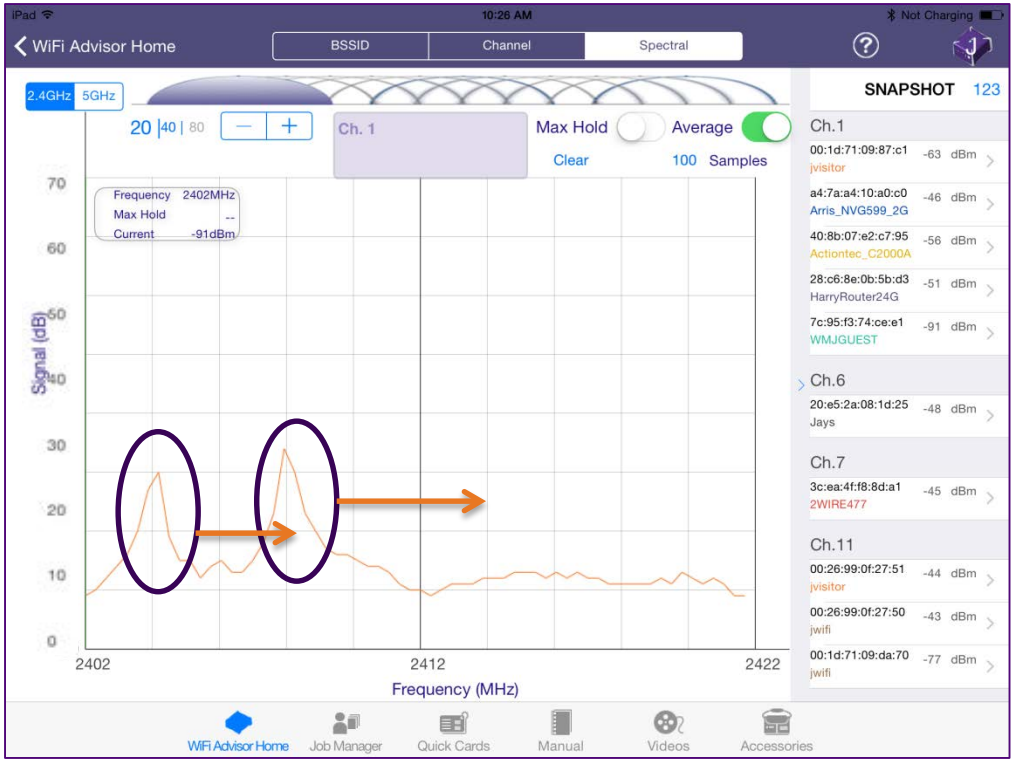
Non 802.11 Interferers – Bluetooth™



- Bluetooth devices appear as spikes and appear to “roll” through the spectral view. They are fast moving and you may only see them occasionally.
- Bluetooth and WiFi are designed to be interoperable, but Bluetooth will still impact WiFi throughput.

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How to Reduce Noise

What have *you* seen in the field?

- Symptom: Can't connect, slow speed, buffering/pixelating video (frequently periodic)
- Problem: High noise in the channel (Signal level seems to be OK!)
- Actions:
  - Limit high signal strength adjacencies
    - WiFi activity on strong adjacents will appear as noise to your AP.
    - Move your AP to a channel that optimizes the combination of adjacent and co-channel AP's.
  - *High Utilization can also drive noise in the channel up*
  - Detect, locate and mitigate non-802.11 interference with a WiFi Spectrum Analyzer
    - Remove the interferer
    - Move your AP to a channel not affected by the non-802.11 interference
    - Move to another band
    - Move your WiFi devices and the interferer further apart to minimize impact.
  - Install CAT 5/6 Ethernet, MoCA, HPNA or PLT connection to the location(s) most strongly affected by the interference.

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Channel Utilization Problems

Channel Utilization and the Distribution Control Function

Checkpoint for understanding

- WiFi is *half duplex* and a channel may be shared by many AP's
- All devices associated with an AP also use the same channel
- All AP's / devices on a given channel share air time, *but only one AP or client can "talk" at a time.*
- WiFi uses Carrier Sense Multiple Access with Collision Avoidance, or *CSMA/CA* to control access to the medium.
- An AP or device will listen on the channel before trying to transmit, and will start transmission only if no one else is transmitting (sounds familiar, right?)
- BUT, a radio can't hear while it's transmitting. Therefore if a packet is not acknowledged at L2, then a *collision is assumed* to have occurred.
- If a collision is assumed, the *radio retries after a random delay*.
- Number of collisions will increase as traffic on the channel (or *channel utilization*) increases.

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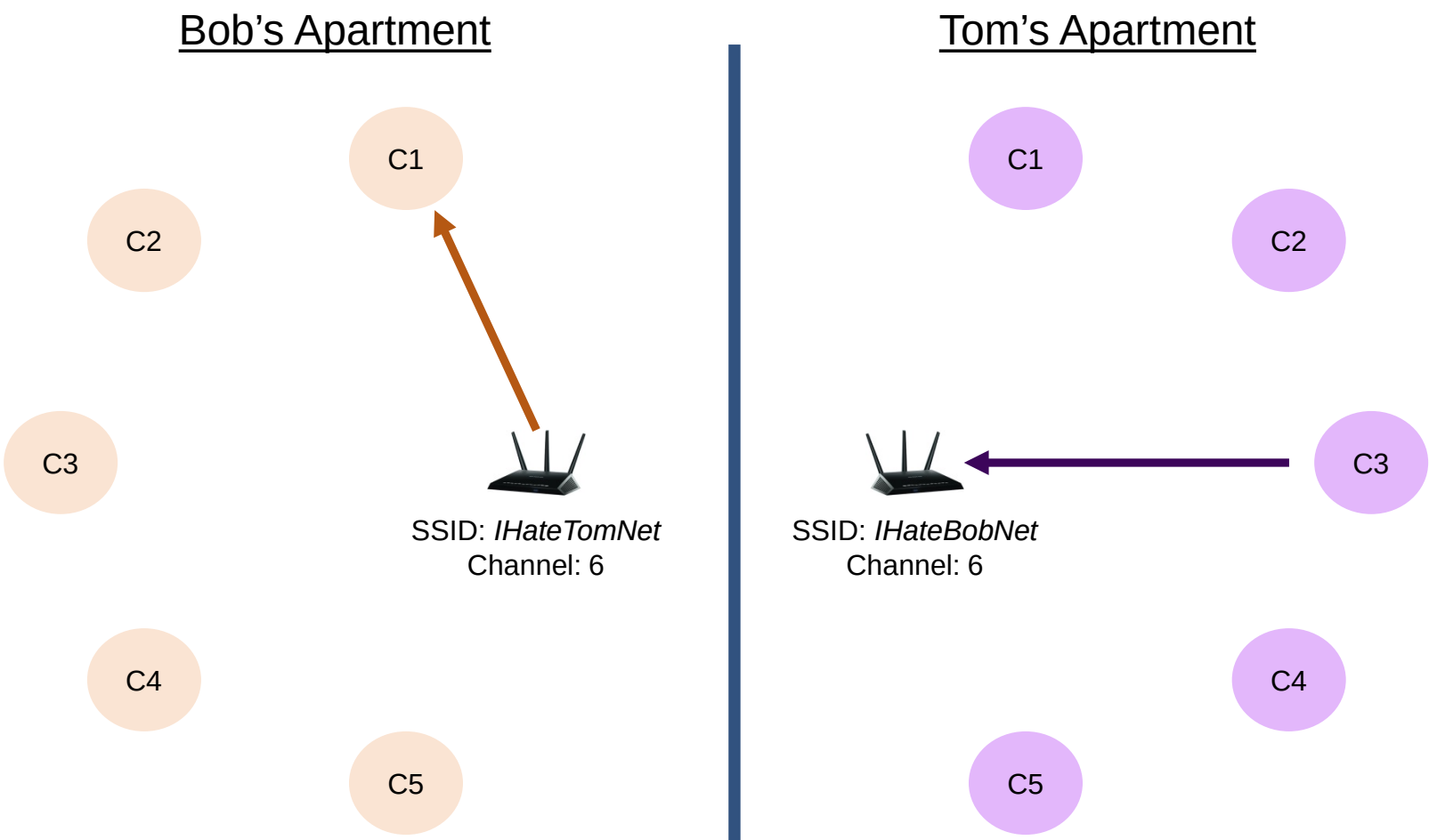
Half-Duplex Operation by Example



While *IHateTomNet* is transmitting to Bob's Client 1, no other transmissions in Bob's or Tom's WiFi networks can happen!

While Tom's Client 3 is transmitting to *IHateBobNet,* no other transmissions in Bob's or Tom's WiFi networks can happen!

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What is Channel Utilization?

- What is the Audience definition of Channel Utilization?

The percentage of time that an AP's configured channel is occupied with RF energy such that the AP determines it ***should not*** transmit on the channel.

- When does the AP think it should not transmit?
  1. When it believes that another WiFi device is currently transmitting in the channel.
     - The radios are good at determining when other WiFi devices are transmitting – even at very, very low signal strength (set via Clear Channel Assessment threshold or RX SoP threshold, typically between -76 and -80dBm.)
  2. When it believes that the detected RF energy is not WiFi (it can't decode the a WiFi PLCP header) and the RF energy is sufficient to disrupt it's own attempt to communicate with it's target device. *Includes adjacent channel WiFi signals!*
     - The radios will sometimes choose to transmit on top of relatively strong non-WiFi interference (set via the noise Energy Detect threshold, 20dB > CCA threshold).
- Knowing this, it's possible to separate channel utilization into 2 parts:
  1. Utilization due to WiFi activity in the channel.
  2. Utilization due to non-WiFi activity in the channel.

Resource: http://www.revolutionwifi.net/revolutionwifi/2011/03/understanding-wi-fi-carrier-sense.html

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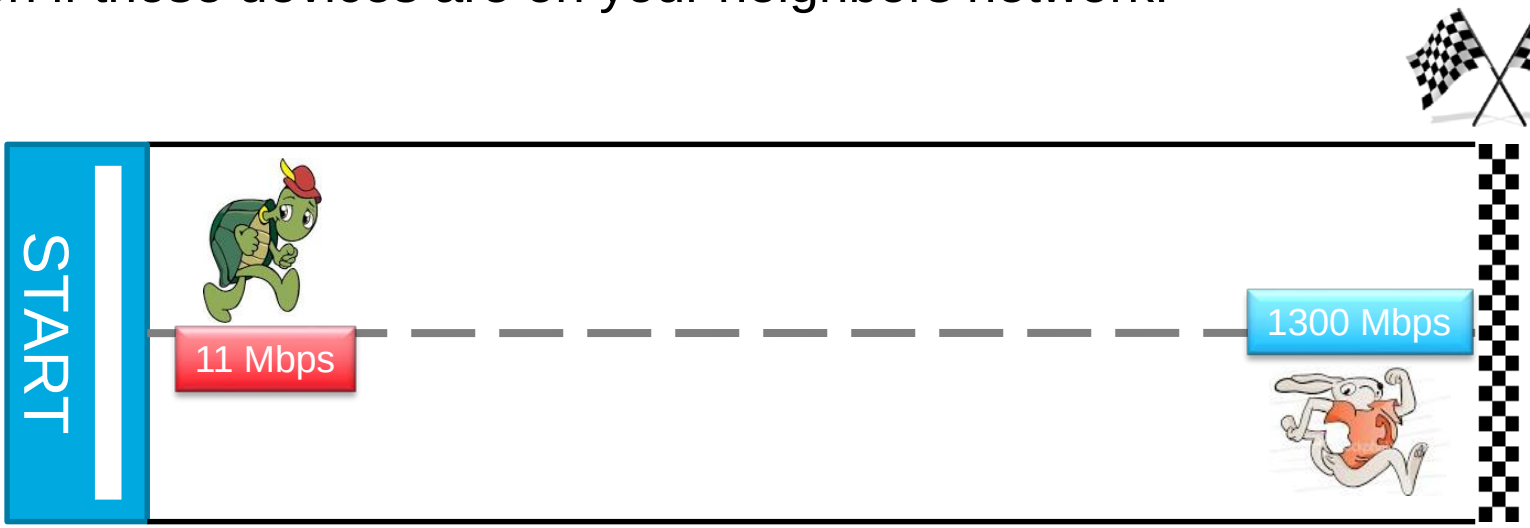
Effect of old 802.11 Stds. on WiFi Performance

Checkpoint for understanding

- Slow PHY rates require more time to transmit a given amount of data than faster PHY rates
- The whole channel is throttled by the slowest talker (PHY rate).
- Use of faster PHY rates allows more data throughput on networks sharing the same channel.
- 802.11 a/b/g AP's and clients on your channel therefore have high potential for impacting channel utilization and WiFi service quality, even if those devices are on your neighbors network!



How long does another device have to wait for the tortoise to move 256k bytes vs. the rabbit?

Over 118 times longer!

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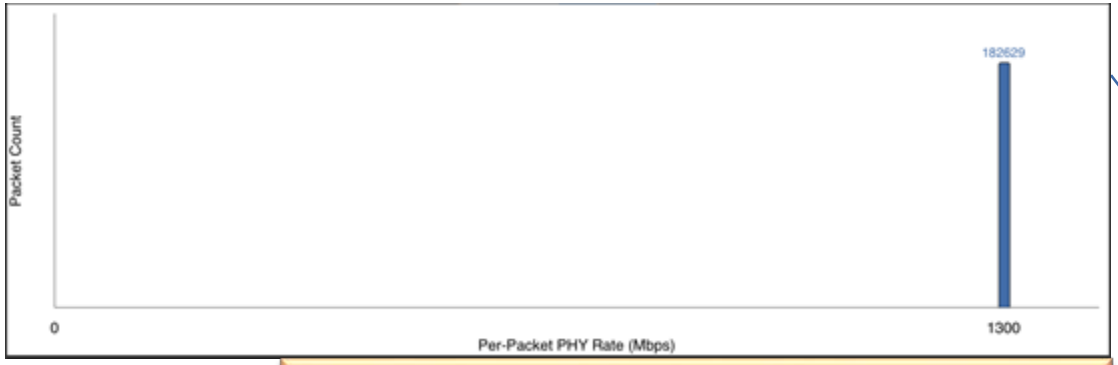
PHY Rate Distribution Examples

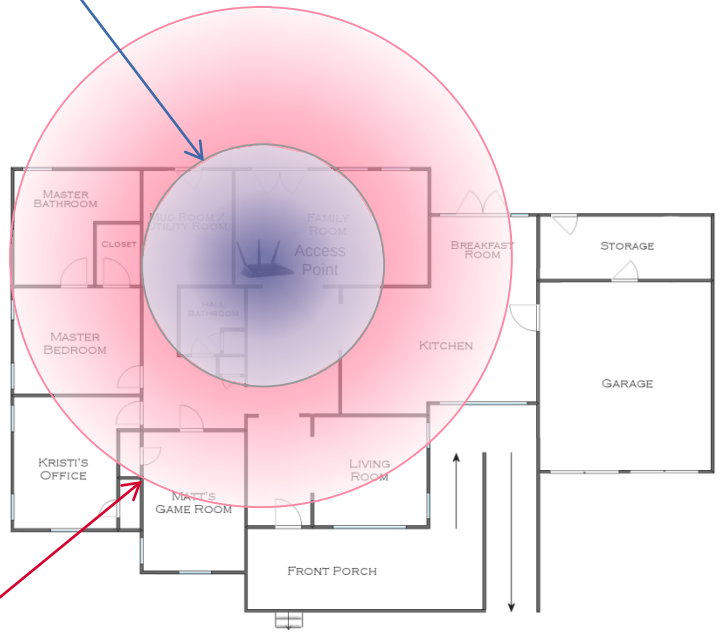
Checkpoint for understanding

Close to the RG, most packets are sent at 1.3Gbps PHY rate.

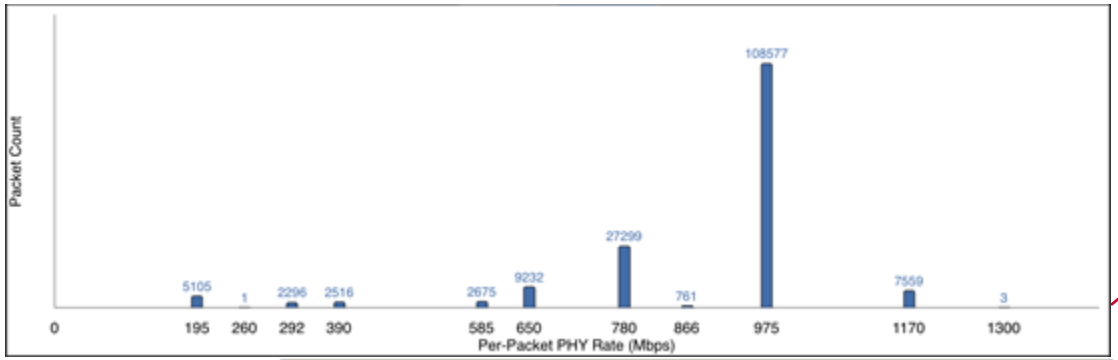


8 sec Throughput Test Configured for 5 GHz 802.11ac 3x3

15 ft. range = high SNR



Further away, packets are sent at a variety of (mostly lower) PHY rates.



8 sec Throughput Test Configured for 5 GHz 802.11ac 3x3

50 ft. range = lower SNR

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How to Optimize Utilization

What have *you* seen in the field?

- Symptom: Slow speed, buffering / pixelating video (user can normally connect)
- Problem: High Channel Utilization (Both RSSI and Noise look OK)
- Actions:
  - Move to a channel with lower Co-channel occupancy
    - Reduces the number of networks (APs) using the selected channel
    - If you can, assess the number of clients active in the channel too!
    - Move your AP to a channel that optimizes the combination of co-channel and adjacent AP's.
  - Make best use of higher 802.11 PHY rates:
    - Improve SNR using previously discussed methods
      - Improve signal strength
      - Reduce noise
    - Change WEP/WPA security settings to WPA2 - AES
    - Replace legacy equipment:
      - AP's and Clients
      - Separate old clients onto their own AP, ***on a different channel*** (allow > 10 ft. between AP's)
      - Remove repeater / extender if it's the type that "doubles" the channel utilization
  - Move to a different band (5GHz is frequently less crowded)
  - Change channel width*:
    - Increase channel width if adjacent channels are clean
    - Decrease channel width if adjacent channels are noisy / occupied

* Take caution configuring for 40MHz in 2.4 GHz.
Adjacencies!

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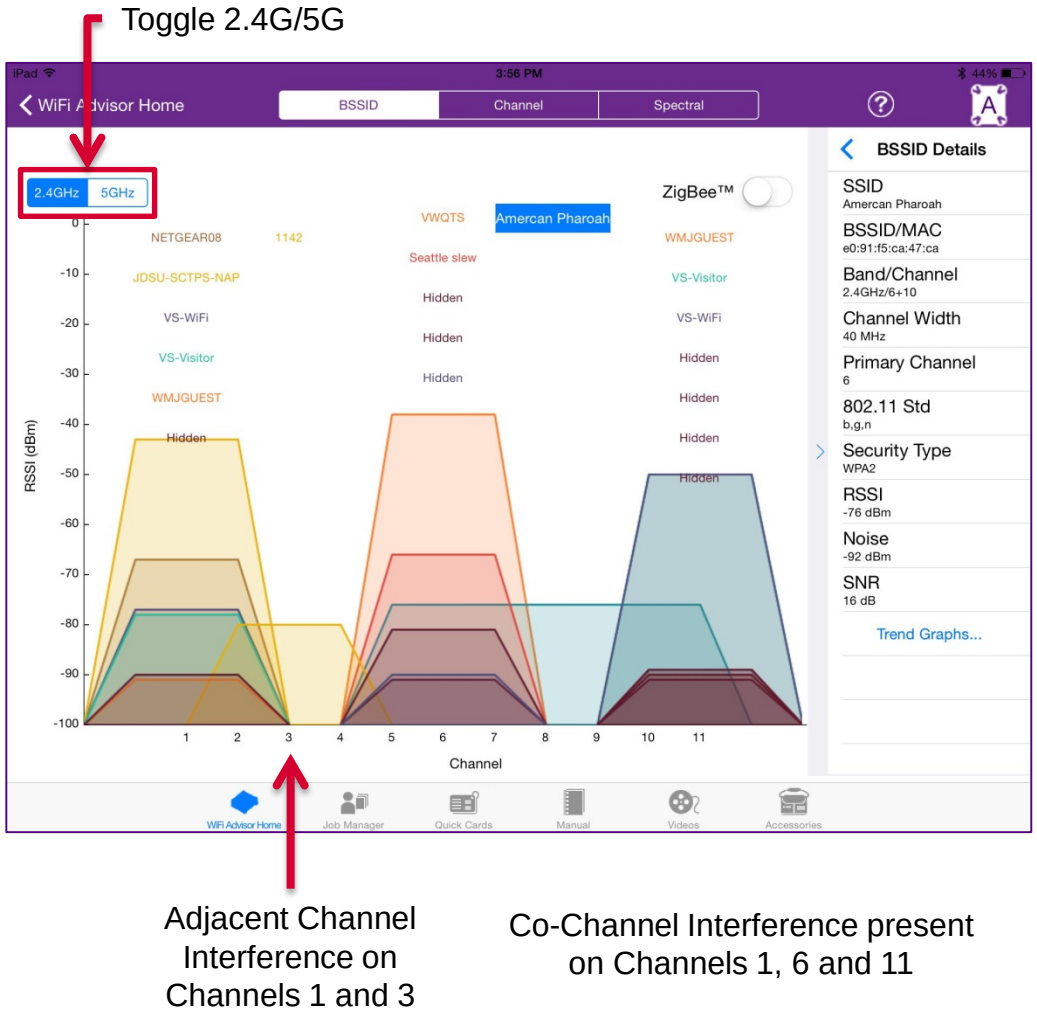
Single-Ended Applications

The BSSID View – *How do I Avoid the Crowd?*

- BSSID View
  - Number of Access Points
  - Signal Strength / SNR
  - Channel Position / Width
  - Security Type

- Understand occupancies relative to customer AP
- Optimize placement of a new AP into the band



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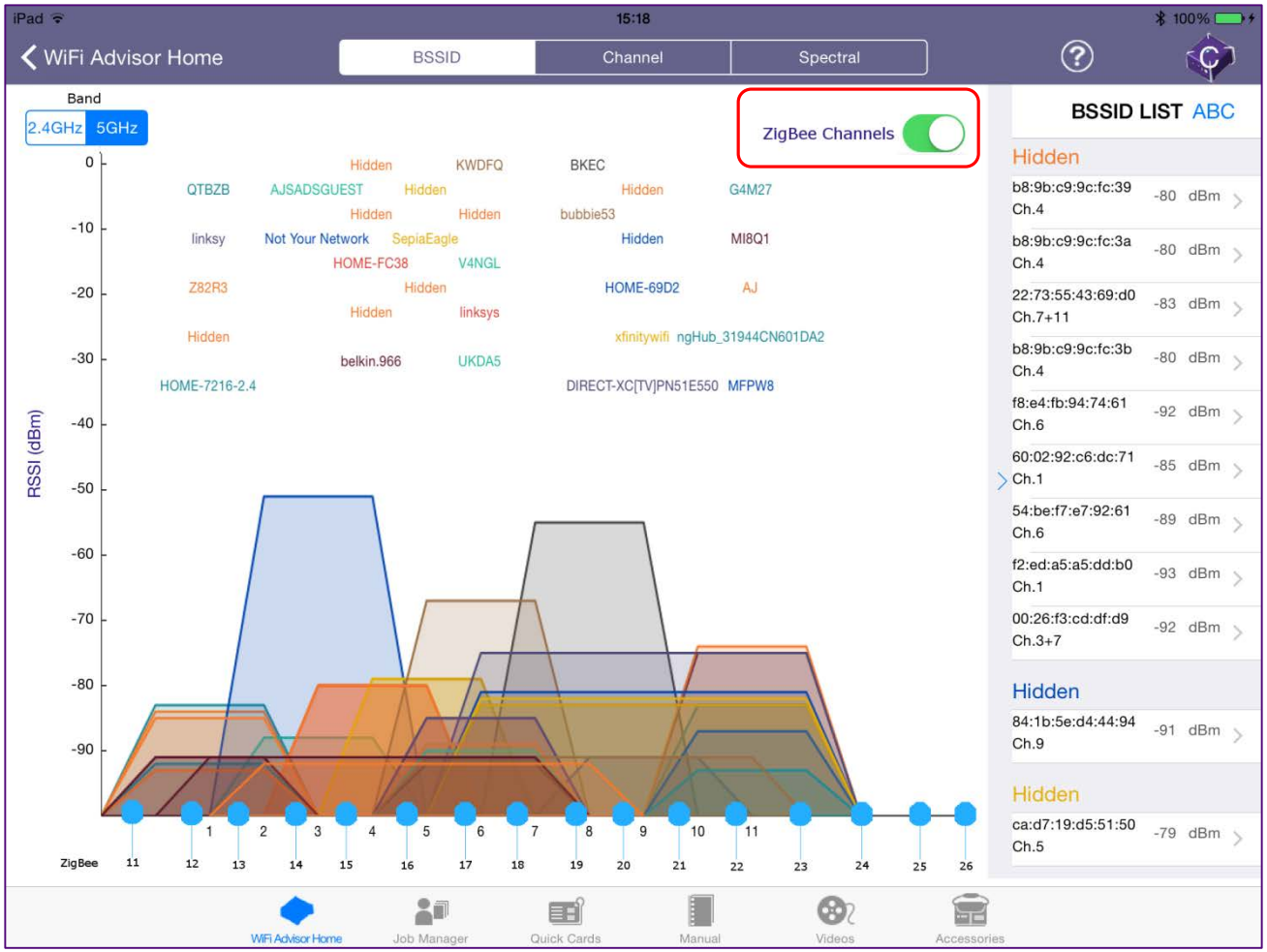
Zigbee Masks in the BSSID View

2.4 GHz Only

Highlights WiFi activity in the environment relative to Zigbee channel positions



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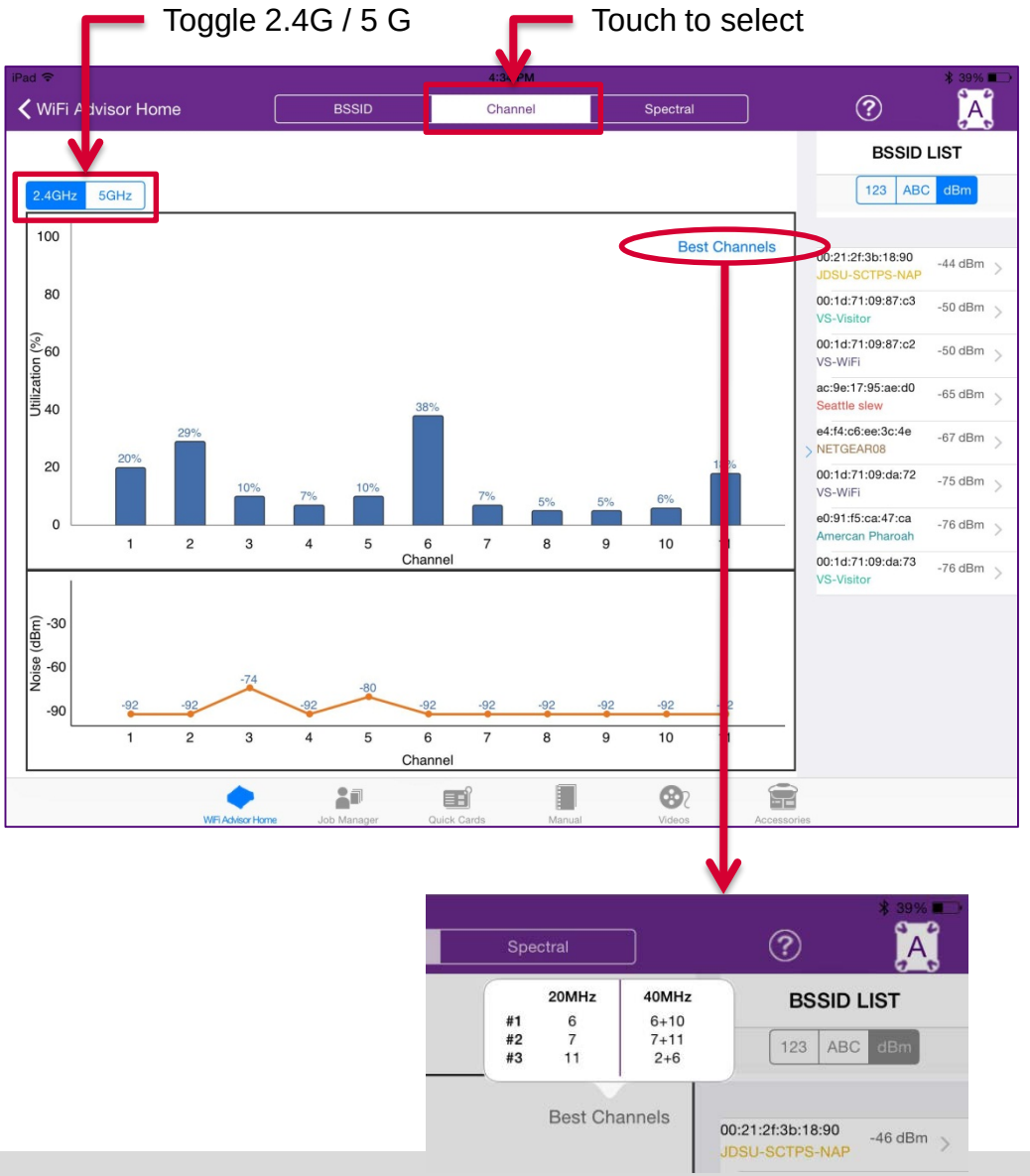
The Channel View – *Where is My Best Channel?*

- Channel View
  - Channel Utilization
  - Noise in 2.4G / 5G Bands
  - Co-channel interferers
  - Adjacent channel interferers
  - Channel Score
- Identify Best Channel

High utilization + low noise = high 802.11 traffic

High utilization + high noise = non-802.11 interference likely. - Use Spectrum Analyzer to confirm



The Spectrum Analyzer – *Is My Channel Really Clean?*

- Spectrum Analyzer
  - 2.4G / 5G Bands
  - Channel & Channel Width Settings
  - Auto-configure to selected BSSID
- Identifies non-802.11 Interferers

Normal 802.11 Trace

Bluetooth in 2.4GHz

Microwave in 2.4Ghz

A/V Transceiver in 5G

Checkpoint for understanding

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Zigbee Masks in the Spectral View

2.4 GHz Only

Highlights <u>any RF activity</u> in the environment relative to Zigbee channel positions

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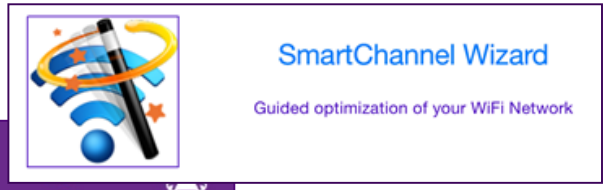
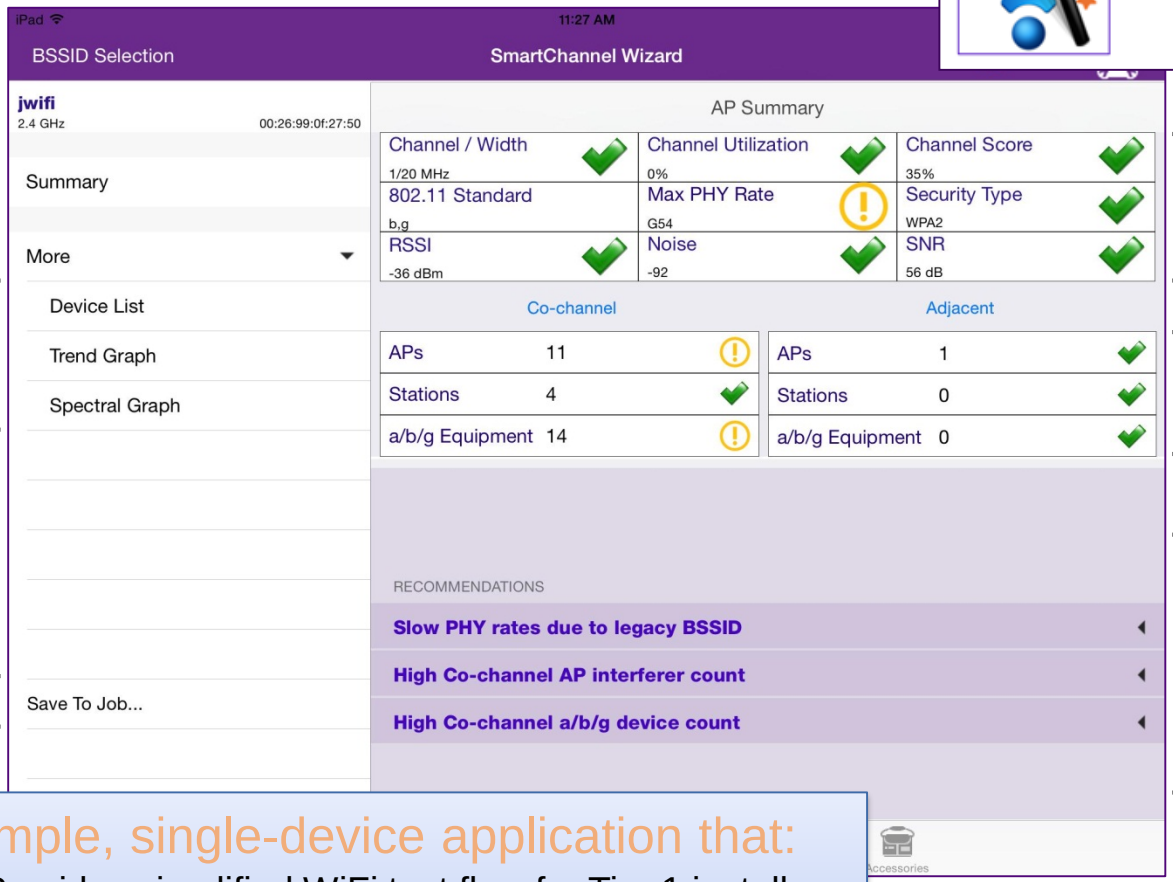
SmartChannel Wizard – *Built for the WiFi Novice*





BSSID and Channel Health

WiFi Interference Details

Real-Time Optimization Tips Expand on Touch

Deeper Insight When Required

Save Results

A simple, single-device application that:

- Provides simplified WiFi test flow for Tier 1 installers
- Generates WiFi optimization tips for novice users
- Sees beyond AP occupancies and into client details
- Saves results and recommendations to job files / reports

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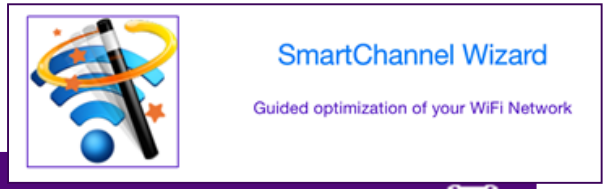
SmartChannel Wizard – Device List



iPad 8:27 AM

BSSID Selection | SmartChannel Wizard

VS-Visitor
00:1d:71:09:87:c3
2.4 GHz / 6

Summary In Job

More

Device List In Job

Trend Graphs

Spectral Graph

AP | Top Talkers | Devices on Channel 6

SSID	SEC.	MAC	MANUFACTURER	STD/Rate	RSSI	UTIL
Kissito Guest	None	02:18:4A:29:64:01		b/g/n	-91	0.0%
2 stations						
VS-WiFi	WPA2	00:1D:71:09:87:C2	Cisco Systems, Inc.	b/g	-54	6%
9 stations						
		18:F6:43:73:F8:2D	Apple	b/g G54	-29	4%
		24:A0:74:44:64:EB	Apple	b/g	-46	0.0%
		2C:1F:23:02:67:52	Apple	b/g	-59	0.0%
		3C:A9:F4:4C:24:E4	Intel Corporate	g	-56	0.0%
		60:67:20:52:24:7E	Intel Corporate	b/g G54	-48	1.0%
		8C:70:5A:51:A9:5C	Intel Corporate	g	-59	0.0%
		B0:10:41:17:36:D7	Hon Hai Precision...	b/g	-61	0.0%
		C8:F6:50:B2:39:F3	Apple	b/g	-40	0.0%
		FC:E9:98:C1:5E:5B	Apple	b/g	-53	0.0%
	WPA2	B4:C7:99:50:5B:92	Zebra Technologies Inc	b/g	-85	0.0%

WiFi Advisor Home | Job Manager | Quick Cards | Manual | Videos | Accessories

Quickly and Easily see:

- Which stations are connected to my RG?
- Which stations have the highest channel utilization?
- Do my stations have weak signal?
- Which stations are using old, legacy PHY rates / standards?

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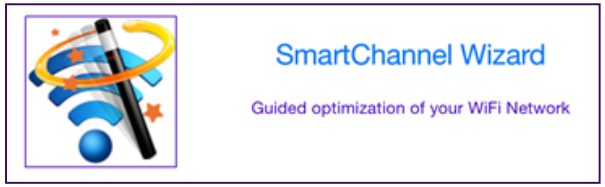
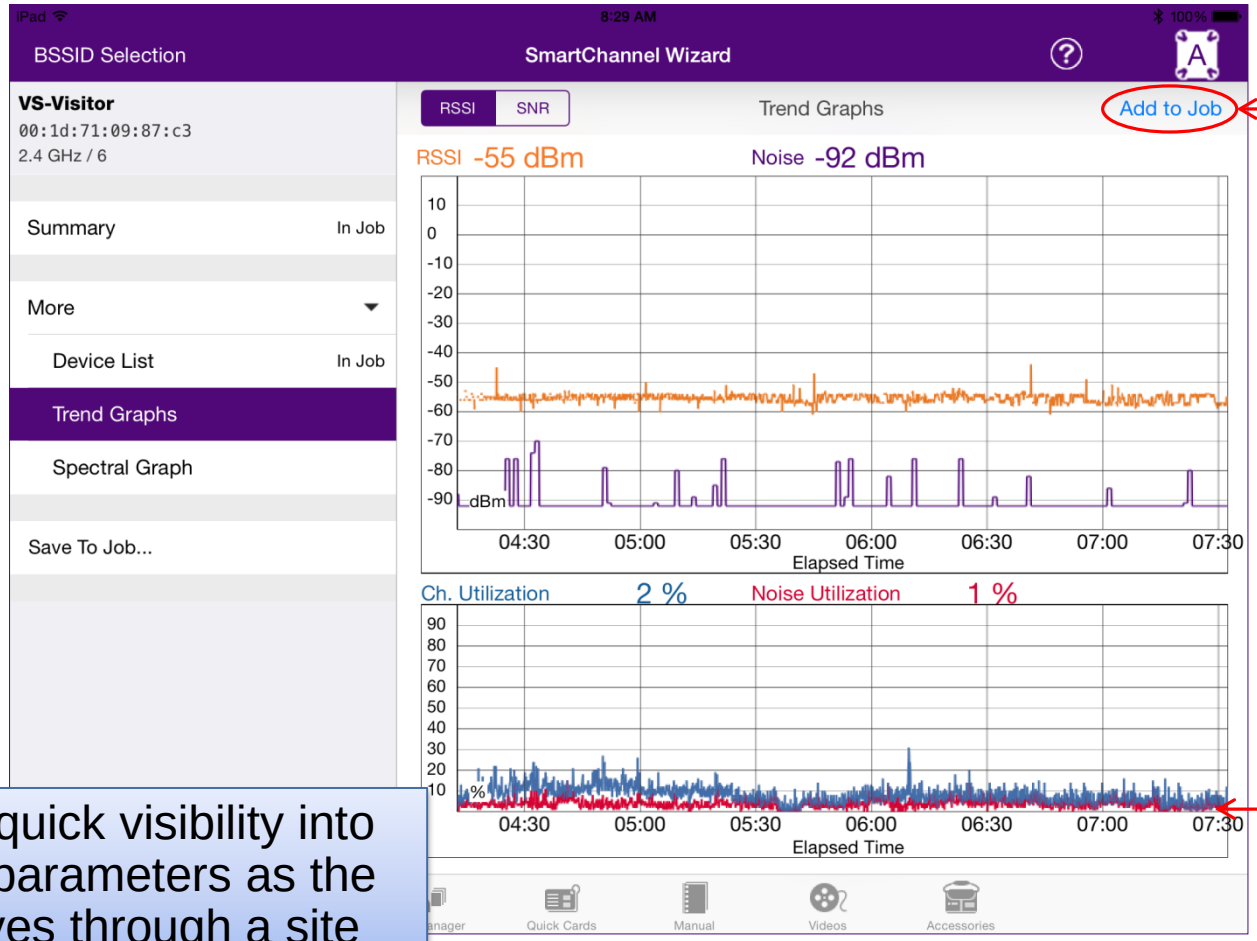
SmartChannel Wizard – Trend Graphs



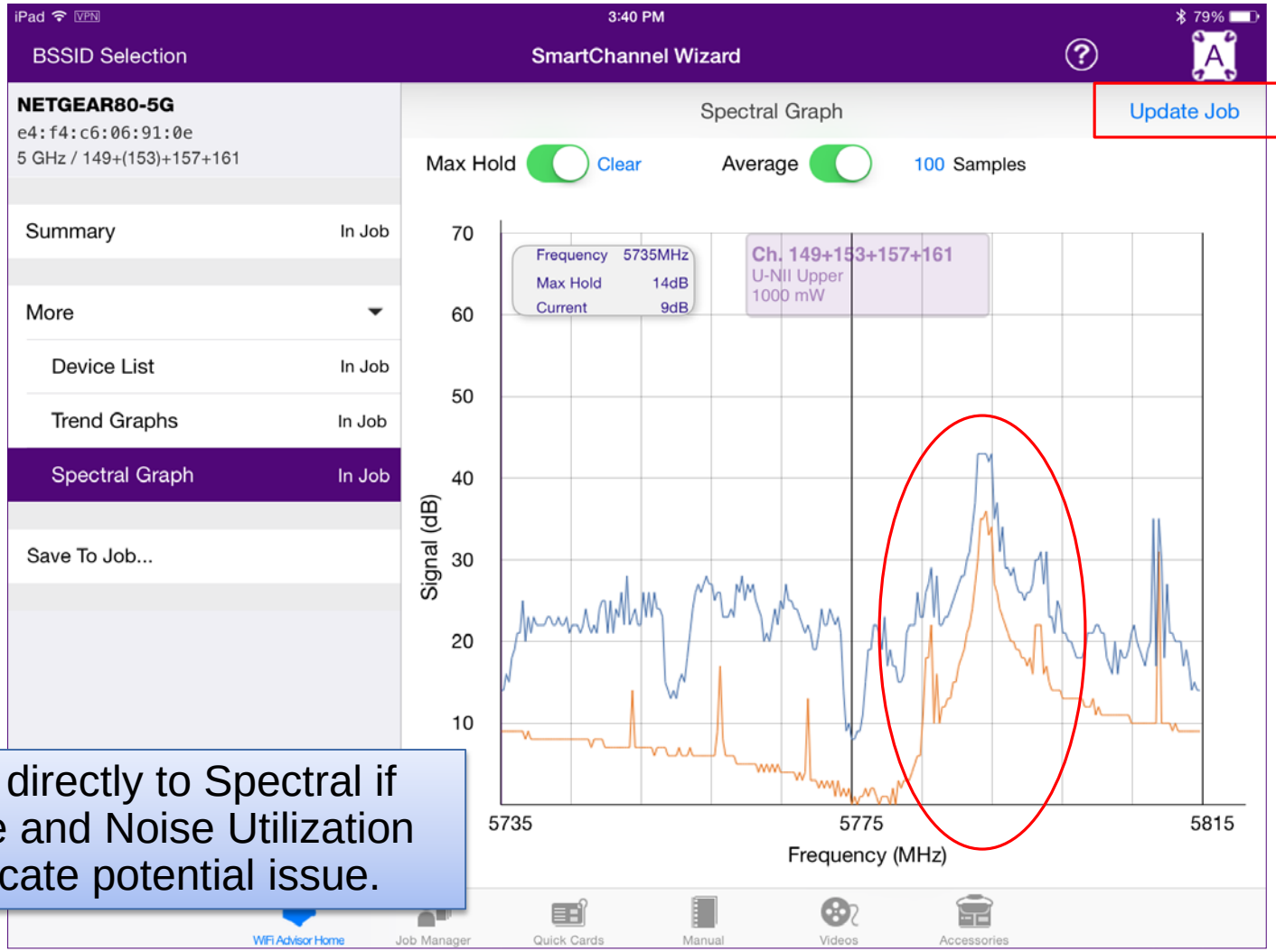


Add to Job File

Utilization due to Noise

Provides quick visibility into key WiFi parameters as the user moves through a site

Spectrum Analyzer Shows the Interferer



Hop directly to Spectral if Noise and Noise Utilization indicate potential issue.

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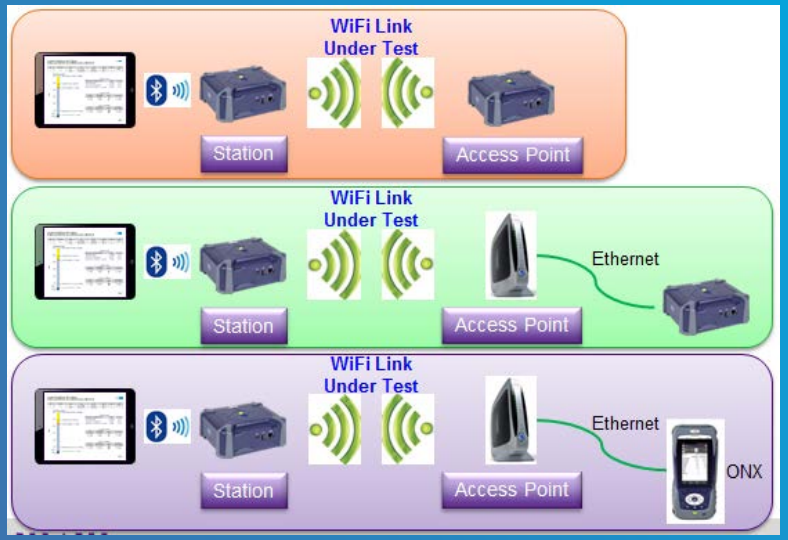


Dual-Ended Applications

How Well does WiFi Work Throughout the Customer's Home?

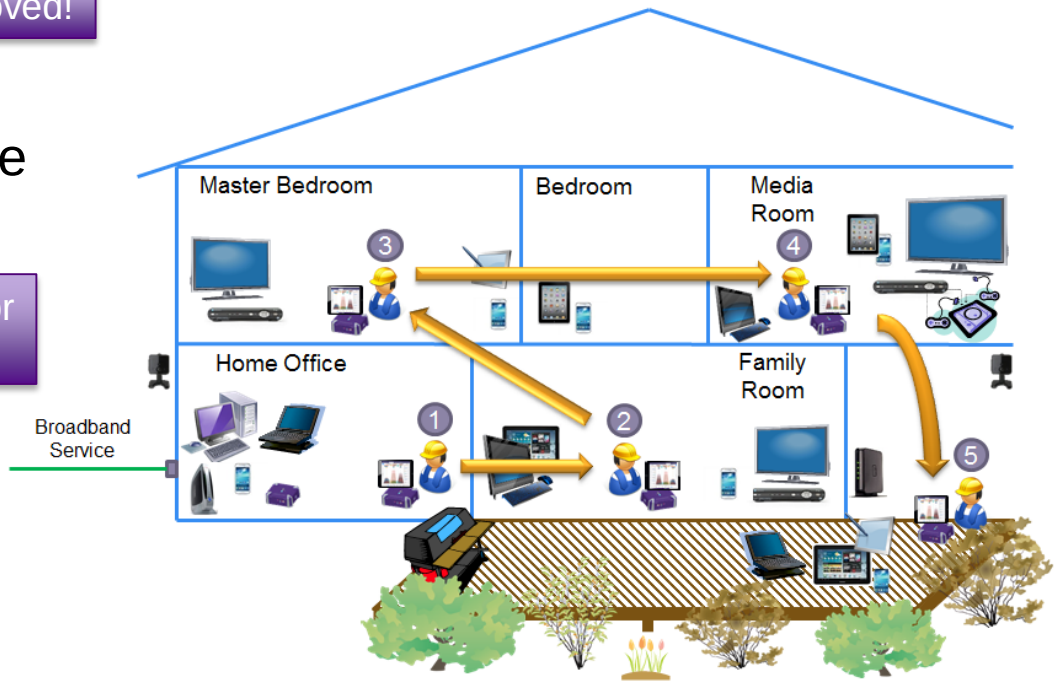
Site Assessment, or L1-L3 performance analysis throughout the Home:

- Gives insight to:
  - Maximum packet throughput that a wireless link can bear
  - Throughput margin above desired service level

    High Margin = High WiFi Resiliency!
  - Sources of throughput degradation

    Indicates what needs to be improved!
- Optimizes AP placement
- Sets realistic WiFi performance expectations with customers

Customer Education Is Crucial for Reducing Trouble Calls



Site Assessment – Summary Results

Checkpoint for understanding

Visualized Throughput Impact

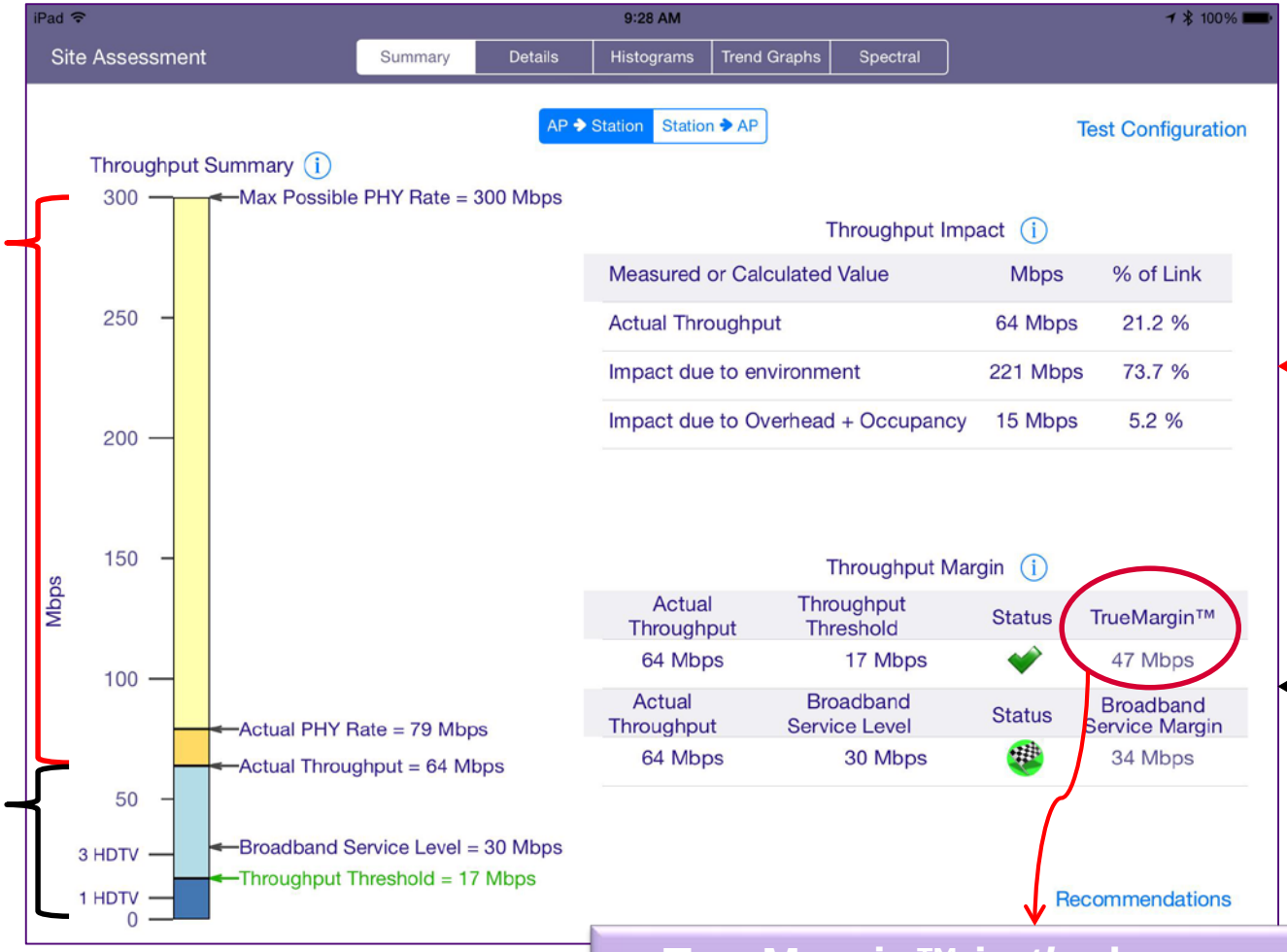
Signal & Noise Loss

Occupancy & Overhead Loss

Visualized Throughput

Throughput Margin

Throughput Threshold



Sources of Degradation

Margin Analysis

TrueMargin™ is *the* key measure!

High throughput margin = High tolerance to changes in the RF environment

Low / no margin = high possibility of repeats

SmartChannel Wizard

Non-802.11 Interferer Use Case

Non-802.11 Interferer Example

No Interferer

iPad VPN 3:39 PM 79%

BSSID Selection | SmartChannel Wizard

NETGEAR80-5G
e4:f4:c6:06:91:0e
5 GHz / 149+(153)+157+161

Summary In Job

More

Save To Job...

AP Summary

Channels [Ch. Width] 149+(153)+157+161 [80MHz]	Channel Utilization 0%	Channel Score 35%
802.11 Standard a,n,ac	Max PHY Rate AC1300	Security Type WPA2
RSSI -41 dBm	Noise -86 dBm	SNR 45 dB

Co-channel		Adjacent	
APs	2	APs	0
Stations	0	Stations	0
a/b/g Equipment	0	a/b/g Equipment	0

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Non-802.11 Interferer Example

Interferer On

iPad VPN 3:39 PM 79%

BSSID Selection | SmartChannel Wizard

NETGEAR80-5G
e4:f4:c6:06:91:0e
5 GHz / 149+(153)+157+161

Summary In Job

More

Save To Job...

AP Summary

Channels [Ch. Width] 149+(153)+157+161 [80MHz]	Channel Utilization 38%	Channel Score 35%
802.11 Standard a,n,ac	Max PHY Rate AC1300	Security Type WPA2
RSSI Out of Range	Noise -64 dBm	SNR Out of Range

Co-channel		Adjacent	
APs	2	APs	0
Stations	0	Stations	0
a/b/g Equipment	0	a/b/g Equipment	0

High noise

Noise in the channel of the selected BSSID is high. Possible actions include:

- Use the Channel view to find a channel with lower noise and acceptable utilization
- Adjacent channel WiFi activity can appear as noise in your channel. Use the BSSID and Channel views to see / avoid high signal strength adjacencies.
- The combination of high noise and high utilization in a channel may indicate the presence of a non-WiFi disturber such as a microwave oven. Use the

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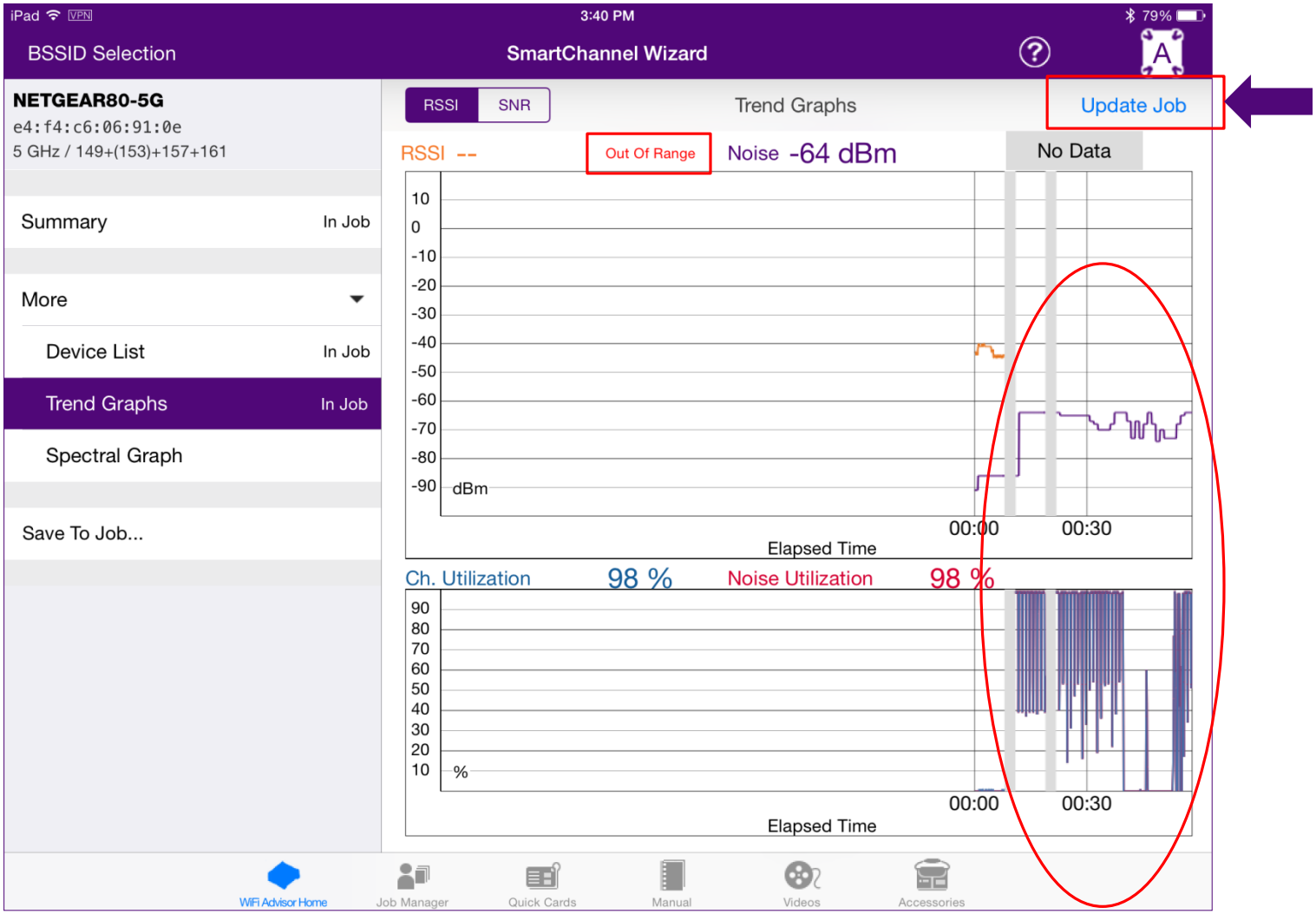
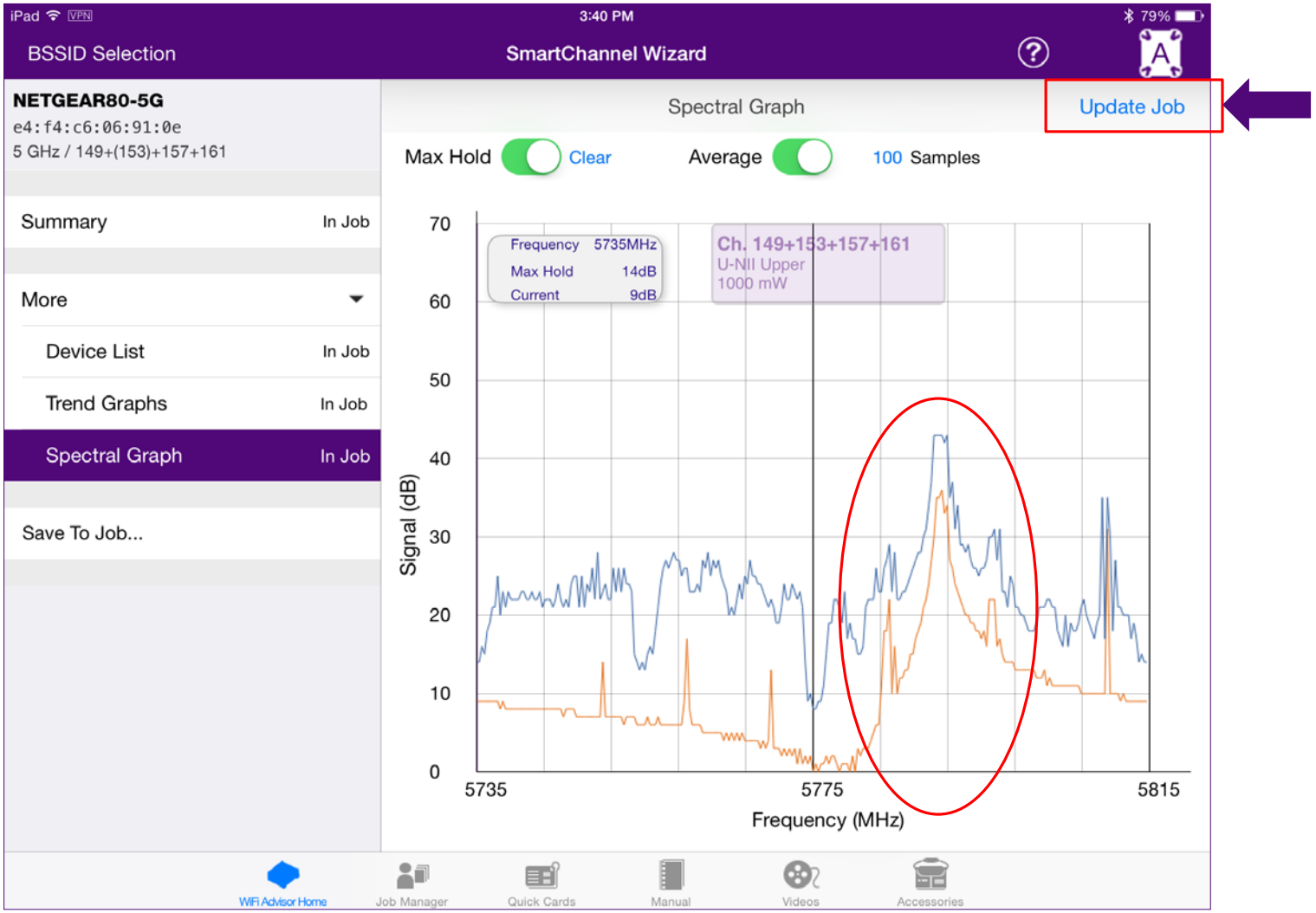
Trend Graph Shows High Noise and High Utilization



Spectrum Analyzer Shows the Interferer



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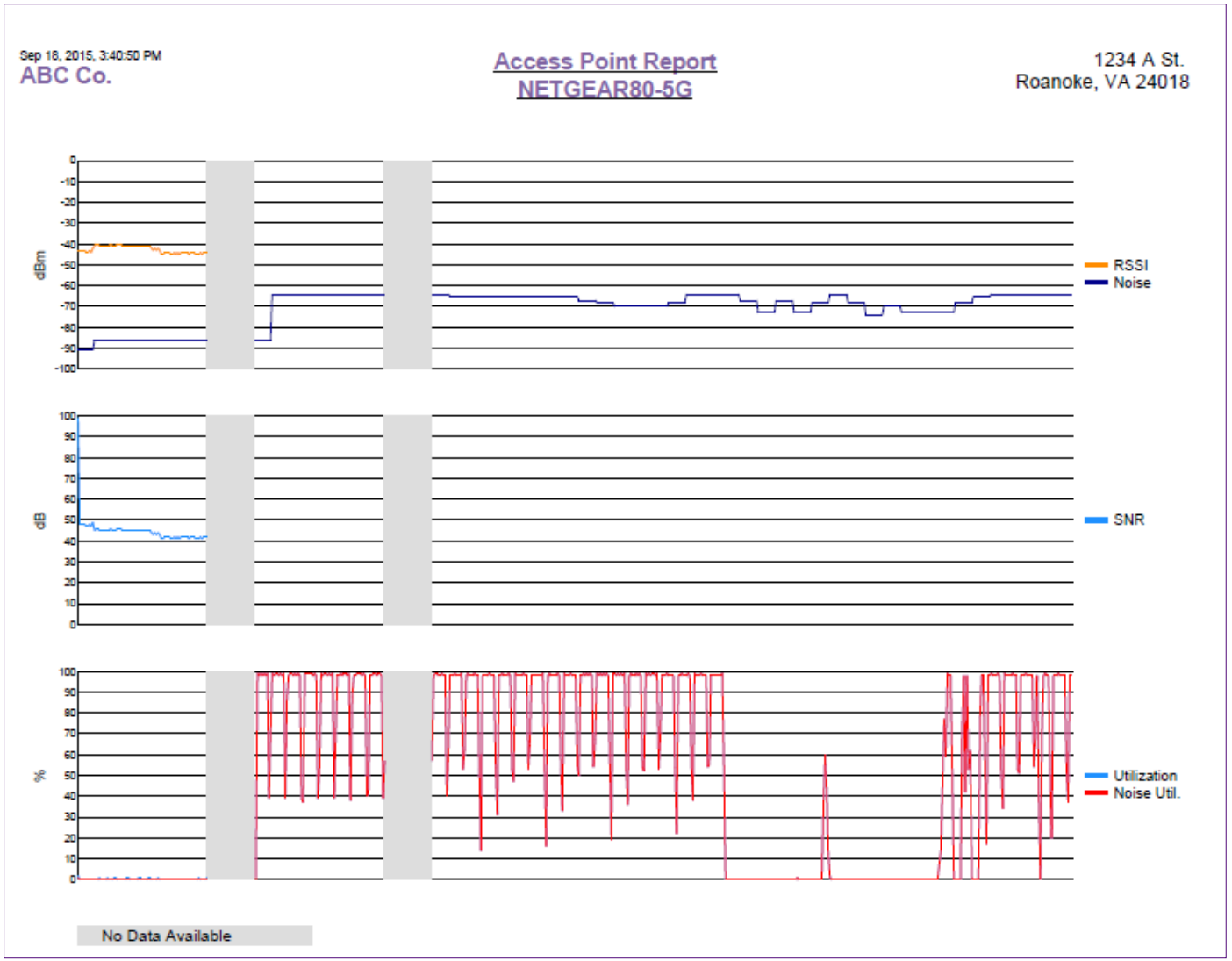
PDF Report Shows High Noise, Poor SNR, High Utilization due to Noise

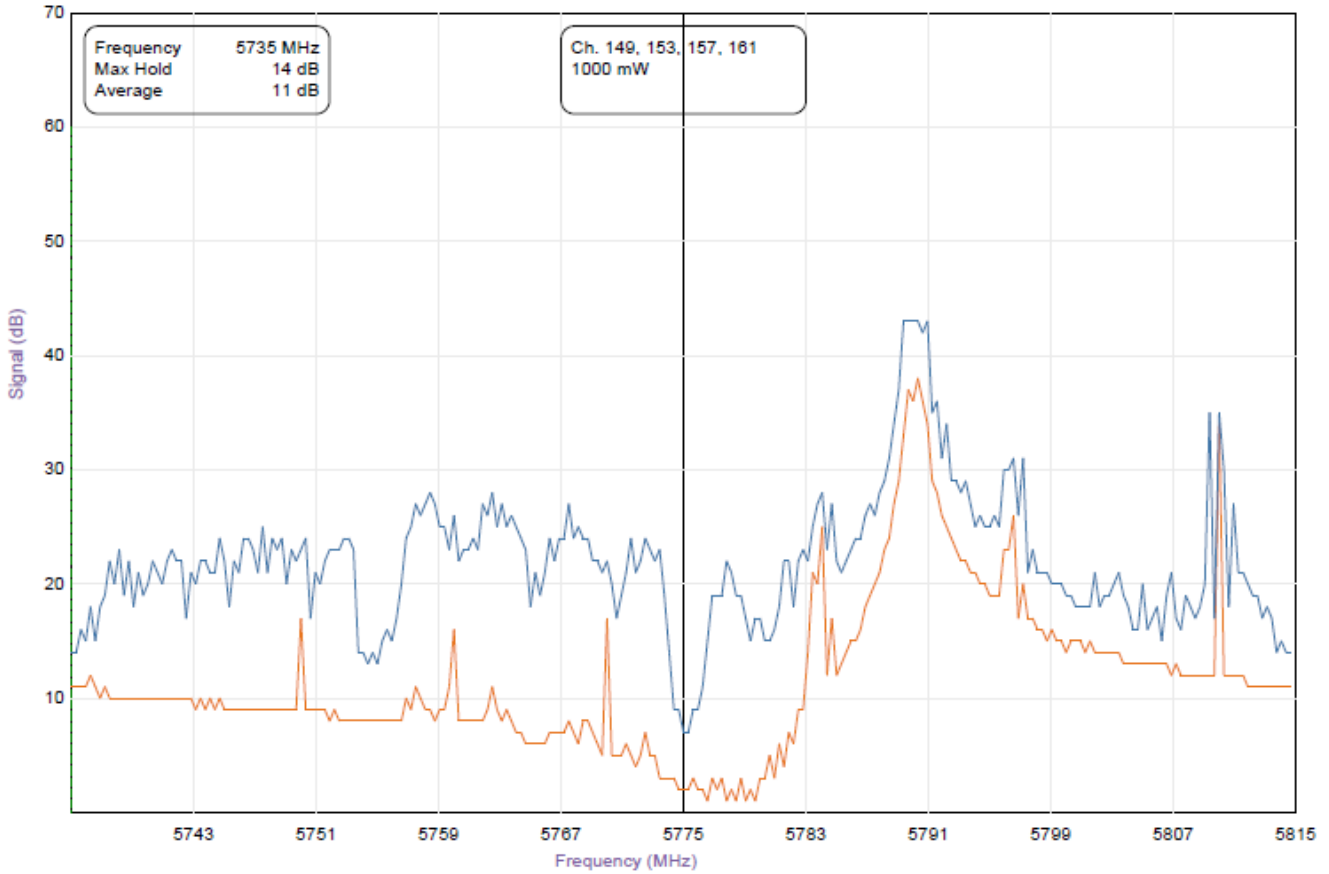


PDF Report Captured Spectral Evidence

Sep 18, 2015, 3:40:50 PM
ABC Co.

Access Point Report
NETGEAR80-5G

1234 A St.
Roanoke, VA 24018



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Reflecting and Absorbing Materials


Mirrors


Large Groups of People

- Situation / Problem: Repeat service call for chronic wireless IPTV issue
  - Unexplained, periodic video pixelization and disconnects
  - AP located in the family room, near the TV.
  - Wireless STB located in the bedroom on the same floor.
  - Family room walls were nearly entirely *covered with mirrors*.
  - Initial thought was that there was no way a wireless STB would work at all
    - yet it did work…. most of the time
- Solution / Course of Events:
  - Signal strength, SNR and Throughput tests were OK when tested between the two locations….
  - …except, when someone was in the hallway connecting family room to bedroom – the only aperture for WiFi signals between the equipment.
  - The larger the person, the more profound the impact.
- Outcome:
  - WiFi testing is fine in and of itself, but one must also apply an understanding and awareness of the surroundings.
  - Simple A-B testing can be used to show the effect of different configurations in the surroundings and / or different placements of equipment.
    - Signal strength / SNR / using Trend Graphs
    - Real Throughput using Site Assessment

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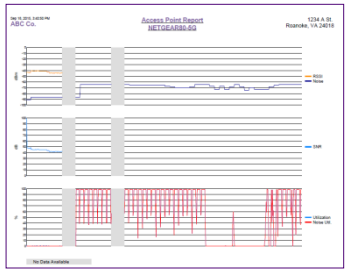
Utilization and Noise in Combination



- Situation: Demonstrating WiFi Advisor capabilities in the Donut Shop
- Course of Events:
  - Using BSSID view, noticed that all AP's were located in channel 6 or below
  - While demonstrating Channel View, utilization in upper channels was near zero, as expected
  - Utilization in channels 8, 9, 10 and 11 suddenly spiked to >80%
  - Noise in channels 8,9,10 and 11 spiked at the same time.
  - Spectral view clearly showed the noise event, which correlated to when the restaurant's institutional microwave was turned on.
- Outcome / Discovery:
  - High Channel Utilization in combination with high noise is a very good indicator that there is a strong, non-WiFi interferer in the channel of interest.
  - **Caution!:** High utilization and high noise can also be driven by high WiFi activity in adjacencies with strong signal levels (see the BSSID view.)

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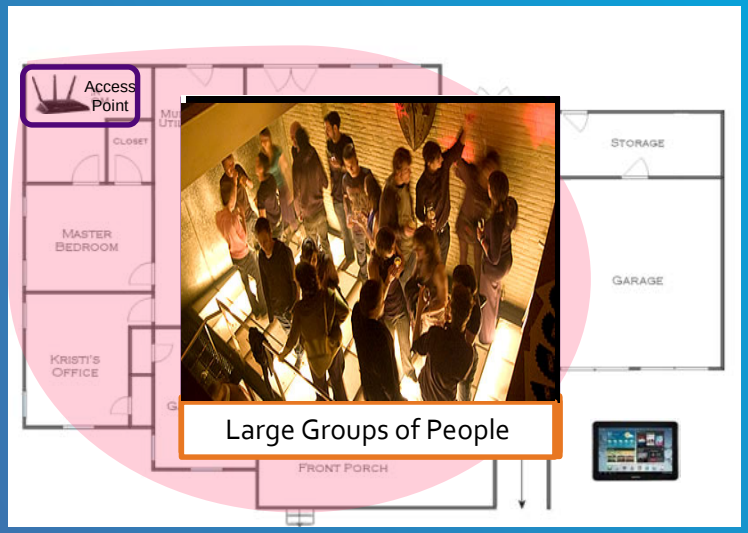
Physical environment

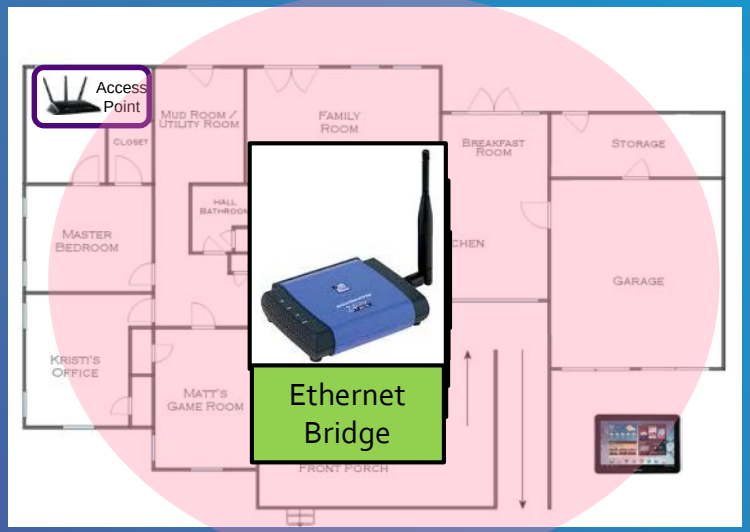
Which Layers effected?
Power level, Noise

Customer Major Complaint?
Cannot Connect

What to look for?
Access Point location in reference to problem location and what is in between the 2 devices/locations

The Fixes?
Move the Access Point, Extend the network – Ethernet, MoCA, PowerLine





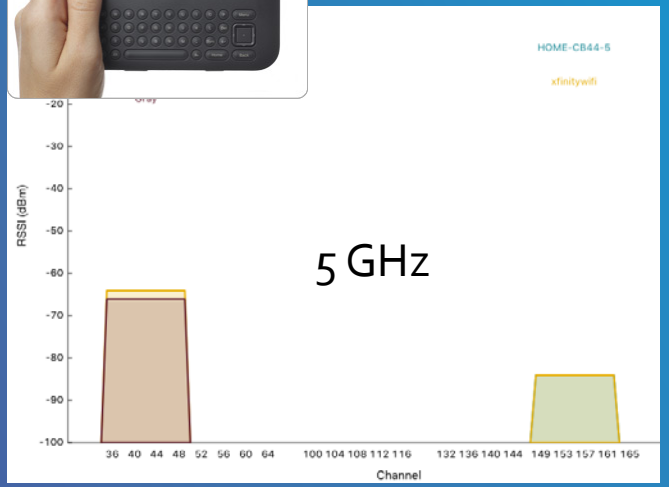
Customer "environment"

Which 5 Layers effected?
Noise, Utilization, Co-Channel, Adjacent Channel

Customer Major Complaint?
Slow Speeds

What to look for?
802.11 b/g devices, WEP encryption, Use of 5GHz devices on 2.4GHz, close proximity to other AP's

The Fixes?
Remove/replace 802.11 b/g devices, WPA2/WPS, change the channel, Move to 5GHz, Change 2.4/5 GHz SSID's to NOT match, do not allow connections of b/g devices



RE-CAP

- Use 5 GHz when possible
- Remove Older / Slower hardware technology
- Remove WEP security encryption
- Name the 5GHz and 2.4 GHz networks differently
- Do not allow 802.11 b/g devices to connect to the AP
- Test wireless throughput before moving an AP
- Look for <35% utilization and low noise
- Number of AP's in a channel doesn't necessarily = best channel
- ALL Layers are relative to Wi-Fi performance
- Get a Wi-Fi analyzer that deciphers all 5 layers + does true throughput testing
- Educate the Customer!!!

Thank You!

Real World Residential WiFi Scenarios

A Typical IPTV Set Top Box Installation

- Situation / Problem: Installation of BB service and single wireless IPTV set top box
- Solution / Course of Events:
  - Customer provided 1 primary and 4 secondary locations where they might want to use the wireless STB in the future.
  - Ran 4-profile Site Assessment sequence in 5 locations
  - Shared results with the customer:
    - Primary STB location showed excellent performance (very close to RG)
    - Outside on the deck showed excellent performance (very close to RG)
    - Master bedroom performance was better than customer had expected
    - Worst location was unexpectedly in the basement, where customer wanted to build a media room. Showed customer why:
      - Although line of site distance to AP was short, poor performance likely due to intervening ductwork and large number of filing cabinets / metal shelves stored in the room.
      - For future media room design, advised:
        1. Move metal cabinets / shelves to rear of room, or out
        2. Pay close attention to position of station vs. duct work
        3. Consider running a CAT-5 Ethernet cable from AP to media room before finishing off space.
- Outcome:
  - Site Assessment results provided excellent opportunity to discuss WiFi performance at important locations within the home, and set expectations
  - Home owner was tremendously appreciative of the insight
  - WiFi Advisor gave “Projection of Power” to the Service Provider

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A Non-802.11 Interference Example

- Situation / Problem: Repeat service call for a chronic (wired) IPTV Service issue
  - Technician quickly solved wired IPTV issue for the customer.
  - Customer then started to complain about their slow WiFi
- Solution / Course of Events:
  - BSSID View showed current RG was old b/g equipment.
  - Removed old RG, installed new b/g/n RG.
  - BSSID View also found previous Service Provider's AP that was still active, but with no internet connection. This was also removed.
  - Used BSSID View, Channel View and Best Channel to find best channel – channel 11.
  - Tech set up router for channel 11 and began instructing family members on how to connect devices to the new SSID and password.
  - All could connect, except for the last child…
  - Jumped to spectral to observe channel 11 for potential interferers and saw a strong spike at the same time as we heard that the microwave was on.
  - Showed spectral and channel utilization impact of the microwave in ch. 11 to the customer
  - Moved customer's AP to next best channel – channel 1.
- Outcome:
  - BSSID, Channel and Spectral views were all instrumental in helping optimize customer's WiFi network and eliminated a likely repeat call
  - Home Owner was impressed and appreciative of the insight
  - Learned to test for effect of customer's microwave on every call – install or trouble

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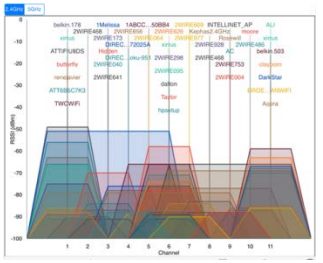
A 2.4 GHz “Across-the-Band” Utilization Problem



- Situation / Problem: WiFi Trouble call – slow WiFi
  - Insufficient WiFi speeds in customer’s home office to support work-related video conferencing
  - 2.4GHz b/g/n RG located in upstairs media room at back of house
  - Home office located ground floor, front of house
  - Customer had tried multiple channels in 2.4GHz to no avail. Customer’s attempts to solve the problem with Power Line Networking were also not effective.
- Solution / Course of Events:
  - At first take, the open floor plan and the reasonable distance from RG to home office appeared manageable.
  - But, WiFi Advisor showed the 2.4GHz band to be very crowded
    - BSSID view showed a huge number of AP’s in the environment, with poor adherence to the 1-6-11 grooming guidelines.
    - The Channel View showed continuous high utilization across nearly the entire band.
    - Site Assessment tests on multiple channels confirmed customer’s slow speeds in 2.4 GHz.
  - BSSID view showed 5GHz band was very clean.
  - Site Assessment was used to demonstrate that significant improvement in throughput was possible between the two locations using the 5GHz band.
  - Customer pulled out a dual band AP that they were thinking of trying. Advised the customer to:
    1. Turn off the 2.4 GHz band in the new AP as it would likely conflict with the RG’s 2.4 GHz radio
    2. Set up the 5 GHz band in the new n/ac AP to use channel sets 36/40/44/48 or 149/153/157/161 as these were very open according to the BSSID / Channel views
    3. Separate AP’s by > 10 feet
- Outcome:
  - WiFi Advisor was able to prove that poor across the band 2.4GHz throughputs could be greatly improved by moving to the 5GHz band.
  - Home Owner was impressed and appreciative of the insight and advice.

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