Future of Wi-Fi 6 and Beyond!

Keith R. Parsons - 18 JAN 2023

wirelessLAN PROFESSIONALS

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Introduction

Keith R. Parsons

110+ Certifications/Countries

CWNE #3 - Produce #WLPC

20+ Years WLAN Experience

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Speed and Complexity of Wi-Fi Upgrades

Hang on for the ride!

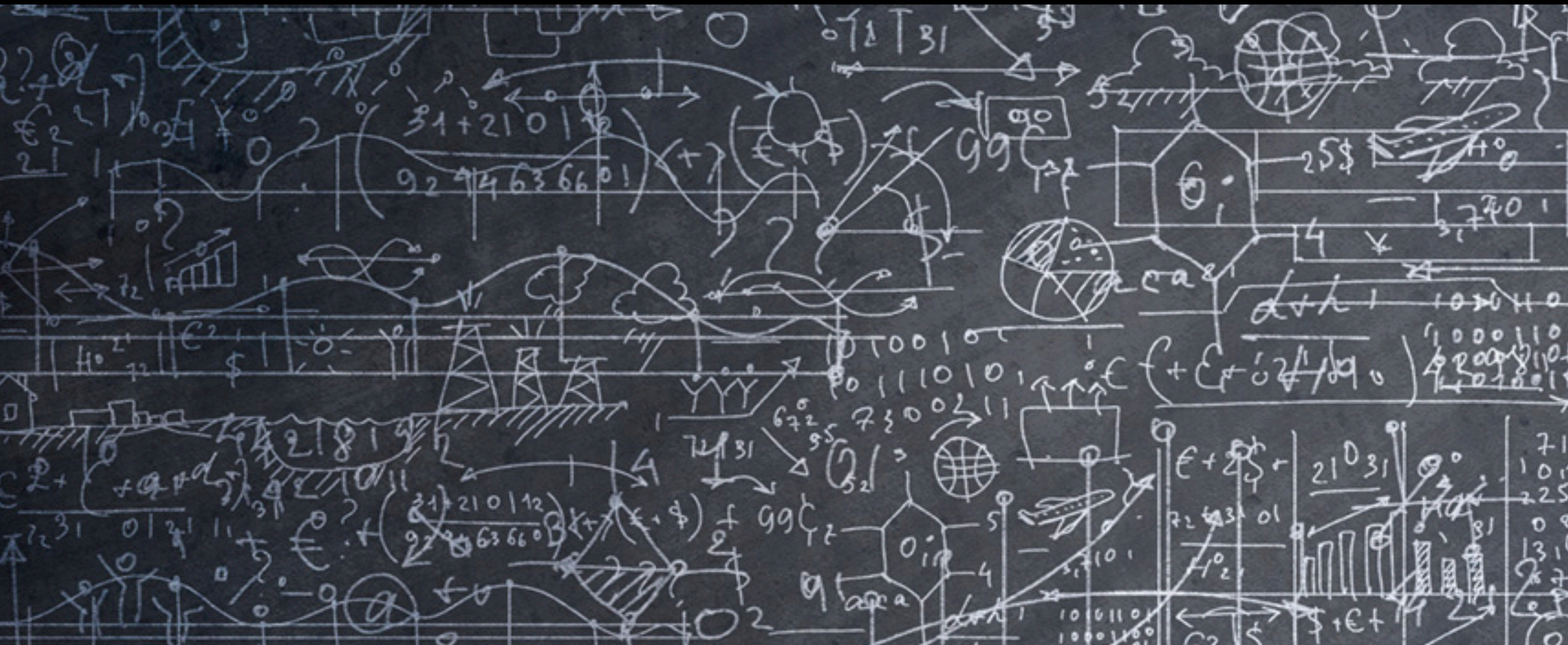
- 802.11 Evolution
- Complexity is mind boggling

802.11 Upgrade Cycles

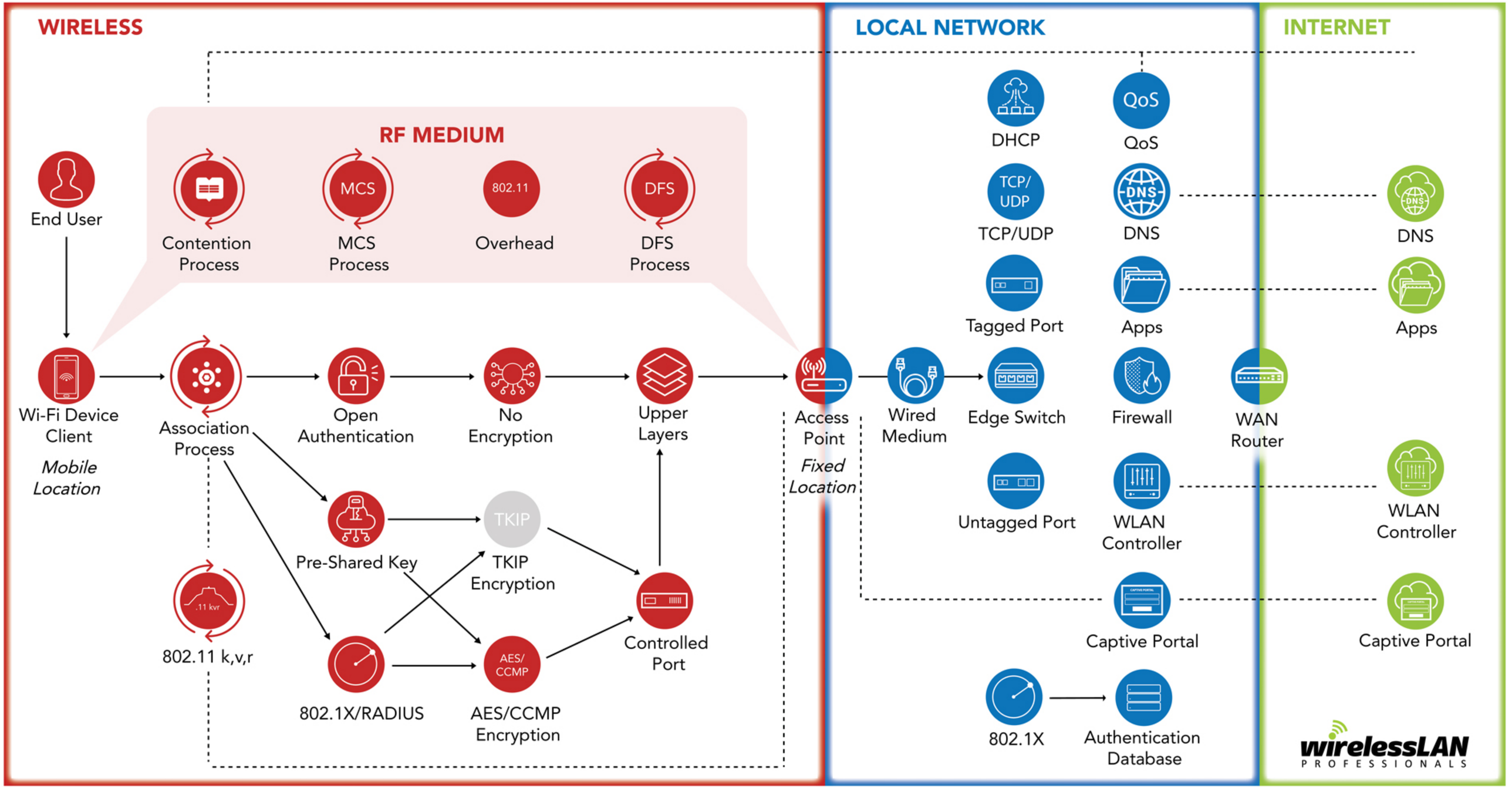
Year	Years	IEEE Name	WFA Name	# MCS	Max Speed	SS	Frequencies	Max CH BW	# Ch	Total BW
1997		802.11		2	2Mb	1	2.4GHz	22MHz	3	80MHz
1999	2	802.11 a		11	54Mb	1	5GHz	20MHz	9	180MHz
1999	0	802.11 b		4	11Mb	1	2.4GHz	22Mhz	3	80MHz
2003	4	802.11 g		11	54Mb	1	2.4GHz	20MHz	21	80MHz
2009	6	802.11 n	Wi-Fi 4	77	600Mb	4	2.4GHz & 5GHz	20MHz, 40MHz	28	580MHz
2013	4	802.11 ac	Wi-Fi 5	624	1.73Gb	8	5GHz	80MHz	25	500MHz
2019	6	802.11 ax	Wi-Fi 6	1728	9.6Gb	8	2.4GHz & 5GHz	20MHz/160MHz	28	580MHz
2021	2	802.11 ax	Wi-Fi 6E	1728	9.6Gb	8	2.4GHz, 5GHz, 6GHz	20MHz/160MHz	87	1780MHz
2023	2	802.11 be	Wi-Fi 7	4032	46Gb	16	2.4GHz, 5GHz, 6GHz	20MHz/320MHz	87	1840MHz

Complexity is Mind-Boggling

PhD’s in RF, AI, and Chip Design are stretched to their limits!



Potential Wireless LAN Troubleshooting Causes



Potential Wireless LAN Troubleshooting Causes

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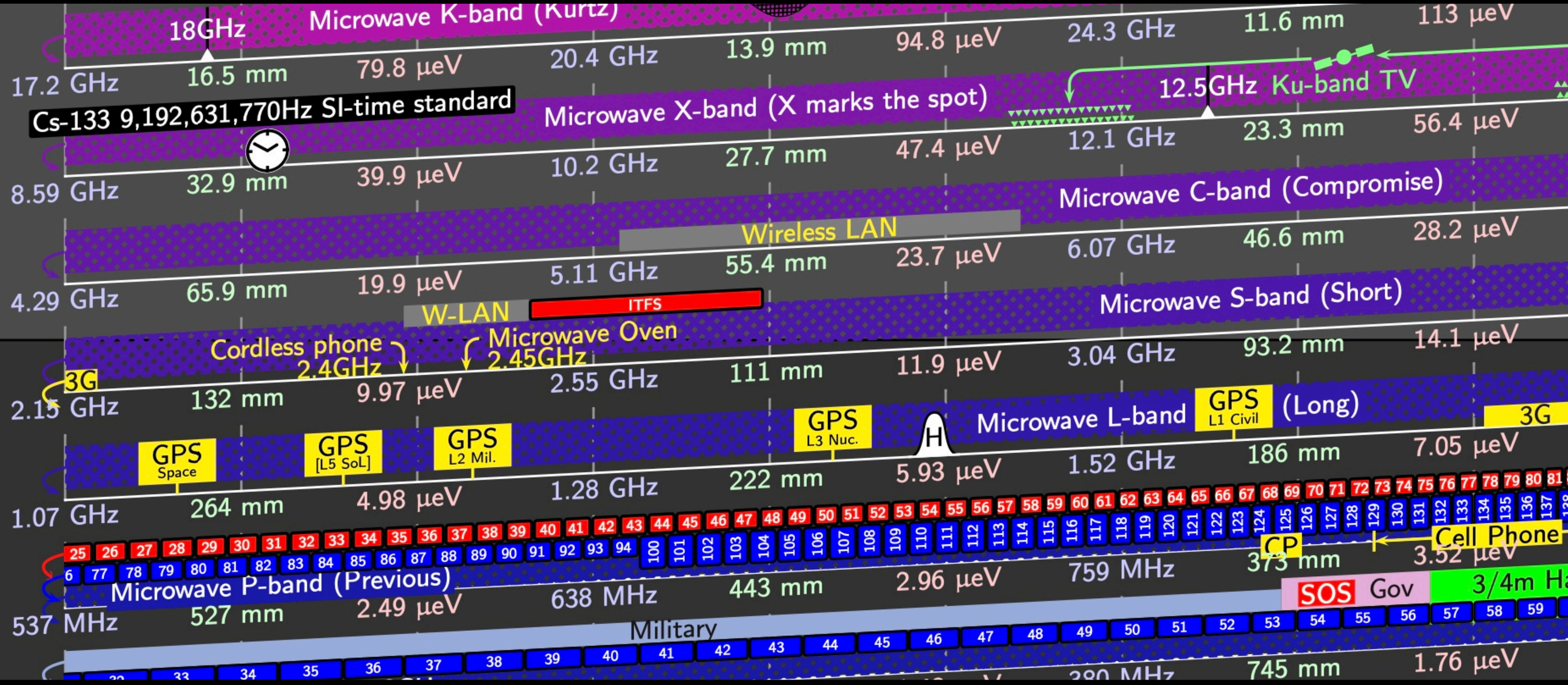
	Wired/Wireless	Location	Potential Issues
1	**Wireless**	End User	Skills, Knowledge Perceptions, Device on/off, Understanding of Concepts & Device capabilities, Wi-Fi vs Cellular
2	*Mobile*	Wi-Fi Client Device	Drivers, Radio Capabilities, Profiles, Supported PHY, QoS, Power Save, Applications, Location, Vendor IE Support, Chipset Behavior, Roaming Algorithms, Auto-Negotiated MCS, MDM, Protection
3		RF Media	RSSI, SNR, SNiR, Primary & Secondary Coverage, CCI/ACI, Retry Rates, Average MCS, Jitter, Latency, Consistency, Regulatory Domains, Non-Wi-Fi Interference, Spectrum Analysis
4	Per Frame Tx	Contention Process	Preamble Detect, Energy Detect, Triggers, NAV Timers, TxOP, AIFS, Random Slots, QoS, WMM, Duration ID, Ch Capacity, Non-Wi-Fi Inteference
5	Per Frame Tx	MCS Process	Per Frame Decisions - Modulation Technique, Coding Technique, Ch Width, Guard Interval, Spatial Streams, Tx Power, ACK vs No ACK, TX decides
6	Per Time	DFS Process	802.11 is NOT primary User - AP Scans for 60-Seconds, AP Enabled, Continuos Scanning, If RADAR detected, send CSA, Change to new CH, After 30-min can return, after 60-second scan
7	Per Frame Tx	Single Frame on RF	Overhead to delivery IP Payload - AIFS, CW, BPSK Preamble, RTS, SIFS, Preamble BPSK, CTS, SIFS, Preamble, Preamble VHT, Header MBR, Payload PHY rate, CRC, SIFS, Preamble, ACK
8	Per Timers	Association Process	Beacon, Probe Request, Probe Reponse, Authentication Request, Authentication Response, Association Request, Association Response, Decide on which AP by: RSSI, SNR, Auth Method, Encrypt Method, Channel Switch Announcement, Error Ratios, MCS/Data Rates Supported, Heuristics, Internal Lists, De-Authentication, Dis-Associate, 802.11 k, v, r, MBR, Proprietary Methods!
9		802.11 k, v, r	AP's try to influence the roaming decisions via 'standard' modes
10	Per Changes	Authentication Process	Open, Pre-Shared Key, 802.1X RADIUS, PSK includes Exchange of 4-Way Handshake to trigger Encryption Keys, 802.1X EAP Exchange, ending in 4-Way Handshake
11		Encrytion Process	None, TKIP, AES/CCMP, Punishment for using TKIP, Confusion with Wi-Fi Alliance naming - WPA2 PSK... is PSK-WPA2
12	From LAN	Upper Layers	DHCP, IP , DNS, VLAN, Subnet Mask, Default Gateway, Captive Portal
13		Controlled Port	AP Controls which 802.11 Frames can cross Wireless to Wired Boundary
14	*Fixed*	Access Point	Configurations, SSIDs, Minimum Basic Rates, Supported PHY Rates, Band Steering, Client Control, Radio Capabilities, Tx Rates, Client Isolation, Roaming, QOS PoE, Antenna Pattern, Mounting, 1GB backhaul limit, AP Locations, Physcial Layer Issues, Firmware Revisions, Custom Configurations, RRM/ARM, Proprietary
15	**Local Network**	Wired Medium	EIA/TIA 568A/B, Category Mismatch, Validation Tests, Grounding, other issues
16		Edge Switch	VLANs, Port Speeds, PoE, Configurations, QoS, End-to-End?, COS vs DSCP
17		Local Network	Distributed vs Centralized Forwarding, ACLs, VLANs, QoS, Tunnels, Layers, NAT
18		TCP/UDP	Following all TCP issues as well as UDP reasons for using each
19		Quality of Service	Tagged Port vs Untagged Port, DSCP, WMM Categories, End-to-End QoS
20		Applicatons	MTU, TCP Window, Round Trip Time, Processing Time, TCP Retransmission times
21		DHCP Server	Lease Durations, Configurations, Broadcast Storms, Latency, Performance, Address Pool Scopes, Scalability, DHCP Options, Auto Renew
22		DNS	Configuration, Scalability, Security, Accuracy, Customization, Control, Blacklists
23		802.1X/RADIUS	Configuration, Ports, Ranges, Licensing Issues, EAP types, Custom VSA, Scalability, Resouces, Certificate Issues, Fast/Secure Roaming types
24		Active Directory	Accounts, Credentials, EAP Compatibility, Custom RADIUS Attributes
25		Controller Functions	Code Versions, Bugs, Configurations, Local vs Cloud, Licensing Issues, Distributed vs Centralized Forwarding, VLAN choices
26		Firewall	Firewall Rules, Capacity, Compatibility, Rate Limiting, Bandwidth Shaping
27		WAN Router	Size of Internet Pipe, Inernet Destination Issues, Costs, Availability, Consistency
28	**Internet**	Internet Connection	Bandwidth Throttling, Jitter, Latency
29		Captive Portal	Security, Client Issues, Privacy, Friction, Triggers, Certificates, DNS, Captive Portal Location, Control, Monetization, Legal, MiFi

Frequencies Available



Radio Frequencies Details

More than you need to know…

Unlicensed Spectrum and Channel Allocations

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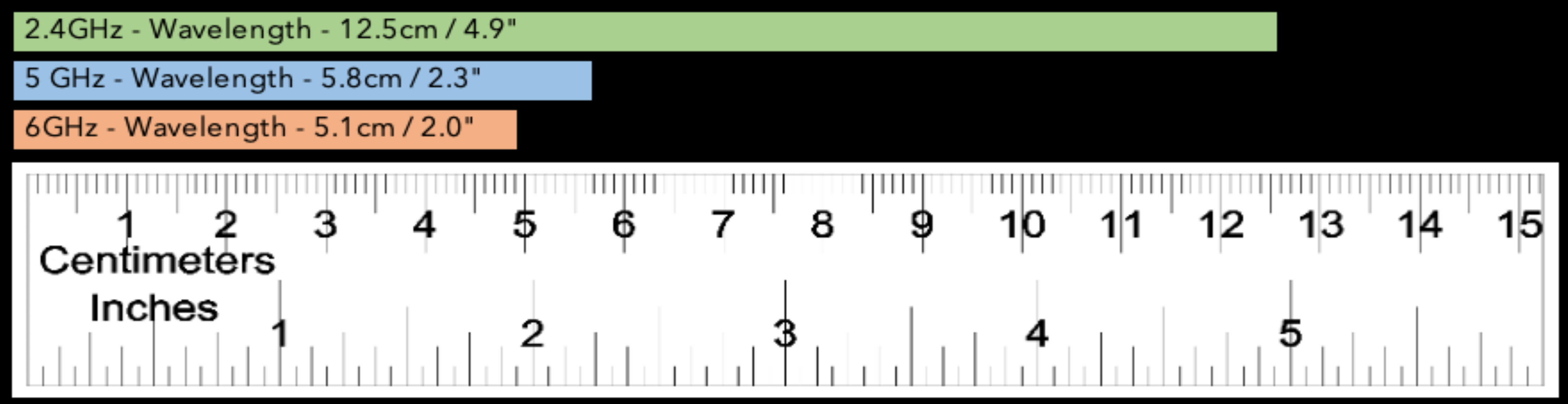
2.4 GHz Channels

80 MHz

	ISM Band	*2407 + 5 X Ch. Number Wavelength 12.5cm - 4.9" to 12.0cm - 4.7"*		
Qty	Channel	1	6	11
3	Center Freq	2.412	2.437	2.462



5 GHz Channels

500 MHz

Frequency *5000 + 5 X Ch. Number Wavelength 5.8cm - 2.3" to 5.1cm - 2.0"*

U-NII-2a: DFS Channels; U-NII-2c (Extended): DFS Channels; TDWR: 5.600–5.640 (channels 120, 124, 128)

Qty	Radio Band	U-NII-1				U-NII-2a				U-NII-2c (Extended)												U-NII-3					Qty
	Center Freq	5.180	5.200	5.220	5.240	5.260	5.280	5.300	5.320	5.500	5.520	5.540	5.560	5.580	5.600	5.620	5.640	5.660	5.680	5.700	5.720	5.745	5.765	5.785	5.805	5.825	
25	20 MHz	36	40	44	48	52	56	60	64	100	104	108	112	116	120	124	128	132	136	140	144	149	153	157	161	165	25
11	40 MHz	38		46		54		62		102		110		118		126		134		142		151		159			11
5	80 MHz	42				58				106				122				138				155					5
2	160 MHz	50								114												*165 was ISM, now U-NII-3*					2

6 GHz Channels

1,200 MHz

FCC - USA *5950 + 5 X Ch. Number Wavelength 5.1cm - 2.0" to 4.2cm - 1.6"*

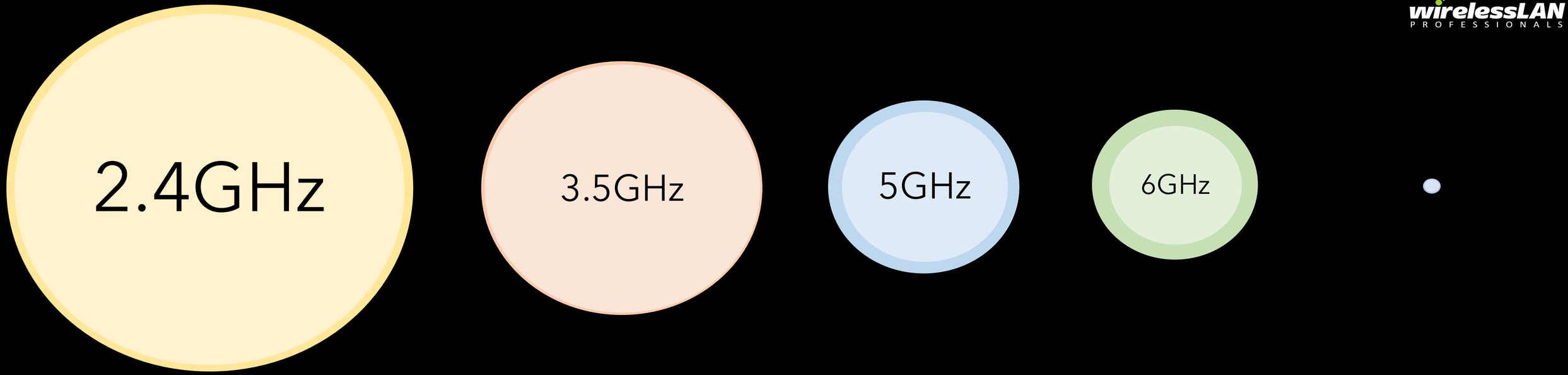
Low Power Indoor: 5925 **5dBm/MHz - Net EIRP 18dBM**; 6425; 6525; 6875

Qty	Radio Band	UNII-5																							
	Center Freq	5.955	5.975	5.995	6.015	6.035	6.055	6.075	6.095	6.115	6.135	6.155	6.175	6.195	6.215	6.235	6.255	6.275	6.295	6.315	6.335	6.355	6.375	6.395	6.415
59	20 MHz	1	**5**	9	13	17	**21**	25	29	33	**37**	41	45	49	**53**	57	61	65	**69**	73	77	81	**85**	89	93
29	40 MHz	3		11		19		27		35		43		51		59		67		75		83		91	
14	80 MHz	7				23				39				55				71				87			
7	160 MHz	15								47								79							

Radio Band	UNII-6					UNII-7																
Center Freq	6.435	6.455	6.475	6.495	6.515	6.535	6.555	6.575	6.595	6.615	6.635	6.655	6.675	6.695	6.715	6.735	6.755	6.775	6.795	6.815	6.835	6.855
20 MHz	97	**101**	105	109	113	117	**121**	125	129	**133**	137	141	145	**149**	153	157	161	**165**	169	173	177	**181**
40 MHz	99		107		115		123		131		139		147		155		163		171		179	
80 MHz	103				119				135				151				167				183	
160 MHz	111								143								175					

Radio Band	UNII-8												
Center Freq		6.895	6.915	6.935	6.955	6.975	6.995	7.015	7.035	7.055	7.075	7.095	7.115
20 MHz	185	189	193	**197**	201	205	209	**213**	217	221	225	229	233
40 MHz	187		195		203		211		219		227		
80 MHz			199				215						
160 MHz			207										

Antenna Receive Aperture



2.4GHz
12.0cm - 12.4cm
4.7" - 4.9"
FPSL 1m -39.1dB

3.5GHz
8.11cm - 8.19cm
3.20" - 3.23"
FPSL 1m -42.7dB

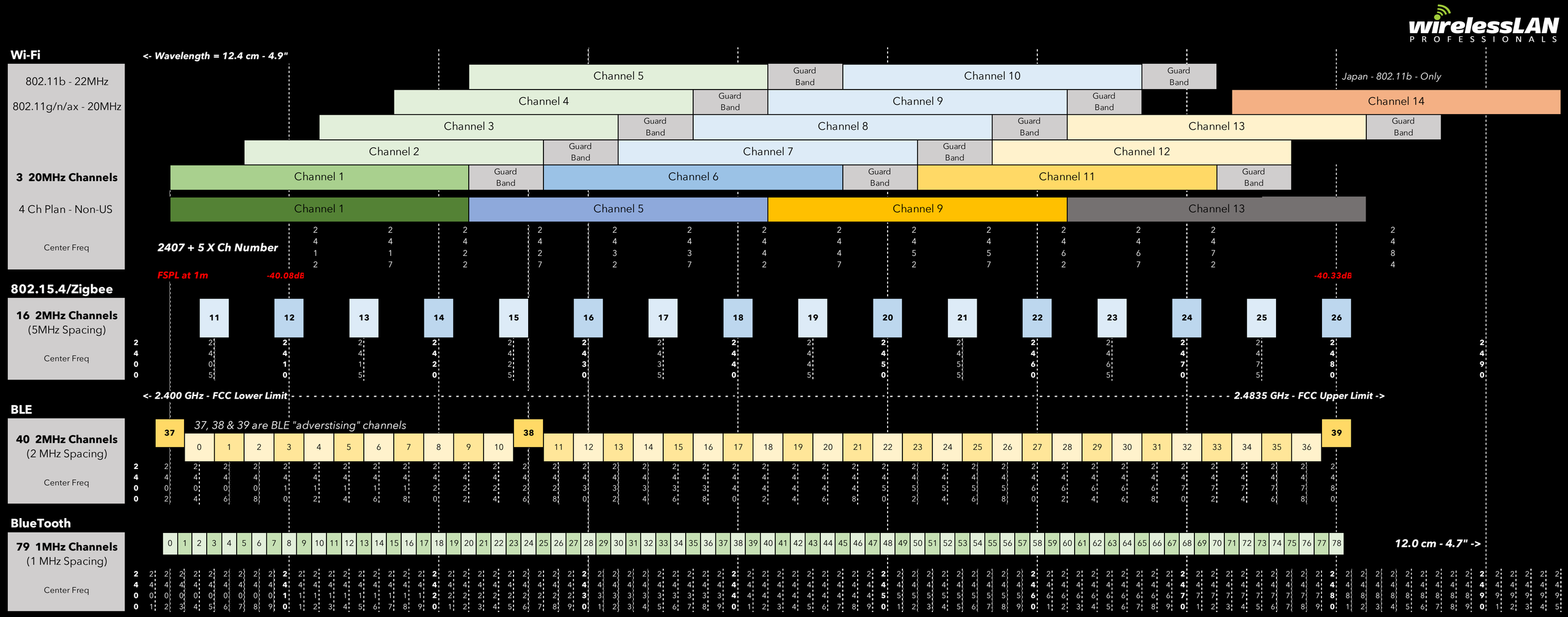
5GHz
5.1cm - 5.8cm
2.0" - 2.3"
FPSL 1m -45.7dB

6GHz
4.2cm - 5.1cm
1.6" - 2.0"
FPSL 1m -46.9dB

60GHz
.46cm - .52cm
.18" - .20"
FPSL 1m -66.8dB

2.4GHz Details

Did you really want to know all this?



5GHz Details

5 GHz Channel Allocations 500 MHz

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	Frequency	*5000 + 5 X Ch. Number*				DFS Channels			
	Radio Band	U-NII-1				U-NII-2a			
Qty	Center Freq	5.180	5.200	5.220	5.240	5.260	5.280	5.300	5.320
25	20 MHz	36	40	44	48	52	56	60	64
12	40 MHz	38		46		54		62	
6	80 MHz	42				58			
3	160 MHz	50							
	FCC - US	1,000 mW Tx Power Indoor & Outdoor No DFS needed				250 mw w/6dBi Indoor & Outdoor DFS Required			
	ISED - Canada	FCC - Except Outdoor License Req. >200 mW				Same as FCC			
	ACMA - Australia	200 mW EIRP Indoor				200 mW EIRP - DFS & TPC 100 mW EIRP - DFS-Only Indoor			
	ETSI - EU	100 mW No DFS/TPC Indoor; 200 mW EIRP DFS/TPC - Indoor				200 mW EIRP DFS/TPC Indoor			
	20 MHz	36	40	44	48	52	56	60	64
	Center Freq	5.180	5.200	5.220	5.240	5.260	5.280	5.300	5.320
	Free Space Path Loss 1m	-45.74	-45.77	-45.80	-45.84	-45.87	-45.90	-45.94	-45.97

	Past Proposal							
Radio Band	UNII-2b							
Center Freq	5.340	5.360	5.380	5.400	5.420	5.440	5.460	5.480
20 MHz	68	72	76	80	84	88	92	96
40 MHz	70		78		86		94	
80 MHz	74				90			
160 MHz	82							
FCC - US	**Not Currently Available for Unlicensed**							
ISED - Canada								
ACMA - Australia								
ETSI - EU								
20 MHz	68	72	76	80	84	88	92	96
Center Freq	5.340	5.360	5.380	5.400	5.420	5.440	5.460	5.480
Free Space Path Loss 1m	-46.00	-46.03	-46.07	-46.10	-46.13	-46.16	-46.19	-46.23

Frequency	DFS Channels											
						TDWR						
Radio Band	U-NII-2c (Extended)											
Center Freq	5.500	5.520	5.540	5.560	5.580	5.600	5.620	5.640	5.660	5.680	5.700	5.720
20 MHz	100	104	108	112	116	120	124	128	132	136	140	144
40 MHz	102		110		118		126		134		142	
80 MHz	106				122				138			
160 MHz	114											
FCC - US	250 mw w/6dBi Indoor & Outdoor DFS Required					120, 124, 128 US - Allowed						*144 Now Allowed*
ISED - Canada	Same as FCC					TDWR Not Allowed			Same as FCC			
ACMA - Australia	1,000 mW - DFS & TPC 500 mW - DFS-Only - No TPC Indoor/Outdoor					TDWR Not Allowed			1,000 mW - DFS & TPC 500 mW - DFS-Only Indoor/Outdoor			
ETSI - EU	1,000 mW EIRP DFS/TPC Indoor/Outdoor					10-min TWDR Scan Time						UK No 144; 25mW SRD
20 MHz	100	104	108	112	116	120	124	128	132	136	140	144
Center Freq	5.500	5.520	5.540	5.560	5.580	5.600	5.620	5.640	5.660	5.680	5.700	5.720
Free Space Path Loss 1m	-46.26	-46.29	-46.32	-46.35	-46.38	-46.41	-46.44	-46.48	-46.51	-46.54	-46.57	-46.60

	165 was ISM, now U-NII-3					*New FCC*				
Radio Band	U-NII-3					UNII-4				
Center Freq	5.745	5.765	5.785	5.805	5.825	5.845	5.865	5.885	Qty	Qty
20 MHz	149	153	157	161	165	169	173	177	25	28
40 MHz	151		159		167		175		12	14
80 MHz	155				171				6	7
160 MHz	163								3	4
FCC - US	1,000 mW Tx Power Indoor & Outdoor No DFS needed									
ISED - Canada	Canada PtP allows Higher EIRP									
ACMA - Australia	4,000 mW Tx Power Indoor & Outdoor No DFS needed									
ETSI - EU	4,000 mW EIRP DFS/TPC - Outdoor Fixed Wireless Access; 25mW - SRD - No DFS									
20 MHz	149	153	157	161	165	169	173	177		
Center Freq	5.745	5.765	5.785	5.805	5.825	5.845	5.865	5.885		
Free Space Path Loss 1m	-46.64	-46.67	-46.70	-46.73	-46.76	-46.79	-46.82	-46.84		

<- Wavelength 5.8cm - 2.3"

Wavelength 5.1cm - 2.0" ->

6GHz

6 GHz Channel Allocations

1,200 MHz

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FCC - USA

5950 + 5 X Ch. Number

Low Power Indoor

5925 — **5dBm/MHz - Net EIRP 18dBM** — **1.2 Gigahertz Proposed** — 6425

UNII-5

Qty	Radio Band / Center Freq	5.955	5.975	5.995	6.015	6.035	6.055	6.075	6.095	6.115	6.135	6.155	6.175	6.195	6.215	6.235	6.255	6.275	6.295	6.315	6.335	6.355	6.375	6.395	6.415
59	20 MHz	1	**5**	9	13	17	**21**	25	29	33	**37**	41	45	49	**53**	57	61	65	**69**	73	77	81	**85**	89	93
12	40 MHz	3		11		19		27		35		43		51		59		67		75		83		91	
6	80 MHz	7				23				39				55				71				87			
3	160 MHz	15								47								79							

Standard Power AP

5925 — **36dBm with Automated Frequency Coordination (AFC)** — 6425

UNII-5

Qty	Radio Band / Center Freq	5.955	5.975	5.995	6.015	6.035	6.055	6.075	6.095	6.115	6.135	6.155	6.175	6.195	6.215	6.235	6.255	6.275	6.295	6.315	6.335	6.355	6.375	6.395	6.415
24	20 MHz	1	**5**	9	13	17	**21**	25	29	33	**37**	41	45	49	**53**	57	61	65	**69**	73	77	81	**85**	89	93
12	40 MHz	3		11		19		27		35		43		51		59		67		75		83		91	
6	80 MHz	7				23				39				55				71				87			
3	160 MHz	15								47								79							

Low Power Indoor

6425 — **UNII-6** — 6525 — **UNII-7** — 6875 — **UNII-8**

Radio Band / Center Freq	6.435	6.455	6.475	6.495	6.515	6.535	6.555	6.575	6.595	6.615	6.635	6.655	6.675	6.695	6.715	6.735	6.755	6.775	6.795	6.815	6.835	6.855	6.895	6.915	6.935	6.955	6.975	6.995	7.015	7.035	7.055	7.075	7.095	7.115
20 MHz	97	**101**	105	109	113	**117**	121	125	129	**133**	137	141	145	**149**	153	157	161	**165**	169	173	177	**181**	185	189	193	**197**	201	205	209	**213**	217	221	225	**229**	233
40 MHz	99		107		115		123		131		139		147		155		163		171		179		187		195		203		211		219		227		
80 MHz	103				119				135				151				167				183				199				215					
160 MHz	111								143								175								207									

Standard Power AP

6425 — **UNII-6** — 6525 — **UNII-7** — 6875 — **UNII-8**

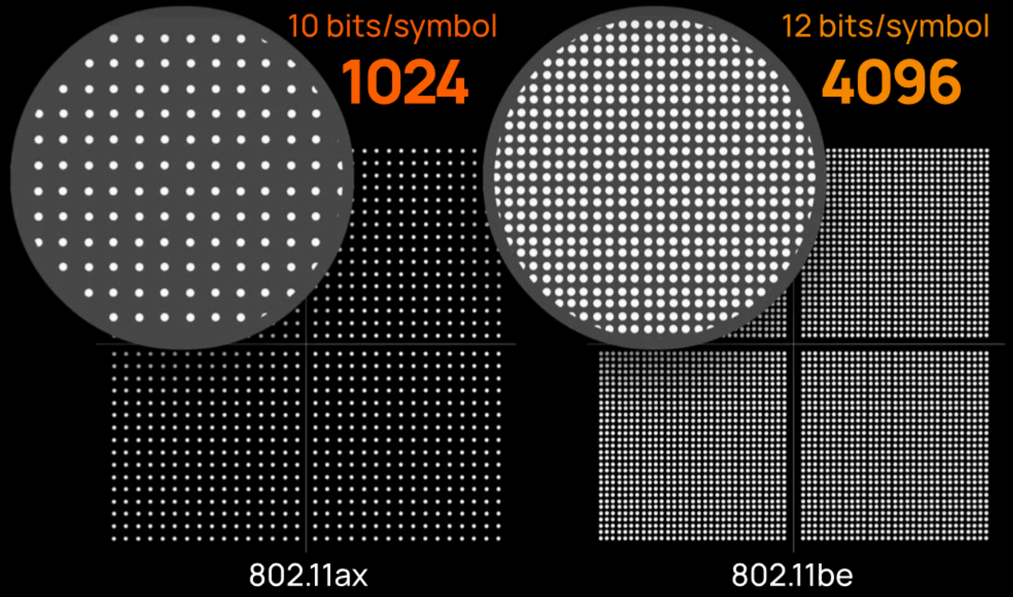
Radio Band / Center Freq	6.435	6.455	6.475	6.495	6.515	6.535	6.555	6.575	6.595	6.615	6.635	6.655	6.675	6.695	6.715	6.735	6.755	6.775	6.795	6.815	6.835	6.855	6.895	6.915	6.935	6.955	6.975	6.995	7.015	7.035	7.055	7.075	7.095	7.115
20 MHz						**4**	8	12	16	**20**	24	28	32	**36**	40	44	48	**52**	56	60	64	**68**														
40 MHz							10		18		26		34		42		50		58		66														
80 MHz									22				38				54																		
160 MHz									30																										

Client Devices

6dB Below AP max Net EIRP of 18dBm - Anticipating 12dBm

Modulation getting more difficult

Need to design for more SNR



802.11n and 802.11ac

										802.11n	**802.11ac**		
HT VHT					20MHz		40MHz		80MHz		160MHz		
MCS	MCS	SS	Modulation	Coding	No SGI	SGI	No SGI	SGI	No SGI	SGI	No SGI	SGI	
0	0	1	BPSK	1/2	6.5	7.2	13.5	15	29.3	32.5	58.5	65	
1	1	1	QPSK	1/2	13	14.4	27	30	58.5	65	117	130	
2	2	1	QPSK	3/4	19.5	21.7	40.5	45	87.8	97.5	175.5	195	
3	3	1	16-QAM	1/2	26	28.9	54	60	117	130	234	260	
4	4	1	16-QAM	3/4	39	43.3	81	90	175.5	195	351	390	
5	5	1	64-QAM	5/6	52	57.8	108	120	234	260	468	520	
6	6	1	64-QAM	3/4	58.5	65	121.5	135	263.3	292.5	526.5	585	
7	7	1	64-QAM	5/6	65	72.2	135	150	292.5	325	585	650	
	8	1	256-QAM	3/4	78	86.7	162	180	351	390	702	780	
	9	1	256-QAM	5/6	n/a	n/a	180	200	390	433.3	780	866.7	

Additional Details of 802.11ac

HT MCS	VHT MCS	Modulation	Coding	20MHz				40MHz				80MHz				160MHz			
				Data Rate		Min. SNR	RSSI	Data Rate		Min. SNR	RSSI	Data Rate		Min. SNR	RSSI	Data Rate		Min. SNR	RSSI
				800ns	400ns			800ns	400ns			800ns	400ns			800ns	400ns		
1 Spatial Stream																			
0	0	BPSK	1/2	6.5	7.2	2	-82	13.5	15	5	-79	29.3	32.5	8	-76	58.5	65	11	-73
1	1	QPSK	1/2	13	14.4	5	-79	27	30	8	-76	58.5	65	11	-73	117	130	14	-70
2	2	QPSK	3/4	19.5	21.7	9	-77	40.5	45	12	-74	87.8	97.5	15	-71	175.5	195	18	-68
3	3	16-QAM	1/2	26	28.9	11	-74	54	60	14	-71	117	130	17	-68	234	260	20	-65
4	4	16-QAM	3/4	39	43.3	15	-70	81	90	18	-67	175.5	195	21	-64	351	390	24	-61
5	5	64-QAM	2/3	52	57.8	18	-66	108	120	21	-63	234	260	24	-60	468	520	27	-57
6	6	64-QAM	3/4	58.5	65	20	-65	121.5	135	23	-62	263.3	292.5	26	-59	526.5	585	29	-56
7	7	64-QAM	5/6	65	72.2	25	-64	135	150	28	-61	292.5	325	31	-58	585	650	34	-55
	8	256-QAM	3/4	78	86.7	29	-59	162	180	32	-56	351	390	35	-53	702	780	38	-50
	9	256-QAM	5/6			31	-57	180	200	34	-54	390	433.3	37	-51	780	866.7	40	-48
2 Spatial Streams																			
8	0	BPSK	1/2	13	14.4	2	-82	27	30	5	-79	58.5	65	8	-76	117	130	11	-73
9	1	QPSK	1/2	26	28.9	5	-79	54	60	8	-76	117	130	11	-73	234	260	14	-70
10	2	QPSK	3/4	39	43.3	9	-77	81	90	12	-74	175.5	195	15	-71	351	390	18	-68
11	3	16-QAM	1/2	52	57.8	11	-74	108	120	14	-71	234	260	17	-68	468	520	20	-65
12	4	16-QAM	3/4	78	86.7	15	-70	162	180	18	-67	351	390	21	-64	702	780	24	-61
13	5	64-QAM	2/3	104	115.6	18	-66	216	240	21	-63	468	520	24	-60	936	1040	27	-57
14	6	64-QAM	3/4	117	130.3	20	-65	243	270	23	-62	526.5	585	26	-59	1053	1170	29	-56
15	7	64-QAM	5/6	130	144.4	25	-64	270	300	28	-61	585	650	31	-58	1170	1300	34	-55
	8	256-QAM	3/4	156	173.3	29	-59	324	360	32	-56	702	780	35	-53	1404	1560	38	-50
	9	256-QAM	5/6			31	-57	360	400	34	-54	780	866.7	37	-51	1560	1733	40	-48

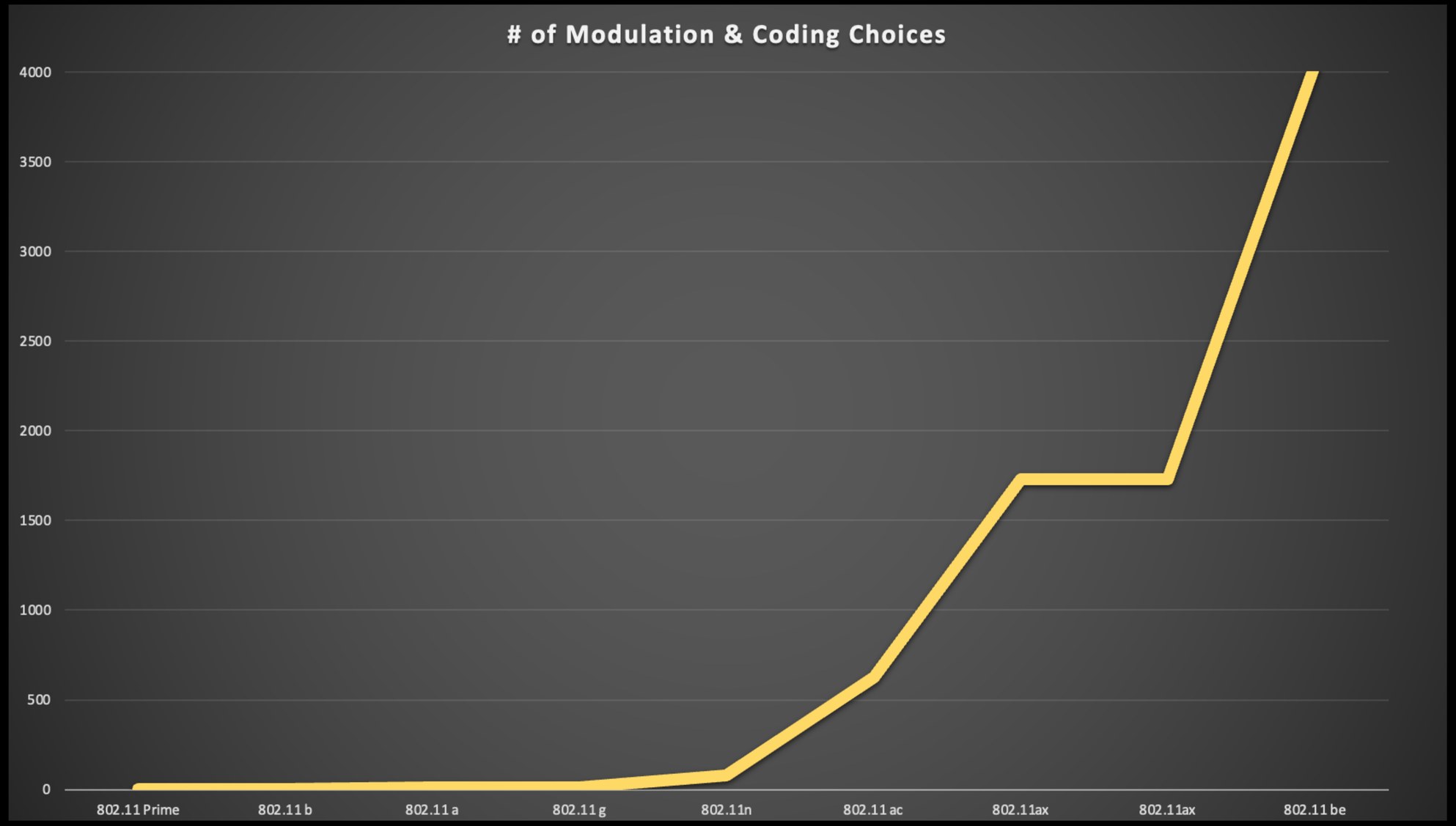
Adding 802.11ax

MCS Index			Spatial Stream	Modulation	Coding	OFDM (Prior 11ax)								OFDM (802.11ax)												MU-OFDMA (802.11ax)																	
						20MHz		40MHz		80MHz		160MHz		20MHz			40MHz			80MHz			160MHz			26-tone RU			52-tone RU			106-tone RU			242-tone RU			484-tone RU			996-tone RU		
HT	VHT	HE				0.8µs GI	0.4µs GI	0.8µs GI	0.4µs GI	0.8µs GI	0.4µs GI	0.8µs GI	0.4µs GI	0.8µs GI	1.6µs GI	3.2µs GI	0.8µs GI	1.6µs GI	3.2µs GI	0.8µs GI	1.6µs GI	3.2µs GI	0.8µs GI	1.6µs GI	3.2µs GI	0.8µs GI	1.6µs GI	3.2µs GI	0.8µs GI	1.6µs GI	3.2µs GI	0.8µs GI	1.6µs GI	3.2µs GI	0.8µs GI	1.6µs GI	3.2µs GI	0.8µs GI	1.6µs GI	3.2µs GI	0.8µs GI	1.6µs GI	3.2µs GI
0	0	0	1	BPSQ	1/2	6.5	7.2	13.5	15.0	29.3	32.5	58.5	65.0	8.6	8.1	7.3	17.2	16.3	14.6	36.0	34.0	30.6	72.1	68.1	61.3	0.9	0.8	0.8	1.8	1.7	1.5	3.8	3.5	3.2	8.6	8.1	7.3	17.2	16.3	14.6	36.0	34.0	30.6
1	1	1	1	QPSK	1/2	13.0	14.4	27.0	30.0	58.5	65.0	117.0	130.0	17.2	16.3	14.6	34.4	32.5	29.3	72.1	68.1	61.3	144.1	136.1	122.5	1.8	1.7	1.5	3.5	3.3	3.0	7.5	7.1	6.4	17.2	16.3	14.6	34.4	32.5	29.3	72.1	68.1	61.3
2	2	2	1	QPSK	3/4	19.5	21.7	40.5	45.0	87.8	97.5	175.5	195.0	25.8	24.4	21.9	51.6	48.8	43.9	108.1	102.1	91.9	216.2	204.2	183.8	2.6	2.5	2.3	5.3	5.0	4.5	11.3	10.6	9.6	25.8	24.4	21.9	51.6	48.8	43.9	108.1	102.1	91.9
3	3	3	1	16-QAM	1/2	26.0	28.9	54.0	60.0	117.0	130.0	234.0	260.0	34.4	32.5	29.3	68.8	65.0	58.5	144.1	136.1	122.5	288.2	272.2	245.0	3.5	3.3	3.0	7.1	6.7	6.0	15.0	14.2	12.8	34.4	32.5	29.3	68.8	65.0	58.5	144.1	136.1	122.5
4	4	4	1	16-QAM	3/4	39.0	43.3	81.0	90.0	175.5	195.0	351.0	390.0	51.6	48.8	43.9	103.2	97.5	87.8	216.2	204.2	183.8	432.4	408.3	367.5	5.3	5.0	4.5	10.6	10.0	9.0	22.5	21.3	19.1	51.6	48.8	43.9	103.2	97.5	87.8	216.2	204.2	183.8
5	5	5	1	64-QAM	2/3	52.0	57.8	108.0	120.0	234.0	260.0	468.0	520.0	68.8	65.0	58.5	137.6	130.0	117.0	288.2	272.2	245.0	576.5	544.4	490.0	7.1	6.7	6.0	14.1	13.3	12.0	30.0	28.3	25.5	68.8	65.0	58.5	137.6	130.0	117.0	288.2	272.2	245.0
6	6	6	1	64-QAM	3/4	58.5	65.0	121.5	135.0	263.3	292.5	526.5	585.0	77.4	73.1	65.8	154.9	146.3	131.6	324.3	306.3	275.6	648.5	612.5	551.3	7.9	7.5	6.8	15.9	15.0	13.5	33.8	31.9	28.7	77.4	73.1	65.8	154.9	146.3	131.6	324.3	306.3	275.6
7	7	7	1	64-QAM	5/6	65.0	72.2	135.0	150.0	292.5	325.0	585.0	650.0	86.0	81.3	73.1	172.1	162.5	146.3	360.3	340.3	306.3	720.6	680.6	612.5	8.8	8.3	7.5	17.6	16.7	15.0	37.5	35.4	31.9	86.0	81.3	73.1	172.1	162.5	146.3	360.3	340.3	306.3
	8	8	1	256-QAM	3/4	78.0	86.7	162.0	180.0	351.0	390.0	702.0	780.0	103.2	97.5	87.8	206.5	195.0	175.5	432.4	408.3	367.5	864.7	816.7	735.0	10.6	10.0	9.0	21.2	20.0	18.0	45.0	42.5	38.3	103.2	97.5	87.8	206.5	195.0	175.5	432.4	408.3	367.5
	9	9	1	256-QAM	5/6	N/A	N/A	180.0	200.0	390.0	433.3	780.0	866.7	114.7	108.3	97.5	229.4	216.7	195.0	480.4	453.7	408.3	960.8	907.4	816.7	11.8	11.1	10.0	23.5	22.2	20.0	50.0	47.2	42.5	114.7	108.3	97.5	229.4	216.7	195.0	480.4	453.7	408.3
		10	1	1024-QAM	3/4									129.0	121.9	109.7	258.1	243.8	219.4	540.4	510.4	459.4	1080.9	1020.8	918.8	13.2	12.5	11.3	26.5	25.0	22.5	56.3	53.1	47.8	129.0	121.9	109.7	258.1	243.8	219.4	540.4	510.4	459.4
		11	1	1024-QAM	5/6									143.4	135.4	121.9	286.8	270.8	243.8	600.5	567.1	510.4	1201.0	1134.3	1020.8	14.7	13.9	12.5	29.4	27.8	25.0	62.5	59.0	53.1	143.4	135.4	121.9	286.8	270.8	243.8	600.5	567.1	510.4
8	0	0	2	BPSQ	1/2	13.0	14.4	27.0	30.0	58.5	65.0	117.0	130.0	17.2	16.3	14.6	34.4	32.5	29.3	72.1	68.1	61.3	144.1	136.1	122.5	1.8	1.7	1.5	3.5	3.3	3.0	7.5	7.1	6.4	17.2	16.3	14.6	34.4	32.5	29.3	72.1	68.1	61.3
9	1	1	2	QPSK	1/2	26.0	28.9	54.0	60.0	117.0	130.0	234.0	260.0	34.4	32.5	29.3	68.8	65.0	58.5	144.1	136.1	122.5	288.2	272.2	245.0	3.5	3.3	3.0	7.1	6.7	6.0	15.0	14.2	12.8	34.4	32.5	29.3	68.8	65.0	58.5	144.1	136.1	122.5
10	2	2	2	QPSK	3/4	39.0	43.3	81.0	90.0	175.5	195.0	351.0	390.0	51.6	48.8	43.9	103.2	97.5	87.8	216.2	204.2	183.8	432.4	408.3	367.5	5.3	5.0	4.5	10.6	10.0	9.0	22.5	21.3	19.1	51.6	48.8	43.9	103.2	97.5	87.8	216.2	204.2	183.8
11	3	3	2	16-QAM	1/2	52.0	57.8	108.0	120.0	234.0	260.0	468.0	520.0	68.8	65.0	58.5	137.6	130.0	117.0	288.2	272.2	245.0	576.5	544.4	490.0	7.1	6.7	6.0	14.1	13.3	12.0	30.0	28.3	25.5	68.8	65.0	58.5	137.6	130.0	117.0	288.2	272.2	245.0
12	4	4	2	16-QAM	3/4	78.0	86.7	162.0	180.0	351.0	390.0	702.0	780.0	103.2	97.5	87.8	206.5	195.0	175.5	432.4	408.3	367.5	864.7	816.7	735.0	10.6	10.0	9.0	21.2	20.0	18.0	45.0	42.5	38.3	103.2	97.5	87.8	206.5	195.0	175.5	432.4	408.3	367.5
13	5	5	2	64-QAM	2/3	104.0	115.6	216.0	240.0	468.0	520.0	936.0	1040.0	137.6	130.0	117.0	275.3	260.0	234.0	576.5	544.4	490.0	1152.9	1088.9	980.0	14.1	13.3	12.0	28.2	26.7	24.0	60.0	56.7	51.0	137.6	130.0	117.0	275.3	260.0	234.0	576.5	544.4	490.0
14	6	6	2	64-QAM	3/4	117.0	130.0	243.0	270.0	526.5	585.0	1053.0	1170.0	154.9	146.3	131.6	309.7	292.5	263.3	648.5	612.5	551.3	1297.1	1225.0	1102.5	15.9	15.0	13.5	31.8	30.0	27.0	67.5	63.8	57.4	154.9	146.3	131.6	309.7	292.5	263.3	648.5	612.5	551.3
15	7	7	2	64-QAM	5/6	130.0	144.4	270.0	300.0	585.0	650.0	1170.0	1300.0	172.1	162.5	146.3	344.1	325.0	292.5	720.6	680.6	612.5	1441.2	1361.1	1225.0	17.6	16.7	15.0	35.3	33.3	30.0	75.0	70.8	63.8	172.1	162.5	146.3	344.1	325.0	292.5	720.6	680.6	612.5
	8	8	2	256-QAM	3/4	156.0	173.3	324.0	360.0	702.0	780.0	1404.0	1560.0	206.5	195.0	175.5	412.9	390.0	351.0	864.7	816.7	735.0	1729.4	1633.3	1470.0	21.2	20.0	18.0	42.4	40.0	36.0	90.0	85.0	76.5	206.5	195.0	175.5	412.9	390.0	351.0	864.7	816.7	735.0
	9	9	2	256-QAM	5/6	N/A	N/A	360.0	400.0	780.0	866.7	1560.0	1733.3	229.4	216.7	195.0	458.8	433.3	390.0	960.8	907.4	816.7	1921.6	1814.8	1633.3	23.5	22.2	20.0	47.1	44.4	40.0	100.0	94.4	85.0	229.4	216.7	195.0	458.8	433.3	390.0	960.8	907.4	816.7
		10	2	1024-QAM	3/4									258.1	243.8	219.4	516.2	487.5	438.8	1080.9	1020.8	918.8	2161.8	2041.7	1837.5	26.5	25.0	22.5	52.9	50.0	45.0	112.5	106.3	95.6	258.1	243.8	219.4	516.2	487.5	438.8	1080.9	1020.8	918.8
		11	2	1024-QAM	5/6									286.8	270.8	243.8	573.5	541.7	487.5	1201.0	1134.3	1020.8	2402.0	2268.5	2041.7	29.4	27.8	25.0	58.8	55.6	50.0	125.0	118.1	106.3	286.8	270.8	243.8	573.5	541.7	487.5	1201.0	1134.3	1020.8
16	0	0	3	BPSQ	1/2	19.5	21.7	40.5	45.0	87.8	97.5	175.5	195.0	25.8	24.4	21.9	51.6	48.8	43.9	108.1	102.1	91.9	216.2	204.2	183.8	2.6	2.5	2.3	5.3	5.0	4.5	11.3	10.6	9.6	25.8	24.4	21.9	51.6	48.8	43.9	108.1	102.1	91.9
17	1	1	3	QPSK	1/2	39.0	43.3	81.0	90.0	175.5	195.0	351.0	390.0	51.6	48.8	43.9	103.2	97.5	87.8	216.2	204.2	183.8	432.4	408.3	367.5	5.3	5.0	4.5	10.6	10.0	9.0	22.5	21.3	19.1	51.6	48.8	43.9	103.2	97.5	87.8	216.2	204.2	183.8
18	2	2	3	QPSK	3/4	58.5	65.0	121.5	135.0	263.3	292.5	526.5	585.0	77.4	73.1	65.8	154.9	146.3	131.6	324.3	306.3	275.6	648.5	612.5	551.3	7.9	7.5	6.8	15.9	15.0	13.5	33.8	31.9	28.7	77.4	73.1	65.8	154.9	146.3	131.6	324.3	306.3	275.6
19	3	3	3	16-QAM	1/2	78.0	86.7	162.0	180.0	351.0	390.0	702.0	780.0	103.2	97.5	87.8	206.5	195.0	175.5	432.4	408.3	367.5	864.7	816.7	735.0	10.6	10.0	9.0	21.2	20.0	18.0	45.0	42.5	38.3	103.2	97.5	87.8	206.5	195.0	175.5	432.4	408.3	367.5
20	4	4	3	16-QAM	3/4	117.0	130.0	243.0	270.0	526.5	585.0	1053.0	1170.0	154.9	146.3	131.6	309.7	292.5	263.3	648.5	612.5	551.3	1297.1	1225.0	1102.5	15.9	15.0	13.5	31.8	30.0	27.0	67.5	63.8	57.4	154.9	146.3	131.6	309.7	292.5	263.3	648.5	612.5	551.3
21	5	5	3	64-QAM	2/3	156.0	173.3	324.0	360.0	702.0	780.0	1404.0	1560.0	206.5	195.0	175.5	412.9	390.0	351.0	864.7	816.7	735.0	1729.4	1633.3	1470.0	21.2	20.0	18.0	42.4	40.0	36.0	90.0	85.0	76.5	206.5	195.0	175.5	412.9	390.0	351.0	864.7	816.7	735.0
22	6	6	3	64-QAM	3/4	175.5	195.0	364.5	405.0	N/A	N/A	1579.5	1755.0	232.3	219.4	197.4	464.6	438.8	394.9	972.8	918.8	826.9	1945.6	1837.5	1653.8	23.8	22.5	20.3	47.6	45.0	40.5	101.3	95.6	86.1	232.3	219.4	197.4	464.6	438.8	394.9	972.8	918.8	826.9
23	7	7	3	64-QAM	5/6	195.0	216.7	405.0	450.0	877.5	975.0	1755.0	1950.0	258.1	243.8	219.4	516.2	487.5	438.8	1080.9	1020.8	918.8	2161.8	2041.7	1837.5	26.5	25.0	22.5	52.9	50.0	45.0	112.5	106.3	95.6	258.1	243.8	219.4	516.2	487.5	438.8	1080.9	1020.8	918.8
	8	8	3	256-QAM	3/4	234.0	260.0	486.0	540.0	1053.0	1170.0	2106.0	2340.0	309.7	292.5	263.3	619.4	585.0	526.5	1297.1	1225.0	1102.5	2594.1	2450.0	2205.0	31.8	30.0	27.0	63.5	60.0	54.0	135.0	127.5	114.8	309.7	292.5	263.3	619.4	585.0	526.5	1297.1	1225.0	1102.5
	9	9	3	256-QAM	5/6	260.0	288.9	540.0	600.0	1170.0	1300.0	N/A	N/A	344.1	325.0	292.5	688.2	650.0	585.0	1441.2	1361.1	1225.0	2882.4	2722.2	2450.0	35.3	33.3	30.0	70.6	66.7	60.0	150.0	141.7	127.5	344.1	325.0	292.5	688.2	650.0	585.0	1441.2	1361.1	1225.0
		10	3	1024-QAM	3/4									387.1	365.6	329.1	774.3	731.3	658.1	1621.3	1531.3	1378.1	3242.6	3062.5	2756.3	39.7	37.5	33.8	79.4	75.0	67.5	168.8	159.4	143.4	387.1	365.6	329.1	774.3	731.3	658.1	1621.3	1531.3	1378.1
		11	3	1024-QAM	5/6									430.1	406.3	365.6	860.3	812.5	731.3	1801.5	1701.4	1531.3	3602.9	3402.8	3062.5	44.1	41.7	37.5	88.2	83.3	75.0	187.5	177.1	159.4	430.1	406.3	365.6	860.3	812.5	731.3	1801.5	1701.4	1531.3
24	0	0	4	BPSQ	1/2	26.0	28.9	54.0	60.0	117.0	130.0	234.0	260.0	34.4	32.5	29.3	68.8	65.0	58.5	144.1	136.1	122.5	288.2	272.2	245.0	3.5	3.3	3.0	7.1	6.7	6.0	15.0	14.2	12.8	34.4	32.5	29.3	68.8	65.0	58.5	144.1	136.1	122.5
25	1	1	4	QPSK	1/2	52.0	57.8	108.0	120.0	234.0	260.0	468.0	520.0	68.8	65.0	58.5	137.6	130.0	117.0	288.2	272.2	245.0	576.5	544.4	490.0	7.1	6.7	6.0	14.1	13.3	12.0	30.0	28.3	25.5	68.8	65.0	58.5	137.6	130.0	117.0	288.2	272.2	245.0
26	2	2	4	QPSK	3/4	78.0	86.7	162.0	180.0	351.0	390.0	702.0	780.0	103.2	97.5	87.8	206.5	195.0	175.5	432.4	408.3	367.5	864.7	816.7	735.0	10.6	10.0	9.0	21.2	20.0	18.0	45.0	42.5	38.3	103.2	97.5	87.8	206.5	195.0	175.5	432.4	408.3	367.5
27	3	3	4	16-QAM	1/2	104.0	115.6	216.0	240.0	468.0	520.0	936.0	1040.0	137.6	130.0	117.0	275.3	260.0	234.0	576.5	544.4	490.0	1152.9	1088.9	980.0	14.1	13.3	12.0	28.2	26.7	24.0	60.0	56.7	51.0	137.6	130.0	117.0	275.3	260.0	234.0	576.5	544.4	490.0
28	4	4	4	16-QAM	3/4	156.0	173.3	324.0	360.0	702.0	780.0	1404.0	1560.0	206.5	195.0	175.5	412.9	390.0	351.0	864.7	816.7	735.0	1729.4	1633.3	1470.0	21.2	20.0	18.0	42.4	40.0	36.0	90.0	85.0	76.5	206.5	195.0	175.5	412.9	390.0	351.0	864.7	816.7	735.0
29	5	5	4	64-QAM	2/3	208.0	231.1	432.0	480.0	936.0	1040.0	1872.0	2080.0	275.3	260.0	234.0	550.6	520.0	468.0	1152.9	1088.9	980.0	2305.9	2177.8	1960.0	28.2	26.7	24.0	56.5	53.3	48.0	120.0	113.3	102.0	275.3	260.0	234.0	550.6	520.0	468.0	1152.9	1088.9	980.0
30	6	6	4	64-QAM	3/4	234.0	260.0	486.0	540.0	1053.0	1170.0	2106.0	2340.0	309.7	292.5	263.3	619.4	585.0	526.5	1297.1	1225.0	1102.5	2594.1	2450.0	2205.0	31.8	30.0	27.0	63.5	60.0	54.0	135.0	127.5	114.8	309.7	292.5	263.3	619.4	585.0	526.5	1297.1	1225.0	1102.5
31	7	7	4	64-QAM	5/6	260.0	288.9	540.0	600.0	1170.0	1300.0	2340.0	2600.0	344.1	325.0	292.5	688.2	650.0	585.0	1441.2	1361.1	1225.0	2882.4	2722.2	2450.0	35.3	33.3	30.0	70.6	66.7	60.0	150.0	141.7	127.5	344.1	325.0	292.5	688.2	650.0	585.0	1441.2	1361.1	1225.0
	8	8	4	256-QAM	3/4	312.0	346.7	648.0	720.0	1404.0	1560.0	2808.0	3120.0	412.9	390.0	351.0	825.9	780.0	702.0	1729.4	1633.3	1470.0	3458.8	3266.7	2940.0	42.4	40.0	36.0	84.7	80.0	72.0	180.0	170.0	153.0	412.9	390.0	351.0	825.9	780.0	702.0	1729.4	1633.3	1470.0
	9	9	4	256-QAM	5/6	N/A	N/A	720.0	800.0	1560.0	1733.3	3120.0	3466.7	458.8	433.3	390.0	917.6	866.7	780.0	1921.6	1814.8	1633.3	3843.1	3629.6	3266.7	47.1	44.4	40.0	94.1	88.9	80.0	200.0	188.9	170.0	458.8	433.3	390.0	917.6	866.7	780.0	1921.6	1814.8	1633.3
		10	4	1024-QAM	3/4									516.2	487.5	438.8	1032.4	975.0	877.5	2161.8	2041.7	1837.5	4323.5	4083.3	3675.0	52.9	50.0	45.0	105.9	100.0	90.0	225.0	212.5	191.3	516.2	487.5	438.8	1032.4	975.0	877.5	2161.8	2041.7	1837.5
		11	4	1024-QAM	5/6									573.5	541.7	487.5	1147.1	1083.3	975.0	2402.0	2268.5	2041.7	4803.9	4537.0	4083.3	58.8	55.6	50.0	117.6	111.1	100.0	250.0	236.1	212.5	573.5	541.7	487.5	1147.1	1083.3	975.0	2402.0	2268.5	2041.7
	0	0	5	BPSQ	1/2	32.5	36.1	67.5	75.0	146.3	162.5	292.5	325.0	43.0	40.6	36.6	86.0	81.3	73.1	180.1	170.1	153.1	360.3	340.3	306.3	4.4	4.2	3.8	8.8	8.3	7.5	18.8	17.7	15.9	43.0	40.6	36.6	86.0	81.3	73.1	180.1	170.1	153.1
	1	1	5	QPSK	1/2	65.0	72.2	135.0	150.0	292.5	325.0	585.0	650.0	86.0	81.3	73.1	172.1	162.5	146.3	360.3	340.3	306.3	720.6	680.6	612.5	8.8	8.3	7.5	17.6	16.7	15.0	37.5	35.4	31.9	86.0	81.3	73.1	172.1	162.5	146.3	360.3	340.3	306.3
	2	2	5	QPSK	3/4	97.5	108.3	202.5	225.0	438.8	487.5	877.5	975.0	129.0	121.9	109.7	258.1	243.8	219.4	540.4	510.4	459.4	1080.9	1020.8	918.8	13.2	12.5	11.3	26.5	25.0	22.5	56.3	53.1	47.8	129.0	121.9	109.7	258.1	243.8	219.4	540.4	510.4	459.4
	3	3	5	16-QAM	1/2	130.0	144.4	270.0	300.0	585.0	650.0	1170.0	1300.0	172.1	162.5	146.3	344.1	325.0	292.5	720.6	680.6	612.5	1441.2	1361.1	1225.0	17.6	16.7	15.0	35.3	33.3	30.0	75.0	70.8	63.8	172.1	162.5	146.3	344.1	325.0	292.5	720.6	680.6	612.5
	4	4	5	16-QAM	3/4	195.0	216.7	405.0	450.0	877.5	975.0	1755.0	1950.0	258.1	243.8	219.4	516.2	487.5	438.8	1080.9	1020.8	918.8	2161.8	2041.7	1837.5	26.5	25.0	22.5	52.9	50.0	45.0	112.5	106.3	95.6	258.1	243.8	219.4	516.2	487.5	438.8	1080.9	1020.8	918.8
	5	5	5	64-QAM	2/3	260.0	288.9	540.0	600.0	1170.0	1300.0	2340.0	2600.0	344.1	325.0	292.5	688.2	650.0	585.0	1441.2	1361.1	1225.0	2882.4	2722.2	2450.0	35.3	33.3	30.0	70.6	66.7	60.0	150.0	141.7	127.5	344.1	325.0	292.5	688.2	650.0	585.0	1441.2	1361.1	1225.0
	6	6	5	64-QAM	3/4	292.5	325.0	607.5	675.0	1316.3	1462.5	2632.5	2925.0	387.1	365.6	329.1	774.3	731.3	658.1	1621.3	1531.3	1378.1	3242.6	3062.5	2756.3	39.7	37.5	33.8	79.4	75.0	67.5	168.8	159.4	143.4	387.1	365.6	329.1	774.3	731.3	658.1	1621.3	1531.3	1378.1
	7	7	5	64-QAM	5/6	325.0	361.1	675.0	750.0	1462.5	1625.0	2925.0	3250.0	430.1	406.3	365.6	860.3	812.5	731.3	1801.5	1701.4	1531.3	3602.9	3402.8	3062.5	44.1	41.7	37.5	88.2	83.3	75.0	187.5	177.1	159.4	430.1	406.3	365.6	860.3	812.5	731.3	1801.5	1701.4	1531.3
	8	8	5	256-QAM	3/4	390.0	433.3	810.0	900.0	1755.0	1950.0	3510.0	3900.0	516.2	487.5	438.8	1032.4	975.0	877.5	2161.8	2041.7	1837.5	4323.5	4083.3	3675.0	52.9	50.0	45.0	105.9	100.0	90.0	225.0	212.5	191.3	516.2	487.5	438.8	1032.4	975.0	877.5	2161.8	2041.7	1837.5
	9	9	5	256-QAM	5/6	N/A	N/A	900.0	1000.0	1950.0	2166.7	3900.0	4333.3	573.5	541.7	487.5	1147.1	1083.3	975.0	2402.0	2268.5	2041.7	4803.9	4537.0	4083.3	58.8	55.6	50.0	117.6	111.1	100.0	250.0	236.1	212.5	573.5	541.7	487.5	1147.1	1083.3	975.0	2402.0	2268.5	2041.7
		10	5	1024-QAM	3/4									645.2	609.4	548.4	1290.4	1218.8	1096.9	2702.2	2552.1	2296.9	5404.4	5104.2	4593.8	66.2	62.5	56.3	132.4	125.0	112.5	281.3	265.6	239.1	645.2	609.4	548.4	1290.4	1218.8	1096.9	2702.2	2552.1	2296.9
		11	5	1024-QAM	5/6									716.9	677.1	609.4	1433.8	1354.2	1218.8	3002.5	2835.6	2552.1	6004.9	5671.3	5104.2	73.5	69.4	62.5	147.1	138.9	125.0	312.5	295.1	265.6	716.9	677.1	609.4	1433.8	1354.2	1218.8	3002.5	2835.6	2552.1
	0	0	6	BPSQ	1/2	39.0	43.3	81.0	90.0	175.5	195.0	351.0	390.0	51.6	48.8	43.9	103.2	97.5	87.8	216.2	204.2	183.8	432.4	408.3	367.5	5.3	5.0	4.5	10.6	10.0	9.0	22.5	21.3	19.1	51.6	48.8	43.9	103.2	97.5	87.8	216.2	204.2	183.8
	1	1	6	QPSK	1/2	78.0	86.7	162.0	180.0	351.0	390.0	702.0	780.0	103.2	97.5	87.8	206.5	195.0	175.5	432.4	408.3	367.5	864.7	816.7	735.0	10.6	10.0	9.0	21.2	20.0	18.0	45.0	42.5	38.3	103.2	97.5	87.8	206.5	195.0	175.5	432.4	408.3	367.5

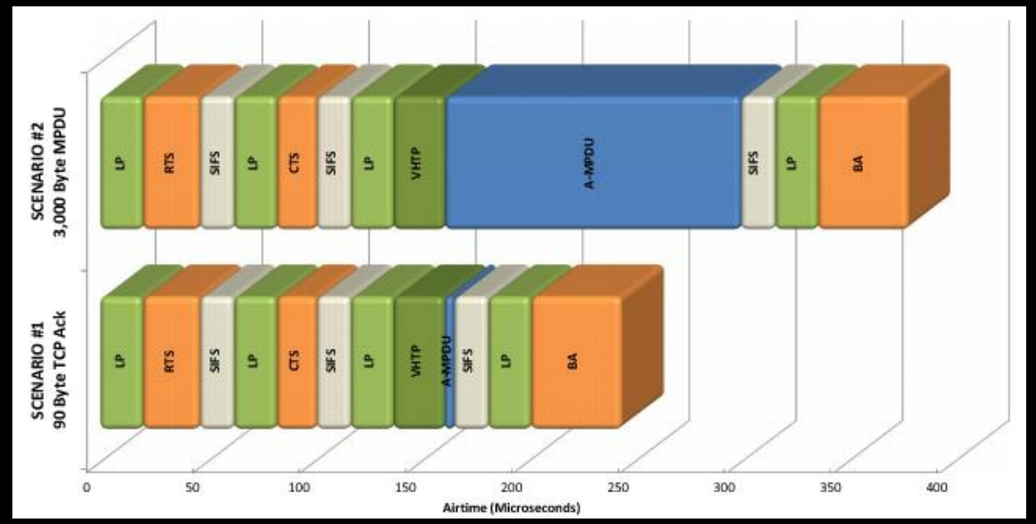
802.11 Upgrade Cycles

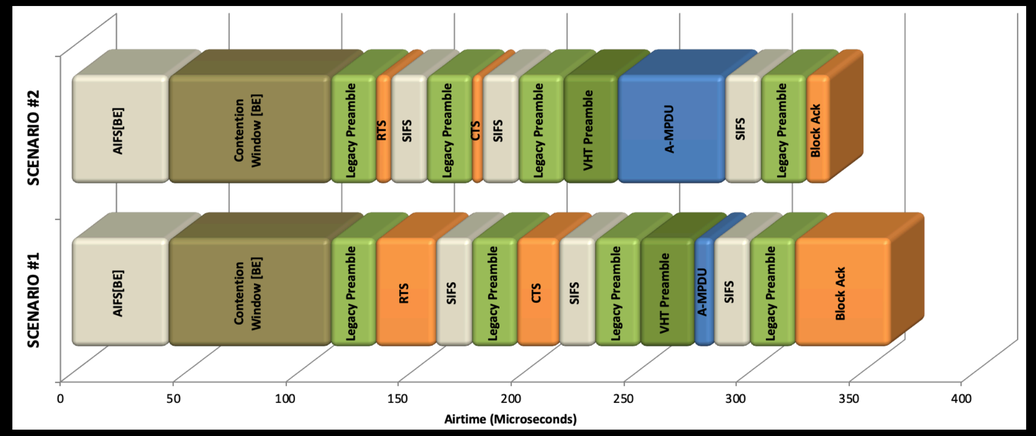
Year	Years	IEEE Name	WFA Name	# MCS	Max Speed	SS	Frequencies	Max CH BW	# Ch	Total BW
1997		802.11		2	2Mb	1	2.4GHz	22MHz	3	80MHz
1999	2	802.11 a		11	54Mb	1	5GHz	20MHz	9	180MHz
1999	0	802.11 b		4	11Mb	1	2.4GHz	22Mhz	3	80MHz
2003	4	802.11 g		11	54Mb	1	2.4GHz	20MHz	21	80MHz
2009	6	802.11 n	Wi-Fi 4	77	600Mb	4	2.4GHz & 5GHz	20MHz, 40MHz	28	580MHz
2013	4	802.11 ac	Wi-Fi 5	624	1.73Gb	8	5GHz	80MHz	25	500MHz
2019	6	802.11 ax	Wi-Fi 6	1728	9.6Gb	8	2.4GHz & 5GHz	20MHz/160MHz	28	580MHz
2021	2	802.11 ax	Wi-Fi 6E	1728	9.6Gb	8	2.4GHz, 5GHz, 6GHz	20MHz/160MHz	87	1780MHz
2023	2	802.11 be	Wi-Fi 7	4032	46Gb	16	2.4GHz, 5GHz, 6GHz	20MHz/320MHz	87	1840MHz

Modulation & Coding Schemes…



Sample Single Frame Transmission





- AIFS - Arbitration Inter-frame Space
- Contention Window (*CW*)
- Preamble - *BPSK*
- RTS - *MBR*
- SIFS - *Fixed Tme*
- Preamble - *BPSK*
- CTS - *MBR*
- SIFS - *Fixed Tme*
- Preamble - *BPSK*
- Preamble - *VHT*
- Header - *MBR*
- ***Payload - PHY Rate***
- CRC
- SIFS - *Fixed Tme*
- Preamble - *BPSK*
- ACK - *MBR*

Marketing vs Reality

Who can you believe?

Wi-Fi 4

IEEE 802.11n

Bands

2.4GHz, 5GHz

Channel Bandwidths

20, 40MHz

64QAM

Key Advances

- WPA2 Security
- 4x4 MIMO
- LDPC Error Correction

Wi-Fi 5

IEEE 802.11ac

Bands

5GHz

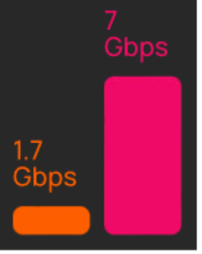
Channel Bandwidths

20, 40, 80, 160MHz

256QAM

Key Advances

- Up to 8x8 MIMO
- DL MU-MIMO
- Beamforming



Wi-Fi 6 / 6E

IEEE 802.11ax

Bands

2.4GHz, 5GHz, 6GHz (6E)

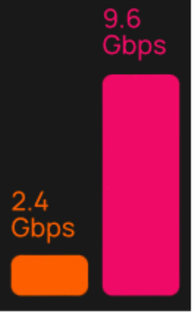
Channel Bandwidths

20, 40, 80, 160MHz

1024QAM

Key Advances

- Best-in-class WPA3 Security
- UL & DL MU-MIMO, OFDMA
- Target wait time (TWT)



Wi-Fi 7

IEEE 802.11be

Bands

2.4GHz, 5GHz, 6GHz

Channel Bandwidths

20, 40, 80, 160, 320MHz

4096QAM

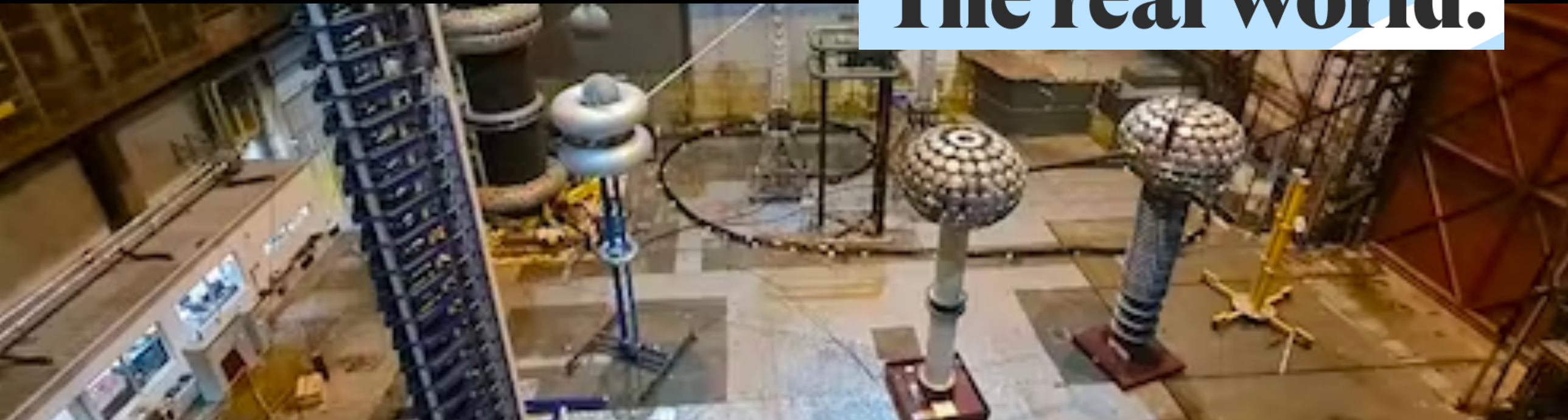
Key Advances

- Multi-link operation (MLO)
- Multi-RU & puncturing
- Managed QoS & Restricted Service Periods

Do marketing features work?

Real-World Testing?

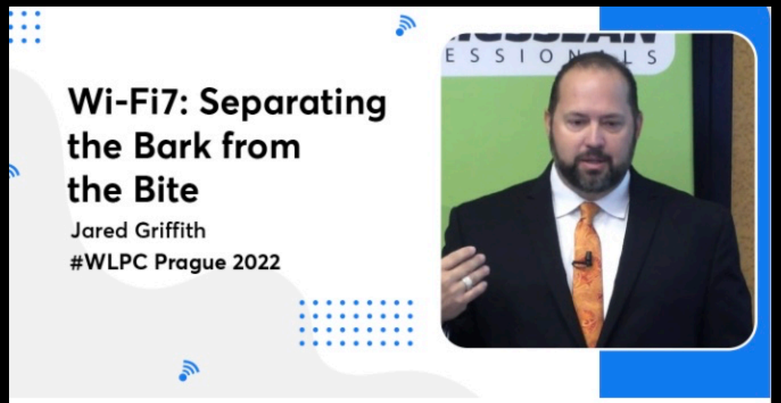
Real people.
Real devices.
The real world.



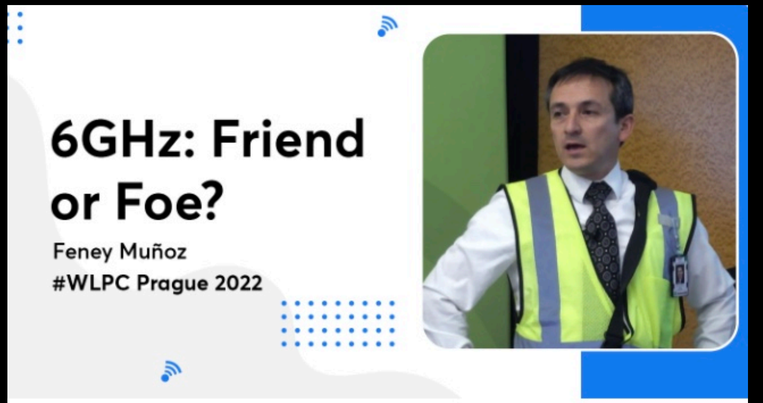
Where to go for details

#WLPC Videos

WI-FI 6E, WI-FI 7 AND BEYOND – ALL ABOUT THE SPECTRUM | DAVID COLEMAN | WLPC PRAGUE 2022



WI-FI7: SEPARATING THE BARK FROM THE BITE | JARED GRIFFITH | WLPC PRAGUE 2022



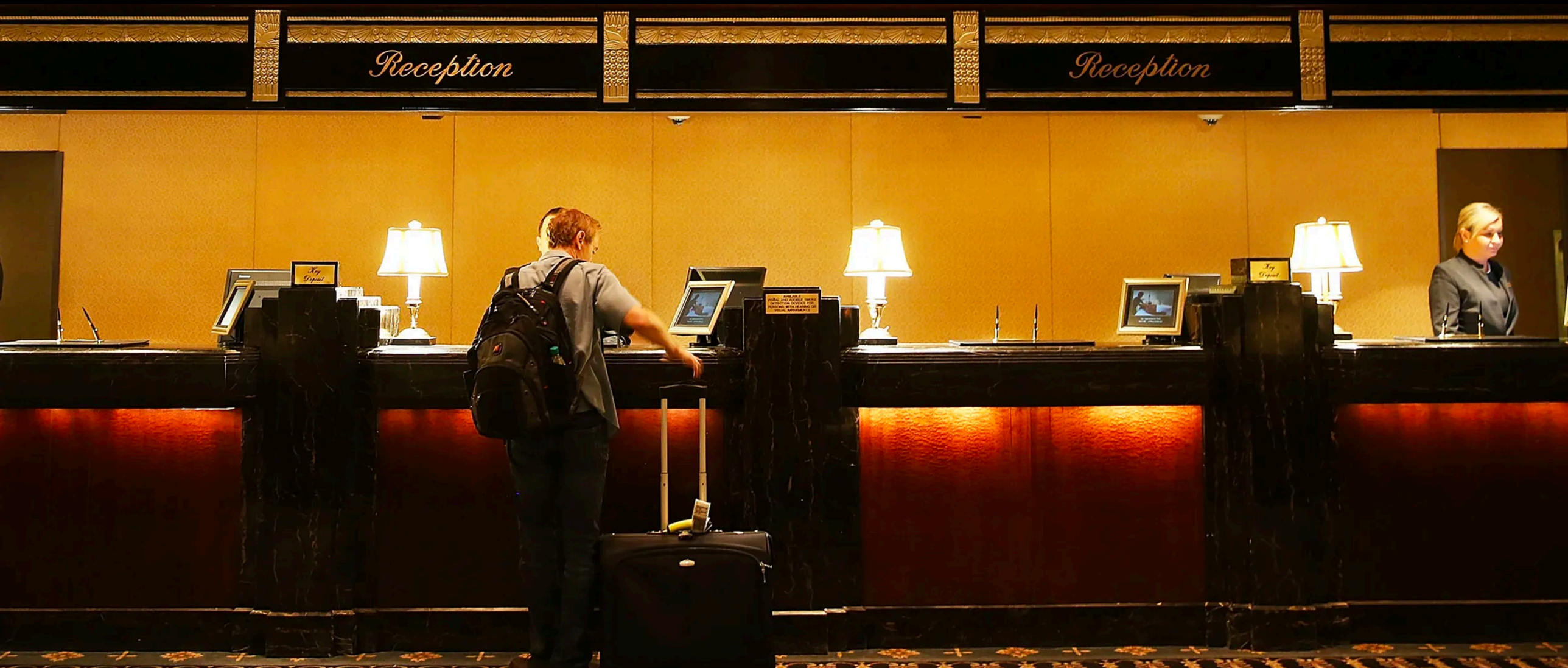
6GHZ: FRIEND OR FOE? | FENEY MUÑOZ | WLPC PRAGUE 2022

One of These Things is NOT Like the Others

Wi-Fi, CBRS/Private LTE, HaLOW, LoRaWAN, Carrier Cellular

Do You Need to Upgrade

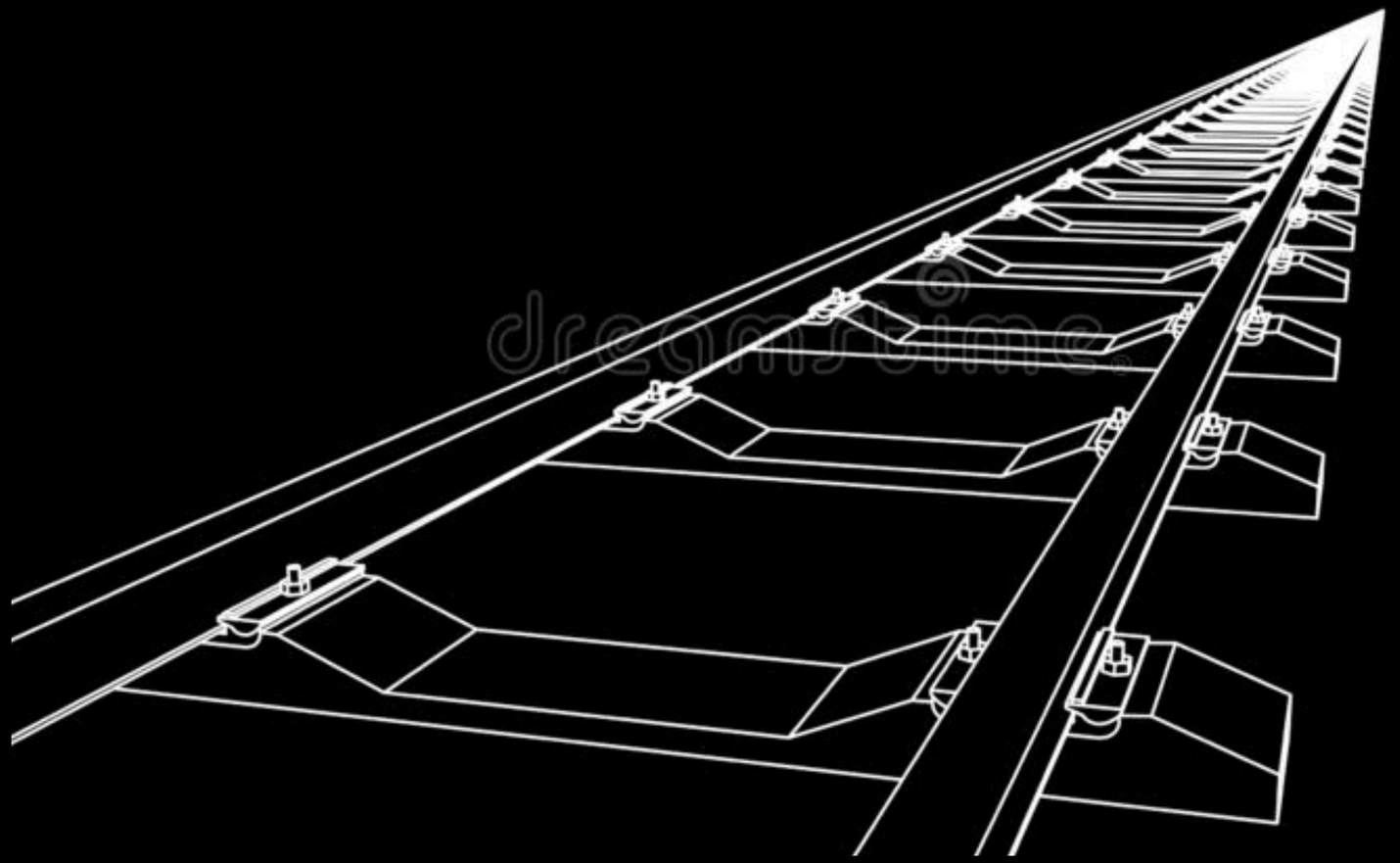
How is your Wi-Fi working today?



Moving Forward

What You Need To Know

- Backward Compatible?
- Multi-User - Up/Down
- Multi-Gig Needed?
- Network designed 40+dB SNR?
- PoE 802.3af not enough
- Wi-Fi Security - two levels?
- Eduroam Questions abound!



Bonus!

It is all about the clients…

Questions?

Contact Me

wirelessLAN
PROFESSIONALS

How to Present to a Technical Audience

Rules to follow… and rules to break!