

关于无线网络的 Data Rate

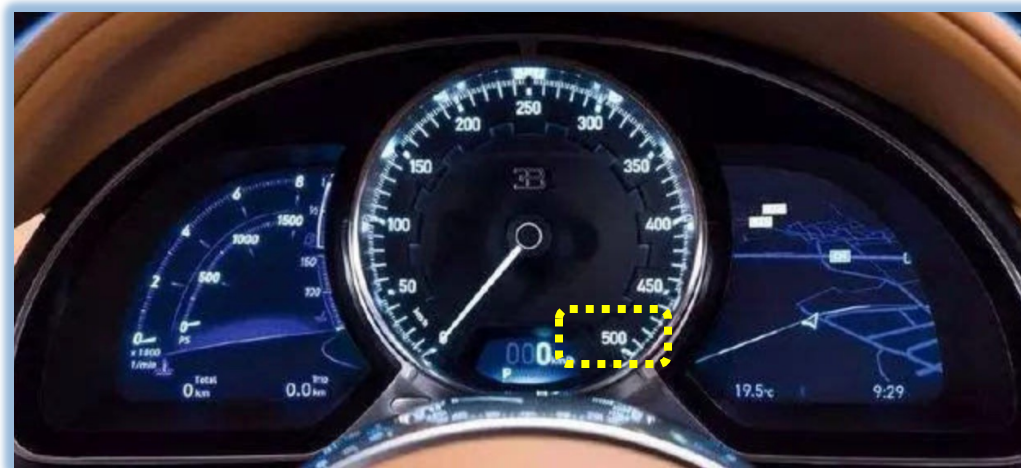
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什么是MCS？

- MCS --- Modulation and Coding Scheme (调制和编码方案)
- MCS 用作确定无线连接的数据速率。



AP 支持最大速率

	AP-50x (BRCM)	AP-51x (BRCM)	AP-53x (QCA)	AP-555 (QCA)
5GHz radio (HE80)	2x2	4x4	4x4	8x8 or dual 4x4 (tri-radio)
5GHz radio (HE160)	N/A	160	80 + 80	80 + 80
2.4GHz radio	2x2	2x2	4x4	4x4
Peak datarates 峰值速率 (2.4GHz, 5GHz)	574Mbps / 1.2Gbps	574Mbps / 4.8Gbps	1.15Gbps / 2.4Gbps	1.15Gbps / 4.8Gbps
Peak datarates 峰值速率 (HE20 2.4GHz, HE80 5GHz)	287Mbps / 1.2Gbps	287Mbps / 2.4Gbps	574Mbps / 2.4Gbps	574Mbps / 4.8Gbps

	AP-303 (QCA)	AP-305 (QCA)	AP-315 (QCA)	AP-325 (QCA)	AP-335 (QCA)	AP-345 (BRCM)
5GHz radio (VHT160)	No	No	2x2	No	2x2	2x2
5GHz radio (VHT80)	2x2	3x3	4x4	4x4	4x4	4x4
2.4GHz radio (HT40)	2x2	2x2	2x2	4x4	4x4	4x4
MU-MIMO	2SS	2SS	3SS	3SS	4SS	4SS
Peak datarates 峰值速率 (2.4GHz / 5GHz)	300 / 867 Mbps	300 / 1300 Mbps	300 / 1,733 Mbps	600 / 1,733 Mbps	600 / 1,733 Mbps	600 / 1,733 Mbps

终端协商速率

```
(Aruba7010) *[mynode] #show ap association ap-name AP-325 | include 5e:0b,5f:0b,2d:eb
```

AP-325	ac:a3:1e:57:94:d1	a4:83:e7:b2:5e:0b	y	y	1	10	mo	99	0x1000b	a-VHT-80sgi-3ss	1d:5h:59m:47s	1	WAB	101/4	<u>a-VHT-80sgi-3ss</u>
AP-325	ac:a3:1e:57:94:d0	e2:98:c1:e5:5f:0b	y	y	2	20	Momo	88	0x10009	a-VHT-80sgi-2ss	21m:14s	1	WVAB	121/78	<u>a-HE-80-2ss-V</u>
AP-325	ac:a3:1e:57:94:d0	76:b0:42:2f:2d:eb	y	y	3	10	Momo	88	0x10009	a-VHT-80sgi-2ss	2h:45m:9s	1	WVMAB	10/7	<u>a-HE-160-2ss-VM</u>

Aruba AP-325



5GHz 射频：
- 4x4:4,
- 20/40/80MHz
- 1.733Gbps

Apple Macbook pro 13'



Wi-Fi5, 3x3

Apple iPhone 12 Pro Max



Wi-Fi6, 2x2

Samsung S21 Ultra



Wi-Fi6E, 2x2

Interface Name: en0
Address: a4:83:e7:b2:5e:0b
Wi-Fi: On
Turn Wi-Fi Off
mo
Disconnect from mo
IP Address: 192.168.100.105
Router: 192.168.100.1
Security: WPA2 Personal
BSSID: ac:a3:1e:57:94:d1
Channel: 52 (5 GHz, 80 MHz)
Country Code: CN
RSSI: -51 dBm
Tx Rate: 780 Mbps
MCS Index: 5
NSS: 3
1206
204
ChinaNet-EkKU
ChinaNet-WiFi5-4725
CMCC-HM
Coco
Momo

Momo
已连接
780 Mbps
WPA2 PSK
192.168.88.163
fe80::74b0:42ff:fe2f:2deb

```
(Aruba7010) *[mynode] #show ap debug client-table ap-name AP-325 | include e2:98:c1:e5:5f:0b
```

e2:98:c1:e5:5f:0b	Momo	ac:a3:1e:57:94:d0	Associated	cAWsSE	0x2	Power-save	(0,0,0,0,N/A,0)	(0,0)	851	1356	0	117	433	<u>702</u>	35	39	2[0x3]	Sun Jul 4 17:09:14 2021
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“Data Rate” vs “MCS Index”

* MCS table请参考: <http://mcsindex.com/>

						OFDM (Prior 11ax)							
MCS Index			Spatial Stream	Modulation	Coding	20MHz		40MHz		80MHz		160MHz	
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
		11	1	1024-QAM	5/6								
8	0	0	2	BPSK	1/2	13.00	14.40	27.00	30.00	58.50	65.00	117.00	130.00
9	1	1	2	QPSK	1/2	26.00	28.90	54.00	60.00	117.00	130.00	234.00	260.00
10	2	2	2	QPSK	3/4	39.00	43.30	81.00	90.00	175.50	195.00	351.00	390.00
11	3	3	2	16-QAM	1/2	52.00	57.80	108.00	120.00	234.00	260.00	468.00	520.00
12	4	4	2	16-QAM	3/4	78.00	86.70	162.00	180.00	351.00	390.00	702.00	780.00
13	5	5	2	64-QAM	2/3	104.00	115.60	216.00	240.00	468.00	520.00	936.00	1040.00
14	6	6	2	64-QAM	3/4	117.00	130.00	243.00	270.00	526.50	585.00	1053.00	1170.00
15	7	7	2	64-QAM	5/6	130.00	144.40	270.00	300.00	585.00	650.00	1170.00	1300.00
	8	8	2	256-QAM	3/4	156.00	173.30	324.00	360.00	702.00	780.00	1404.00	1560.00
	9	9	2	256-QAM	5/6	N/A	N/A	360.00	400.00	780.00	866.70	1560.00	1733.30
		10	2	1024-QAM	3/4								
		11	2	1024-QAM	5/6								
16	0	0	3	BPSK	1/2	19.50	21.70	40.50	45.00	87.80	97.50	175.50	195.00
17	1	1	3	QPSK	1/2	39.00	43.30	81.00	90.00	175.50	195.00	351.00	390.00
18	2	2	3	QPSK	3/4	58.50	65.00	121.50	135.00	263.30	292.50	526.50	585.00
19	3	3	3	16-QAM	1/2	78.00	86.70	162.00	180.00	351.00	390.00	702.00	780.00
20	4	4	3	16-QAM	3/4	117.00	130.00	243.00	270.00	526.50	585.00	1053.00	1170.00
21	5	5	3	64-QAM	2/3	156.00	173.30	324.00	360.00	702.00	780.00	1404.00	1560.00
22	6	6	3	64-QAM	3/4	175.50	195.00	364.50	405.00	N/A	N/A	1579.50	1755.00
23	7	7	3	64-QAM	5/6	195.00	216.70	405.00	450.00	877.50	975.00	1755.00	1950.00
	8	8	3	256-QAM	3/4	234.00	260.00	486.00	540.00	1053.00	1170.00	2106.00	2340.00
	9	9	3	256-QAM	5/6	260.00	288.90	540.00	600.00	1170.00	1300.00	N/A	N/A
		10	3	1024-QAM	3/4								
		11	3	1024-QAM	5/6								

终端	支持协议	天线	MCS rate	MCS Index	Modulation	Guard Interval
Macbook Pro	Wi-Fi5	3	780Mbps	5	64-QAM	0.4 μs GI
iPhone12 Pro Max	Wi-Fi6	2	702Mbps	8	256-QAM	0.8 μs GI
三星S21 Ultra	Wi-Fi6E	2	780Mbps	8	256-QAM	0.4 μs GI

Apple iPhone Maximum PHY data rate

Wi-Fi specifications for iPhone 11 and iPhone 12

The table below details the Wi-Fi specifications for the iPhone 11 and iPhone 12 models listed in the above table.

802.11 standard, name, frequency	Maximum PHY data rate	Maximum channel bandwidth	Maximum MCS index	Maximum spatial streams
ax@5 GHz	1200 Mbps	80 MHz	11 (HE)	2/MIMO
ac@5 GHz	866 Mbps	80 MHz	9 (VHT)	2/MIMO
a/n@5 GHz	300 Mbps	40 MHz	7 (HT)	2/MIMO
ax@2.4 GHz	195 Mbps	20 MHz	9 (HE)	2/MIMO
b/g/n@2.4 GHz	144 Mbps	20 MHz	7 (HT)	2/MIMO

Wi-Fi specifications for iPhone X

The table below details the Wi-Fi specifications for all iPhone X models: iPhone X, iPhone XR, iPhone Xs, and iPhone Xs Max.

802.11 standard, name, frequency	Maximum PHY data rate	Maximum channel bandwidth	Maximum MCS index	Maximum spatial streams
ac@5 GHz	866 Mbps	80 MHz	9 (VHT)	2/MIMO
a/n@5 GHz	300 Mbps	40 MHz	7 (HT)	2/MIMO
b/g/n@2.4 GHz	144 Mbps	20 MHz	7 (HT)	2/MIMO

						OFDM (Prior 11ax)								OFDM (802.11ax)											
MCS Index			Spatial Stream	Modulation	Coding	20MHz		40MHz		80MHz		160MHz		20MHz			40MHz			80MHz			160MHz		
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
8	0	0	2	BPSK	1/2	13.00	14.40	27.00	30.00	58.50	65.00	117.00	130.00	17.20	16.30	14.60	34.40	32.50	29.30	72.10	68.10	61.30	144.10	136.10	122.50
9	1	1	2	QPSK	1/2	26.00	28.90	54.00	60.00	117.00	130.00	234.00	260.00	34.40	32.50	29.30	68.80	65.00	58.50	144.10	136.10	122.50	288.20	272.20	245.00
10	2	2	2	QPSK	3/4	39.00	43.30	81.00	90.00	175.50	195.00	351.00	390.00	51.60	48.80	43.90	103.20	97.50	87.80	216.20	204.20	183.80	432.40	408.30	367.50
11	3	3	2	16-QAM	1/2	52.00	57.80	108.00	120.00	234.00	260.00	468.00	520.00	68.80	65.00	58.50	137.60	130.00	117.00	288.20	272.20	245.00	576.50	544.40	490.00
12	4	4	2	16-QAM	3/4	78.00	86.70	162.00	180.00	351.00	390.00	702.00	780.00	103.20	97.50	87.80	206.50	195.00	175.50	432.40	408.30	367.50	864.70	816.70	735.00
13	5	5	2	64-QAM	2/3	104.00	115.60	216.00	240.00	468.00	520.00	936.00	1040.00	137.60	130.00	117.00	275.30	260.00	234.00	576.50	544.40	490.00	1152.90	1088.90	980.00
14	6	6	2	64-QAM	3/4	117.00	130.00	243.00	270.00	526.50	585.00	1053.00	1170.00	154.90	146.30	131.60	309.70	292.50	263.30	648.50	612.50	551.30	1297.10	1225.00	1102.50
15	7	7	2	64-QAM	5/6	130.00	144.40	270.00	300.00	585.00	650.00	1170.00	1300.00	172.10	162.50	146.30	344.10	325.00	292.50	720.60	680.60	612.50	1441.20	1361.10	1225.00
	8	8	2	256-QAM	3/4	156.00	173.30	324.00	360.00	702.00	780.00	1404.00	1560.00	206.50	195.00	175.50	412.90	390.00	351.00	864.70	816.70	735.00	1729.40	1633.30	1470.00
	9	9	2	256-QAM	5/6	N/A	N/A	360.00	400.00	780.00	866.70	1560.00	1733.30	229.40	216.70	195.00	458.80	433.30	390.00	960.80	907.40	816.70	1921.60	1814.80	1633.30
		10	2	1024-QAM	3/4									258.10	243.80	219.40	516.20	487.50	438.80	1080.90	1020.80	918.80	2161.80	2041.70	1837.50
		11	2	1024-QAM	5/6									286.80	270.80	243.80	573.50	541.70	487.50	1201.00	1134.30	1020.80	2402.00	2268.50	2041.70

Apple MacBook Pro Maximum PHY data rate

Wi-Fi specification details for Mac Book Pro computers with Apple silicon

- 13-inch, M1, 2020

802.11 standard, name, frequency	Maximum PHY data rate	Maximum channel bandwidth	Maximum MCS index	Maximum spatial streams
<u>ax@5 GHz</u>	<u>1200 Mbps</u>	80 MHz	11 (HE)	2/MIMO
ac@5 GHz	<u>866 Mbps</u>	80 MHz	9 (VHT)	2/MIMO
a/n@5 GHz	300 Mbps	40 MHz	15 (HT)	2/MIMO
<u>ax@2.4 GHz</u>	195 Mbps	20 MHz	9 (HE)	2/MIMO
b/g/n@2.4 GHz	144 Mbps	20 MHz	15 (HT)	2/MIMO

Wi-Fi specification details for Intel-based MacBook Pro computers (2020)

- 13-inch, 2020, Two Thunderbolt 3 ports
- 13-inch, 2020, Four Thunderbolt 3 ports

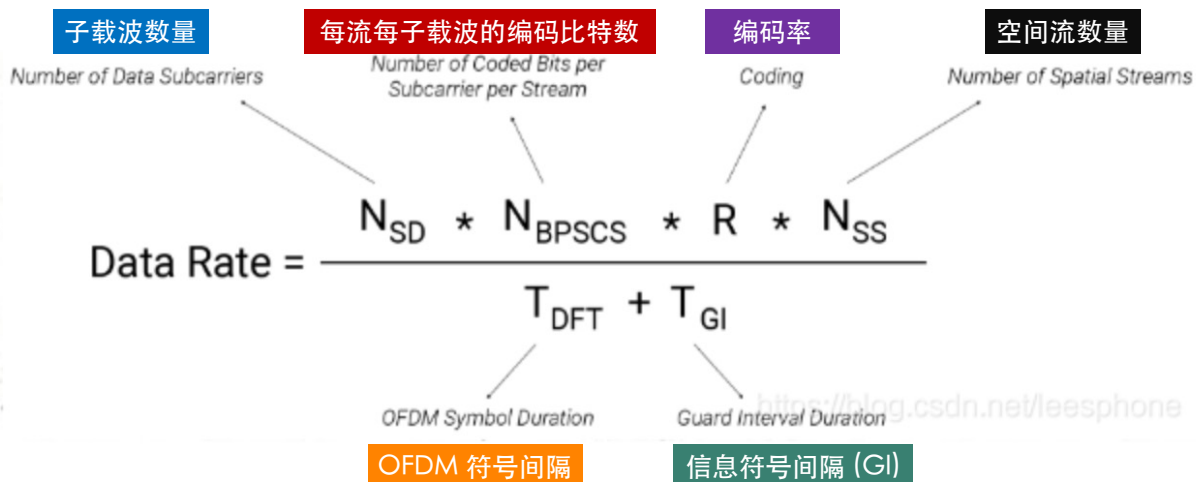
802.11 standard, name, frequency	Maximum PHY data rate	Maximum channel bandwidth	Maximum MCS index	Maximum spatial streams
ac@5 GHz	<u>866 Mbps</u>	80 MHz	9 (VHT)	2/MIMO
a/n@5 GHz	300 Mbps	40 MHz	15 (HT)	2/MIMO
b/g/n@2.4 GHz	144 Mbps	20 MHz	15 (HT)	2/MIMO

Wi-Fi specification details for Intel-based MacBook Pro models from 2017-2019

802.11 standard, name, frequency	Maximum PHY data rate	Maximum channel bandwidth	Maximum MCS index	Maximum spatial streams
ac@5 GHz	<u>1300 Mbps</u>	80 MHz	9 (VHT)	<u>3/MIMO</u>
a/n@5 GHz	450 Mbps	40 MHz	23 (HT)	<u>3/MIMO</u>
b/g/n@2.4 GHz	217 Mbps	20 MHz	23 (HT)	<u>3/MIMO</u>

Data Rate 如何计算 (与什么有关系?)

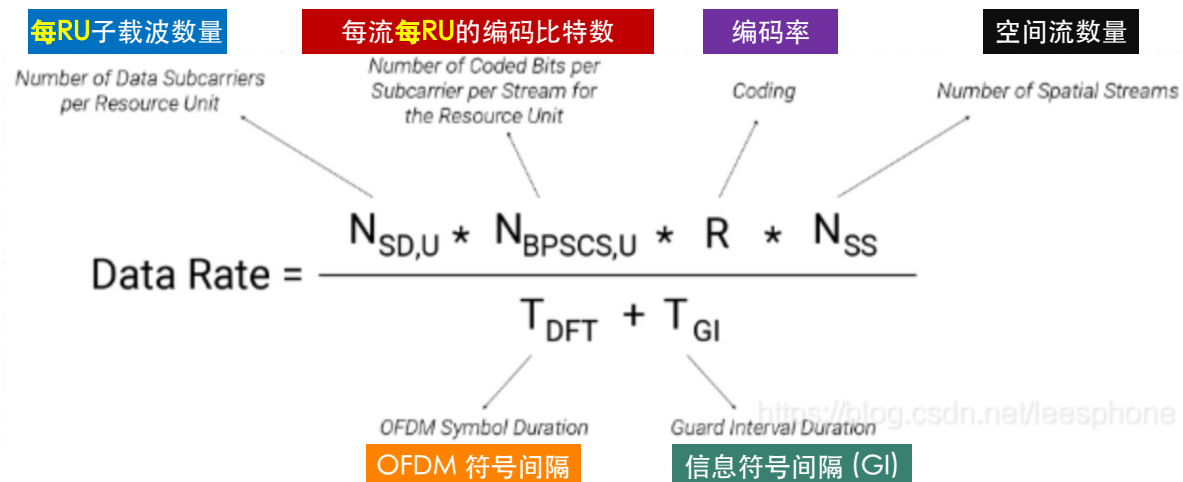
802.11n, 802.11ac



PHY	Modulation		R	N _{SS}	N _{SD}				T _{DFT}	T _{GI}	
	Name	N _{BPSCS}			20MHz	40MHz	80MHz	160MHz		Long	Short
802.11n (HT)	BPSK	1	1/2	1 to 4	52	108	234	468	3.2 μs	0.8 μs	0.4 μs
	QPSK	2	1/2 & 3/4								
	16-QAM	4	1/2 & 3/4								
	64-QAM	6	1/2 & 2/3 & 3/4								
802.11ac (VHT)	BPSK	1	1/2	1 to 8	52	108	234	468	3.2 μs	0.8 μs	0.4 μs
	QPSK	2	1/2 & 3/4								
	16-QAM	4	1/2 & 3/4								
	64-QAM	6	1/2 & 2/3 & 3/4								
	256-QAM	8	2/3 & 5/6								

HT and VHT OFDM Parameters

802.11ax



PHY	Modulation		R	N _{SS}	N _{SD}				T _{DFT}	T _{GI}		
	Name	N _{BPSCS}			20MHz	40MHz	80MHz	160MHz		Long	Medium	Long
802.11ax (HE)	BPSK	1	1/2	1 to 8	234	468	980	1960	12.8 μs	0.8 μs	1.2 μs	3.2 μs
	QPSK	2	1/2 & 3/4									
	16-QAM	4	1/2 & 3/4									
	64-QAM	6	1/2 & 2/3 & 3/4									
	256-QAM	8	2/3 & 5/6									
	1024-QAM	10	3/4 & 5/6									

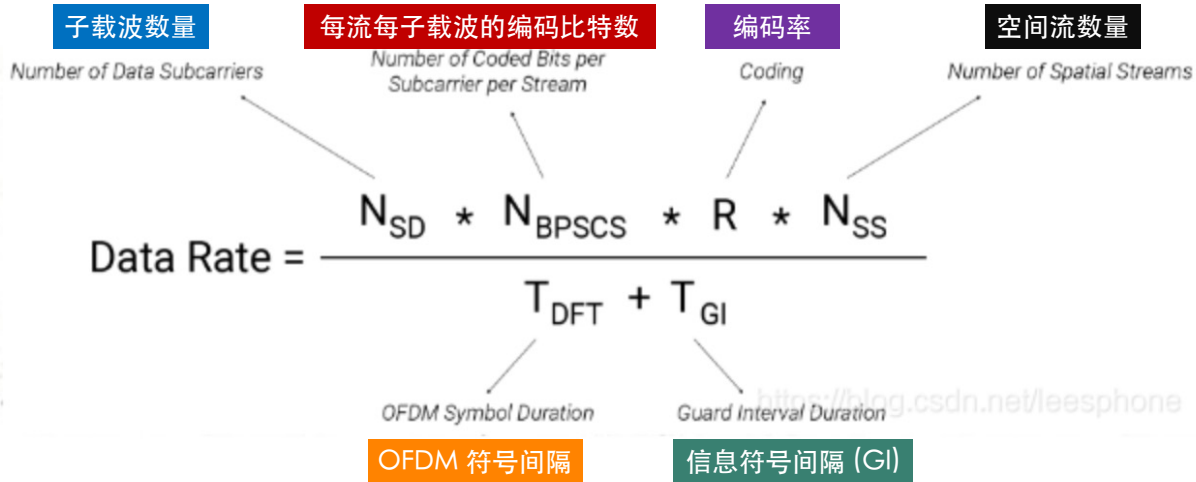
HE OFDM Parameters

PHY	Modulation		R	N _{SS}	N _{SD}						T _{DFT}	T _{GI}		
	Name	N _{BPSCS}			26-tone	52-tone	106-tone	242-tone	484-tone	996-tone		Long	Medium	Long
802.11ax (HE)	BPSK	1	1/2	1 to 8	24	48	102	234	468	980	12.8 μs	0.8 μs	1.2 μs	3.2 μs
	QPSK	2	1/2 & 3/4											
	16-QAM	4	1/2 & 3/4											
	64-QAM	6	1/2 & 2/3 & 3/4											
	256-QAM	8	2/3 & 5/6											
	1024-QAM	10	3/4 & 5/6											

HE OFDMA Parameters

Data Rate 举例说明

802.11n, 802.11ac



PHY	Modulation		R	N _{ss}	N _{SD}				T _{DFT}	T _{GI}	
	Name	N _{BPSCS}			20MHz	40MHz	80MHz	160MHz		Long	Short
802.11n (HT)	BPSK	1	1/2	1 to 4	52	108	234	468	3.2 μs	0.8 μs	0.4 μs
	QPSK	2	1/2 & 3/4								
	16-QAM	4	1/2 & 3/4								
	64-QAM	6	1/2 & 2/3 & 3/4								
802.11ac (VHT)	BPSK	1	1/2	1 to 8	52	108	234	468	3.2 μs	0.8 μs	0.4 μs
	QPSK	2	1/2 & 3/4								
	16-QAM	4	1/2 & 3/4								
	64-QAM	6	1/2 & 2/3 & 3/4								
	256-QAM	8	2/3 & 5/6								

HT and VHT OFDM Parameters

5GHz 射频：
- 4x4:4,
- 80MHz

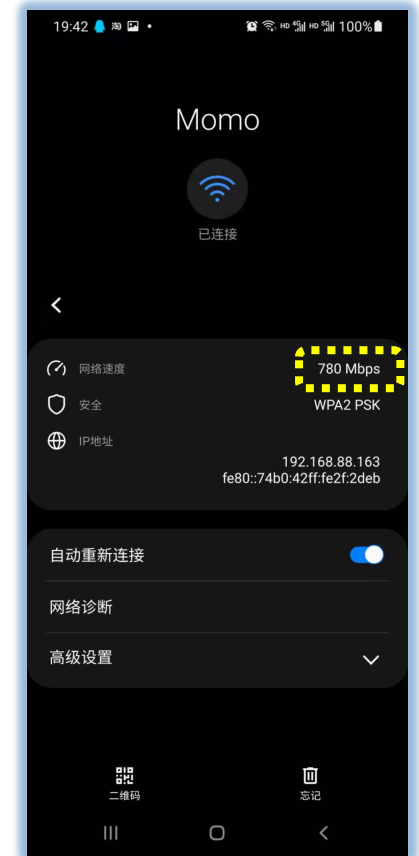
Aruba AP-325



Samsung S21 Ultra



Wi-Fi6E, 2x2



$$\text{Data Rate} = \frac{234 \times 8_{(256\text{-QAM})} \times (3/4) \times 2}{3.2\mu\text{s} + 0.4\mu\text{s}} = 780 \text{ Mbps}$$

影响Data Rate的参数

$$\text{Data Rate} = \frac{N_{SD} * N_{BPSCS} * R * N_{SS}}{T_{DFT} + T_{GI}}$$

The diagram includes the following labels and their corresponding parameters:

- 子载波数量 (Number of Data Subcarriers) → N_{SD}
- 每流每子载波的编码比特数 (Number of Coded Bits per Subcarrier per Stream) → N_{BPSCS}
- 编码率 (Coding) → R
- 空间流数量 (Number of Spatial Streams) → N_{SS}
- OFDM 符号间隔 (OFDM Symbol Duration) → T_{DFT}
- 信息符号间隔 (GI) (Guard Interval Duration) → T_{GI}

➤ Symbol Duration 符号间隔

HT和VHT的符号间隔为 $3.2\mu\text{s}$ ，HE的符号间隔为 $12.8\mu\text{s}$ 。

➤ Spatial Streams 空间流

MIMO 允许相同的频率空间发送和接收多个数据流。

➤ 调制类型和编码率

这决定了如何通过无线方式发送数据。更新和更复杂的调制方法可以维持高数据速率，但通常需要更少的干扰和良好的接入点视线 Line of Sight (LOS)。相比之下，BPSK 等旧方法可用于保持高错误率链路的连接性。编码率是用于传输可用网络数据的数据流百分比的指示。

➤ Guard Interval 保护间隔

保护间隔 (GI) 实际上是数据包传输之间的一个非常短的暂停，以允许忽略任何错误信息。更长的保护间隔使无线更可靠。该保护间隔对于抵消多径影响是必要的，否则会导致符号间干扰 (ISI)。保护间隔就像在对着扩音器说话的单词之间暂停以克服回声 (声波反射)。传统 802.11a/g 设备使用 800 ns 保护间隔，但 802.11n 设备可以选择暂停 400 ns。较短的保护间隔会导致更多的干扰和提升吞吐量，而较长的保护间隔会导致无线环境中出现不必要的空闲时间。短保护间隔 (SGI) 将数据速率提高了 11%(HT/VHT)，同时保持了对大多数环境来说足够的符号分离。

➤ Channel Width 信道宽度

子载波数量

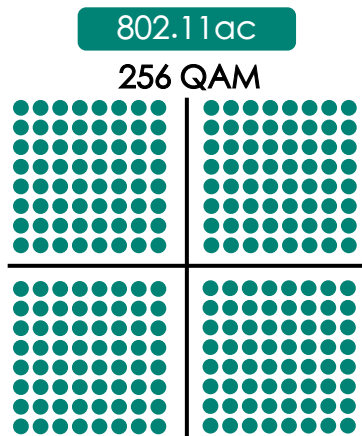
这是无线链路使用的信道宽度。通道越宽，数据速率就越高。虽然我们总是想拥有 40MHz 频道，但在使用 2.4GHz Wi-Fi 时无法部署的，因为只有 3 个非重叠的 20MHz 频道可用。此外，在 RF 干扰常见的挑战性环境中更难维持更宽的频道。

如何理解VHT到HE的“Modulation”和“Symbol Duration”的变化？

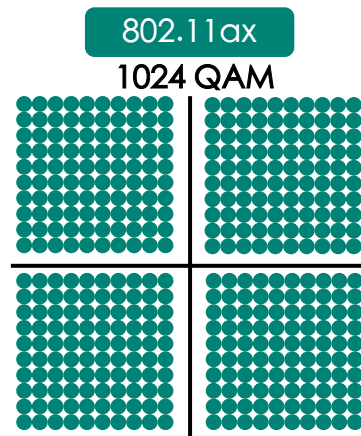
1024 QAM supported, 10 bits per symbol, **25%** higher capacity

New MCS data rate:

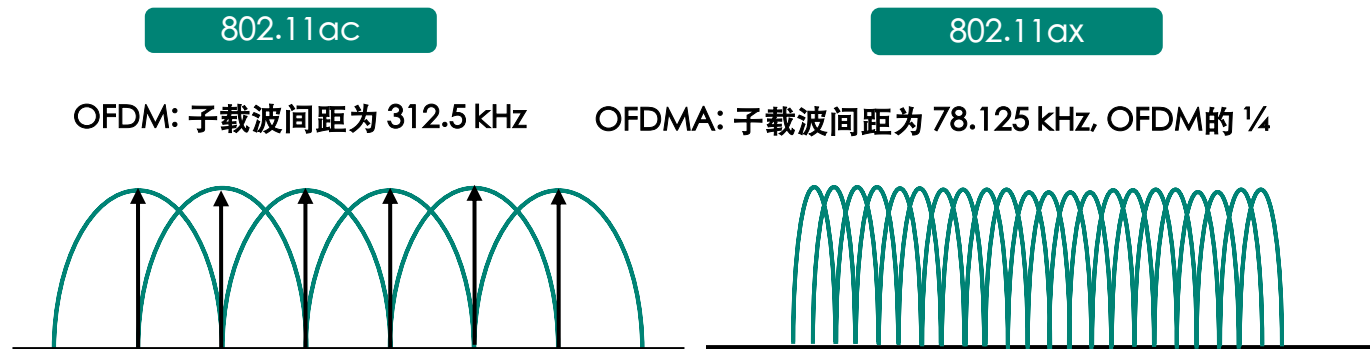
- MCS 10 (1024QAM with 3/4 code rate)
- MCS 11 (1024QAM with 5/6 code rate)



256 = 2的8次方



1024 = 2的10次方



子载波间距减少4倍，携带数据量增加**4倍**

如何判断终端可获取的无线速率范围？

- (1) 确定无线AP支持和开启的射频参数，包括频宽(20/40/80/160MHz)、无线协议(802.11n/ac/ax)
- (2) 了解终端支持的空间流数量、支持的无线协议
 - 通过终端彩页了解相关型号设备的无线射频参数；
 - 通过无线控制器命令了解相关信息 (show ap association)。

```
(Aruba7010) *[mynode] #show ap association

The phy column shows client's operational capabilities for current association

Flags: A: Active, B: Band Steerable, H: Hotspot(802.11u) client, K: 802.11K client, M: Mu beam formee, R: 802.11R client, W: WMM client, w: 802.11w client, V: 802.11v BSS trans capable, P: Punctured preamble, U: HE UL Mu-mimo, O: O
WE client, S: SAE client, E: Enterprise client, m: Agile Multiband client, C: Cellular Data Capable - network available, c: Cellular Data Capable - network unavailable, p: Pending GSM activation, T: Individual TWT client, t: Broad
ast TWT client

PHY Details: HT : High throughput; 20: 20MHz; 40: 40MHz; t: turbo-rates (256-QAM)
VHT : Very High throughput; 80: 80MHz; 160: 160MHz; 80p80: 80MHz + 80MHz
HE : High Efficiency; 80: 80MHz; 160: 160MHz; 80p80: 80MHz + 80MHz
<n>ss: <n> spatial streams

Association Table
-----
Name bssid mac auth assoc aid l-int essid vlan-id tunnel-id phy assoc. time num assoc Flags Band steer moves (T/S) phy_cap
-----
AP-325 ac:a3:1e:57:94:d1 50:a0:09:e9:09:da y y 2 10 mo 99 0x1000b a-HT-40sgi-1ss 50d:18h:17m:21s 1 WAB 0/0 a-HT-40sgi-1ss
AP-225-MPortal 18:64:72:09:14:a0 44:23:7c:4e:71:07 y y 2 10 Momo 88 0x10011 g-HT-20-1ss 61d:4h:38m:1s 1 WA 0/0 g-HT-20-1ss
AP-325 ac:a3:1e:57:94:d1 a4:83:e7:b2:5e:0b y y 1 10 mo 99 0x1000b a-VHT-80sgi-3ss 2h:1m:51s 1 WAB 102/4 a-VHT-80sgi-3ss
AP-225-MPortal 18:64:72:09:14:b3 5c:f9:38:b3:29:fd y y 1 20 mo 99 0x10010 a-HT-40sgi-1ss 61d:5h:34m:35s 1 WAB 0/0 a-HT-40sgi-1ss
AP-325 ac:a3:1e:57:94:d0 e2:98:c1:e5:5f:0b y y 2 20 Momo 88 0x10009 a-VHT-80sgi-2ss 2h:14m:0s 1 WVAB 122/79 a-HE-80-2ss-V
AP-325 ac:a3:1e:57:94:d0 f8:3f:51:c4:ea:3f y y 1 10 Momo 88 0x10009 a-HT-40sgi-2ss 1h:58m:55s 1 WAB 4/0 a-HT-40sgi-2ss
AP-325 ac:a3:1e:57:94:d0 76:b0:42:2f:2d:eb y y 3 10 Momo 88 0x10009 a-VHT-80sgi-2ss 2h:3m:0s 1 WVAB 11/8 a-HE-160-2ss-VM
AP-225-MPoint 94:b4:0f:85:67:d2 78:4f:43:88:24:29 y y 3 10 Momo 88 0x10013 a-VHT-20sgi-3ss 14d:11h:26m:42s 1 WAB 0/0 a-VHT-80sgi-3ss
AP-225-MPoint 94:b4:0f:85:67:c1 18:82:19:fc:13:23 y y 1 2 mo 99 0x10017 g-HT-20sgi-1ss 8d:12h:6m:4s 1 WA 0/0 g-HT-20sgi-1ss
AP-225-MPortal 18:64:72:09:14:b2 24:24:0e:00:12:e1 y y 1 20 Momo 88 0x1000e a-HT-40sgi-2ss 2d:13h:47m:8s 1 WVAB 10/3 a-HT-40sgi-2ss-V
AP-225-MPortal 18:64:72:09:14:a1 ec:41:18:70:af:e5 y y 1 2 mo 99 0x10012 g-HT-20sgi-1ss 4d:4h:30m:3s 1 WVA 0/0 g-HT-20sgi-1ss-KV
AP-225-MPortal 18:64:72:09:14:a0 44:23:7c:84:dc:1a y y 1 10 Momo 88 0x10011 g-HT-20-1ss 2d:5h:37m:48s 1 WA 0/0 g-HT-20-1ss
AP-225-MPoint 94:b4:0f:85:67:d3 f6:a2:0e:35:36:f1 y y 1 20 mo 99 0x10015 a-VHT-20sgi-2ss 1d:3h:15m:17s 1 WVAB 79/55 a-VHT-80sgi-2ss-V
Num Clients:13
Total num of dual-band capable clients:9
Total num of dual-band capable clients in 2.4G band:0
Total num of dual-band capable clients in 5G band:9
Total num of single-band only clients:4
```


示例：

- ❖ AP：Aruba AP-325 (支持11ac，支持4空间流；支持并配置80MHz，配置VHT，)
- ❖ 终端：Samsung S21 Ultra (支持11ax，支持80MHz，支持2空间流)

						OFDM (Prior 11ax)												OFDM (802.11ax)																			
MCS Index			Spatial Stream	Modulation	Coding	20MHz				40MHz				80MHz				160MHz				20MHz				40MHz				80MHz				160MHz			
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	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	0	0	1	BPSK	1/2	6.50	7.20	13.50	15.0	29.30	32.5	58.50	65.00	117.00	130.00	17.20	16.30	14.60	34.40	32.50	29.30	72.10	68.10	61.30	144.10	136.10	122.50										
1	1	1	1	QPSK	1/2	13.00	14.40	27.00	30.0	58.50	65.0	117.00	130.00	17.20	16.30	14.60	34.40	32.50	29.30	72.10	68.10	61.30	144.10	136.10	122.50												
2	2	2	1	QPSK	3/4	19.50	21.70	40.50	45.0	87.80	97.5	175.50	195.00	25.80	24.40	21.90	51.60	48.80	43.90	108.10	102.10	91.90	216.20	204.20	183.80												
3	3	3	1	16-QAM	1/2	26.00	28.90	54.00	60.0	117.00	130.00	234.00	260.00	34.40	32.50	29.30	68.80	65.00	58.50	144.10	136.10	122.50	288.20	272.20	245.00												
4	4	4	1	16-QAM	3/4	39.00	43.30	81.00	90.0	175.50	195.00	351.00	390.00	51.60	48.80	43.90	103.20	97.50	87.80	216.20	204.20	183.80	432.40	408.30	367.50												
5	5	5	1	64-QAM	2/3	52.00	57.80	108.00	120.0	234.00	260.00	468.00	520.00	68.80	65.00	58.50	137.60	130.00	117.00	288.20	272.20	245.00	576.50	544.40	490.00												
6	6	6	1	64-QAM	3/4	78.00	86.70	162.00	180.0	351.00	390.00	702.00	780.00	103.20	97.50	87.80	206.50	195.00	175.50	432.40	408.30	367.50	864.70	816.70	735.00												
7	7	7	1	64-QAM	5/6	104.00	115.60	216.00	240.0	468.00	520.00	936.00	1040.00	137.60	130.00	117.00	275.30	260.00	234.00	576.50	544.40	490.00	1152.90	1088.90	980.00												
8	8	8	1	256-QAM	3/4	156.00	173.30	324.00	360.0	702.00	780.00	1404.00	1560.00	206.50	195.00	175.50	412.90	390.00	351.00	864.70	816.70	735.00	1729.40	1633.30	1470.00												
9	9	9	1	256-QAM	5/6	N/A	N/A	360.00	400.0	780.00	866.7	1560.00	1733.30	229.40	216.70	195.00	458.80	433.30	390.00	960.80	907.40	816.70	1921.60	1814.80	1633.30												
		10	1	1024-QAM	3/4									258.10	243.80	219.40	516.20	487.50	438.80	1080.90	1020.80	918.80	2161.80	2041.70	1837.50												
		11	1	1024-QAM	5/6									286.80	270.80	243.80	573.50	541.70	487.50	1201.00	1134.30	1020.80	2402.00	2268.50	2041.70												
16	0	0	3	BPSK	1/2	19.50	21.70	40.50	45.00	87.80	97.5	175.50	195.00	25.80	24.40	21.90	51.60	48.80	43.90	108.10	102.10	91.90	216.20	204.20	183.80												
17	1	1	3	QPSK	1/2	39.00	43.30	81.00	90.00	175.50	195.00	351.00	390.00	51.60	48.80	43.90	103.20	97.50	87.80	216.20	204.20	183.80	432.40	408.30	367.50												
18	2	2	3	QPSK	3/4	58.50	65.00	121.50	135.00	263.30	292.5	526.50	585.00	77.40	73.10	65.80	154.90	146.30	131.60	324.30	306.30	275.60	648.50	612.50	551.30												
19	3	3	3	16-QAM	1/2	78.00	86.70	162.00	180.00	351.00	390.00	702.00	780.00	103.20	97.50	87.80	206.50	195.00	175.50	432.40	408.30	367.50	864.70	816.70	735.00												
20	4	4	3	16-QAM	3/4	117.00	130.00	243.00	270.00	526.50	585.00	1053.00	1170.00	154.90	146.30	131.60	309.70	292.50	263.30	648.50	612.50	551.30	1297.10	1225.00	1102.50												
21	5	5	3	64-QAM	2/3	156.00	173.30	324.00	360.00	702.00	780.00	1404.00	1560.00	206.50	195.00	175.50	412.90	390.00	351.00	864.70	816.70	735.00	1729.40	1633.30	1470.00												
22	6	6	3	64-QAM	3/4	234.00	260.00	504.00	540.00	1053.00	1170.00	2106.00	2340.00	309.70	292.50	263.30	619.40	585.00	526.50	1297.10	1225.00	1102.50	2594.10	2450.00	2205.00												
23	7	7	3	64-QAM	5/6	351.00	390.00	756.00	810.00	1579.50	1755.00	3459.00	3915.00	518.40	495.00	445.50	1077.00	1012.50	913.50	2161.80	2041.70	1837.50	4323.60	4083.50	3675.00												
	8	8	3	256-QAM	3/4	516.00	567.00	1116.00	1224.00	2433.00	2670.00	5266.00	5850.00	774.00	731.00	658.00	1647.00	1560.00	1407.00	3459.00	3244.50	2925.00	7028.10	6633.00	5985.00												
	9	9	3	256-QAM	5/6	774.00	850.50	1674.00	1810.00	3651.00	4005.00	8012.00	8925.00	1171.00	1117.50	987.00	2470.50	2325.00	2080.50	5184.00	4912.50	4417.50	11042.40	10417.50	9375.00												
		10	3	1024-QAM	3/4									387.10	365.60	329.10	774.30	731.30	658.10	1621.30	1531.30	1378.10	3242.60	3062.50	2756.30												
		11	3	1024-QAM	5/6									430.10	406.30	365.60	860.30	812.50	731.30	1801.50	1701.40	1531.30	3602.90	3402.80	3062.50												
24	0	0	4	BPSK	1/2	26.00	28.90	54.00	60.00	117.00	130.00	234.00	260.00	34.40	32.50	29.30	68.80	65.00	58.50	144.10	136.10	122.50	288.20	272.20	245.00												
25	1	1	4	QPSK	1/2	52.00	57.80	108.00	120.00	234.00	260.00	468.00	520.00	68.80	65.00	58.50	137.60	130.00	117.00	288.20	272.20	245.00	576.50	544.40	490.00												
26	2	2	4	QPSK	3/4	78.00	86.70	162.00	180.00	351.00	390.00	702.00	780.00	103.20	97.50	87.80	206.50	195.00	175.50	432.40	408.30	367.50	864.70	816.70	735.00												
27	3	3	4	16-QAM	1/2	104.00	115.60	216.00	240.00	468.00	520.00	936.00	1040.00	137.60	130.00	117.00	275.30	260.00	234.00	576.50	544.40	490.00	1152.90	1088.90	980.00												
28	4	4	4	16-QAM	3/4	156.00	173.30	324.00	360.00	702.00	780.00	1404.00	1560.00	206.50	195.00	175.50	412.90	390.00	351.00	864.70	816.70	735.00	1729.40	1633.30	1470.00												
29	5	5	4	64-QAM	2/3	208.00	231.10	432.00	480.00	936.00	1040.00	1872.00	2080.00	275.30	260.00	234.00	550.60	520.00	468.00	1152.90	1088.90	980.00	2305.90	2177.80	1960.00												
30	6	6	4	64-QAM	3/4	312.00	346.60	648.00	720.00	1404.00	1560.00	2808.00	3120.00	409.50	390.00	351.00	869.40	816.70	735.00	1729.40	1633.30	1470.00	4243.60	4008.30	3675.00												
31	7	7	4	64-QAM	5/6	468.00	513.90	972.00	1080.00	2106.00	2340.00	4612.00	5130.00	614.25	585.00	526.50	1304.10	1225.00	1102.50	2594.10	2450.00	2205.00	6365.40	6028.20	5475.00												

Aruba 802.11ax 无线网络部署建议

Aruba Recommendations for AP Placements

AP placement recommendations for an enterprise network, which needs to support high-performing 802.11ax network along with real-time voice and video applications, are as follows:

- Distance between two APs should be approximately 40 to 60 feet. **AP 间隔12米-18米**
- Minimum RSSI should be -55 dBm throughout the coverage area. **覆盖区域保证最少-55 dBm RSSI**

The reason behind choosing RSSI to be -55 is that it could reliably provide MCS11 on 40 MHz for most high density deployments. The minimum receive sensitivity for HE MCS11 rates are:

- a. HE20: -60 dBm
- b. HE40: -57 dBm
- c. HE80: -54 dBm
- d. HE160: -51 dBm

获得HE MCS11对应各种频宽设置下的RSSI要求

- SNR should be at least 35dB to achieve the highest 1024-QAM rates (MCS10 – 11). **SNR 最少35dB以获得1024-QAM**

查看各无线传输速率的比例情况

第一步，先清除计数器

```
(Aruba7010) *[mynode] #clear ap debug radio-stats ap-name AP-325 radio 0
```

```
(Aruba7010) *[mynode] #clear ap debug client-stats client-mac a4:83:e7:b2:5e:0b
```

第二步，检查ap和client的无线传输速率使用情况

```
(Aruba7010) *[mynode] #show ap debug radio-stats ap-name AP-325 radio 0
```

```
Tx Data Priority [BK]          8
Tx Data Priority [BE]         746
Tx Data Priority [VI]        1014
Tx Data Priority [VO]        1416
Tx Data Frames 12 Mbps (Mon) 1682
Tx Data Frames 24 Mbps (Mon) 291
Tx Data Frames 36 Mbps (Mon) 0
Tx Data Frames 54 Mbps (Mon) 0
Tx Data Frames 72 Mbps (Mon) 0
Tx Data Frames 108 Mbps (Mon) 0
Tx Data Frames 300 Mbps (Mon) 12
Tx Data Frames 450 Mbps (Mon) 8
Tx Data Frames 1300 Mbps (Mon) 2054
Tx Data Frames 1300 Mbps+ (Mon) 0
Tx Data Bytes 12 Mbps (Mon) 172203
Tx Data Bytes 24 Mbps (Mon) 81758
Tx Data Bytes 36 Mbps (Mon) 0
Tx Data Bytes 54 Mbps (Mon) 0
Tx Data Bytes 72 Mbps (Mon) 0
Tx Data Bytes 108 Mbps (Mon) 0
Tx Data Bytes 300 Mbps (Mon) 1260
Tx Data Bytes 450 Mbps (Mon) 2110
Tx Data Bytes 1300 Mbps (Mon) 2703783
Tx Data Bytes 1300 Mbps+ (Mon) 0
Tx HT 6.5 Mbps                1682
Tx HT 162 Mbps                10
Tx HT 216 Mbps                2
Tx VHT 433.3 Mbps             8
Tx VHT 468 Mbps               470
Tx VHT 526.5 Mbps             939
Tx VHT 585 Mbps               13
Tx VHT 650 Mbps               9
Tx VHT 702 Mbps               592
Tx VHT 877.5 Mbps             30
Tx VHT 975 Mbps               1
```

```
(Aruba7010) *[mynode] #show ap debug client-stats client-mac a4:83:e7:b2:5e:0b
```

```
Tx Data Priority [BE]          165
Tx Data Priority [VI]         813
Tx Data Priority [VO]          1
Tx Data Frames 12 Mbps (Mon) 0
Tx Data Frames 24 Mbps (Mon) 0
Tx Data Frames 36 Mbps (Mon) 0
Tx Data Frames 54 Mbps (Mon) 0
Tx Data Frames 72 Mbps (Mon) 0
Tx Data Frames 108 Mbps (Mon) 0
Tx Data Frames 300 Mbps (Mon) 0
Tx Data Frames 450 Mbps (Mon) 0
Tx Data Frames 1300 Mbps (Mon) 1709
Tx Data Frames 1300 Mbps+ (Mon) 0
Tx Data Bytes 12 Mbps (Mon) 0
Tx Data Bytes 24 Mbps (Mon) 0
Tx Data Bytes 36 Mbps (Mon) 0
Tx Data Bytes 54 Mbps (Mon) 0
Tx Data Bytes 72 Mbps (Mon) 0
Tx Data Bytes 108 Mbps (Mon) 0
Tx Data Bytes 300 Mbps (Mon) 0
Tx Data Bytes 450 Mbps (Mon) 0
Tx Data Bytes 1300 Mbps (Mon) 2525735
Tx Data Bytes 1300 Mbps+ (Mon) 0
Tx VHT 468 Mbps               399
Tx VHT 526.5 Mbps             883
Tx VHT 585 Mbps               13
Tx VHT 650 Mbps               9
Tx VHT 702 Mbps               381
Tx VHT 877.5 Mbps             23
Tx VHT 975 Mbps               1
```

The Aruba logo consists of the word "aruba" in a lowercase, bold, orange sans-serif font. The letters are closely spaced, and the 'a' and 'u' have a distinctive shape with a small gap at the top.

a Hewlett Packard
Enterprise company

The text "Thank you" is written in a large, bold, orange sans-serif font. It is centered horizontally and positioned in the middle of the slide. The background behind the text is a light blue grid of dots that fades out towards the edges of the slide.