Answers for Session 5b - Wi-Fi6 New Features

(ODFMA, Mu-MIMO, BSS Coloring, 1024 QAM, WPA3)

1. **What are the differences between SU-MIMO and the period before the implementation of MIMO?**

Feature	SU-MIMO	Pre-MIMO
Number of Antennas	Uses multiple antennas on both TX and RX	Uses only one antenna on both TX and RX
Data Streams	Sends and receives data in multiple spatial streams simultaneously	Sends and receives data in a single stream sequentially
Spatial Diversity	Can leverage multipath propagation to exploit better signal paths and minimise interference	Susceptible to signal fading and interference due to relying on a single path
Overall Performance	Offers significant improvements in data throughput, range, and link reliability compared to pre-MIMO	Limited by single-stream transmission, resulting in lower data rates, shorter range, and higher susceptibility to interference

2. **During the Color Collision event (BSS) sent by STA, what packets are exchanged?**

BSS colour is used to determine quickly if the incoming frame is sent from a device within the same BSS or not.

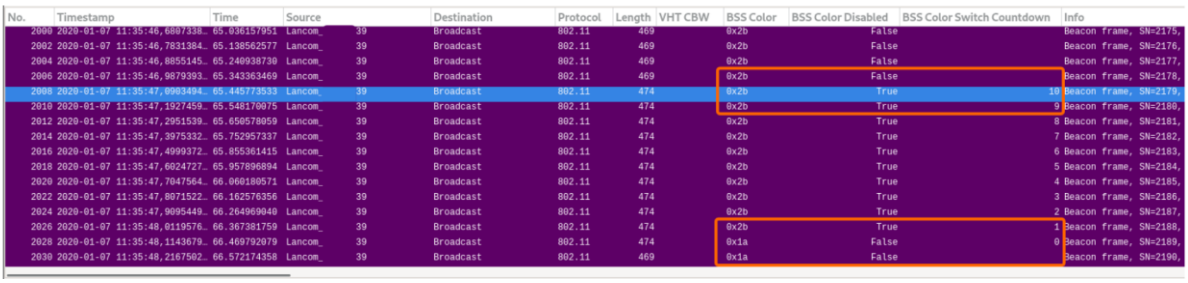
Whenever the client senses another BSS colour it will send a BSS collision report to the associated AP, it will add all the details of the colours it is able to detect and the signal strengths.

Based on the BSS collision report the AP needs to change the colour:

1. BSS colour disable flag will be made true, informing the clients regarding the colour change (generally sent in beacon)

2. BSS colour switch countdown, in every beacon frame we observe the count down (In this whole count down time the BSS colour disable flag is enabled)

3. When the BSS colour switch count reaches 0, new colour is taken and the BSS Color disabled flag is turned to False



No.	Timestamp	Time	Source		Destination	Protocol	Length	VHT CBW	BSS Color	BSS Color Disabled	BSS Color Switch Countdown	Info
2000	2020-01-07 11:35:46,6807338…	65.936157951	Lancom_	39	Broadcast	802.11	469		0x2b	False		Beacon frame, SN=2175,
2002	2020-01-07 11:35:46,7831384…	65.138562577	Lancom_	39	Broadcast	802.11	469		0x2b	False		Beacon frame, SN=2176,
2004	2020-01-07 11:35:46,8855145…	65.240938730	Lancom_	39	Broadcast	802.11	469		0x2b	False		Beacon frame, SN=2177,
2006	2020-01-07 11:35:46,9879393…	65.343363469	Lancom_	39	Broadcast	802.11	469		0x2b	False		Beacon frame, SN=2178,
2008	2020-01-07 11:35:47,0903494…	65.445773533	Lancom_	39	Broadcast	802.11	474		0x2b	True	10	Beacon frame, SN=2179,
2010	2020-01-07 11:35:47,1927459…	65.548170075	Lancom_	39	Broadcast	802.11	474		0x2b	True	9	Beacon frame, SN=2180,
2012	2020-01-07 11:35:47,2951539…	65.650578059	Lancom_	39	Broadcast	802.11	474		0x2b	True	8	Beacon frame, SN=2181,
2014	2020-01-07 11:35:47,3975332…	65.752957337	Lancom_	39	Broadcast	802.11	474		0x2b	True	7	Beacon frame, SN=2182,
2016	2020-01-07 11:35:47,4999372…	65.855361415	Lancom_	39	Broadcast	802.11	474		0x2b	True	6	Beacon frame, SN=2183,
2018	2020-01-07 11:35:47,6024727…	65.957896894	Lancom_	39	Broadcast	802.11	474		0x2b	True	5	Beacon frame, SN=2184,
2020	2020-01-07 11:35:47,7047564…	66.060180571	Lancom_	39	Broadcast	802.11	474		0x2b	True	4	Beacon frame, SN=2185,
2022	2020-01-07 11:35:47,8071522…	66.162576356	Lancom_	39	Broadcast	802.11	474		0x2b	True	3	Beacon frame, SN=2186,
2024	2020-01-07 11:35:47,9095449…	66.264969040	Lancom_	39	Broadcast	802.11	474		0x2b	True	2	Beacon frame, SN=2187,
2026	2020-01-07 11:35:48,0119576…	66.367381759	Lancom_	39	Broadcast	802.11	474		0x2b	True	1	Beacon frame, SN=2188,
2028	2020-01-07 11:35:48,1143679…	66.469792079	Lancom_	39	Broadcast	802.11	474		0x1a	False	0	Beacon frame, SN=2189,
2030	2020-01-07 11:35:48,2167502…	66.572174358	Lancom_	39	Broadcast	802.11	469		0x1a	False		Beacon frame, SN=2190,

For more information please refer : https://wlan1nde.wordpress.com/2020/01/10/11ax-wi-fi6-bss-color/

3. Can MU-MIMO function independently without OFDMA in 11ax?

Yes, MU-MIMO can function independently of OFDMA in Wi-Fi 6 (802.11ax). While both MU-MIMO and OFDMA are features introduced in the 802.11ax standard to enhance Wi-Fi performance, they serve different purposes, and the implementation of one does not strictly depend on the other.

4. In the 26-tone RU, what is the maximum throughput achievable?

It's based on the number of spatial streams, AP and client device standard i.e.,(802.11 n/ac/ax/be) and the client device RSSI.
If the client is operating on 2x2 spatial streams, AP and client device supports 802.11ax standard and signal strength is around -30 to -35 dBm, then the expected phy rate in this scenario is 29.4 Mbps. The achievable throughput is 70% of phy rate which is around 20.58Mbps.

MCS Index				Spatial Stream	Modulation	Coding	20MHz		40MHz		80MHz		160MHz		26-tone RU		
HT	VHT	HE	EHT				0.8µs GI	0.4µs GI	0.8µs GI	0.4µs GI	0.8µs GI	0.4µs GI	0.8µs GI	0.4µs GI	3.2µs GI	1.6µs GI	0.8µs GI
0	0	0	0	1	BPSQ	1/2	6.5	7.2	13.5	15	29.3	32.5	58.5	65	0.8	0.8	0.9
1	1	1	1	1	QPSK	1/2	13	14.4	27	30	58.5	65	117	130	1.5	1.7	1.8
2	2	2	2	1	QPSK	3/4	19.5	21.7	40.5	45	87.8	97.5	175.5	195	2.3	2.5	2.6
3	3	3	3	1	16-QAM	1/2	26	28.9	54	60	117	130	234	260	3.0	3.3	3.5
4	4	4	4	1	16-QAM	3/4	39	43.3	81	90	175.5	195	351	390	4.5	5.0	5.3
5	5	5	5	1	64-QAM	2/3	52	57.8	108	120	234	260	468	520	6.0	6.7	7.1
6	6	6	6	1	64-QAM	3/4	58.5	65	121.5	135	263.3	292.5	526.5	585	6.8	7.5	7.9
7	7	7	7	1	64-QAM	5/6	65	72.2	135	150	292.5	325	585	650	7.5	8.3	8.8
	8	8	8	1	256-QAM	3/4	78	86.7	162	180	351	390	702	780	9.0	10.0	10.6
	9	9	9	1	256-QAM	5/6	N/A	N/A	180	200	390	433.3	780	866.7	10.0	11.1	11.8
		10	10	1	1024-QAM	3/4									11.3	12.5	13.2
		11	11	1	1024-QAM	5/6									12.5	13.9	14.7
			12	1	4096-QAM	3/4									13.5	15.0	15.9
			13	1	4096-QAM	5/6									15.0	16.7	17.6
8	0	0	0	2	BPSQ	1/2	13	14.4	27	30	58.5	65	117	130	1.5	1.7	1.8
9	1	1	1	2	QPSK	1/2	26	28.9	54	60	117	130	234	260	3.0	3.3	3.5
10	2	2	2	2	QPSK	3/4	39	43.3	81	90	175.5	195	351	390	4.5	5.0	5.3
11	3	3	3	2	16-QAM	1/2	52	57.8	108	120	234	260	468	520	6.0	6.7	7.1
12	4	4	4	2	16-QAM	3/4	78	86.7	162	180	351	390	702	780	9.0	10.0	10.6
13	5	5	5	2	64-QAM	2/3	104	115.6	216	240	468	520	936	1040	12.0	13.3	14.1
14	6	6	6	2	64-QAM	3/4	117	130	243	270	526.5	585	1053	1170	13.5	15.0	15.9
15	7	7	7	2	64-QAM	5/6	130	144.4	270	300	585	650	1170	1300	15.0	16.7	17.6
	8	8	8	2	256-QAM	3/4	156	173.3	324	360	702	780	1404	1560	18.0	20.0	21.2
	9	9	9	2	256-QAM	5/6	N/A	N/A	360	400	780	866.7	1560	1733.3	20.0	22.2	23.5
		10	10	2	1024-QAM	3/4									22.5	25.0	26.5
		11	11	2	1024-QAM	5/6									25.0	27.8	29.4
			12	2	4096-QAM	3/4									27.0	30.0	31.8

5. **In OFDMA, is frequency allocation done in a sequential manner (e.g., allocating the first frequency band to client 1, the next small band to the next client), or is it random?**

   In OFDMA, frequency allocation isn't done in a sequential manner, where each user is assigned a portion, nor is it random. Instead, it operates dynamically by taking into account the requirements of users, such as data demands, channel quality, and Quality of Service (QoS). It employs a range of techniques, including fairness mechanisms and prioritization strategies, with the goal of optimizing resource utilization and ensuring a positive user experience.

6. **How does the station determine which Resource Unit (RU) to use for transmitting BSR (Uplink OFDMA)?**

   Stations don't actively choose RUs for BSRs. The AP schedules them based on information the stations provide in their BSRs and based on overall network conditions

7. **Does MU-MIMO only work with beamforming in both 11ac and 11ax?**

   Yes, MU-MIMO often works in conjunction with beamforming in both 802.11ac and 802.11ax standards. Explicit beamforming, based on channel sounding between the Access Point (AP) and the Station (STA), enhances the effectiveness of MU-MIMO by focusing signals towards specific devices, improving MU-MIMO performance.

8. **Will BSS color work in a WiFi testing lab with dimensions of 10x10 meters, where more than 30 APs are closely located to each other?**

   BSS coloring is not expected to be effective in compact, densely populated WiFi testing labs because of the constrained spatial arrangement and the presence of numerous access

points.

9. **Could you explain the relationship between modulation and sensitivity, specifically the minimum sensitivity in terms of dB as mentioned in the slides?**

   Modulation and sensitivity are interconnected concepts that play crucial roles in the performance of a communication system. Modulation refers to the process of varying a carrier signal's properties, such as amplitude, frequency, or phase, to transmit information. Sensitivity, on the other hand, is a measure of how well a receiver can detect and demodulate weak signals.
   The minimum sensitivity in terms of dB is a critical parameter that defines the weakest signal strength a receiver can reliably detect and process. It is usually expressed as a negative value in decibels (dB) and represents the minimum input power level required for the receiver to achieve a specified level of performance, such as a certain bit error rate. In practical terms, higher sensitivity means that the receiver can detect weaker signals, allowing for longer communication ranges or better performance in challenging environments with low signal strength. The relationship between modulation and sensitivity lies in the fact that the choice of modulation scheme can impact the receiver's sensitivity. Different modulation schemes have different power efficiency, and some may be more robust in low signal conditions than others.
   Therefore, when designing wireless communication systems, it is essential to consider the modulation scheme and its impact on sensitivity to ensure reliable signal reception, especially in scenarios where the signal strength may be low, such as in distant or obstructed communication links.

10. **What is the difference between BTWT and ITWT?**

Aspect	BTWT (Basic Triggered Wake Time)	ITWT (Inactivity Triggered Wake Time)
Definition	Mode in TWT allowing wake scheduling with basic triggers	Mode in TWT allowing wake scheduling based on inactivity
Trigger Event	Basic triggers such as predetermined time or specific frame	Inactivity period exceeding a specified duration
Application Suitability	Periodic communication or wake-ups	Sporadic communication with long idle periods

Power Efficiency	May lead to more frequent wake-ups	Promotes power efficiency by reducing unnecessary wake-ups
Power Consumption	May result in higher power consumption	Reduces overall power consumption during idle periods