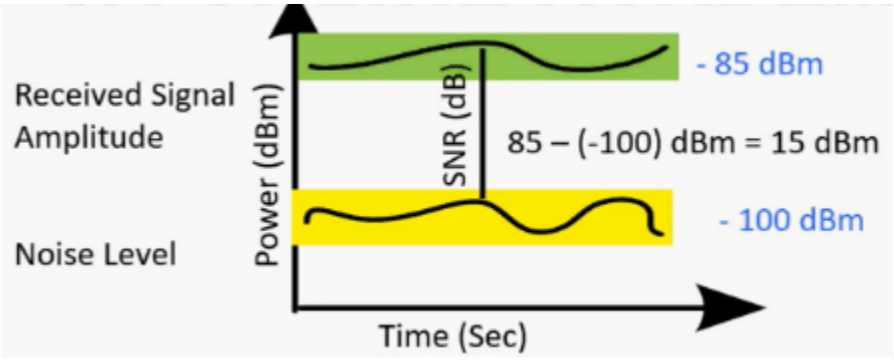
Answers for Session 2c - MCS Table / PHY Data Rates and Throughput

1. Why are SNR values positive and RSSI values negative?

RSSI (Received Signal Strength Indicator) values are negative because they measure the power level of the received signal relative to a reference level in dBm (decibels relative to 1 milliwatt). Negative RSSI values indicate that the received signal is weaker than the reference, which is often the case in wireless communication when signals attenuate over distance.

SNR (Signal-to-Noise Ratio) values are positive because they represent the ratio of the signal power (desired) to the noise power (undesired), and both are positive values. A higher positive SNR indicates a stronger, more reliable signal with less interference from noise.

SNR:



Noise floor: Background level of radio energy (modulated and unmodulated energy).

2. Looking at the Wi-Fi technology/MCS table, is it correct to say that according to the modulation will be reduced, the station and the AP will change the technology? Is that the backwards compatible meaning? Eg: 11ax has 1.2Gbps, if the link quality reduces, the handshake will be moved to 11ac?

Yes, your understanding is correct. When the link quality reduces, the station and the AP will change the technology to a lower MCS (modulation and coding scheme) or even a lower Wi-Fi standard, such as from 11ax to 11ac, to maintain a reliable connection.

This is known as backward compatibility, which is a feature of Wi-Fi that allows newer Wi-Fi devices to communicate with older Wi-Fi devices. Backward compatibility is achieved by using a variety of techniques, such as supporting different Wi-Fi standards and MCS levels. For example, if a 11ax station is trying to communicate with an 11ac AP, the station will automatically negotiate the highest MCS level that is supported by both the station and the AP.

If the link quality reduces, the station and the AP will negotiate a lower MCS level until they find a level that works reliably. If the link quality reduces further, the station and the AP may even negotiate to switch to a lower Wi-Fi standard, such as from 11ax to 11ac.

This is because lower Wi-Fi standards are more robust to interference and noise than higher Wi-Fi standards.

3. Does guard intervals guarantee collision free transmission due to multipath?

Guard intervals do not guarantee collision-free transmission due to multipath. They can reduce the probability of collisions, but they cannot eliminate them entirely.

Multipath is a phenomenon where a signal travels from the transmitter to the receiver over multiple paths. This can cause the signal to arrive at the receiver at different times, which can lead to collisions.

Guard intervals can reduce the probability of collisions by providing a buffer between symbols. This buffer allows the receiver to wait for the entire symbol to be received before it starts demodulating it. This helps to reduce the likelihood of collisions caused by multipath.

However, guard intervals cannot eliminate collisions entirely. If the multipath delay spread is greater than the length of the guard interval, then collisions can still occur**.**

4. What about Cyclic prefixes?

To combat the intersymbol interference (ISI) in a multipath channel, a cyclic prefix (CP) is inserted in the OFDM symbol.

They are essential for maintaining signal integrity by adding a guard interval at the start of each symbol. This guard interval allows for a more reliable transmission, especially in the presence of multipath interference, which can cause signal reflections and delay spread.

Cyclic prefixes play a crucial role in mitigating inter-symbol interference (ISI) and improving the performance and reliability of wireless communication systems.

5. Can you please give more details regarding coding rates.

Coding rates in WiFi are used to improve the reliability of data transmission. They do this by adding redundancy to the data being transmitted. The redundancy can then be used to detect and correct errors that occur during transmission.

The coding rate that is used in a WiFi link is negotiated between the station (client device) and the AP (access point). The station and the AP will select the highest MCS level that can be supported reliably based on the current link quality. MCS levels are a combination of modulation and coding schemes.

Modulation determines how the data bits are represented on the radio signal, while coding determines how the redundancy is added to the data. Higher MCS levels use higher modulation schemes, which can achieve higher data rates.

However, higher modulation schemes are also more susceptible to errors. This is because higher modulation schemes use more complex representations of the data bits, which makes it more likely that errors will occur.

Coding rates can help to mitigate the increased susceptibility to errors of higher modulation schemes. By adding redundancy to the data, coding rates can help to ensure that errors can be detected and corrected.

MCS Index			Spatial Stream	Modulation	Coding
HT	VHT	HE			
0	0	0	1	BPSK	1/2
1	1	1	1	QPSK	1/2
2	2	2	1	QPSK	3/4
3	3	3	1	16-QAM	1/2
4	4	4	1	16-QAM	3/4
5	5	5	1	64-QAM	2/3
6	6	6	1	64-QAM	3/4
7	7	7	1	64-QAM	5/6
	8	8	1	256-QAM	3/4
	9	9	1	256-QAM	5/6
		10	1	1024-QAM	3/4
		11	1	1024-QAM	5/6

As you can see, the coding rate increases as the MCS level increases.

6.Why is GI 800 better than 400?

Guard Interval 800 is better than GI 400 because it provides more protection against multipath ,delay spread and adjacent / co channel interference.

Multipath is a phenomenon where a signal travels from the transmitter to the receiver over multiple paths, which can cause the signal to arrive at the receiver at different times.

Delay spread is the difference between the longest and shortest signal paths from the transmitter to the receiver.

A longer GI length can accommodate a longer delay spread, which can improve performance in environments with multipath and delay spread. However, a longer GI length also reduces the data rate, because it takes up more time in each symbol.

GI 800 is typically used in environments with high levels of multipath and delay spread, such as outdoor environments and industrial environments. GI 400 is typically used in environments with lower levels of multipath and delay spread, such as indoor environments and office environments.

Here are some of the benefits of using GI 800:

- Improved performance in environments with high levels of multipath and delay spread
- Reduced probability of collisions caused by multipath
- Increased range
- Increased reliability

7. MCS on Wifi 4 is from (MCS 0 to MCS 7) ?

In the case of Wi-Fi 4 (802.11n), the MCS indices extend up to 31. It's important to note that the assignment of MCS indexes based on spatial streams was introduced after Wi-Fi 4. This is why we have MCS indices ranging from 0 to 31, accommodating all spatial streams.But for HE and VHT we have the range of MCS indexes for each spatial stream

Example:

For different spatial streams , the indices range from 0 to 9 for VHT and 0 to 11 for HE , reflecting the specific modulation and coding configurations for this stream.

MCS Index			Spatial Stream	Modulation	Coding
HT	VHT	HE			
0	0	0	1	BPSK	1/2
1	1	1	1	QPSK	1/2
2	2	2	1	QPSK	3/4
3	3	3	1	16-QAM	1/2
4	4	4	1	16-QAM	3/4
5	5	5	1	64-QAM	2/3
6	6	6	1	64-QAM	3/4
7	7	7	1	64-QAM	5/6
	8	8	1	256-QAM	3/4
	9	9	1	256-QAM	5/6
		10	1	1024-QAM	3/4
		11	1	1024-QAM	5/6
8	0	0	2	BPSK	1/2
9	1	1	2	QPSK	1/2
10	2	2	2	QPSK	3/4
11	3	3	2	16-QAM	1/2
12	4	4	2	16-QAM	3/4
13	5	5	2	64-QAM	2/3
14	6	6	2	64-QAM	3/4
15	7	7	2	64-QAM	5/6
	8	8	2	256-QAM	3/4
	9	9	2	256-QAM	5/6
		10	2	1024-QAM	3/4
		11	2	1024-QAM	5/6

8. As the data rate increases it does not become very sensitive for multipath, interference , diffraction etc . Is this data rate achievable at all in a real time environment ?

As data rates increase in wireless communication, they can become more sensitive to various factors, including multipath interference, diffraction, and other environmental conditions.

Achieving high data rates in real-time environments is feasible under the right conditions, but it depends on various factors, including the technology used,

environmental conditions, and the specific application's requirements. In less-than-ideal conditions, it may be necessary to make trade-offs between data rate and reliability.

9. Share the MCS spreadsheet, please.

https://mcsindex.com/

10. Is MU-MIMO implemented UP-Link ?

Yes, MU-MIMO is implemented in uplink in WiFi 6 and 6E. This means that an access point can simultaneously receive data from multiple clients that support uplink MU-MIMO.

This can significantly improve the performance of uplink traffic, especially in congested environments where multiple clients are competing for bandwidth.

For example, in a video conference call, all of the participants could be sending their video streams to the access point at the same time using uplink MU-MIMO. To take advantage of uplink MU-MIMO, a client device must have at least two antennas. If the client device only has one antenna, it will still be able to communicate with the access point, but it will not be able to use uplink MU-MIMO. Uplink MU-MIMO is a relatively new technology, but it is becoming increasingly common in WiFi 6 and 6E devices. As more and more devices support uplink MU-MIMO, we can expect to see significant improvements in the performance of uplink traffic in congested environments.

11. MIMO capabilities fully leveraged in a practical wireless system ? I believe acquisition of Channel Quality Information is a big challenge that limits the capability of a MIMO technology in practice.

You're correct. In practical wireless systems, fully leveraging MIMO (Multiple Input, Multiple Output) capabilities can be challenging due to the acquisition of Channel Quality Information (CQI). CQI is essential for MIMO to work effectively by optimizing spatial multiplexing and beamforming. Overcoming CQI challenges is crucial for maximizing the benefits of MIMO technology.

12. Does data rate depend on frequency, then in rate adaption even though the frequency is same when we switch to lower modulation due to low snr our data rate decreases right.

Yes, data rate in wireless communication can depend on frequency, but it's not the sole factor. The relationship between data rate and frequency can be influenced by various factors such as modulation, signal-to-noise ratio (SNR), and channel conditions.

In rate adaptation, when the SNR drops and it's necessary to switch to a lower modulation scheme, the data rate decreases. This is because lower modulation schemes transmit fewer bits per symbol, which reduces the data rate even if the frequency remains the same. Rate adaptation is a common technique used to maintain a reliable connection in challenging wireless environments by sacrificing data rate for better reliability.

13. Does bit duration change wrt channel bandwidth? is it not supposed to depend on msg bandwidth?

We are achieving more data rates when we are moving to higher frequency bands like in 5G because of a combination of two factors:

- Higher carrier frequency: Higher frequency bands allow for wider channels, which can carry more data.
- More available bandwidth: There is more spectrum available at higher frequencies, which means that there is more room for multiple channels.

14. What is MU-MIMO?

MU-MIMO stands for Multi-User Multiple-Input Multiple-Output. It is a wireless technology that allows an access point (AP) to communicate with multiple devices simultaneously using multiple antennas.

MU-MIMO is a significant improvement over single-user MIMO (SU-MIMO), which is the technology that is used in older wireless networks. In SU-MIMO, the AP can only communicate with one device at a time.

This can lead to performance bottlenecks when there are multiple devices on the network that are trying to communicate with the AP at the same time. MU-MIMO solves this problem by allowing the AP to communicate with multiple devices simultaneously.

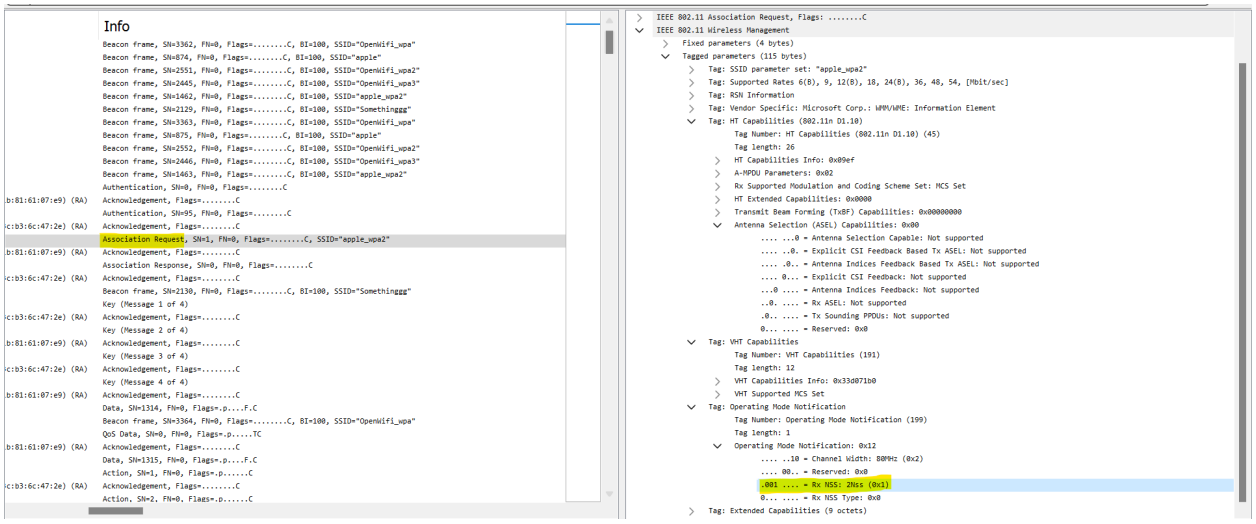
This can significantly improve the overall performance of the network, especially in congested environments. MU-MIMO is supported by the 802.11ac and 802.11ax (WiFi - 6) wireless standards. In order to benefit from MU-MIMO, both the AP and the client devices must support the technology.

16. What does frame size/packet size mean?

Frame size or packet size refers to the length or size of the blocks of data that are transmitted over a network. The size can vary based on the specific network technology and communication protocols in use.

17. Spatial diversity/diversity gain how does ap adapt based on client capabilities?

The capabilities of clients is usually communicated in the association request



Above is the pcap in which the client's NSS is shown which is sent to AP.

18. I saw in Lanforge, the sensitivity level was -20dBm. is there a possibility to saturate the receiver and then decrease the link quality?

Yes, if the received signal is too strong and exceeds the receiver's sensitivity level of -20dBm, it can saturate the receiver and potentially decrease the link quality.

19. What is DFS in Wifi6?

We all know that the 5Ghz band has a lot more channels than 2.4Ghz. But there is a catch. In the 5Ghz spectrum, two sets of bands (U-NII-2A and U-NII-2C) include DFS channels. These bands are also used for Radar communication for critical operations like satellite communications, surveillance, and weather forecasting.

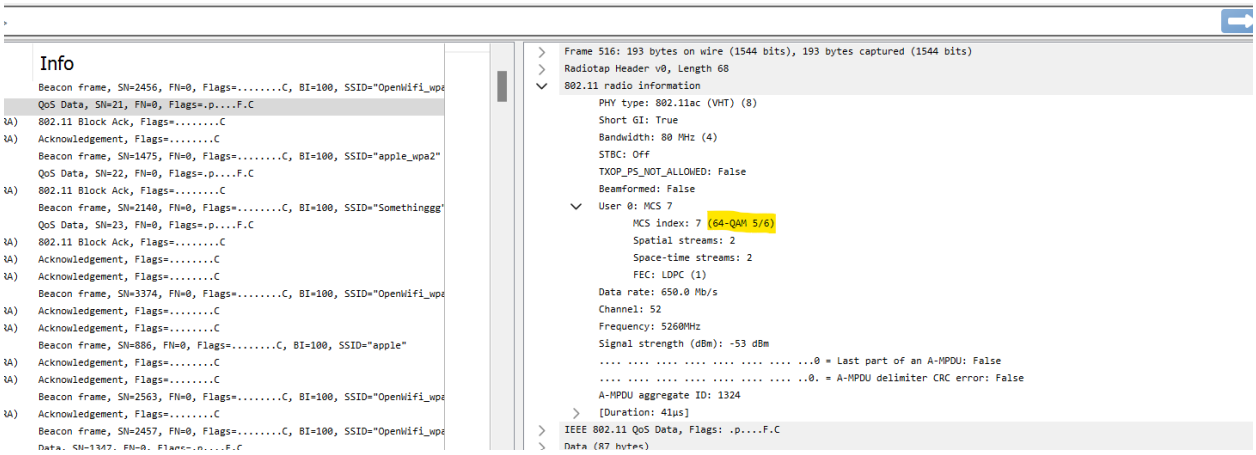
So, whenever a Wi-Fi Access Point detects the radar signal on its active channel, it needs to honor the radar signals by moving off from its active channel to a different

channel. How does the AP do that? It uses a feature called Dynamic Frequency Selection (DFS) which is implemented as part of IEEE 802.11h standard.

DFS compliance testing has their own drafts (they are regulated by governing bodies, not IEEE)
If the question meant is regarding DFS in 6Ghz, then DFS is being replaced by AFC to avoid interference with other RF systems

20. How can we know which modulation the station is connected to?
Can it be shown in Wireshark?

Yes we can see MCS index, spatial streams in the radio information. Below is the example of the pcap



21. If we have ax client with 2x2 antenna , does it support 16 * 16 spatial stream or the ax client should have 16 antennas ?

An ax client with 2x2 antennas does not support 16x16 spatial streams. To support 16x16 spatial streams, an ax client must have at least 16 antennas.

The number of spatial streams that a client can support is determined by the number of antennas that it has. Each spatial stream uses a separate antenna to transmit and receive data. This allows the client to achieve higher data rates and improve its performance in noisy environments.

The maximum number of spatial streams that an ax client can support is 16. However, most ax clients only support a few spatial streams, such as 2x2 or 4x4

22. What is the tool used to measure the tput?

Here, we have used LANforge tool to measure the throughput
We can also use other tools like Iperf as well to measure the throughput

23. Was Wi-Fi Chamber used for Throughput tests?

RF chamber was used to run the throughput tests to maintain an ideal environment.
An RF chamber is a shielded box that is used to test wireless devices in a controlled environment. RF chambers are designed to block out external interference, such as noise from other wireless devices, and to provide a consistent signal strength.

It's just a faraday cage.