



Module-2
WLAN Physical Layer
Session-2c

MCS Table / PHY Data Rates and Throughput

# Last Session Recap.....



Module-2
WLAN Physical Layer
Session-2b
Modulation/Coding, MIMO Basics

- ✓ PSK, QAM Modulations
- ✓ Throughput/Reliability Tradeoff
- ✓Tx Power, RSSI, EVM, SNR
- ✓ Coding Techniques
- ✓OFDM, Multipath, MIMO

## **Advertised Speeds**





## Wi-Fi Data Rates across generations



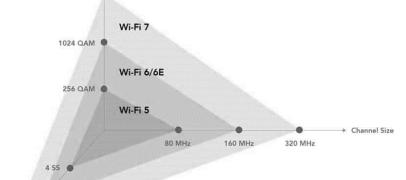
	x 1	1.5 x	1.3 x 4	4.8
	Wi-Fi 4	Wi-Fi 5	Wi-Fi 6/6E	Wi-Fi 7
Standard	802.11n	802.11ac	802.11ax	802.11be
Max Speed with 1 Spatial Stream	150 Mbps	866.7 Mbps	1.2 Gbps	2.9 Gbps
Max Speed with 2 Spatial Streams	300 Mbps	1.73 Gbps	2.5 Gbps	5.8 Gbps
Max Speed with Max # Spatial Streams	600 Mbps	6.92 Gbps	9.6 Gbps	46.4 Gbps



Wi-Fi	generations	
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V	• ]	•	E

Generation	IEEE standard	Adopted	Maximum link rate (Mbit/s)	Radio frequency (GHz)
Wi-Fi 7	802.11be	(2024)	1376 to 46120	2.4/5/6
Wi-Fi 6E	000 44 04	2020	574 to 9608 <sup>[1]</sup>	6 <sup>[a]</sup>
Wi-Fi 6	802.11ax	2019	574 (0 960813	2.4/5
Wi-Fi 5	802.11ac	2014	433 to 6933	5 <sup>[b]</sup>
Wi-Fi 4	802.11n	2008	72 to 600	2.4/5
(IA/i Ei 2\*	802.11g	2003	C to E4	2.4
(Wi-Fi 3)*	802.11a	1999	6 to 54	5
(Wi-Fi 2)*	802.11b	1999	1 to 11	2.4
(Wi-Fi 1)*	802.11	1997	1 to 2	2.4
*Wi-Fi 1, 2, a	and 3 are by	retroactive	inference [2][3][4]	[5][6]



Modulation

4096 QAM @

16 SS @

Number of Spatial Streams

## What is an MCS Table?



MCS Table is used to calculate/list the possible PHY dates for the various Wi-Fi Standards

Modulation Rate	Coding Rate	Number of Spatial Streams	Channel Bandwidth	Guard Interval
BPSK	1/2	1x1	20 MHz	800 ns
QPSK	3/4	2x2	40 MHz	1600 ns
16QAM	5/6	4x4	80 MHz	3200 ns
64QAM		8x8	160 MHz	
256QAM		16x16	320 MHz	
1024QAM				
4096QAM				

#### **Modulation Rate**

Number of bits that can be carried on a symbol

## **Coding Rate** Rate of

data/redundant bits transferred for Forward Error Correction

## Number of **Spatial Streams** Number of MIMO

#### **Channel BW** The width of the frequency BW radios chains used for single Tx/Rx

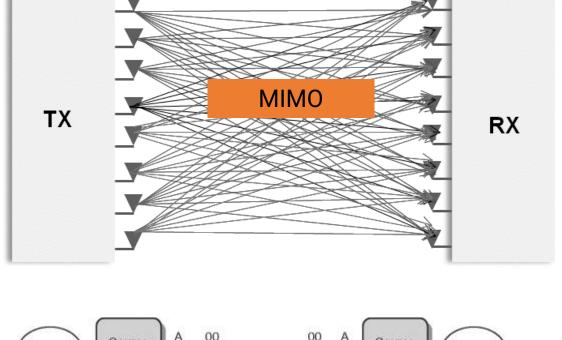
#### **Guard Interval**

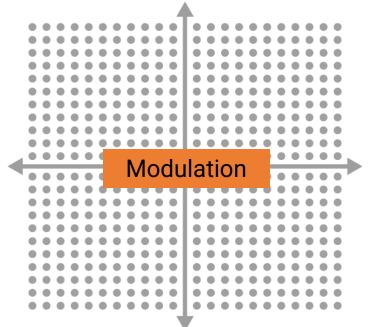
Waiting time between each packet transmission. The smaller the guard interval, the faster the throughput

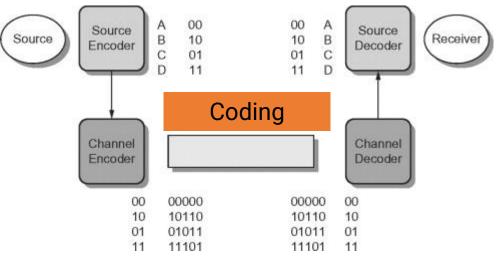
## **Data Rate Parameters**









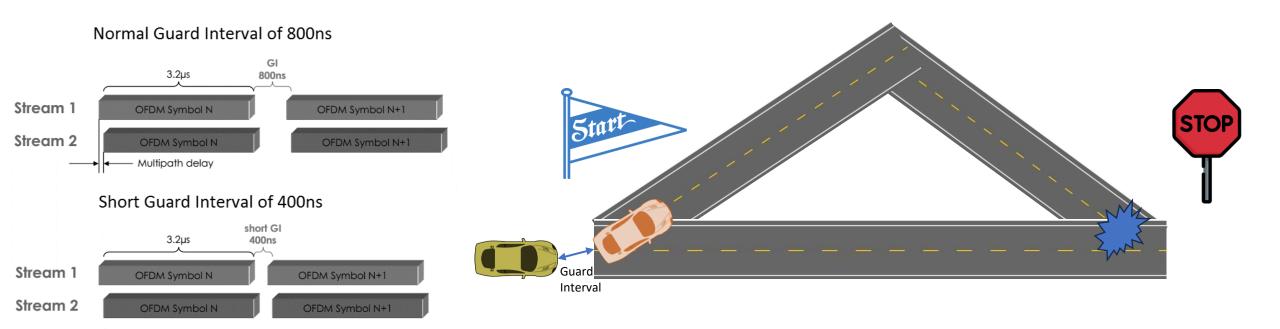


## **Guard Interval**



**Guard intervals** are used to ensure that distinct transmissions do not interfere with one another, or otherwise cause overlapping transmissions. These transmissions may belong to different users (as in TDMA) or to the same user (as in OFDM).

In OFDM, the beginning of each symbol is preceded by a guard interval. As long as the echoes fall within this interval, they will not affect the receiver's ability to safely decode the actual data, as data is only interpreted outside the guard interval.



# 802.11a/b/g MCS Rates



	Data rate (Mbps)	Encoding		-	Bits encoded		dulation
DSSS	1	Barker coding	11		1	DB	PSK
DSSS	2	Barker			1	DQ	PSK
		coding		Bas	se 802.1	1	

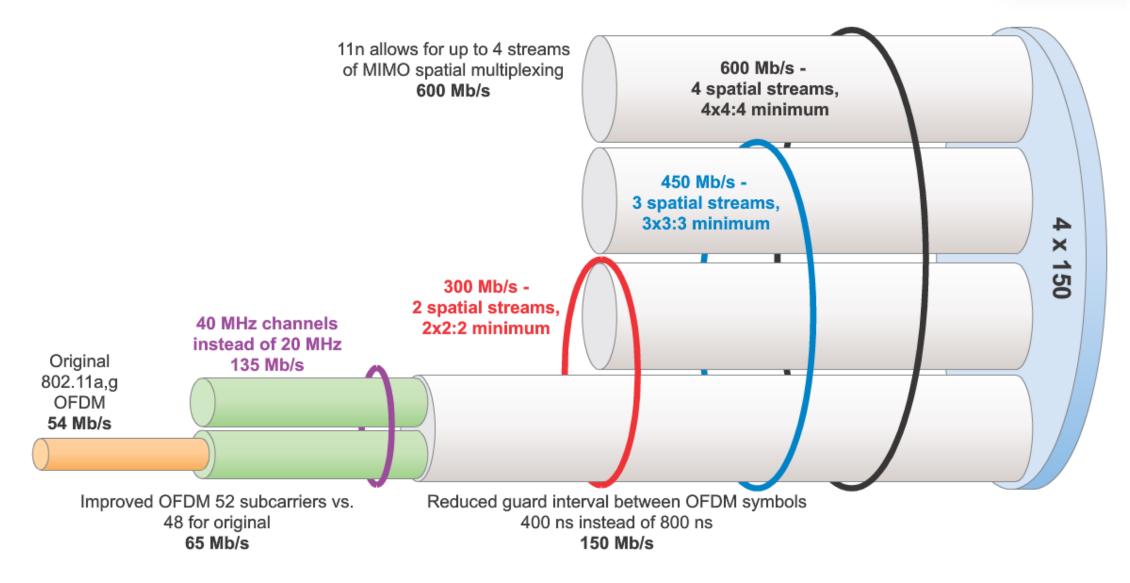
	Data rate (Mbps)	Encoding	_	Bits encoded	Modulation
DSSS	1	Barker coding	11	1	DBPSK
DSSS	2	Barker coding	11	1	DQPSK
HR- DSSS	5.5	CCK coding	8	4	DQPSK
HR- DSSS	11	CCK coding	8	8	DQPSK
			8	02.11b	

Data rates (Mbps)	Modulation method	Coded bits per subcarrier	bits per OFDM	Coded bits per OFDM symbol	Coding rate (data bits/ coded bits)
6	BPSK	1	24	48	1/2
9	BPSK	1	36	48	3/4
12	QPSK	2	48	96	1/2
18	QPSK	2	72	96	3/4
24	16-QAM	4	96	192	1/2
36	16-QAM	4	144	192	3/4
48	64-QAM	6	192	288	2/3
54	64-QAM	6	216	288	3/4

802.11a/g

## 802.11n(Wi-Fi4) Data Rates





# 802.11n(Wi-Fi4) MCS Table



				Data rate (Mbit/s)				
MCS	•	Modulation	_	20 MHz	channel		channel	
index	streams	type	rate			800 ns Gl		
0	1	BPSK	1/2	6.50	7.20	13.50	15.00	
1	1	QPSK	1/2	13.00	14.40	27.00	30.00	
2	1	QPSK	3/4	19.50	21.70	40.50	45.00	
3	1	16-QAM	1/2	26.00	28.90	54.00	60.00	
4	1	16-QAM	3/4	39.00	43.30	81.00	90.00	
5	1	64-QAM	2/3	52.00	57.80	108.00	120.00	
6	1	64-QAM	3/4	58.50	65.00	121.50	135.00	
7	1	64-QAM	5/6	65.00	72.20	135.00	150.00	
8	2	BPSK	1/2	13.00	14.40	27.00	30.00	
9	2	QPSK	1/2	26.00	28.90	54.00	60.00	
10	2	QPSK	3/4	39.00	43.30	81.00	90.00	
11	2	16-QAM	1/2	52.00	57.80	108.00	120.00	
12	2	16-QAM	3/4	78.00	86.70	162.00	180.00	
13	2	64-QAM	2/3	104.00	115.60	216.00	240.00	
14	2	64-QAM	3/4	117.00	130.00	243.00	270.00	
15	2	64-QAM	5/6	130.00	144.40	270.00	300.00	

				Data rate (Mbit/s)				
MCS	Spatial streams	Modulation type	rate	20 MHz	channel	40 MHz	channel	
IIIGCA	3ti cums	type	ruto	800 ns Gl	400 ns Gl	800 ns Gl	400 ns GI	
16	3	BPSK	1/2	19.50	21.70	40.50	45.00	
17	3	QPSK	1/2	39.00	43.30	81.00	90.00	
18	3	QPSK	3/4	58.50	65.00	121.50	135.00	
19	3	16-QAM	1/2	78.00	86.70	162.00	180.00	
20	3	16-QAM	3/4	117.00	130.70	243.00	270.00	
21	3	64-QAM	2/3	156.00	173.30	324.00	360.00	
22	3	64-QAM	3/4	175.50	195.00	364.50	405.00	
23	3	64-QAM	5/6	195.00	216.70	405.00	450.00	
24	4	BPSK	1/2	26.00	28.80	54.00	60.00	
25	4	QPSK	1/2	52.00	57.60	108.00	120.00	
26	4	QPSK	3/4	78.00	86.80	162.00	180.00	
27	4	16-QAM	1/2	104.00	115.60	216.00	240.00	
28	4	16-QAM	3/4	156.00	173.20	324.00	360.00	
29	4	64-QAM	2/3	208.00	231.20	432.00	480.00	
30	4	64-QAM	3/4	234.00	260.00	486.00	540.00	
31	4	64-QAM	5/6	260.00	288.80	540.00	600.00	

## 802.11ac(Wi-Fi5) MCS Table



- 80 MHz and 160 MHz channel bandwidths
- Support for up to 8 spatial streams
- Multi User MIMO
- 256-QAM Modulation, rate 3/4 and 5/6, added as optional modes
- Coexistence mechanisms for 20/40/80/160 MHz channels, 11ac and 11a/n devices

#### Example 802.11ac configurations (all rates assume 256-QAM, rate 5/6)

Scenario	Typical Client Form Factor	PHY Link Rate	Aggregate Capacity
1-antenna AP, 1-antenna STA, 80MHz	Handheld	433 Mbit/s	433 Mbit/s
2-antenna AP, 2-antenna STA, 80MHz	Tablet, Laptop	867 Mbit/s	867 Mbit/s
1-antenna AP, 1-antenna STA, 160MHz	Handheld	867 Mbit/s	867 Mbit/s
2-antenna AP, 2-antenna STA, 160MHz	Tablet, Laptop	1.73 Gbit/s	1.73 Gbit/s
4-antenna AP, 4 1-antenna STAs, 160MHz (MU-MIMO)	Handheld	867 Mbit/s to each STA	3.47 Gbit/s
8-antenna AP, 160MHz (MU-MIMO) 1 4-antenna STA 1 2-antenna STA 2 1-antenna STAs	Digital TV, Set-top Box, Tablet, Laptop, PC, Handheld	3.47 Gbit/s to 4-antenna STA 1.73 Gbit/s to 2-antenna STA 867 Mbit/s to each 1-antenna STA	6.93 Gbit/s
8-antenna AP, 4 2-antenna STAs, 160MHz (MU-MIMO)	Digital TV, Tablet, Laptop, PC	1.73 Gbit/s to each STA	6.93 Gbit/s

Source: Wikipedia

# 802.11ac (Wi-Fi5) Configurations



Channel bandwidth	Transmit – Receive antennas	Modulation and coding etc.	Typical client scenario	Throughput (individual link rate)	Throughput (aggregate link rate)
80 MHz	1x1	256-QAM 5/6, short guard interval	Smartphone	433 Mbps	433 Mbps
80 MHz	2x2	256-QAM 5/6, short guard interval	Tablet, PC	867 Mbps	867 Mbps
160 MHz	1x1	256-QAM 5/6, short guard interval	Smartphone	867 Mbps	867 Mbps
160 MHz	2x2	256-QAM 5/6, short guard interval	Tablet, PC	1.73 Gbps	1.73 Gbps
160 MHz	4x Tx AP, 4 clients of 1x Rx	256-QAM 5/6, short guard interval	Multiple smartphones	867 Mbps per client	3.47 Gbps
160 MHz	8x Tx AP, 4 clients with to- tal of 8x Rx (with multi-user MIMO)	256-QAM 5/6, short guard interval	Digital TV, set-top box, tablet, PC, smartphone	867 Mbps to two 1x clients 1.73 Gbps to one 2x client 3.47 Gbps to one 4x client	6.93 Gbps
160 MHz	8x Tx AP, 4 clients of 2x Rx (with multi-user MIMO)	256-QAM 5/6, short guard interval	Multiple set-top boxes, PC	1.73 Gbps to each client	6.93 Gbps

MCS		ntes Mbps nnnel, 1x SS)	Channel width	Spatial streams		ates Mbps annel, 8x SS)
	Long GI	Short GI			Long GI	Short GI
0	6.5	7.2		x2 for 2 SS	468.0	520.0
1	13.0	14.4		x3 for 3 SS	939.0	1040.0
2	19.5	21.7			1404.0	1560.0
3	26.0	28.9	x2.1 for 40 MHz	x4 for 4 SS	1872.0	2080.0
4	39.0	43.3		x5 for 5 SS	2808.0	3120.0
5	52.0	57.8	x4.5 for 80 MHz	x6 for 6 SS	3744.0	4160.0
6	58.5	65.0	x9.0 for 160 MHz		4212.0	4680.0
7	65.0	72.2		x7 for 7 SS	4680.0	5200.0
8	78.0	86.7		x8 for 8 SS	5616.0	6240.0
9	(86.7)	(96.3)			6240.0	6933.3

# 802.11ax(Wi-Fi6 Data Rates)



#### Modulation and coding schemes for single spatial stream

						Data rate (in Mbit/s) <sup>[b]</sup>									
MCS index <sup>[a]</sup>	Modulation type	Coding	20 MHz ch	nannels	40 MHz c	hannels	80 MHz c	hannels	160 MHz channels						
illuex	type	rate	1600 ns GI <sup>[c]</sup>	800 ns GI	1600 ns GI	800 ns GI	1600 ns GI	800 ns GI	1600 ns GI	800 ns GI					
0	BPSK	1/2	8	8.6	16	17.2	34	36.0	68	72					
1	QPSK	1/2	16	17.2	33	34.4	68	72.1	136	144					
2	QPSK	3/4	24	25.8	49	51.6	102	108.1	204	216					
3	16-QAM	1/2	33	34.4	65	68.8	136	144.1	272	282					
4	16-QAM	3/4	49	51.6	98	103.2	204	216.2	408	432					
5	64-QAM	2/3	65	68.8	130	137.6	272	288.2	544	576					
6	64-QAM	3/4	73	77.4	146	154.9	306	324.4	613	649					
7	64-QAM	5/6	81	86.0	163	172.1	340	360.3	681	721					
8	256-QAM	3/4	98	103.2	195	206.5	408	432.4	817	865					
9	256-QAM	5/6	108	114.7	217	229.4	453	480.4	907	961					
10	1024-QAM	3/4	122	129.0	244	258.1	510	540.4	1021	1081					
11	1024-QAM	5/6	135	143.4	271	286.8	567	600.5	1134	1201					

#### Notes

- a. ^ MCS 9 is not applicable to all channel width/spatial stream combinations.
- b. A second stream doubles the theoretical data rate, a third one triples it, etc.
- c. A GI stands for the guard interval.

# 802.11be (Wi-Fi7) Data Rates



									Data rate	e (Mbit/s) <sup>[</sup>	i]						
MCS	Modulation	Coding	20 N	1Hz chann	iels	40 N	MHz chanr	iels	80 MH	lz channe	ls	160 M	Hz chann	els	320 M	Hz chann	els
index <sup>[i]</sup>	type	rate	3200 ns Gl <sup>[iii]</sup>	1600 ns GI	800 ns GI	3200 ns GI	1600 ns GI	800 ns Gl	3200 ns GI	1600 ns Gl	800 ns GI	3200 ns GI	1600 ns GI	800 ns Gl	3200 ns GI	1600 ns GI	800 ns GI
0	BPSK	1/2	7	8	9	15	16	17	31	34	36	61	68	72	123	136	144
1	QPSK	1/2	15	16	17	29	33	34	61	68	72	122	136	144	245	272	288
2	QPSK	3/4	22	24	26	44	49	52	92	102	108	184	204	216	368	408	432
3	16-QAM	1/2	29	33	34	59	65	69	123	136	144	245	272	282	490	544	577
4	16-QAM	3/4	44	49	52	88	98	103	184	204	216	368	408	432	735	817	865
5	64-QAM	2/3	59	65	69	117	130	138	245	272	288	490	544	576	980	1089	1153
6	64-QAM	3/4	66	73	77	132	146	155	276	306	324	551	613	649	1103	1225	1297
7	64-QAM	5/6	73	81	86	146	163	172	306	340	360	613	681	721	1225	1361	1441
8	256-QAM	3/4	88	98	103	176	195	207	368	408	432	735	817	865	1470	1633	1729
9	256-QAM	5/6	98	108	115	195	217	229	408	453	480	817	907	961	1633	1815	1922
10	1024-QAM	3/4	110	122	129	219	244	258	459	510	540	919	1021	1081	1838	2042	2162
11	1024-QAM	5/6	122	135	143	244	271	287	510	567	600	1021	1134	1201	2042	2269	2402
12	4096-QAM	3/4	131	146	155	263	293	310	551	613	649	1103	1225	1297	2205	2450	2594
13	4096-QAM	5/6	146	163	172	293	325	344	613	681	721	1225	1361	1441	2450	2722	2882

## Full MCS Table



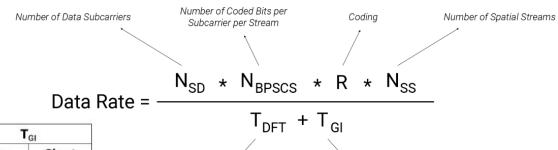
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https://semfionetworks.com/blog/mcs-table-updated-with-80211ax-data-rates/

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HE THE		-	Coding							She S	14a (t	State Of	She II	1 Special	1500		Size D	1500		Hilph III	State III	1840	Black.	-	1440	Elpa III	Billion DI	Marie 1	in the state	1 1 April	B Black	1840		Adjust 10	Adjust 10	State Di	Não B	1440	50 B	See St.
	* 1	SPEC	1/2	10.0	7.5	19.8	19.0	29.3	10:1 65:0	247.0	195.0	114	10.7	73	172	16.7	76.6	70.7	94.0	30-8 81-8	79.1	100.7	95.3	8.0	00.00	2.5	3.8	107	1.0 A	A.	88.	9.0	47	73	17.2	16.3	38.6	me	34.5	10.4
1 2	2 1	OPSK.	310	18.9	20.7	40.5	mid	878	925	179.5	195.0	25.6	344	21.8	11A	48.8	41.9	1061	1001	91.9	216.2	204.2	100.0	28	2.5	2.9	12	50	48 11	1 104	9.0	20.8	364	25.N	51 A	48.8	40.5	108.1	100.1	90.6
		THI GAME	34	26.0	40.0	91.0	ma .	175.6	190.0	234.0	196.0	20.6	50.5 40.6	40.0	100.0	60.5	100 E	216.2	2942	100.0	400.4	279.2	240.0	33	3.8	30	75	10.0	8.0 15 9.0 20			964	HEE.	29.0	199.2	10.0	98.8	1961		1006
		844,5444	0.0	10.0	618	708.0	7,00.0	2369	260.0	448.0	508.6	188.	460	10.0	190.4	190.0	9000	396.7	2012	2466	876.6	204.0	466.0	21	4.7	8.0	361	94	118 10		46.8	10.0	86.00	10.0	1974	196.0	111.6	per à	ITEE	sec.
* *	2 3	90/5/M	34	10.0	66.E	101.8 195.0	1968	20.1	290.1 205.0	124.1 195.1	195.0	TT #	FD.1	ALE.	1949	146.3	191.6	30x3	300.3	275.6	700.0	912.E	101 A	7.8	7.6	68	10.9	THE .	100 00	21.0	28.7	27.6	781	95.8	154.R	146.3	195.A	1013	906.2	EPR. II
		250-0466	308	760	96.7	190.0	790.0	MILE	340.0	790.0	796.0	106.2	67.5	87.6	206.5	190.0	1053	40.4	406.7	367.5	964.7	99.7	7968	10.6	16.0	188	31.2	26.0	160 45	40	38.3	1012	67.9	87.0	304.6	1960	175.6	AULA	406.9	MOS
	2 1	218-QAM 100H-QAM	34	No.	No.	186.0	384	346.0	400.0	790.0	968.7	1167	106.2	1067	2016	200.7	195.0	100.4	100.6	406.0	960.8	100.4	89.7	11,8	113	16.6	78.8	213	PER M	413	46.5	3987	100.0	97.6	209.8	29.7	775.6	245.4	#80.7 715.4	406.0
	31 1	THE GAME	3/6									146.4	130.4	191.0	386.0	276.8	265.9	mint	867.7	SHEA!	1001.0	TORK	100.0	367	199	78.6	20.4	20.0	FEE 44	0.000	1000	1664	1964	1019	384.8	179.8	366.4	ARRS .	9677	200 A
		BPSG GPSA	107	10.0	14.6	27.0	26.0 16.0	VIEW	1900	717.0 This	1984	1012	16.2	140	16.6	90.9	26.2	160	136.7	113	164.5	1061	THER	14	125	28.00	3800	83	40 10	71	CONT.	112	14.3	14.8	36.6	10.9	29.3	THE R. L.	THE P	AALB
10 2		DPSK	394	26.0	98.0 40.0 67.6 96.7 715.6	81.8	-968	1755	795.0	267.6	390.0	21.6	46.6	40.0	101.2	17.5	47.8	296.3	204.2	160.0	400.4	408.3	para	3.0	5.0	4.5	18.6	MACO	98 22		93	MA.	468	40.9	389.2	47.5	40.6	276.2	2042	1800
10 4		10-04M	10	50.6 79.0	67.0	768.0	1968	294.0	2400 2600	MAR. 790.0	509.0 796.0	100.7	450	98.3 97.6	197,6	199.0	105.6	3963	170.0	345.0	106.5	200.0	700.0	75.5	5.7	4.0	34.1	163	10.0	281	355	96.0	91.0	58.5	107.6	190.5	912.6	200.2	ATTENDED.	145.00 PMT 8
38 X	(A) A	900MM	8/9	1663	715.6.	275.0	1968	ARC:	use	316.0	1968	HITA.	1900	1916	276.0	190.0	294.0	553	546.6	400.00	1766.9	1000.9	100.0	34.5	98	168	38.2	m/C	10.0	100	0.8	100 A	3,186.0	11706	190	200.5	204.95	25.5	546.4	PRO 0
14 (4)	100	SHIGHM	24	117:0	1968	383.0. (196.0	270.0	121.1 191.0	185.0	1176.0	10000	194.9	140.3	1918.	309.7	290.4	2013	MES	81210	9013	1297.1	1201.0	THERE	10.9	16.5	16.6	31.6	ME	278 47	C COL	BEA.	194.9	146.2	191.6	201.7	290.5	2013	885	W12.2	MIT I
	(A) 1	EN-GAM.	3/4	1566	373.0	304.0	3650	790.0	790.0	1404.0	1966	206.7	1000	179.30	WIER	396.0	981.0	9907	896.7	7968	1729.4	7603	5476.8	212	36.6	16.0	45.4	468	ME W	NO DOM	26.8	394.5	766.0	175.8	atta	200.2	101.6	8647	816.7	200/0
	2 1	STO-DAM TOXHQAM	24	No.	NE	366.0	400.0	740.0	964.7	1980.0	1000.0	206.4	296.7	1952	416.5	400.0	2003	960.8	9014	896.7	THEN A	1014.6	5600.5	21.5	22.0	26.0	405	ALC:	400 100	8 944	86.8	200.0	216.7	785.2	100	405.3	200.0	1000	MOT A	816.7°
	23. 1	HORGAM	50									200.0	170.0	2613	175.5	Set 2	mes	1904	11943	1686.6	3400.0	Det	2001.7	28.6	97.8	25.0	98.8	MA	No. 10	E 118	196.3	260.0	276.6	3614	101.5	641.7	MITS.	1001.0	****	1000
16.0	(A)	areq area	1/2	19.3	20.7	415	46.0	176	190.6	175.5. 200.0	105.0	268	26.6	31.9	91.0	44	40.9	1001	1901	100.0	294.2	2543	100.0	24	2.5	85	58	SA	AT 15	E EMA	(88)	200	DAA	CHA	MX	-	10 N	MAX	MEX	41. R
* 2	2 1	DPSK.	10	10.0	61	723.5	3968	262	290.9	106.5	96.0	20.4	79.1	MER.	194.9	146.3	100.6	8083	101.1	275.6	648.5	113.5	801.3	78	:78	44	25.00	168	19.9	31.0	267	20.6	5-74 F	85.E	754.0	146.3	705.K	1043	100.3	ETTLE
10 (10)		10-0466	10	79.0	1900	162.6 263.6	275.0	301.0	940.0	700.0	196.0	1062	40.0	618	106.5	795.0	1068	60.4	AME	MER	964.7	MA.F	THE	15.6	188	78	21.2		16 8 77 67		MIL	766.0	CREAT.	#5.B	206.5	195.0	125.5	ASSA 23	406.0	MATE
	193 9	10-Q466 60-Q466	3/2	1968	175.0	104.0	200.0	796.0	790.0	7404.0	1000.0	106.1	1962	194	412.0	790.0	901.0	968.7	\$16.7	796.0	1798.0	1600.0	hartes	17.2	.004	19.8	15.0	40	27.0 67 96.0 96	-	26.8	100.0	796.0	THE	403.9	200.0	WEA	mer.	816.7	P90.00
20 1		BACKM.	24	175.8	196.E 216.7	3943 MEG	401.0	N/A	16/4. 17/10/2	1079.9:	1796.0	200.3	225.4	197.6	MAKE	406.0	200.9	WEEK .	916.0	ROLE	TRACE	MATE	NAME OF TAXABLE PARTY.	20.8	22.5	20.0	ATR	MA	403 101	E 1964	CHAN	2023	228.8	190A	MAR	498.8	206,9	NO.	PIER	626 S
		SHIPM SHIPM	34	7968	2800	ent.	1966	1000-0	11768	2106.0	2340.0	104.7	PRES	Spax	100.4	185.0	SSS :	33003	YES .	1790.0	2594.1	2666.6	- 2300.6	20.0	90.0	276	10.7	MARK IN	ME TH	a 107	200	89.7	THE	DESCRIPTION	Carles	96.0	DAX -	Special Inc.	SERVICE STREET	1160.0
	29. 0	255-0,000	84	340.0	386.6	346.6	000.0	1176.0	1864	No.	N/A	346.1	200.0	PRES	188.2	100.0	565.0	5400.0	1000	10264	3888.A	200.2	2496.0	3630	00.0	98	MA	947	868 18	561	MAKE	200.7	NAME OF TAXABLE PARTY.	296A	100.2	100.0	MIX	TABLE !	SMAN CO	1064
	30 3	100H-DAM 100H-DAM	34									490.1	MOLE.	3011	996.3	812.9	791.9	185.5	1301.0	189130	3000.0	3401.6	20003	ALC:	41.7	10.0	42		75.0° 16.			401	49.3	201.0	9463	803	700.3	1801.5	CREA	1000
26 (8)	(A) 4	amon	NE	26.0	38.9	56.0	100.0	9178	1909	294.0	200.0	364	C WEST	26.5	968	68.8	988	TAKT	THE	100.6	200.5	279.8	2468	30	3.0	CNE	200	107	48 S 18		HA	900	THE REAL PROPERTY.	28.0	. 16.6		ME	TALL	THE	12076
2 2	2 1	SPSK SPSK	94	79.0	67.0	762.0	196.0	200.0	290.0	700.0	76.0	705.7	90.0	MAR.	205.3	790.0	1055	45.1	400.0	945.0	316.5 384.7	204.E	795.5	20.0	18.0	AR III	20.2		100 10	-	MA.	100	100	47.6	204.5	75.2	105.5	477.6	400.0	DATE
87,181	181 4	191044	168	2000	99.7 715.8 779.8 301.1	216.0	246.0	***	500.00	496.0	7940.6	161A	1968	1919	RPER	200.0	3968	593	SMIR	496.8	7790.F	THE R.	983	345	75.0	100	EMP()		DER M		STATE OF THE REAL PROPERTY.	1978	DAMAGE	1119	SAME.	200.0	200.0	SAX III	240.0	496 B
2 2		NI-GRAN BRIGHAN	22	756.0	175.3 201.1	104.0	346.0 M6.0	700.0	7600	1404.0	1960	200.5	790.0	176.X	412.0	190.0	901.0	1100 P	10057	796.6	2006.4	207.8	1968	26.5	26.7	14.0	40.4 M.E.		MARIE MO	9 11k	100.0	253	CHARLE STATE	176.8	403.9 500.6	100.0	-	1982	816.7 1086 W	195.0
W (8)	580 4	MISSING	204	2342	210.0	465.0	345.5	1010.0	11750	2196.0	'zhee e	206.7	7911	265.5	275.0	965.8	206.5	THEFT	32000	1186.8	2004.7	3668	2268	200	MAG	27.0	MASS	MER III	ME IN	B 127	S 2500	2017	200.0	CHAR	100.4	955	200.5	TORSE	SERVICE OF	CTRUE NO.
(M) (N)	28	Section .	24	312.0	3667	100.0	701	1476.6	1900	2540.0	2120.0	900.1	201.0	PRIA	MINE	700.0	700.0	1204	2600.0	1470.0	2428.0	17013	THE	M.A	A1.0	-	MA.	MAX.	100 TH	101	MAN	200.7	MARKET	PRIA	807.0	700.0	MILE.	TAXABLE DESCRIPTION OF THE PERSON OF T	MALE OF THE PERSON NAMED IN	1676.0
	(8) 4	MAD HELD	8/9	-	min.	788.0	F01.5	1040.0	1794.6	1150.0	1006.7	***	400.00	2968	907.8	996.7	765	THUCK	18148	1660.6	3660.7	NO.	3306.7	#15.33	86.8	M.E.	96500	817	MIR. 198		CHARLES SHOW	OFFICE AND ADDRESS.	CARR	200.0	MON	M8.7	296.6	PRODUCTION OF	MINE CO.	AGEN
	100	100H-DAM	54									894.2 974.5	ARTS MICS	498.8	104014	975.0 1090.1	975.6	2018	2041.7 2048.5	1887.6	4000 E	AUST I	2000	11.5	MAR.	45.5	101.6		W. H 201		100.0	NN2	MIS	AMERICA	1900A	1005.0	807.N	PRICE OF	MARIE TO SERVICE AND ADDRESS OF THE PERSON NAMED IN COLUMN TWO IN COLUMN	MATERIAL PROPERTY.
100		serso	102	HX	COMMON .	47.5	258 cm	3465	- MIR.	- PRESCH	MAR.	448	466	766	96.0	91.8	763	1801	1761	168.5	360.9	3483	99.3	44	4800	3811	NA.	DOMESTIC DE	79 3 34		CHAPTER STATE	418	E-MAIL	386	MAG	913	78X	STREET, SQUARE,	1763	156.5
- 12		GPSK GPSK	NO	17.5	79.0	700.0	2014	PRET	MUCH	196.0 a19.5	100.0	MAX.	100	100.7	193	100.0	753	NO.	100	104.2	700.6	SHIELD .	F15.6	153	42	78.0	100		10.0		CONTRACTOR OF STREET	-	100	THE REAL PROPERTY.	178.5	700.0	1953	-	MES	MALE IN
		TEGRM	10	130.0	184.6	275.6	min.	Detail.	1000	11768	7000.0	101	760.0	166.0	946.1	BEAA	393	789	1000	NUE	TARLE	190.5.0	- NIRA	37.8	16.7	16.0	MAT I	MAX	MR			1997	NAME OF TAXABLE PARTY.	160	246.0	100.0	MAX.	754	-	410.0
12	12 :	TA-GAM BA-GAM	31	1868	216.7	ARCH.	-	ATTE	170.0	1756.0	1996.6	200	2614	200.0	A16.2	987.5 988.0	4963	TORKY	NAME OF TAXABLE PARTY.	MILE	259.0	2041.7.	SMIT X	96.5	25.0	-	MA.		AUG TO	100	100.0	-	200	2154	962	META .	100.0	Annual Control	ASSESSMENT OF THE PERSON NAMED IN	110.0
		MICHM	24	290.8	205.0	WOTA.	6710	1216.2	14623	2002.0	2001.0	387.7	3614	3291	778.9	70.3	1017	767.3	350.0	12761	MARK I	200.5	2798.3	267	27.0	20.0	75.6	76.5	17.5	F 199	168.4	303	-	A 328 E	2763	201.0	3001	1623	THE R. P.	278.1
1.0	100	SHISAM SNI-SAM	24	301.0 200.0	361.1 400.0	APER	76.5	1600	16013	2655.0	MOSE	TAX.	MER	SHIA	MEST	H24	1913	SMILE.	190.6	18800	9665.9	MICH	MACH.	44.1	ALT	20.5	MA	MARINE STATE	15 P 181	ALC: UNK	100.0	667	THE RES	MAKE	MER	MUA	200.A	THE R. P. LEWIS CO., LANSING, MICH.	MARKET ST	NOT B
1.0	180	250-DAM	319	NA	PAIR S	-	200.0	1998	21067	2006.0	MIN. 1	WAX:	WILT.	MIT	1947.5	1961.0	9759	3402.0	Time 1	2045.7	M003.0	MALE .	# MIN. N	M.	MA.	-	TITAL	THE	180		C MAN	333	DESCRIPTION OF REAL PROPERTY.	MIN.	THEAT	100.0	200	100.0		SHEET STREET
		100H-DAM	94									DATE	600.4	SMEE	1290.4	1258.8	TOTAL ST	THE P	2598.7	2016.70	SADA N	POAT	AND A	86.2	10.5	MAX.	100.4		193 36			100	ACCU.	NAME OF TAXABLE PARTY.	1290 A	-	1000		MIN 17	200.0
100		arrag	10	76.0	40.0	M.R.	100	SPEN I	7952	MAKE	THE R. L.	THE REAL PROPERTY.	SCHOOL STREET	ASS	100.2	97.5	MIX.	296.2	2642	DEED	400.4	AME .	MAX	8.6	5.0	45	26.6	MACH	SE P	20		MA	44.0	(ARK	MAX	NO.	ATR.	242	2002	1000
- 12	= :	GPSK SPSK	10	79.0	198.0	340.0	275	90.0	296.0	THE P.	198.0	7012	100.0	121.6	308.3 308.7	795.0	200.2	100.0	400.5	MES	366.7	MAT.	THE R	100	100	- 12	20.0		H 10			100	10.000	100.0	200.5	-	1953	ALC: N	ADE 2	MATERIA N
		THISPMA	9.0	1968	CARROLL	3048	360	THE R	790.0	Teles	1966	BM F	100.0	191	40EB	190.0	MIN	866.7	80x7	785.0	1798.6	160.1	3498	20.2	-	18.0	-	-			- 84	983	-	179.6	1024		-	BELT .	8167	790 A
		TEIGHM SHIGHM	311	234.R	2600 386.7	66K, R	766.0	1800.0	11768	20018	2000	MKT.	THE REAL PROPERTY.	260.X	****	965.0	306.5	TOWN .	XXXX	1470.0	DESCRIPTION OF THE PERSON NAMED IN	DOG S	100	NO.	-	27.5	10.5	-	10	100	200.0	-	STATE OF THE PARTY OF	MAX	100	200	203		-	100.00
	181	MICHAE	24	255.0	7968.0	7950	9168	MANA	1968	2754.0	MARKE	100.0	400.0	294.9	BIA3	877.5	700.8	7985.6	18073	1000.0	2001.2	NISA	SHE'S	404	46.0	46.5	75.5	44	-	2 200	100.1	865	-	754.5	9093	REEL	700.0	190.5	18515	455.0
181	2	TON-CHAM BANCHAM	24	PRO II	491.2	916.0 975.0	100.0	1500 P	1990.0	M144	9964	275.2	4013	100.0	DESCRIPTION OF THE PERSON OF T	1176.0	ACCUS.	TOWN 1	10417	1907.0	MARKET C	490.1	MITTER I	100	10.0	10.0	100.0	70.0	Will 199	20)	700.0	242	- AUT	400	76364	100.0	100.0	100	STATE OF THE PERSON NAMED IN	4010
	181	MILITARE	200	100.0	1018	1001	1886.6	200	M/A		1001	200.2	A10.0	MILE	1876.3	1986.0	PERSONAL PROPERTY.	200.4	1793.2	DANCE	2254.7	SHIELD !	-	76.0	362	-	365.0	THE R. P. LEWIS CO., LANSING				CONTRACTOR OF THE PERSON NAMED IN	100	100	CHARA	100.5	1110	THE R. P.	11912	-
	100	TOHOM	24									754.3	7913	TOTAL ST	19863	1903	THES	TOCS .	MODE	279A.E	DARKET.	STATE OF	ACCES.	THE	71.0	25.0	100		100			200	PER	200.0	1983	THEFT	THE R. P. LEWIS CO., LANSING, MICH.	251	ADD TO	100
100	18 7	arriso	10	411	10.0	74.5	COMPANIES.	THE	201	40.5	400.0	463	DAY.	1863	CHARLE.	215.8	INCASE OF	292	280	216.6	SOLK I	CLE	-	10	18	63	THE R. P.	167	HE N	100	1000	100	MAX.	100	100 A	TIRE	365.6	PERMIT	2002	236.6
100	2	SPSK	34	1969	185.1 195.7	2011	216.0	9163	455.E	10000	1962	100.4	1000	195.4	MILE.	207.8 207.5	200	200.4	CAR	MARK.	THE R. P.	1403.7	MARKET AND ADDRESS OF THE PERSON NAMED IN	10.0	113	-	187		20 M			100	TABLE .	100.0	MAIN I	MIT A	200.0		THE R. LEWIS CO., LANSING, MICH.	100.0
1	181 7	THIGHN	MB	7808	-	100.0	100.0	819.0	*15.0	THIRD	19/88	COMMON CO.	MIN	max.	MILK I	/ AUDA	MIN.	1000.0	1960	WEAT.	DETAILS.	CHICA'S	CARRE	34.7	10.0	20,0	CARALLY					200	CARLS.	200	- MILE	CHICAGO	MR3	tons a	***	#8/LB
100	1	TH-DAM SHIDAM	27	ama .	W11	100	1007	TOTAL S	THEFT	3457.0	1700.0	-	MIX.	MIT I	MIN	200.5	2007	SHEET STREET	THEFT	1286.0	MIN. II	DOM:	PATE A	200	-	11.5	753	100	100	-	100.0	-	No. of Concession, Name of Street, or other Designation, Name of Street, or other Designation, Name of Street, Original Property and Name of Stree	100	701.0	200	H14.7		ACCUPATION OF	THE R. P. LEWIS CO., LANSING, MICH.
		SHICKM	204	ACT II	101.0 101.0 101.0 101.7	-	100.0	200	NA.	DIAM'S	4010	50.5	AVER	40.7	TOWNS	100.6	MOLA .	2003	2140.6	1925.6	4017	ALC: N	MAKE	10.6	10.5	41.5	375.0	700.0	963 E 19			100.0	BUX	- MALE	70443	THEFT	MEA	2002	21808	100.00
100	2	SHICKM SHICKM	34	145.0	9014	100.0	100.0	2007.5	APRA	MINE	-	MEA.	90.5	974.9	TAKE N	1000.0	TOOLS	MAN A	CHAIN I	STATE OF	2004.5 C	4949 578.7	ADD N	20.0	56.0	50.5	100.0	THE PARTY	100 200	347	H2.1	100	S. Mark	200	1004.0	THEFT	1004.0		-	THE R.
	100	mean	100	ALC:	N/A	THE P	100.0	21968	2000.0	3440	MMA.7	CHARLES .	296.0	ARC S	THE R	2016.7	1969	1007	1000	DESCRIPTION OF THE PERSON NAMED IN	AUDUS.	MOL 9	STS.7	-	77.8	20.0	100.7	100.0			100	-	200	100	2000	DESC.	100.0	mark.	STREET, STREET,	
	2	TEDHOAM TODHOAM	34									MOLE I	MALE S	MATE .	THOUGH	1968	1966	Name of Street	10717	1015.0	7565.2	Deta	CHARLE	20.0	212	70.0	200.00	100	100	271	100	-	See 1	1300	100	1967	100.0	-	ALTERNATION OF THE PERSON NAMED IN	ATT
100	100	arreg	1/2	10.0	10.0	798.6	100	200	IM I	- 44.0	NA.	MARINE.	100	98.5	THEA	100.0	100.00	1907	200	245.0	STATE	204.6	***	28	(ASCIDE	100	CARCO	CHANGE IN	100		100	-	THE RESERVE	Carried Street	CHREA	200.00	THE R. L.	THE REAL PROPERTY.	ATTENDED TO	200
		DPSK DPSK	107	2002	715.0	250	260	200	NO.	100.0	1000.0	THE R. L.	1988	110.0	275.3	3900	2000	100	266.0	461	7790.5	1000	MARK	367	10.0	100	200	70.		- 20	STATE OF THE PARTY.	10161	1000	7100	2018	200	204.9	151	SAME OF THE OWNER, OWNE	490.0
		TAIGHM	NE	-	481.1	400.0	-	116.0	1660	1670.0	-	-		1911	THE R	-	-	TIMES	Town 2		2004.0	DISTA .		83		26.0												-		
	180	TE-GRAN	24	STEEL STEEL	366.7	400.0	1000	1404.0	1008	2000.0	1736.6	1408	PRINT.	MILE.	BILLY	76.0	795.9	STREET,	MARKET	NAME OF	MINE	336.7	2940.9	ACA III	46.0	-	MAL	MA.	100	100	100	900	1	Ser.	MALE	700.0	NA.	TORKS	AMA I	KTG-0
		SHIERE SHIERE	21	ALC: Y	963.7 106.8 101.9	100	-	2176.2	2740.0	#112.F	MARKET.	-			1000	1179.9	2001	1000	Sept.	1000.0	STORY TO	900.0		-	-		707.4								100		7000			
		MATERIAL	54	NAME OF	1019	1000.0	1996.0	2165.0	2400.0	- match	3000.0	100.2	2,460.0	COMP.	STREET,	1900	15/68	20014	27942	1004.6	3764.7	SHEET.	MARKET .	200	M-7	MAN .	140.2	MARIE	10.0		200	-	-	-	3655	2000	NUMBER OF	AND DESCRIPTIONS	CHARLE ST	MINER.
		200-DAM	24	5003	800.3	1256.9	1000	2000	3120.0	NAME OF TAXABLE PARTY.	400.0	MICH N			100.0	1560.0	THE R. L.	MARKET .	NAME OF	DOM:	200.0	TOTAL ST		M1		70.0	100.0	100				100			1951.9	100.0	100			-
	100	NONGAM	34									100.4	NO.	MITA.	MAKE T	7000	TOTAL ST	AMES .	AMERICA	1675.0	MATE.	MINAST.	7994	798.0	700	-	202	-			-	- India	200	CAPE A		MINE	1768	-		ACCR
		TENGAM	84									2100.3	100.0	275.0	SERVER I	SIRT !		MILES.	400 B	-	-	MIN I	m. 1103,245	The same	-			4		and the last		1000	Personal Property lies	No. of Concession, Name of Street, or other party of the Concession, Name of Street, or other pa	120	-	100	- 110	Marie Co.	MARKET NAME OF TAXABLE PARKET

## The PHY Date Rates Calculations





Guard Interval Duration

OFDM Symbol Duration

DUV	Modu	lation		N.		N	SD		-	Т	GI
PHY	Name	N <sub>BPSCS</sub>	R	N <sub>SS</sub>	20MHz	40MHz	80MHz	160MHz	T <sub>DFT</sub>	Long	Short
	BPSK	1	1/2								
802.11n	QPSK	2	1/2 & 3/4	14- 4							
(HT)	16-QAM	4	1/2 & 3/4	1 to 4							
2000 20	64-QAM	6	1/2 & 2/3 & 3/4								
	BPSK	1	1/2		52	108	234	468	3.2 µs	0.8 µs	0.4 µs
000 11	QPSK	2	1/2 & 3/4								
802.11ac	16-QAM	4	1/2 & 3/4	1 to 8							
(VHT)	64-QAM	6	1/2 & 2/3 & 3/4								
	256-QAM	8	2/3 & 5/6								

DUV	Modulation			M		N	SD		-	T <sub>GI</sub>				
PHY	Name	N <sub>BPSCS</sub>	R	N <sub>SS</sub>	20MHz	40MHz	80MHz	160MHz	T <sub>DFT</sub>	Long	Medium	Long		
	BPSK	1	1/2				7							
	QPSK	2	1/2 & 3/4											
802.11ax	16-QAM	4	1/2 & 3/4	1 to 8	234	468	980	1960	12.8 µs	0.8 µs	12.00	22.40		
(HE)	64-QAM	6	1/2 & 2/3 & 3/4	1 10 6	234	400	900	1900	12.0 μδ	υ.ο μδ	1.2 µs	3.2 µs		
	256-QAM	8	2/3 & 5/6											
	1024-QAM	10	3/4 & 5/6											

Source: https://semfionetworks.com/blog/mcs-table-updated-with-80211ax-data-rates/

## Difference between PHY Data Rates and Throughput



The actual Throughput under ideal conditions is expected to be around 60-70% of the PHY data rates.

## Wi-Fi Overhead

- Interframe Spaces
- Management and Control Frames
- Random Backoff
- PHY Signaling
- Interference
- MAC Header
- Guard Intervals
- Virtual Carrier Sensing
- Backward Compatibility/Legacy Mode
- Acknowledgements
- Retransmissions
- Rate Adaptation
- Packet sizes/Frame sizes
- Half Duplex

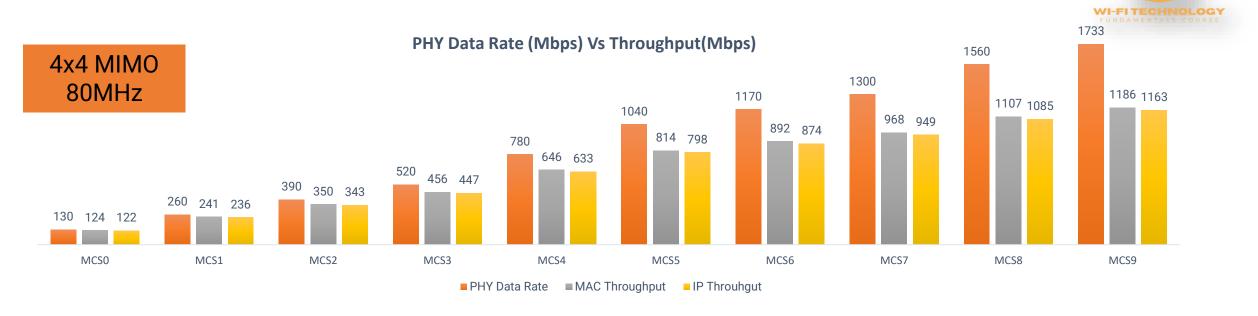


# 802.11ax Throughput Calculator

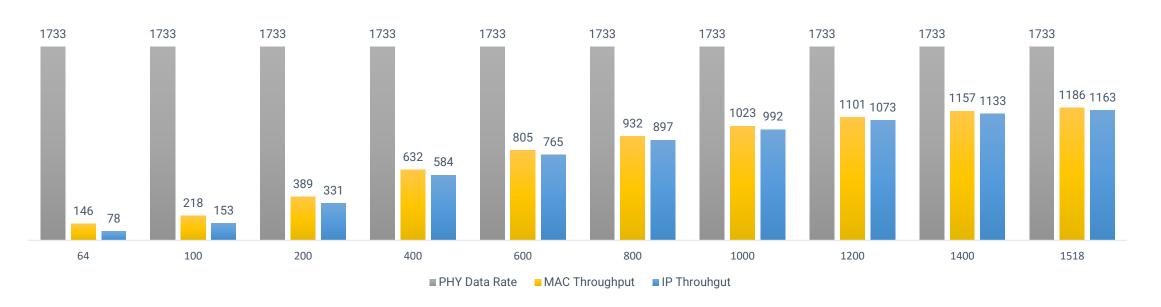


Insure   Parameters	TECHNOLOGY MENTALS COURSE			1			1		0.072042	: 7 d	l\/o			ad for 11ac	Offered Le	Mavimum	Theoretica			
Traffic Type				+				D3.0						au ioi i iac	Ullereu Lo	I Waxiiiuiii	Heoretica			nnut Parameters
DataVoice MCS Index   0									L 1 002	d on.								1	Data -	<u> </u>
Spatial Streams				+					A MCDIII		1/00	* 34CDII /	12 Parkata							**
Channel Bandwidth				-															9 🔻	
Guard Interval   400									r no A-MPDU)	to zero to	▼ (se	per A-MPDU	MAC Frames		Yes	QoS =			4	·
Highest Basic MCS Index																		MHz	80 🔻	Channel Bandwidth
Nighest Basic MCS Index																		nsec	400 🔻	Guard Interval
BSS Basic Rate Set (802.11a/g)																frames only	rement/control	1	1 🔻	Highest Basic MCS Index
Allowed Control Frame Rates   6   0   12   0   24   0   0   0   0   0   0   0   0   0												□ 54 Mb/s	□ 48 Mb/s	□ 36 Mb/s	☑ 24 Mb/s					
B02.11 MAC MPDU Size (Data Traffic)   Syles   CF Packel																		_		
CWmin (leave alone for default)   Mined   Solds   CTS-to-self (protection)   No   Sold   So		-		+								4400 h	U					, ,		
MAC MPDU Size				1								1498	MAC Frame =	,	• .		(IP Packet =	4		` '
MAC MPDU Size											_			No <u>*</u>	(protection)	CTS-to-sell		slots	Mixed <u>▼</u>	
MAC MPOU Size	2 Nes 3 Nes 4	Nes 2	Nes 1	Non-HT Ref	Indices	Guard Interv				Iz Ndb <sub>l</sub> 4	201									Intermediate Values
SIFS   16.00   usec   Slot Time   9.00   usec   MeanBackoff   67.50   usec   10.4   216   488   3.4   3.5   1.5	1 1		1	12	0	400				26									1510	
DIFS	4			12	1	800				52					2.00			-		
Topdu_fixed_(HT_Data_Frames)   52_00   usec   Use BlockAck   True     156   324   702_Encrypt   QoS   4   38     38				10	2					/8										
Typidy   T	4 1			24	3					104										
VHT Data Rate	1 1			36	4	QoS				156										
Non-HT Reference Rate	1 1		1	48	5	No				208										
PHY Bit Rate of Control Frames   24   Mb/s   Ndbps, data bits per symbol (Control)   216   bits/symbol   MSDU Size   1488   bytes   1040   MSDU Size   1488   MSDU Size	4 1		1	54	6					234				-						
Ndbps, data bits per symbol (Control)   Control   Cont	1 1		1	54	1					260				-						
Ndbps, data bits per symbol (Control)   216   bits/symbol   780272   bits	1 1		1	54	8					312										
Nbits, Bits per MAC PPDU   780272   bits	1 1		1	54	9					1040				bytes	1488	MSDU Size		-		
Nes, Number of BCC encoders   3   encoders   3   encoders   3   encoders   3   encoders   4   12   3   Voice   13   1   1   1   1   1   1   1   1	1 1		1		10				Y Rates Ns	TFs P	HT-							-		
Tsymbol(Cata), Data Symbol Period   3.60   usec     4   12   3   Voice   13   1	1 1		1		11		Greenfield I	1	6	1									780272	
Tsymbol(Cata), Data Symbol Period   3.60   usec	1 1		1		12	Data		2	9	2									3	
Tsymbol(Control), Control Symbol Period   4.00   usec	1 1		1		13	Voice		3		4								usec		Tsymbol(Data), Data Symbol Period
Tbtframe (DATA)   505.60   usec   24   15   1	1 1		1		14			4	18	4								usec	4.00	Tsymbol(Control), Control Symbol Period
Ttxframe (Ack)   28.00   usec     36   16   1	1 1		1		15				24									usec	505.60	Ttxframe (DATA)
Ttxframe (Compressed BlockAck)   32.00   usec	1 1		1		16				36									usec	28.00	Ttxframe (Ack)
RTS/CTS Handshake Overhead   0.00   usec   18	1 1		1		17				48											
CTS-to-self Handshake Overhead   0.00   usec	1 1		1		18				54											· · · · · · · · · · · · · · · · · · ·
Ack Response Overhead       0.00 usec       20       1         BlockAck Response Overhead       48.00 usec       21       1         Theoretical Maximum Offered Load       Frame Size       fps       25       1         Theoretical Maximum Offered Load       64       286867       252465       26       1         I Client       2 Clients       5 Clients       10 Clients       50 Clients       100 Clients       153       254069       201575       27       1         MAC PPDU Interval       655.10       621.35       601.10       594.35       590.98       588.95       588.28 usec       242       230964       167759       28       1	1 1		1		19															
BlockAck Response Overhead	1 1		1		20															
Theoretical Maximum Offered Load	1 1		1		21															
Theoretical Maximum Offered Load	1 2		1		25			fps		e Size	Fra									
1 Client   2 Clients   5 Clients   10 Clients   20 Clients   50 Clients   100 Clients   100 Clients   153   254069   201575   27   1     1   1   1   1   1   1   1   1	1 2		1		26		1		286867	-										Theoretical Maximum Offered Load
MAC PPDU Interval 655.10 621.35 601.10 594.35 590.98 588.95 588.28 usec 242 230964 167759 28 1	2 2		1		27		ì						100 Clients	50 Clients	20 Clients	10 Clients	5 Clients	2 Clients	1 Client	Theorem
	2 2		1	/ T	28		1					ucac								MAC PPDI I Interval
	2 3		1	<u> </u>	29		ì	101100	23030-											
Max MAC MPDU Rate 97695 103002 106471 107681 108296 108668 108793 64 286867 252465 4963 4973 30	4			-	30	4973	4063	252465	200007			ips								
Max MAC MPDU Rate 97695 103002 106471 107681 108296 108668 108793 64 286867 252465 4963 4973 30 4973 30 4973 31				+	31						_									
		-		4	32							* # L /o								
		-		4	32															
Max. 802.11 MAC Payload Goodput 1162.961 1226.130 1267.436 1281.831 1289.151 1293.583 1295.068 Mb/s 331 211710 144960 4963 4973 33				4	33															
MAC Goodput Per 802.11 Client 1162.961 613.065 253.487 128.183 64.458 25.872 12.951 Mb/s 420 195420 126607 4963 4885 34				4	34															
Offered Load (802.3 Side) 1170.777 1234.370 1275.954 1290.445 1297.815 1302.277 1303.771 Mb/s 509 179624 112379 4963 4885 35				<u></u>	35	4885	4963I	112379	179624	509I	L	Mb/s	1303.//1	1302.277	<b>12</b> 97.815	1290.445	1275.954	1234.3/0	1170.///	IOffered Load (802.3 Side)

## PHY Data Rates Vs Actual Throughput

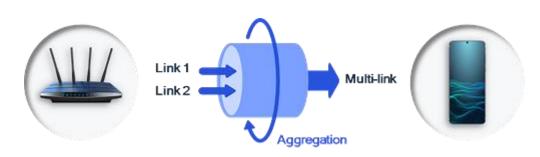


#### PHY Data Rate(Mbps) compared with Throughput(Mbps) at different frame sizes at MCS9



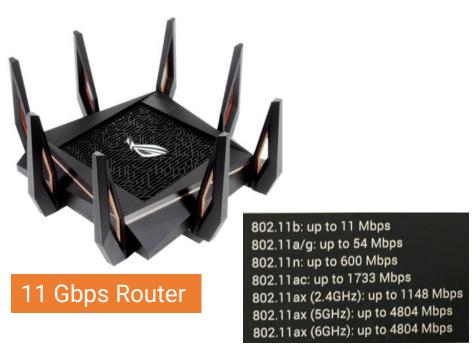
#### The Real Throughput **OFDMA** · OFDMA increases efficiency · OFDMA reduces latency WI-FI TECHNOLOGY · Ideal for low-bandwidth applications **MU-MIMO** MU-MIMO increases capacity · MU-MIMO results in higher speeds IIII · Ideal for high-bandwidth applications MU-MIMO is similar to multiple trucks serving users simultaneously NETGEAR RAX10 WiFi 6 Router **Running Smaller 256** Remove MAC/PHY Overhead At 10meter distance Byte apps – 80Mbps Only Support 2x2 MIMO 100Mbps Only MCS3-120Mbps 2x2 40Mhz - 400Mbps simultaneous more device WiFi streams capacity

What is on the Box 4x4 MIMO 80MHz 11ac – 1733 Mbps



Multi-Link Operation

## The Real Throughput Example



### **ROG Rapture GT-AX11000**

AX11000 Tri-band WiFi 6 Gaming Router –World's first 10 Gigabit WiFi router with a quad-core CPU, PS5 compatible, 2.5G port, DFS band, wtfast, Adaptive QoS, AiMesh for mesh wifi system and free network security

- Next-Gen WiFi Standard 802.11ax WiFi standard for better efficiency, throughput and range.
- Ultrafast WiFi Speed 11000Mbps WiFi speed to handle even the busiest network with ease.
- Triple-level Game Acceleration Accelerate game traffic every step of the way from device to game server.
- Battle-ready-hardware 1.8GHz quad-core CPU and 2.5GBase -T port for ultimate performance.
- Front-line Network Security Neutralize internet threats before they hit your network.



802.11ax

2x2 MIMO 80MHz 1024 QAM Theoretical Rate: 1201 Mbps



802.11ac

2x2 MIMO 80MHz 256 QAM Theoretical Rate: 866 Mbps

802.11n

2x2 MIMO 40MHz 64 QAM Theoretical Rate: 300 Mbps

802.11bg

1x1 MIMO 20MHz 64 QAM Theoretical Rate: 54 Mbps

## References



Theoretical Data Rates vs Real World Throughput <a href="https://www.duckware.com/tech/wifi-in-the-us.html">https://www.duckware.com/tech/wifi-in-the-us.html</a>

MCS Table

https://mcsindex.com/

WiFi7 Theoretical Throughput Calculator

https://www.rfwireless-world.com/calculators/WiFi7-802-11be-data-rate-throughput-calculator.html

Wi-Fi Guard Interval

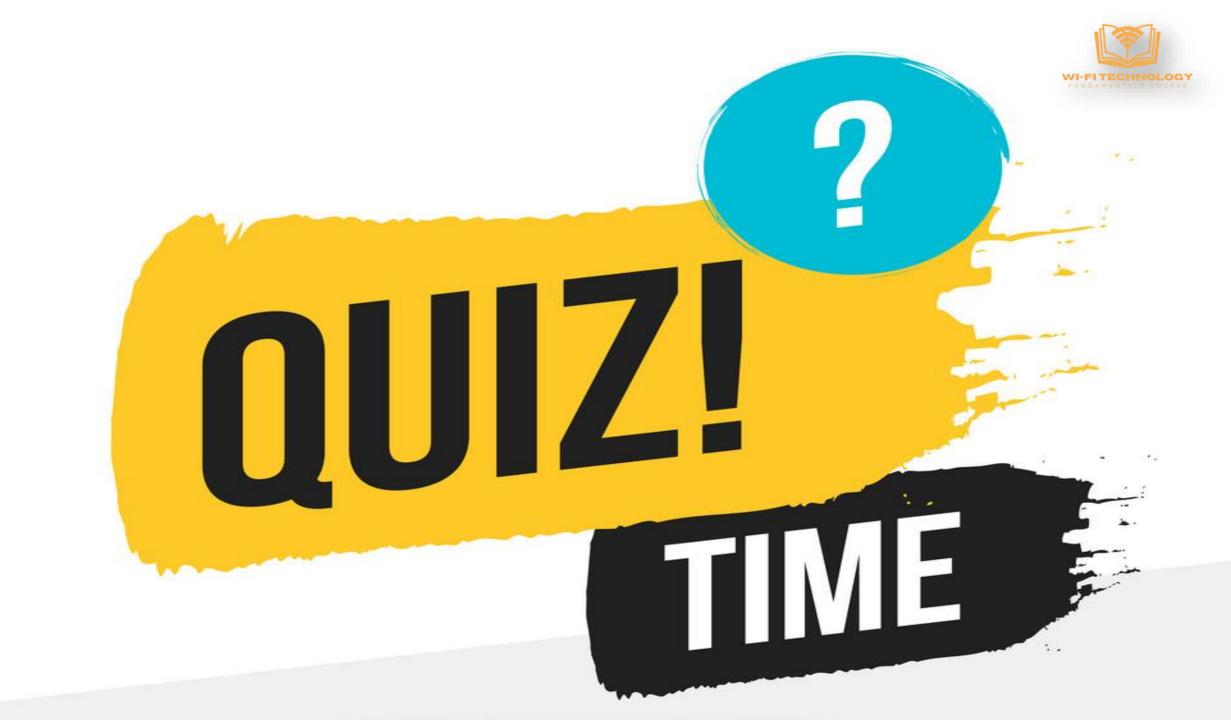
https://en.wikipedia.org/wiki/Guard\_interval#:~:text=The%20shortest%20interval%20(1%2F32,delay%20spread%20of%20the%20channel.

Wi-Fi7 (802.11be) Wiki Page

https://en.wikipedia.org/wiki/IEEE\_802.11be







# Quiz 2b Results



## Number of participants - 167



# Winner S Sushmitha India

