



802.11ah

Wi-Fi HaLow™ – Low Power Wide-Area
Networking

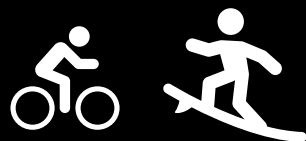
@troymart

Troy Martin  P.Eng., CWNE, CWISE, GAWN, CISSP, CCIE

Like things wireless...



Enjoy cycling &
snowboarding...



LinkedIn



@troymart



Video Surveillance



Wi-Fi CERTIFIED HaLow™ for IoT

Features

 Sub-1 GHz spectrum operation


 Narrow band OFDM channels

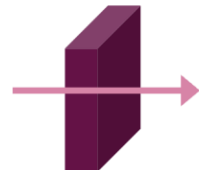
 Several device power saving modes


 Native IP support

 Latest Wi-Fi® security

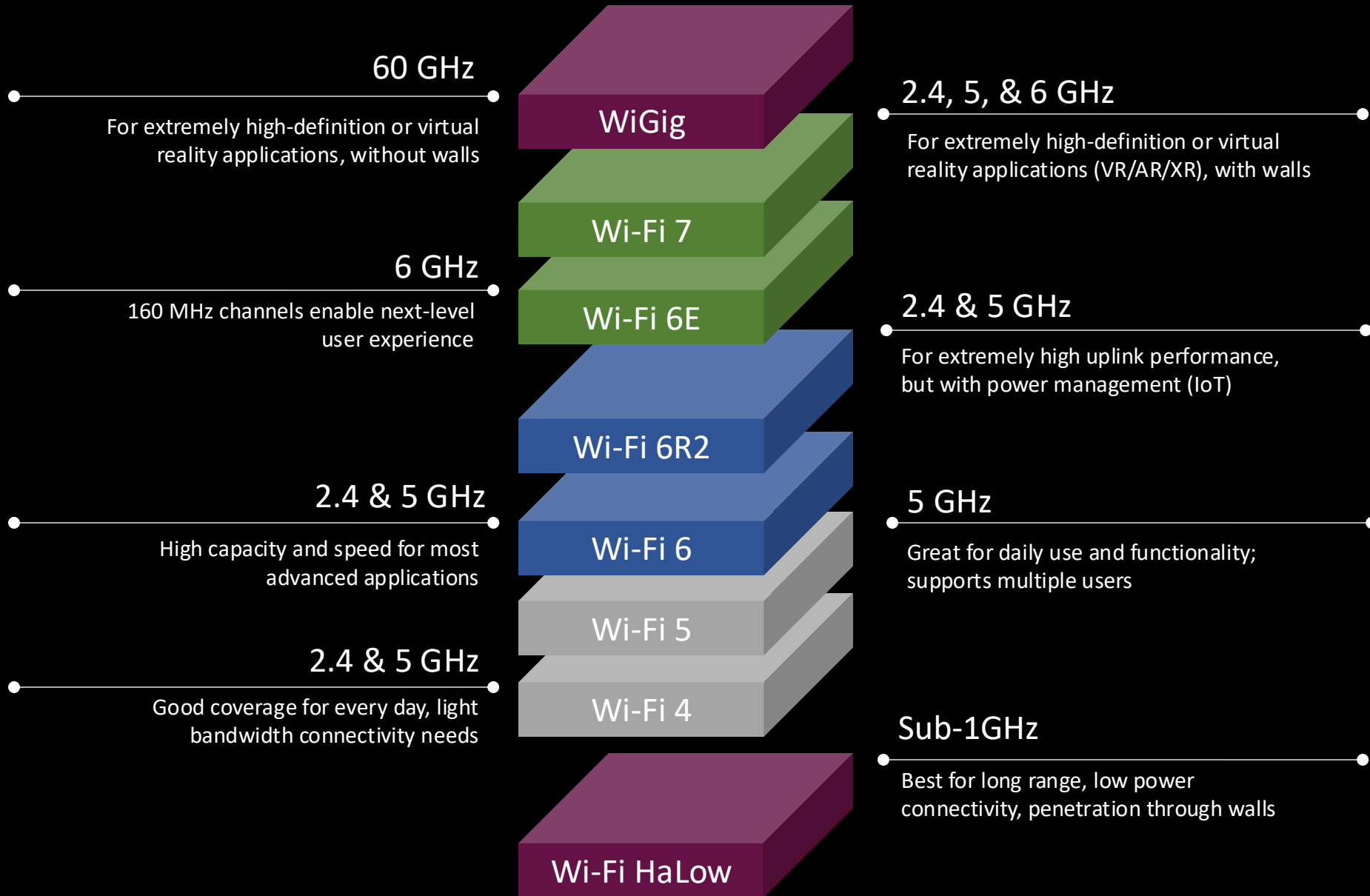
Benefits

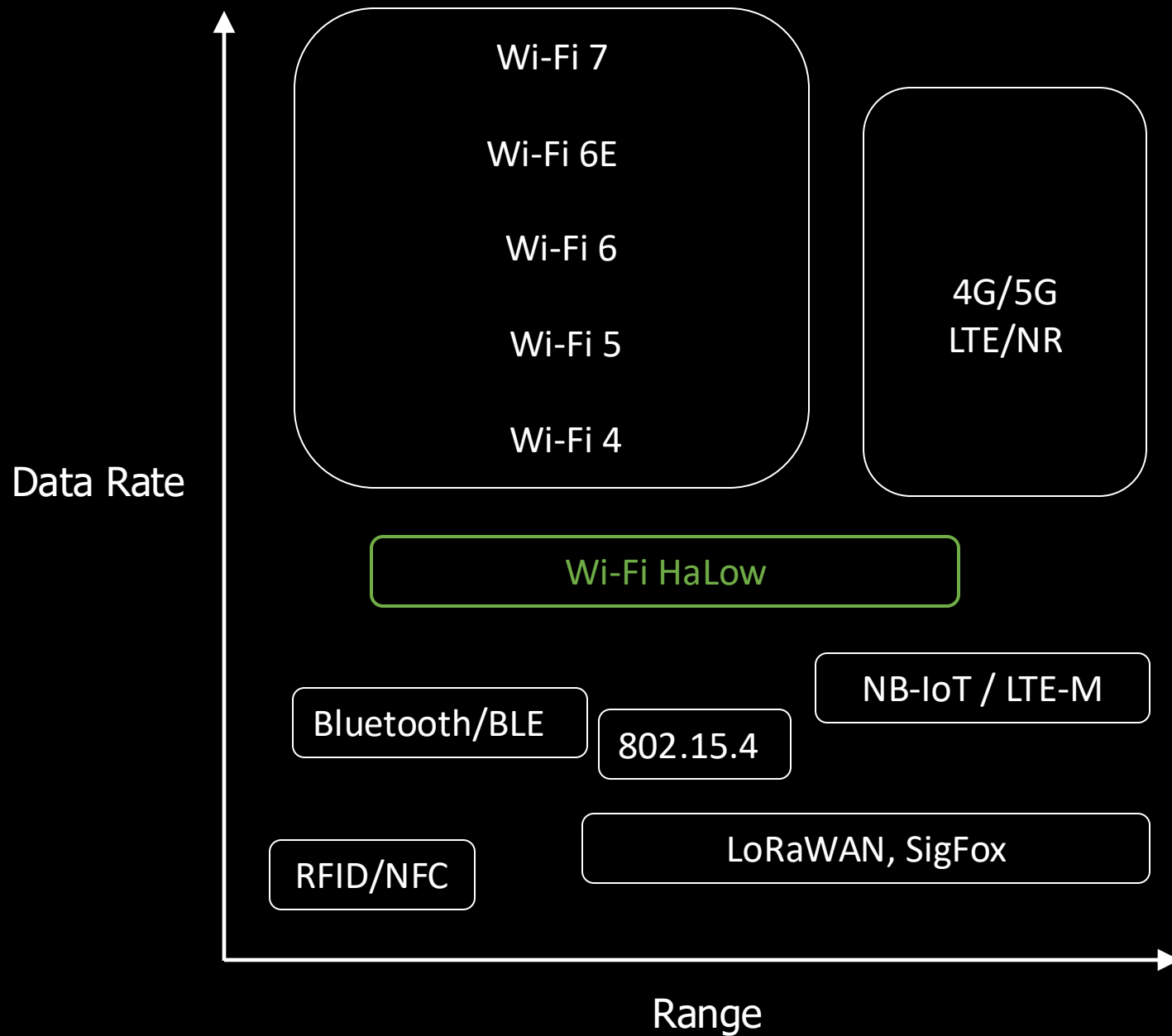
 Long range: approximately 1 km

 Penetration through walls and other obstacles

 Supports coin cell battery devices for months or years

 No need for proprietary hubs or gateways



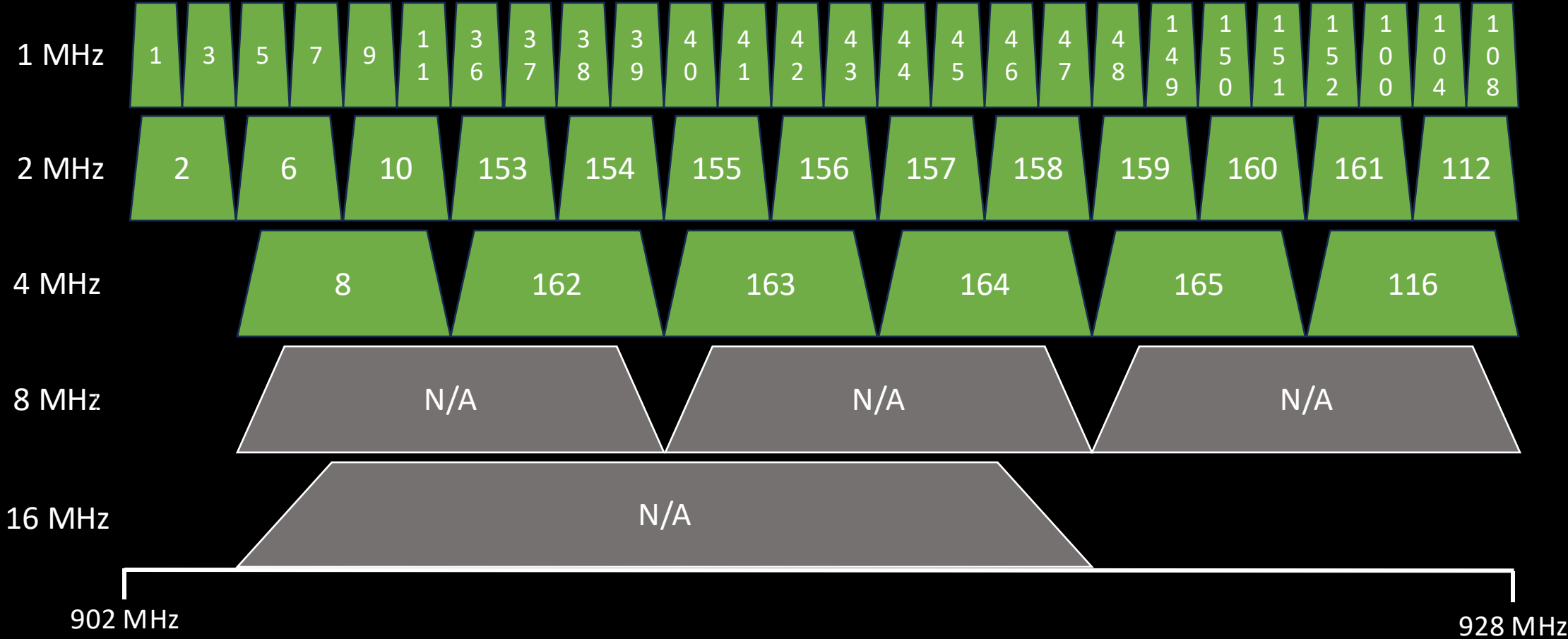


Wi-Fi CERTIFIED HaLow™ for IoT



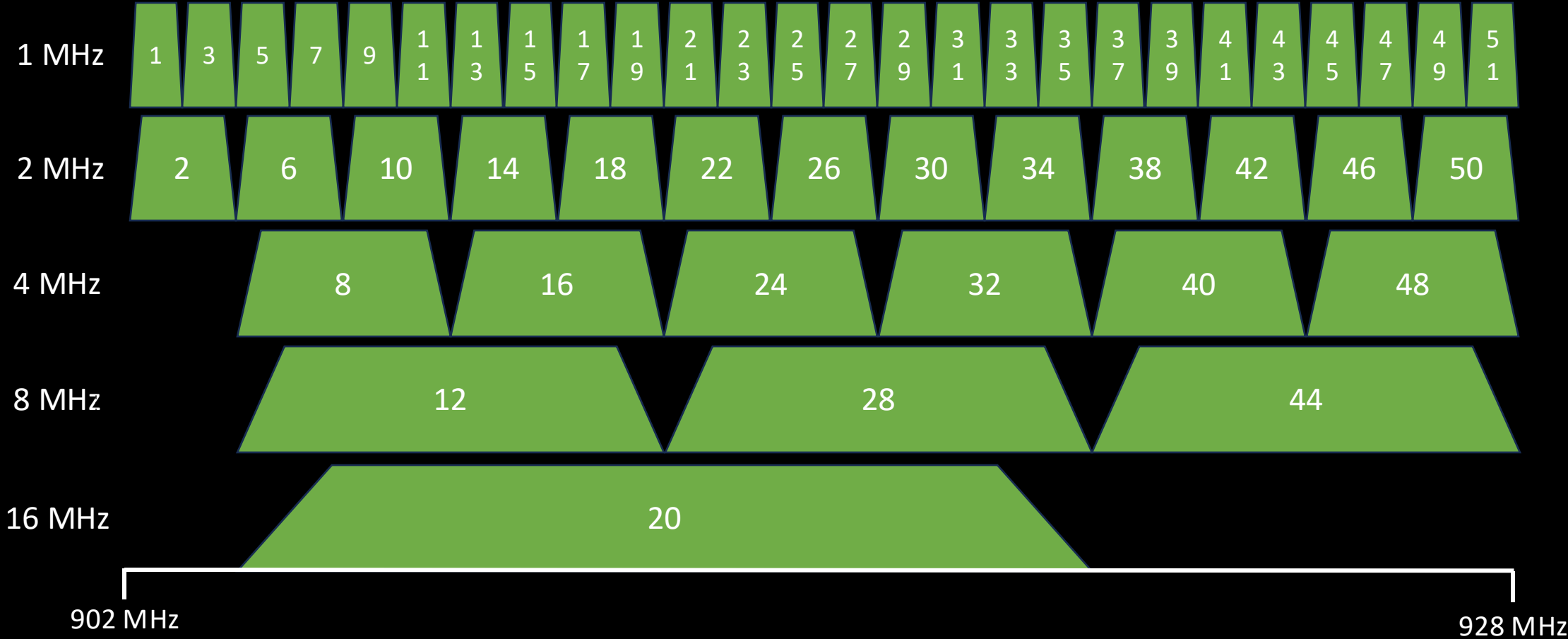
Function	Wi-Fi 5 (IEEE 802.11ac)	Wi-Fi HaLow (IEEE 802.11ah)
Operating frequency band	2.4, 5, and 6 GHz (Wi-Fi 7)	Sub-1 GHz (915 MHz US, 868 MHz EU)
Channel Width	20/40/80/160 MHz	1/2/4/8/16 MHz
Max addressable stations per AP	2007	8191
Single Stream (1SS) MCS data-rate	6.5 to 866.7 Mb/s (802.11ac, Wi-Fi 5) 6.5 to 150 Mb/s (802.11n, Wi-Fi 4)	150 kb/s to 86.7 Mb/s
“Typical” Range	~ 100 m (328 ft)	~1 Km (0.62 mi)
Link Budget	REF	Upwards of 24dB improvement
MCS Index	0-9	0-9 & 10
Subcarrier Width	312.5 kHz	31.2 kHz
Symbol Time	3.2 μs (3.6 or 4.0 μs with SGI/GI)	32 μs (36 or 40.0 μs with SGI/GI)
Spatial Streams	1-8	1-4
Modulation Types	BPSK, QPSK, 16-QAM, 256-QAM	

802.11ah Channels in the US*



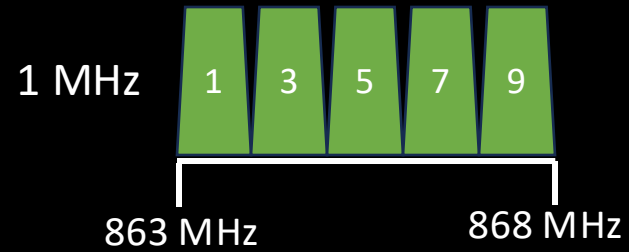
*Index values found in HaLow hardware configuration

802.11ah Channels in the US*



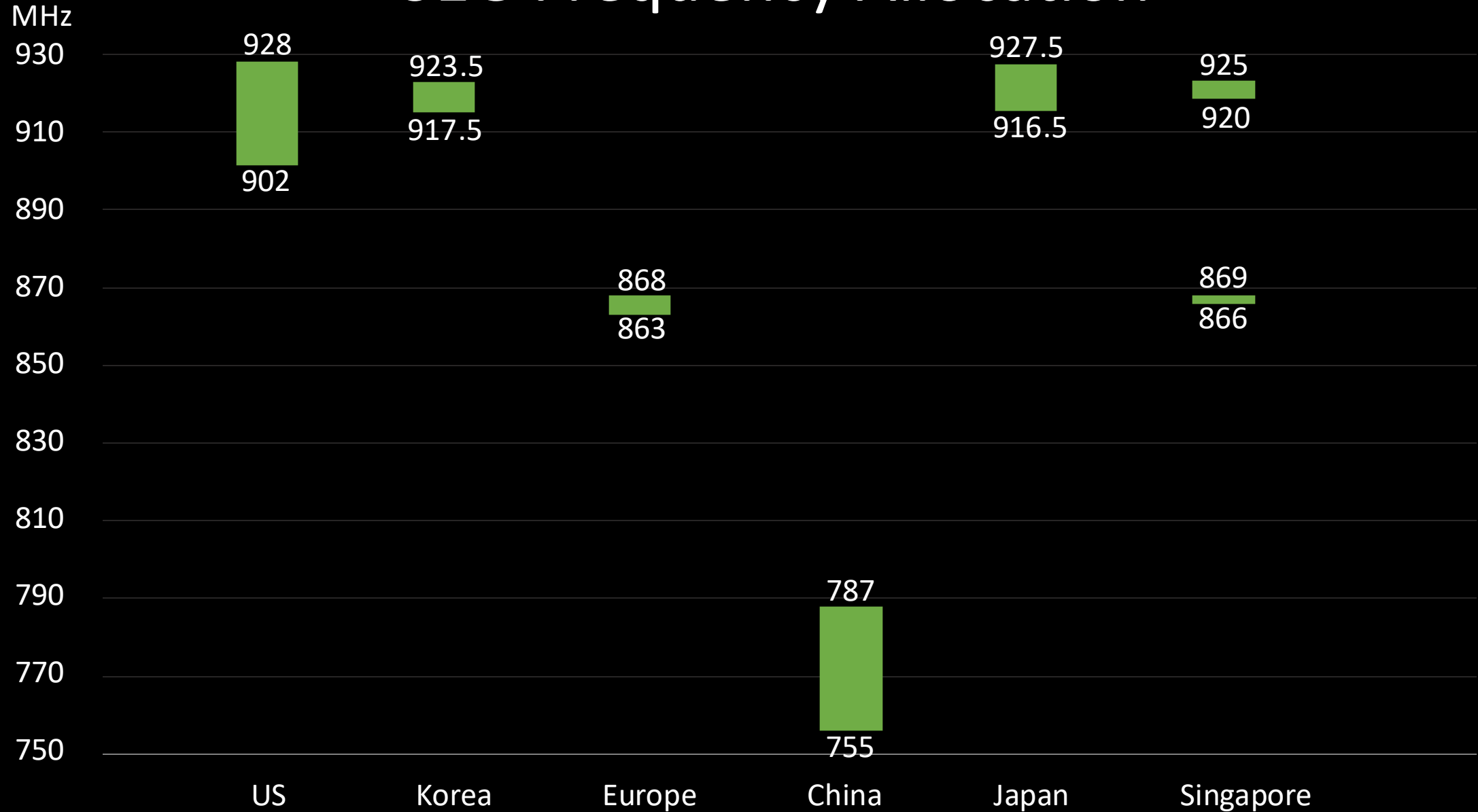
*Index values found in IEEE 802.11ah-2016

802.11ah Channels in the EU*



*Index values found in HaLow hardware configuration

S1G Frequency Allocation



UNITED STATES FREQUENCY ALLOCATIONS

THE RADIO SPECTRUM

RADIO SERVICES COLOR LEGEND

- | | | |
|-------------------------------|---------------------------|--|
| AERONAUTICAL MOBILE | INTER-SATELLITE | RADIO ASTRONOMY |
| AERONAUTICAL MOBILE SATELLITE | LAND MOBILE | RADIODETERMINATION SATELLITE |
| AERONAUTICAL RADIONAVIGATION | LAND MOBILE SATELLITE | RADIOLOCATION |
| AMATEUR | MARITIME MOBILE | RADIOLOCATION SATELLITE |
| AMATEUR SATELLITE | MARITIME MOBILE SATELLITE | RADIONAVIGATION |
| BROADCASTING | MARITIME RADIONAVIGATION | RADIONAVIGATION SATELLITE |
| BROADCASTING SATELLITE | METEOROLOGICAL | SPACE OPERATION |
| EARTH EXPLORATION SATELLITE | METEOROLOGICAL SATELLITE | SPACE RESEARCH |
| FIXED | MOBILE | STANDARD FREQUENCY AND TIME SIGNAL |
| FIXED SATELLITE | MOBILE SATELLITE | STANDARD FREQUENCY AND TIME SIGNAL SATELLITE |

ACTIVITY CODE

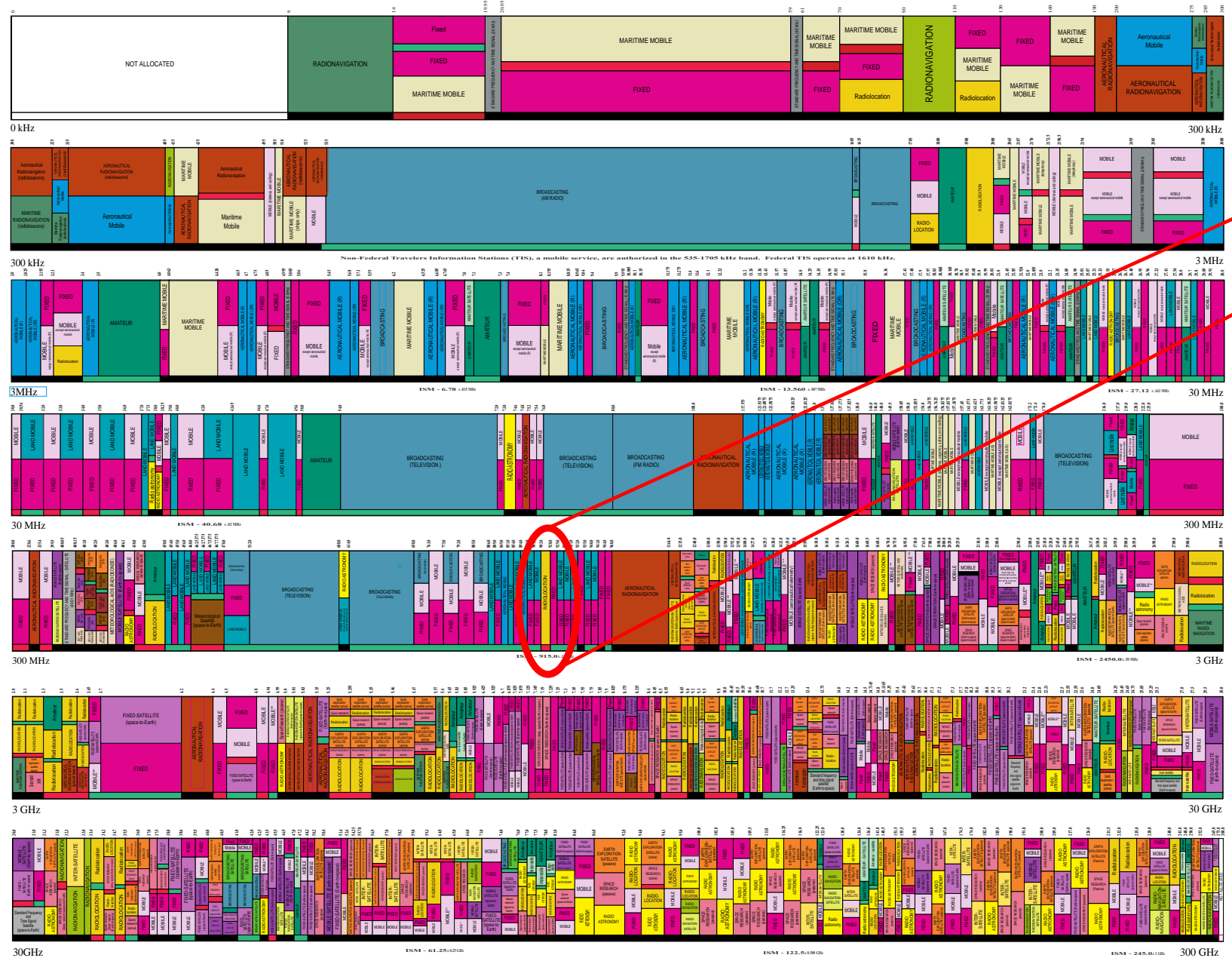
- FEDERAL EXCLUSIVE
- FEDERAL/NON-FEDERAL SHARED
- NON-FEDERAL EXCLUSIVE

ALLOCATION USAGE DESIGNATION

SERVICE	EXAMPLE	DESCRIPTION
Primary	FIXED	Capital Letters
Secondary	MOBILE	1st Capital with lower case letters

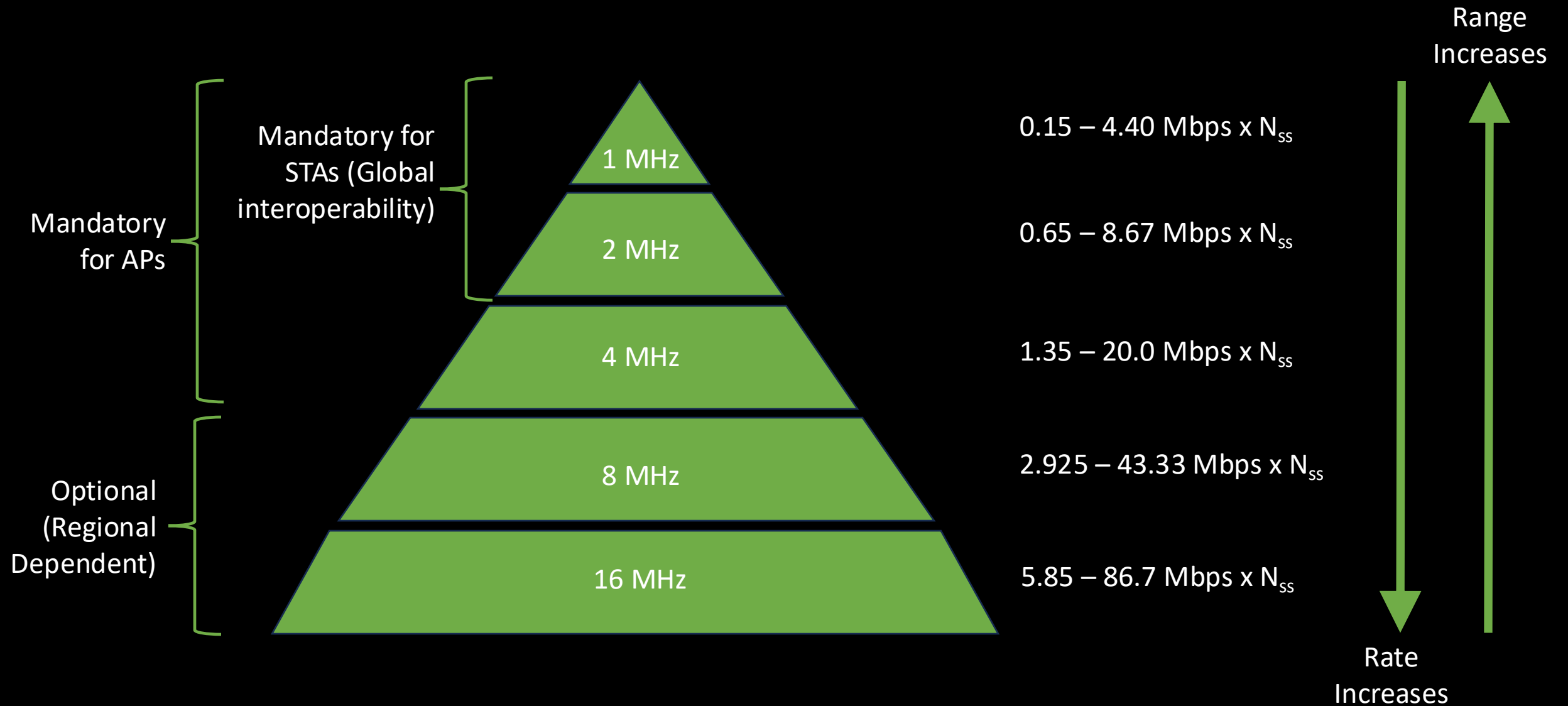
This chart is a graphic single-point-in-time portrayal of the Table of Frequency Allocations used by the FCC and ITU. An allocation is not completed until all aspects of the chart are complete and subject to change as the Table of Frequency Allocations. Therefore, for complete information, you should consult the Table to determine the current status of U.S. allocations.

U.S. DEPARTMENT OF COMMERCE
National Telecommunications and Information Administration
Office of Spectrum Management
JANUARY 2016



30 GHz
* EXCEPT AERONAUTICAL MOBILE (M)
** EXCEPT AERONAUTICAL MOBILE (M)

FILE NAME NOTE: THIS DOCUMENT LISTS THE SERVICES IN THE SPECTRUM SHOWN. IT DOES NOT INDICATE THE ACTUAL SPECTRUM OCCUPANCY.



N_{ss} = Number of Spatial Streams (1-4)

MCS Index	Spatial Stream	Modulation	Coding	OFDM (802.11ah) HaLow									
				1MHz		2MHz		4MHz		8MHz		16MHz	
				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	0.4µs GI
0	1	BPSK	1/2	0.3	0.33	0.65	0.7	1.35	1.5	2.925	3.3	5.85	6.5
1	1	QPSK	1/2	0.6	0.67	1.3	1.44	2.7	3.0	5.85	6.5	11.7	13.0
2	1	QPSK	3/4	0.9	1.00	1.95	2.17	4.05	4.5	8.78	9.8	17.6	19.5
3	1	16-QAM	1/2	1.2	1.33	2.6	2.89	5.4	6.0	11.7	13.0	23.4	26.0
4	1	16-QAM	3/4	1.8	2.00	3.9	4.33	8.1	9.0	17.55	19.5	35.1	39.0
5	1	64-QAM	2/3	2.4	2.67	5.2	5.78	10.8	12.0	23.4	26.0	46.8	52.0
6	1	64-QAM	3/4	2.7	3.00	5.85	6.5	12.15	13.5	26.33	29.3	52.65	58.5
7	1	64-QAM	5/6	3.0	3.33	6.5	7.22	13.5	15.0	29.25	32.5	58.5	65.0
8	1	256-QAM	3/4	3.6	4.00	7.8	8.67	16.2	18.0	35.1	39.0	70.2	78.0
9	1	256-QAM	5/6	4.0	4.44	-	-	18	20.0	39	43.3	78	86.7
10	1	BPSK	1/2 x 2	0.15	0.17	-	-	-	-	-	-	-	-
0	2	BPSK	1/2	0.6	0.7	1.3	1.4	2.7	3.0	5.85	6.5	11.7	13.0
1	2	QPSK	1/2	1.2	1.3	2.6	2.9	5.4	6.0	11.7	13.0	23.4	26.0
2	2	QPSK	3/4	1.8	2.0	3.9	4.3	8.1	9.0	17.55	19.5	35.1	39.0
3	2	16-QAM	1/2	2.4	2.7	5.2	5.8	10.8	12.0	23.4	26.0	46.8	52.0
4	2	16-QAM	3/4	3.6	4.0	7.8	8.7	16.2	18.0	35.1	39.0	70.2	78.0
5	2	64-QAM	2/3	4.8	5.33	10.4	11.6	21.6	24.0	46.8	52.0	93.6	104
6	2	64-QAM	3/4	5.4	6.0	11.7	13.0	24.3	27.0	52.65	58.5	105.3	117
7	2	64-QAM	5/6	6.0	6.67	13	14.4	27	30.0	58.5	65.0	117	130
8	2	256-QAM	3/4	7.2	8.0	15.6	17.3	32.4	36.0	70.2	78.0	140.4	156
9	2	256-QAM	5/6	8.0	8.85	-	-	35.9	39.8	77.7	86.3	155.4	173
0	3	BPSK	1/2	0.9	1.0	2.0	2.2	4.05	4.5	8.78	9.8	17.55	19.5
1	3	QPSK	1/2	1.8	2.0	1.95	4.3	8.1	9.0	17.55	19.5	35.1	39.0
2	3	QPSK	3/4	2.7	3.0	3.90	6.5	12.15	13.5	26.33	29.3	52.65	58.5
3	3	16-QAM	1/2	3.6	4.0	5.85	8.7	16.2	18.0	35.1	39.0	70.2	78
4	3	16-QAM	3/4	5.4	6.0	7.80	13.0	24.3	27.0	52.65	58.5	105.3	117
5	3	64-QAM	2/3	7.2	8.0	11.70	17.3	32.4	36.0	70.2	78.0	140.4	156
6	3	64-QAM	3/4	8.1	9.0	15.60	19.5	36.45	40.5	-	-	157.95	176
7	3	64-QAM	5/6	9.0	10.0	17.55	21.7	40.5	45.0	87.75	97.5	175.5	195
8	3	256-QAM	3/4	10.8	12.0	19.50	26.0	48.6	54.0	105.3	117.0	211	234
9	3	256-QAM	5/6	12.0	13.3	23.40	28.8	53.78	59.8	117	129	-	-
0	4	BPSK	1/2	1.2	1.3	2.6	2.9	5.4	6.0	11.7	13.0	23.4	26.0
1	4	QPSK	1/2	2.4	2.7	5.2	5.8	10.8	12.0	23.4	26.0	46.8	52.0
2	4	QPSK	3/4	3.6	4.0	7.8	8.7	16.2	18.0	35.1	39.0	70.2	78.0
3	4	16-QAM	1/2	4.8	5.3	10.4	11.6	21.6	24.0	46.8	52.0	93.6	104.0
4	4	16-QAM	3/4	7.2	8.0	15.6	17.3	32.4	36.0	70.2	78.0	140.4	156.0
5	4	64-QAM	2/3	9.6	10.7	20.8	23.1	43.2	48.0	93.6	104.0	187.2	208.0
6	4	64-QAM	3/4	10.8	12.0	23.4	26.0	48.6	54.0	105.3	117.0	210.6	234.0
7	4	64-QAM	5/6	12.0	13.3	26	28.9	54	60.0	117	130.0	234	260.0
8	4	256-QAM	3/4	14.4	16.0	31.2	34.7	64.8	72.0	140.4	156.0	280.8	312.0
9	4	256-QAM	5/6	15.9	17.7	-	-	71.71	79.7	155.4	172.6	310.8	345.3

MCSINDEX.NET





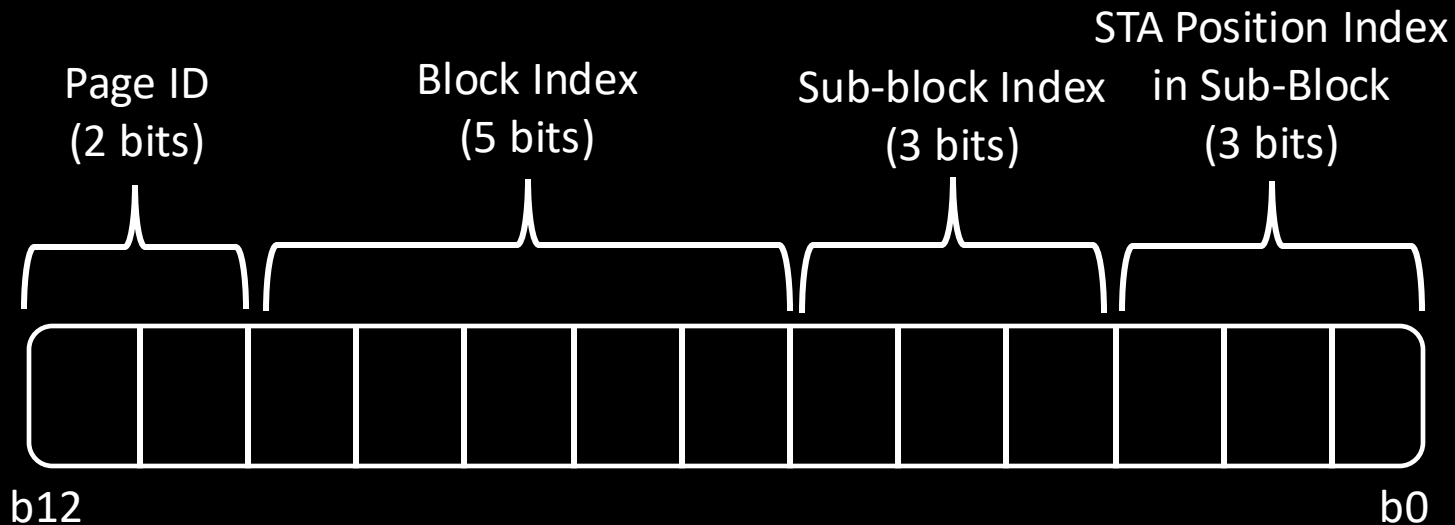
3 Cool Features of HaLow...

Association ID (AID)

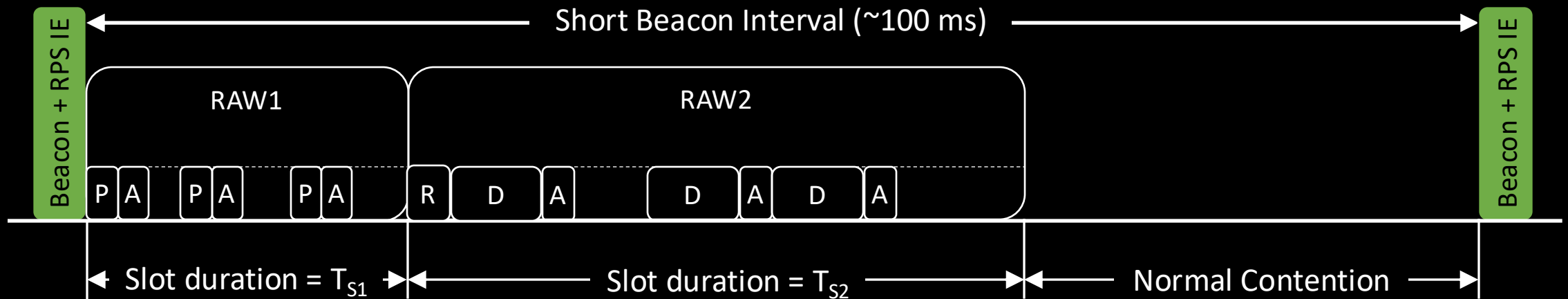


Bits 0–13	Bit 14	Bit 15	Usage
0–32 767	0	0	Duration value (in microseconds) within all frames except PS-Poll frames that are not PS-Poll+BDT
0–16 383	0	1	Reserved
0	1	1	AID 0 is used for broadcast transmission in S1G PPDU, reserved if not in S1G PPDU.
1–2007	1	1	AID in PS-Poll frames other than PS-Poll+BDT.
2008–8191	1	1	Additional AIDs in S1G PS-Poll frames other than PS-Poll+BDT. Reserved if not in S1G PS-Poll frames.
8192–16 383	1	1	Reserved

Duration / ID Field



Restricted Access Window (RAW)



P: PS-Poll/Trigger frame, **D:** DATA, **A:** ACK, **R:** Resource Allocation

Target Wait Time (TWT)

- Individual TWT (802.11ah)
 - AP & STA agree on up to 8 TWT based on different traffic classes or req's
 - STA wakes up at **agreed** upon TWT
- Trigger-enabled TWT (802.11ax)
 - Communication **ONLY** allowed during scheduled times but guaranteed
- Broadcast TWT (802.11ax)
 - AP checks to see who is **awake** and wants to send data
 - AP sets a schedule which can change over time
- Restricted TWT (802.11be) – **future**



Trust measurements you make...

Obligatory HaLow Speed Test



Scenario	1 MHz (ch5)	2 MHz (ch6)	4 MHz (ch8)
Open	1.98	3.14	5.24
WPA3	1.56	2.85	4.93
UDP	2.01	3.97	5.04
2 STAs	1.20	1.97	2.93

1 Spatial Stream ($N_{ss} = 1$)
2 STAs used UDP
Open/WPA3 used TCP
Uncontrolled environment
Results in Mbps



No.	Ref	Source	Length	PHY	Frequency	NSS	MCS	RSSI	Bandwidth	Info
86...	188.433...	192.16...	1584	802.11ah (S1G)	9060MHz	1	7	-120	4MHz channel	35072 → 5001 Len=1470
86...	188.435...	192.16...	1584	802.11ah (S1G)	9060MHz	1	7	-120	4MHz channel	35072 → 5001 Len=1470
86...	188.440...	192.16...	1584	802.11ah (S1G)	9060MHz	1	7	-120	4MHz channel	35072 → 5001 Len=1470

```

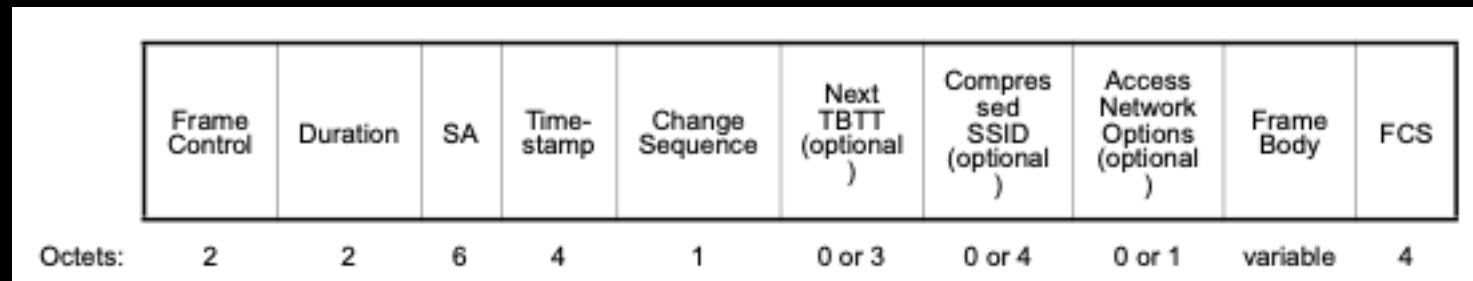
  Channel flags: 0x0044, 900 MHz spectrum, Orthogonal Frequency-Division Multiplexing (OFDM)
    ...0 = 700 MHz spectrum: False
    ...0. = 800 MHz spectrum: False
    ...1. = 900 MHz spectrum: True ←
    ...0 = Turbo: False
    ...0. = Complementary Code Keying (CCK): False
    ...1. = Orthogonal Frequency-Division Multiplexing (OFDM): True
    ...0... = 2 GHz spectrum: False
    ...0 = 5 GHz spectrum: False
    ...0. = Passive: False
    ...0.. = Dynamic CCK-OFDM: False
    ...0... = Gaussian Frequency Shift Keying (GFSK): False
    ...0 = GSM (900MHz): False
    ...0. = Static Turbo: False
    ...0.. = Half Rate Channel (10MHz Channel Width): False
    ...0... = Quarter Rate Channel (5MHz Channel Width): False
  A-MPDU status
    A-MPDU reference number: 1
  > A-MPDU flags: 0x0002
  S1G
    TLV type: S1G (32)
    TLV datalen: 6
  Known: 0x007f, S1G PPDU Format Known, Response Indication Known, Guard Interval Known, NSS Known, Bandwidth Known, MCS Known, Color Known
    ...1 = S1G PPDU Format Known: True
    ...1. = Response Indication Known: True
    ...1.. = Guard Interval Known: True
    ...1... = NSS Known: True
    ...1.... = Bandwidth Known: True
    ...1..... = MCS Known: True
    ...1..... = Color Known: True
    ...0... = Uplink Indication Known: False
    0000 0000 .... = Reserved 1: 0x00
  Data1: 0x7205, S1G PPDU Format: S1G Short, Response Indication: NDP response, Guard Interval: Long GI, NSS: 1, Bandwidth: 4MHz channel, MCS: 7
    ...01 = S1G PPDU Format: S1G Short (1)
    ...01.. = Response Indication: NDP response (1)
    ...0 = Reserved 2: 0x0
    ...0. = Guard Interval: Long GI (0)
    ...00.. = NSS: 1 (0)
    ...0010 = Bandwidth: 4MHz channel (2)
    ...0111 = MCS: 7 (7)
  Data2: 0x8808, Color: 0, Uplink Indication

```

One packet slice from the packet blasting experiment!

Beacon details – S1G

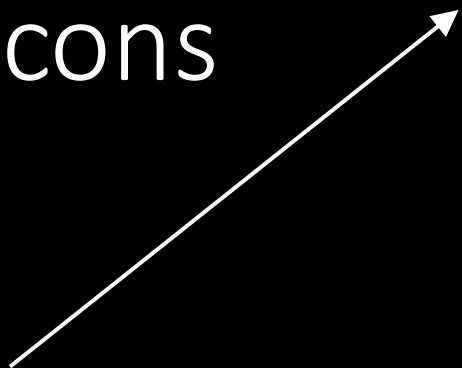
- 2 types of beacons
 - Short beacon (transmitted ~100 TUs)
 - Compressed SSID, RPS
 - Reduce airtime consumption (beacon bloat)
 - Full beacon (transmitted ~1000 TUs)
 - QoS/WMM, Full/short beacon interval times, uncompressed SSID, and many other super exciting IEs for PCAP geeks



S1G Beacon Format

Beacons

Short Beacon



Ref	Source	Length	PHY type	Frequency	NSS	MCS	Info
REF	Alfa_b...	140	802.11ah (S1G)	9045MHz	1	10	S1G Beacon, Flags=...R...C, SSID="WiFiVitae-Hey0h"
0.096395	Alfa_b...	65	802.11ah (S1G)	9045MHz	1	10	S1G Beacon, Flags=...R.FTC
0.198793	Alfa_b...	65	802.11ah (S1G)	9045MHz	1	10	S1G Beacon, Flags=...R.FTC
0.403620	Alfa_b...	65	802.11ah (S1G)	9045MHz	1	10	S1G Beacon, Flags=...R.FTC
0.505994	Alfa_b...	65	802.11ah (S1G)	9045MHz	1	10	S1G Beacon, Flags=...R.FTC
0.608415	Alfa_b...	65	802.11ah (S1G)	9045MHz	1	10	S1G Beacon, Flags=...R.FTC
0.710839	Alfa_b...	65	802.11ah (S1G)	9045MHz	1	10	S1G Beacon, Flags=...R.FTC
0.813242	Alfa_b...	65	802.11ah (S1G)	9045MHz	1	10	S1G Beacon, Flags=...R.FTC
0.915643	Alfa_b...	65	802.11ah (S1G)	9045MHz	1	10	S1G Beacon, Flags=...R.FTC
1.022443	Alfa_b...	140	802.11ah (S1G)	9045MHz	1	10	S1G Beacon, Flags=...R...C, SSID="WiFiVitae-Hey0h"

"Full" Beacon



No.	Source	Length	Frequency	NSS	MCS	RSSI	Bandw	Info
19	Alfa_b...	140	9055MHz	1	10	29	1M...	S1G Beacon, Flags=...R...C, SSID="WiFiVitae-Hey0h"

- Bitmap Control: 0x3e
 -0 = Traffic Indication: 0x0
 - ..11 111. = Page Slice Number: 31
 - 00.. = Page Index: 0
- Tag: S1G Capabilities
 - Tag Number: S1G Capabilities (217)
 - Tag length: 15
- S1G Capabilities Information
 - S1G Capabilities
 - Supported S1G-MCS and NSS Set
 - Supported S1G-MCS and NSS Set: 0x0001fa0fd
 - 1111 1101 = Rx S1G-MCS Map: 0xfd
 - 0000 0000 = Rx Highest Supported Long GI Data Rate: 0x000
 - 1111 101. = Tx S1G-MCS Map: 0xfd
 - 0000 000. = Tx Highest Supported Long GI Data Rate: 0x000
 - 00.. = Rx Single Spatial Stream and S1G-MCS Map for 1MHz: 0x0
 - ..00 = Tx Single Spatial Stream and S1G-MCS Map for 1MHz: 0x0
 - 00.. = Reserved: 0x0
- Tag: S1G Operation
 - Tag Number: S1G Operation (232)
 - Tag length: 6
 - S1G Operation Information
 - Channel Width: 39: 4 MHz BSS operating channel width
 - Operating Class: 2
 - Primary Channel Number: 7
 - Channel Center Frequency: 8
 - Basic S1G-MCS and NSS Set: 0xcc4
- Tag: Short Beacon Interval
 - Tag Number: Short Beacon Interval (214)
 - Tag length: 2
 - Short Beacon Interval: 100
- Tag: SSID parameter set: "Wi-FiVitae-Hey0h"
 - Tag Number: SSID parameter set (0)
 - Tag length: 15
 - SSID: "Wi-FiVitae-Hey0h"
- Tag: Vendor Specific: Microsoft Corp.: WMM/WME: Parameter Element
 - Tag Number: Vendor Specific (221)
 - Tag length: 24

No.	Source	Length	Frequency	NSS	MCS	RSSI	Bandw	Info
3.680478	Alfa_b...	65	802.11ah (S1G)	9045MHz	1	10		S1G Beacon, Flags=...R.FTC

- IEEE 802.11 S1G Beacon, Flags: ...R.FTC
 - Type/Subtype: S1G Beacon (0x0031)
 - Frame Control Field: 0x1c0b
 -00 = Version: 0
 - 11.. = Type: Extension frame (3)
 - 0001 = Subtype: 1
 -1 = Next TBTT Present: Present
 -1. = Compressed SSID Present: Present
 -0.. = ANO Present: Not Present
 - ..00 1... = BSS BW: 1
 - ..0.. = Security: Not supported
 - 0... = AP PM: Not supported
 - .000 0000 0000 0000 = Duration: 0 microseconds
 - Receiver address: Alfa_b4:74:7d (00:c0:ca:b4:74:7d)
 - Source address: Alfa_b4:74:7d (00:c0:ca:b4:74:7d)
 - Frame check sequence: 0x7644c14f [unverified]
 - [FCS Status: Unverified]
 - [WLAN Flags: ...R.FTC]
 - IEEE 802.11 wireless LAN extension frame
 - Fixed parameters (12 bytes)
 - Timestamp: 0x5863a0a8
 - Change Sequence: 0
 - Next TBTT: 0x586b70
 - Compressed SSID: 0x2dcb0204
 - Tagged parameters (5 bytes)
 - Tag: Traffic Indication Map (TIM): DTIM 0 of 2 bitmap
 - Tag Number: Traffic Indication Map (TIM) (5)
 - Tag length: 3
 - DTIM count: 0
 - DTIM period: 2
 - Bitmap Control: 0x3e

Security – WPA3™

Source	Destination	Length	PHY type	Frequency	NSS	MCS	Info
Alfa_b...	Raspbe...	186	802.11ah (S1G)	9050MHz	1	7	QoS Data, SN=791, FN=0, Flags=.p...FTC
Alfa_b...	Broadc...	494	802.11ah (S1G)	9050MHz	1	7	QoS Data, SN=1048, FN=0, Flags=.p...FTC
Alfa_b...	Alfa_b...	166	802.11ah (S1G)	9045MHz	1	10	Authentication, SN=0, FN=0, Flags=.....C
Alfa_b...	Alfa_b...	166	802.11ah (S1G)	9045MHz	1	10	Authentication, SN=1105, FN=0, Flags=.....C
Alfa_b...	Alfa_b...	102	802.11ah (S1G)	9045MHz	1	10	Authentication, SN=1, FN=0, Flags=.....C
Alfa_b...	Alfa_b...	102	802.11ah (S1G)	9045MHz	1	10	Authentication, SN=1106, FN=0, Flags=.....C
Alfa_b...	Alfa_b...	140	802.11ah (S1G)	9045MHz	1	10	Association Request, SN=2, FN=0, Flags=.....C, SSID="WiFiVitae-Hey0h"
Alfa_b...	Alfa_b...	148	802.11ah (S1G)	9045MHz	1	10	Association Response, SN=1107, FN=0, Flags=.....C
Alfa_b...	Alfa_b...	193	802.11ah (S1G)	9045MHz	1	10	Key (Message 1 of 4)
Alfa_b...	Alfa_b...	199	802.11ah (S1G)	9045MHz	1	10	Key (Message 2 of 4)
Alfa_b...	Alfa_b...	259	802.11ah (S1G)	9045MHz	1	10	Key (Message 3 of 4)
Alfa_b...	Alfa_b...	171	802.11ah (S1G)	9045MHz	1	10	Key (Message 4 of 4)
Alfa_b...	Broadc...	100	802.11ah (S1G)	9050MHz	1	7	QoS Data, SN=1049, FN=0, Flags=.p...FTC

```

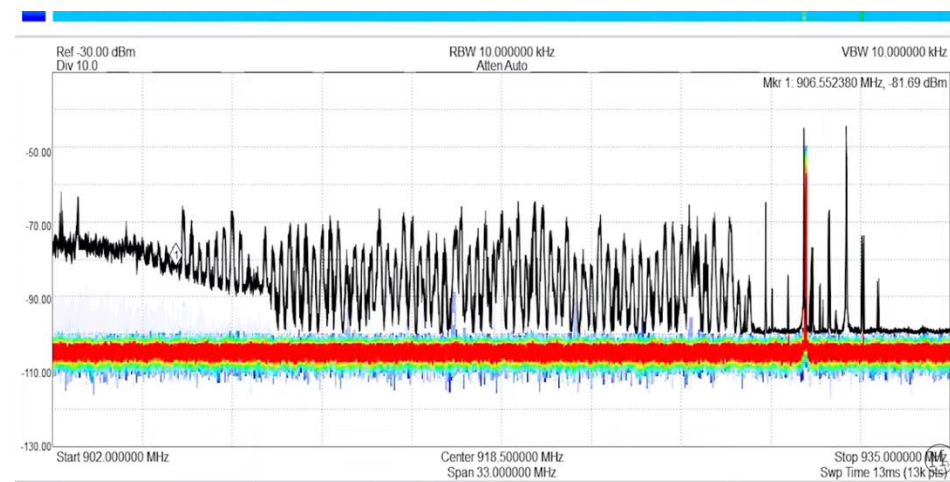
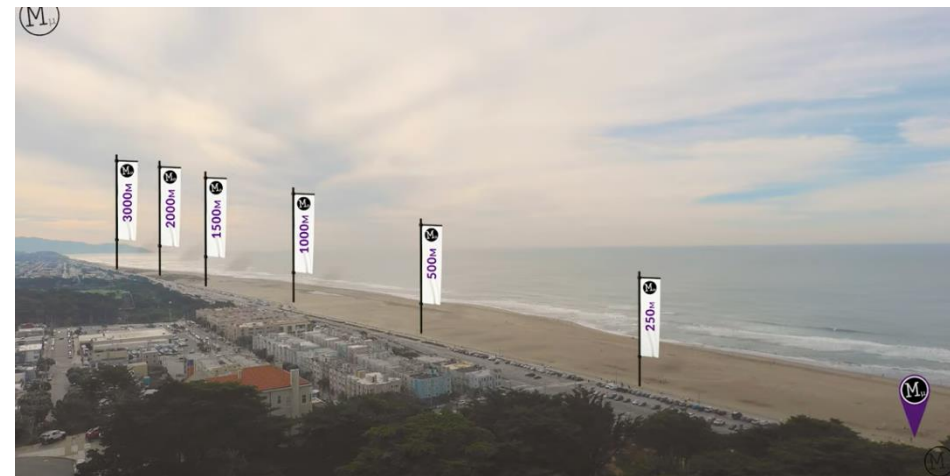
17... Alfa_b... Alfa_b... 193 802.11ah (S1G) 9045MHz 1 10 Key (Message 1 of 4)
  Organization Code: 00:00:00 (Officially Xerox, but
  Type: 802.1X Authentication (0x888e)
  802.1X Authentication
    Version: 802.1X-2004 (2)
    Type: Key (3)
    Length: 117
    Key Descriptor Type: EAPOL RSN Key (2)
    [Message number: 1]
  Key Information: 0x0088
    Key Length: 16
    Replay Counter: 1
    WPA Key Nonce: ff01906f4292a6cb27f70cb19054c59bafae20e827355d2eaae06daf3ad8b2ec
    Key IV: 00000000000000000000000000000000
    WPA Key RSC: 0000000000000000
    WPA Key ID: 0000000000000000
    WPA Key MIC: 00000000000000000000000000000000
    WPA Key Data Length: 22
  WPA Key Data: dd14000fac0437297f26c5e3be00af84092d66ad4209
    Tag: Vendor Specific: IEEE 802.11: RSN PMKID
      Tag Number: Vendor Specific (221)
      Tag length: 20
      OUI: 00:0f:ac (IEEE 802.11)
      Vendor Specific OUI Type: 4
      Data Type: PMKID KDE (4)
      PMKID: 37297f26c5e3be00af84092d66ad4209
  
```

```

17... Alfa_b... Alfa_b... 199 802.11ah (S1G) 9045MHz 1 10 Key (Message 2 of 4)
  802.1X Authentication
    Version: 802.1X-2001 (1)
    Type: Key (3)
    Length: 123
    Key Descriptor Type: EAPOL RSN Key (2)
    [Message number: 2]
  Key Information: 0x0108
    Key Length: 0
    Replay Counter: 1
    WPA Key Nonce: e9af9dc0a1d06dcb2a2db4dab542ff76ac055e57d697ca55f8f08bf5d4efcb8e
    Key IV: 00000000000000000000000000000000
    WPA Key RSC: 0000000000000000
    WPA Key ID: 0000000000000000
    WPA Key MIC: 51cae0a6e6337e253758d8ebc9b2f920
    WPA Key Data Length: 28
  WPA Key Data: 301a010000fac040100000fac040100000fac08c000000000fac06
    Tag: RSN Information
      Tag Number: RSN Information (48)
      Tag length: 26
      RSN Version: 1
    Group Cipher Suite: 00:0f:ac (IEEE 802.11) AES (CCM)
    Pairwise Cipher Suite Count: 1
    Pairwise Cipher Suite List 00:0f:ac (IEEE 802.11) AES (CCM)
    Auth Key Management (AKM) Suite Count: 1
    Auth Key Management (AKM) List 00:0f:ac (IEEE 802.11) SAE (SHA256)
    RSN Capabilities: 0x00c0
    PMKID Count: 0
    PMKID List
    Group Management Cipher Suite: 00:0f:ac (IEEE 802.11) BIP (128)
  
```

HaLow Distance Record – 3 Km (1.86 mi)

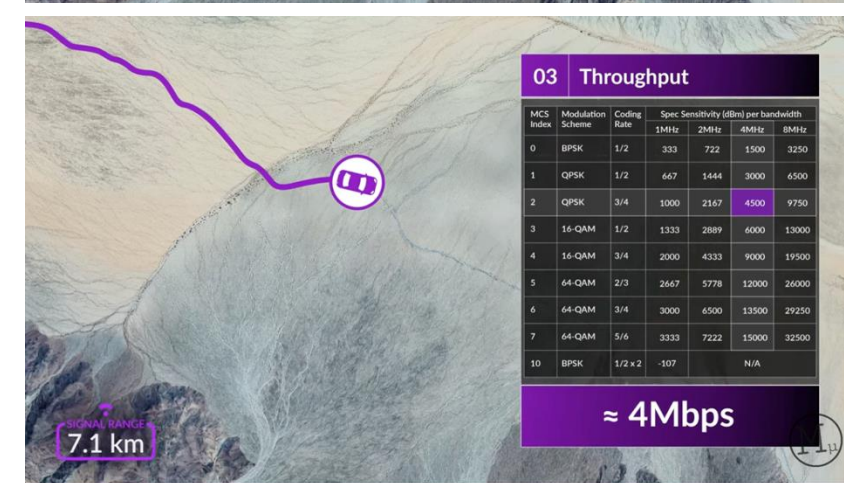
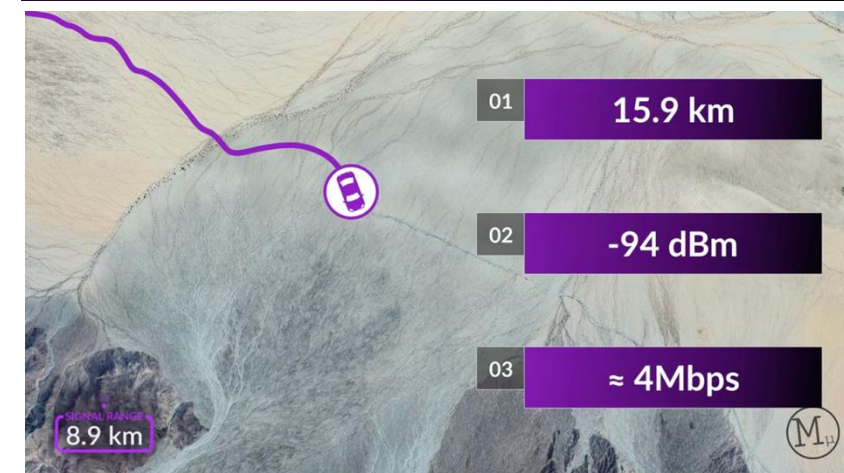
- Using Morse Micro MM6108 SoC
- Ocean Beach, California
- Video call & TP test
- 8 MHz wide channel
- 8 Mbps @ 1500 m / 1 Mbps @ 3000 m



New HaLow Range Test Record – 16 Km (9.94 mi)

New

- Using Morse Micro EKH01 Evaluation Kit
- Joshua Tree, California
- UDP test data
- 4 MHz wide channel
- 4 Mbps @ 7000 m / 2 Mbps @ 16,000 m





Wi-Fi 6

40 MHz Wide
Channel 144

Ping

WPA3

Tx Power: 17dBm



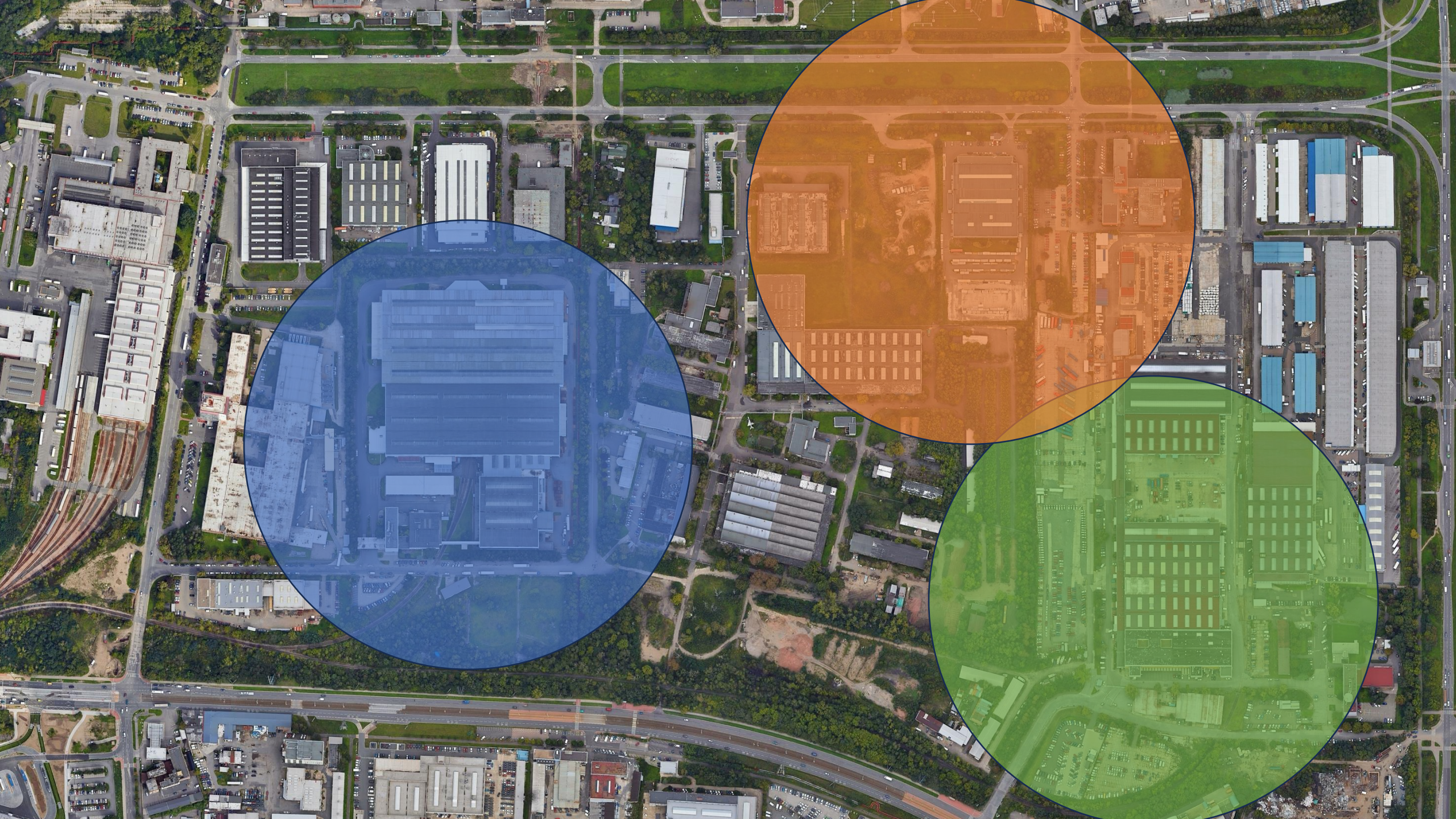
HaLow

2 MHz Wide
Channel 6 (905MHz)
Ping
Open
Max Tx Power

Wi-Fi 6

40 MHz Wide
Channel 144
Ping
WPA3
Tx Power: 17dBm





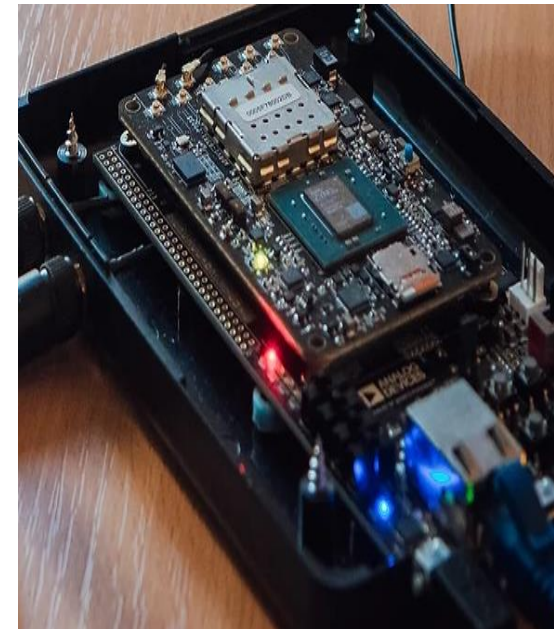


Manufacturers

NEWIRACOM

M_μ Morse Micro

Methods **2** Business



Sort By: Date Certified: Newest to Oldest

Wi-Fi Certified HaLow™

Clear all filters

Keyword Search

Brand

Categories

- Building
- Computers & Accessories
- Gaming, Media & Music
- Phones
- Routers
- Smart Home
- Tablets, Ereaders & Cameras
- Televisions & Set Top Boxes
- Other

Featured Capabilities

- Passpoint®
- Wi-Fi CERTIFIED 7™
- Wi-Fi CERTIFIED HaLow™
- Wi-Fi Location™
- Wi-Fi QoS Management™

Hide Advanced Filters

Product Name: ACERA 331
Model Number: WN-331
Total Variants: 1 (1 result)
Brand: FURUNO SYSTEMS Co., Ltd.
Category: Routers
Last Certified Date: 2023-10-13

Product Name: Wi-Fi HaLow IoT Gateway
Model Number: AP7688-WHM
Total Variants: 1 (1 result)
Brand: AsiaRF Co., Ltd.
Category: Routers
Last Certified Date: 2023-06-02

Product Name: MM6108-EKH01
Model Number: MM6108-EKH01
Total Variants: 1 (1 result)
Brand: Morse Micro
Category: Routers
Last Certified Date: 2023-04-14

Product Name: MM6104-EKH01-STA
Model Number: MM6104-EKH01-STA
Total Variants: 1 (1 result)
Brand: Morse Micro
Category: Other
Last Certified Date: 2021-11-04

Product Name: MM6104-EKH01-AP
Model Number: MM6104-EKH01-AP
Total Variants: 1 (1 result)
Brand: Morse Micro
Category: Routers
Last Certified Date: 2021-11-04

Product Name: NRC7292AP01
Model Number: NRC7292AP01
Total Variants: 1 (1 result)
Brand: Newracom Inc.
Category: Routers
Last Certified Date: 2021-11-04

Product Name: M2B7211-EVB
Model Number: M2B7211-EVB
Total Variants: 1 (1 result)
Brand: Methods2Business
Category: Routers
Last Certified Date: 2021-11-02

Product Name: NRC7292ST01
Model Number: NRC7292ST01
Total Variants: 1 (1 result)
Brand: Newracom Inc.
Category: Other
Last Certified Date: 2021-11-02

Product Name: M2B7111-EVB
Model Number: M2B7111-EVB
Total Variants: 1 (1 result)
Brand: Methods2Business
Category: Other
Last Certified Date: 2021-11-02

Attributes	Wi-Fi HaLow	Wi-Fi Legacy (n/ac)	Zigbee	BLE	LoRaWAN	NB-IoT
Frequency	S1G	2.4 / 5 GHz	S1G / 2.4 GHz	2.4 GHz	S1G / 2.4 GHz	Licensed <5 GHz
Data Rate	150 kbps – 86.7 Mbps*	6.5 Mbps–866.7 Mbps*	250 kbps	125 kbps – 2 Mbps	300 bps – 27 kbps	20 – 127 kbps
Range (m)	<1,000	< 100	< 20	< 100	<20,000	<30,000
Modulation	OFDM over BPSK, QPSK, 16/64/256-QAM	OFDM over BPSK, QPSK, 16/64/256-QAM	BPSK / OQPSK	GFSK	CSS	QPSK
Power	Low	Med	Low	Low	Low	Low
Security	WPA3™	128-bit AES in CCMMode	128-bit AES in CCMMode	128-bit AES in CCMMode	128-bit AES in CCMMode	3GPP security
Device per AP/GW	8192	2007	65,000	Unlimited	>100,00	>100,000
OTA firmware updates	Yes	Yes	Yes	Yes	Yes	Yes

* Single spatial stream

“Be relentlessly curious.”

Troy Martin



LinkedIn