ENSC 833 NETWORK PROTOCOLS AND PERFORMANCE
SPRING 2022

SFU

Implementation of Wi-Fi 6 with ns-3 and Analysis

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Team 06

Agenda

- This project is to understand Wi-Fi 6, some main difference from Wi-Fi 5
- Related work to WiFi 6 implementation in ns-3
- Test case about MCS effect
- Test case about simulation performance in terms of throughput with some basic settings, evaluation on frequency band performance
- Future work

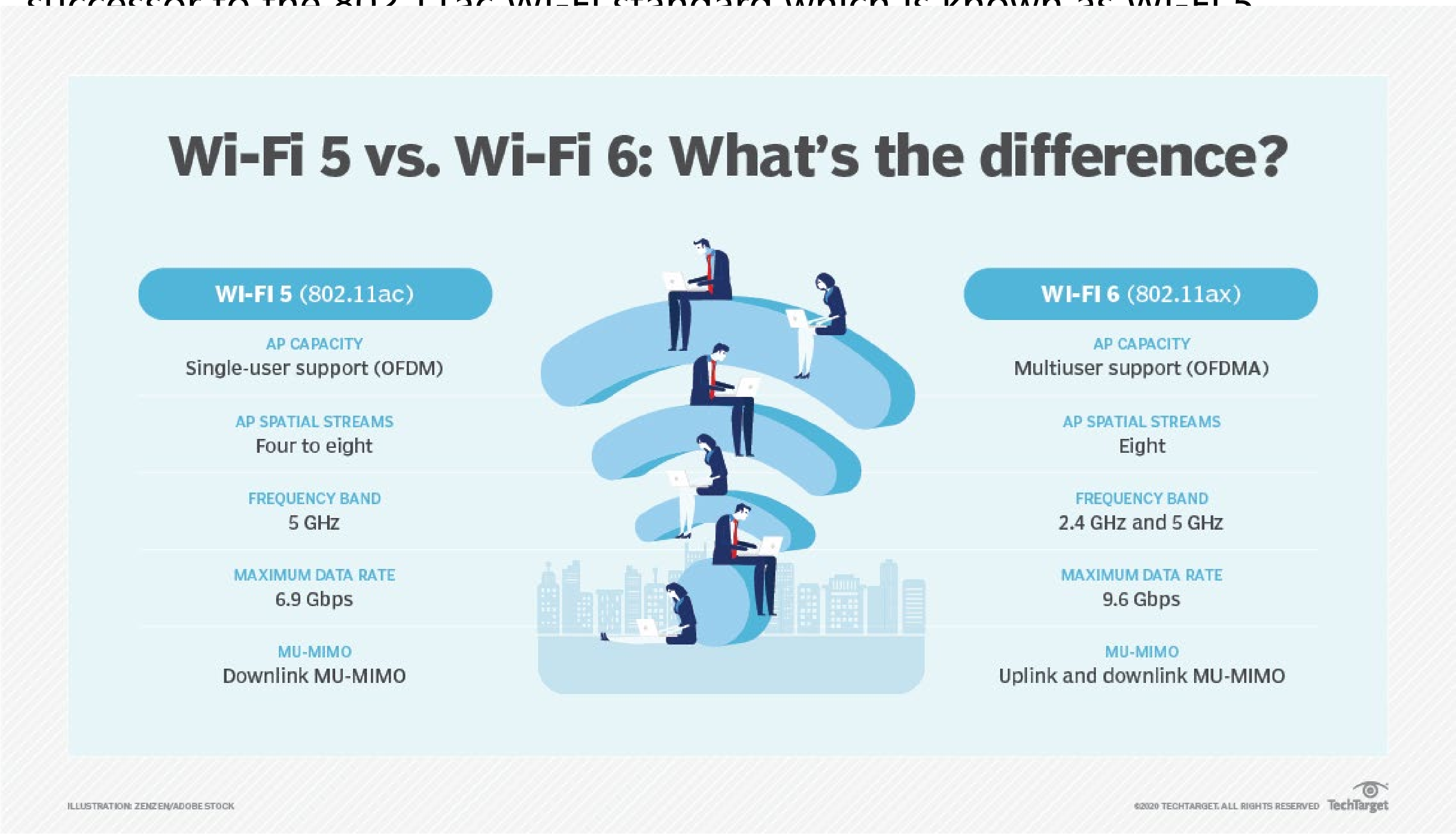
Motivation

- With households consuming **more content as time goes on**, the **increase to WiFi 6** should allow for a **multiple users** to be able to have **High-Throughput** and **High-Efficiency** links so that numerous users on the same local network can stream, download, and game without utilizing all of the network bandwidth or experienced a poor **Quality of Service**
- WiFi 6 has been recently implemented with the ability to have **higher bandwidth channels**, **faster modulation schemes**, and higher resilience to interference.
- The motivation behind this is to assess the **performance** of WiFi 6 for use in local area networks such as home networks
- ns-3 simulator as a tool to evaluate Wi-Fi 6 performance.
  With the latest release of ns-3.35, Wi Fi 6 support regarding rates, configuration and some extension to transmission and receiving modules are in place for user to test[10].

[10]source: [https://depts.washington.edu/funlab/wp-content/uploads/2018/11/11ax-final-report.pdf]

INTRODUCTION

- WiFi 6, also known as 802.11ax wireless standard. WiFi 6 is released in 2019, and is the latest wireless standard that is used in wireless devices and is the successor to the 802.11ac Wi-Fi standard which is known as Wi-Fi 5



source:[https://www.techtarget.com/searchnetworking/feature/Wi-Fi-6-technology-explained-from-speed-to-security-and-more]

INTRODUCTION

Key capabilities sets Wi Fi 6 apart from Wi-Fi 5:

➔ 1024 quadrature amplitude modulation mode (**1024-QAM**, MCS[10,11]) :
increases throughput for emerging, bandwidth intensive uses by encoding more data in the same amount of spectrum

➔ Orthogonal frequency division multiple access (**OFDMA)** :
effectively shares channels to increase network efficiency and lower latency for both uplink and downlink traffic in high demand environments

➔ Multi-user multiple input, multiple output (**MU-MIMO**) :
allows more data to be transferred at one time, enabling access points (APs) to concurrently handle more devices

Other nice updates from Wi-Fi 5:

- **160 MHz** channel utilization capability increases bandwidth to deliver greater performance with low latency
- **Transmit beamforming** enables higher data rates at a given range to increase network capacity
- Target wake time (**TWT**) significantly improves network efficiency and device battery life, including IoT device
- Basic Service Set coloring (**BSS coloring**) can distinguish another network from its own and disregards their interfering distraction.

OVERVIEW OF RELATED WORK

D.Margin, S.Avallone, S.Roy and M.Zorzi,“Validation of the ns-3 802.11ax OFDMA Implementation”Virtual Event, USA,2021

This paper has excellent insights about the ns-3 Wi-Fi model for 802.11ax OFDMA. It provides a good foundation for doing performance testing of WiFi 6 networks in ns-3. There are a number of useful plots, and parameters used for performance experiments. However, It does not describe how to perform MCS related test in ns-3.

J.Sandoval and S.Cespedes, “Performance Evaluation of IEEE 802.11ax for Residential Networks”IEEE, 2021

This paper provides a good reference for a simple WIFI network with many plots to show performance of performance with respect to spatial parameters such as distance from AP.

Arista, “Multi-User MIMO in Wifi6,” ARISTA Corp., Santa Clara, CA, USA

This whitepaper is very useful in understanding the parameters of 802.11ax and how that applies to the physical operation of WiFi 6, as well as the improvements gained from MIMO

MCS design in Wi Fi 6 (OFDM)

test sudo code:

Topology setup and initialization

setup log file header, simulation interval

Loop MCS=0-11
loop Channel Bandwidth= 20-160 MHz
loop GI=3200-800 ns
phyModel selection; // Yans or Spectrum
stream generation;
Mobility model selection;
node installation;
IP address assignment;
simulation schedule;
simulation run();
Collect data;

MCS: **M**odulation **C**oding **S**cheme;
GI: **G**uard **I**nterval Duration

MCS Index	Spatial Stream	Modulation	Coding	OFDM (802.11ax) 20MHz 0.8μs GI	20MHz 1.6μs GI	20MHz 3.2μs GI	40MHz 0.8μs GI	40MHz 1.6μs GI	40MHz 3.2μs GI	80MHz 0.8μs GI	80MHz 1.6μs GI	80MHz 3.2μs GI	160MHz 0.8μs GI	160MHz 1.6μs GI	160MHz 3.2μs GI
0	1	BPSQ	1/2	8.6	8.1	7.3	17.2	16.3	14.6	36.0	34.0	30.6	72.1	68.1	61.3
1	1	QPSK	1/2	17.2	16.3	14.6	34.4	32.5	29.3	72.1	68.1	61.3	144.1	136.1	122.5
2	1	QPSK	3/4	25.8	24.4	21.9	51.6	48.8	43.9	108.1	102.1	91.9	216.2	204.2	183.8
3	1	16-QAM	1/2	34.4	32.5	29.3	68.8	65.0	58.5	144.1	136.1	122.5	288.2	272.2	245.0
4	1	16-QAM	3/4	51.6	48.8	43.9	103.2	97.5	87.8	216.2	204.2	183.8	432.4	408.3	367.5
5	1	64-QAM	2/3	68.8	65.0	58.5	137.6	130.0	117.0	288.2	272.2	245.0	576.5	544.4	490.0
6	1	64-QAM	3/4	77.4	73.1	65.8	154.9	146.3	131.6	324.3	306.3	275.6	648.5	612.5	551.3
7	1	64-QAM	5/6	86.0	81.3	73.1	172.1	162.5	146.3	360.3	340.3	306.3	720.6	680.6	612.5
8	1	256-QAM	3/4	103.2	97.5	87.8	206.5	195.0	175.5	432.4	408.3	367.5	864.7	816.7	735.0
9	1	256-QAM	5/6	114.7	108.3	97.5	229.4	216.7	195.0	480.4	453.7	408.3	960.8	907.4	816.7
10	1	1024-QAM	3/4	129.0	121.9	109.7	258.1	243.8	219.4	540.4	510.4	459.4	1080.9	1020.8	918.8
11	1	1024-QAM	5/6	143.4	135.4	121.9	286.8	270.8	243.8	600.5	567.1	510.4	1201.0	1134.3	1020.8

source: [https://docs.google[…]Ku_YI6DgS6zZMNylhQpQmnKQ1O7abij/pubhtml?gid=1367372895&single=true]

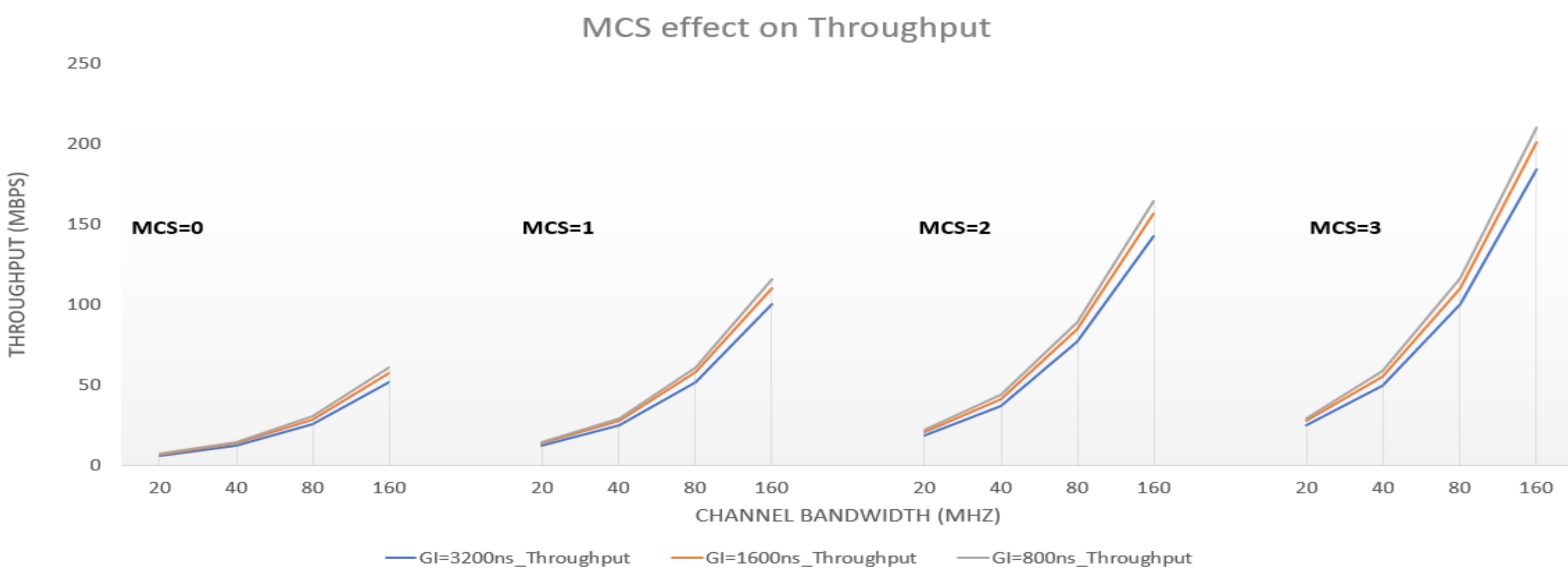
Test output

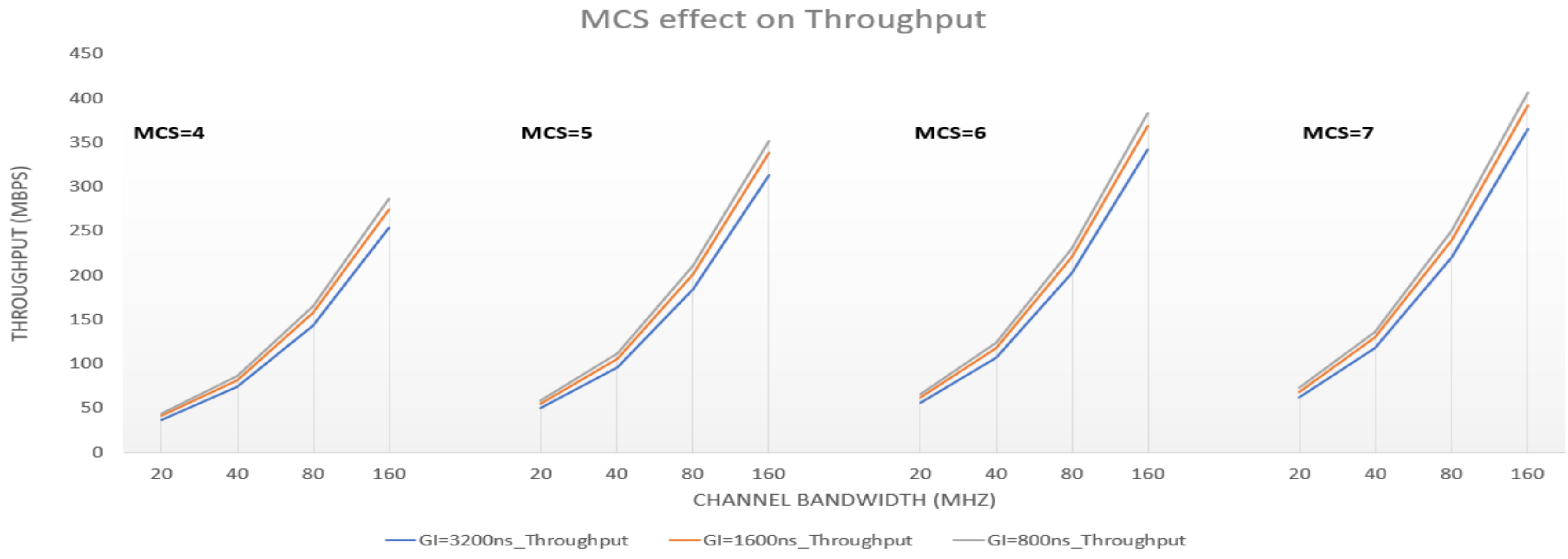
test case:

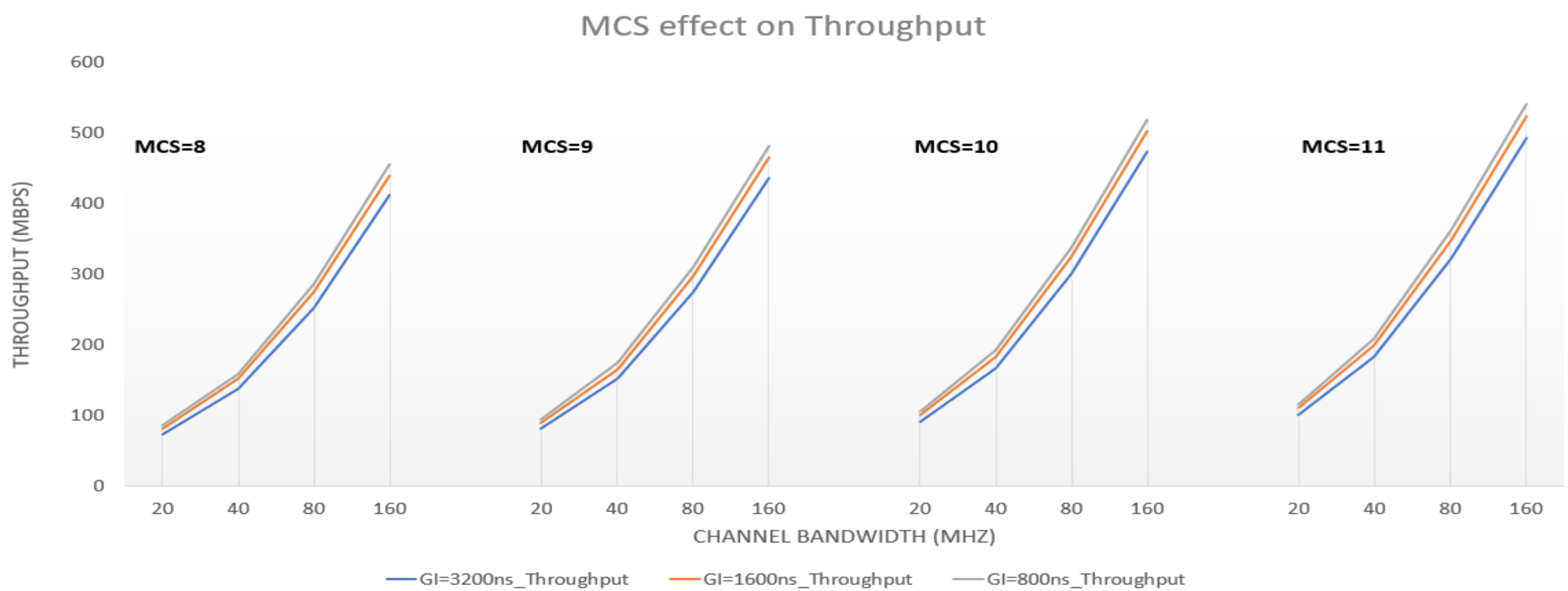
```
// The simulation assumes a configurable number of stations in an infrastructure network:
//
//  STA(1)        AP
//    *            *
//    |            |
//   n1           n2
//
// NO-OFDMA
// Freq = 5G
// Packets in this simulation belong to
//              BestEffort Access Class (AC_BE).
```

// Packets in this simulation belong to BestEffort Access Class (AC_BE).

MCS value	Channel width	GI	Throughput
0	20 MHz	3200 ns	6.12752 Mbit/s
0	20 MHz	1600 ns	6.83312 Mbit/s
0	20 MHz	800 ns	7.21056 Mbit/s
0	40 MHz	3200 ns	12.2937 Mbit/s
0	40 MHz	1600 ns	13.7077 Mbit/s
0	40 MHz	800 ns	14.5426 Mbit/s
0	80 MHz	3200 ns	25.8177 Mbit/s
0	80 MHz	1600 ns	28.6815 Mbit/s
0	80 MHz	800 ns	30.4013 Mbit/s
0	160 MHz	3200 ns	51.5766 Mbit/s
0	160 MHz	1600 ns	57.4465 Mbit/s
0	160 MHz	800 ns	60.7813 Mbit/s




MCS effect on Throughput
450
400
350
300
250
200
150
100
50
0
THROUGHPUT (MBPS)
MCS=4
MCS=5
MCS=6
MCS=7
20 40 80 160
20 40 80 160
20 40 80 160
20 40 80 160
CHANNEL BANDWIDTH (MHZ)
GI=3200ns_Throughput
GI=1600ns_Throughput
GI=800ns_Throughput


MCS effect on Throughput
600
500
400
300
200
100
0
THROUGHPUT (MBPS)
MCS=8
MCS=9
MCS=10
MCS=11
20 40 80 160
20 40 80 160
20 40 80 160
20 40 80 160
CHANNEL BANDWIDTH (MHZ)
GI=3200ns_Throughput
GI=1600ns_Throughput
GI=800ns_Throughput

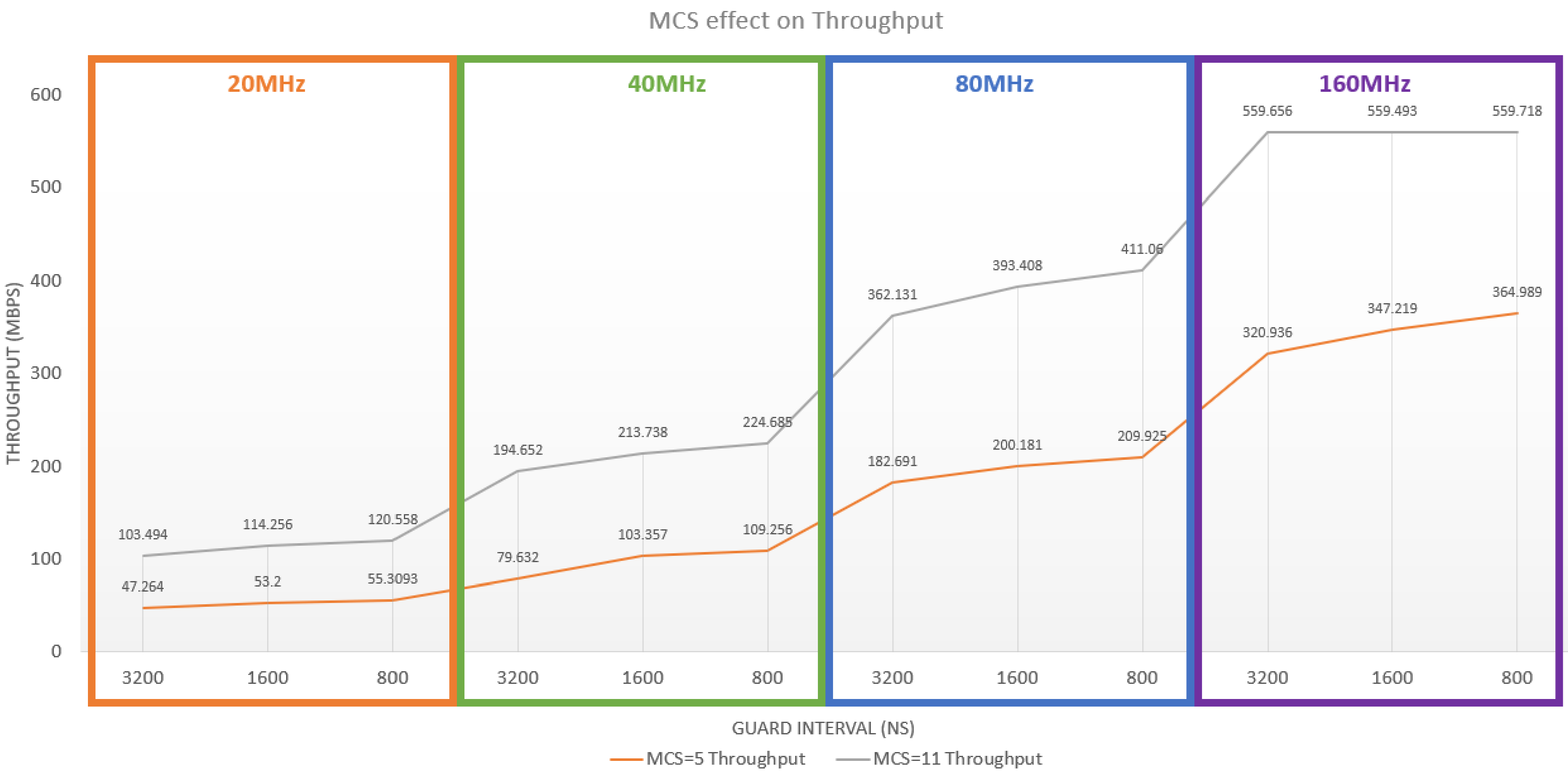
Expected VS. Simulation

MCS Index	Spatial Stream	Modulation	Coding	20MHz		
				0.8µs GI	1.6µs GI	3.2µs GI
0	1	BPSQ	1/2	8.6	8.1	7.3
1	1	QPSK	1/2	17.2	16.3	14.6
2	1	QPSK	3/4	25.8	24.4	21.9
3	1	16-QAM	1/2	34.4	32.5	29.3
4	1	16-QAM	3/4	51.6	48.8	43.9
5	1	64-QAM	2/3	68.8	65.0	58.5
6	1	64-QAM	3/4	77.4	73.1	65.8
7	1	64-QAM	5/6	86.0	81.3	73.1
8	1	256-QAM	3/4	103.2	97.5	87.8
9	1	256-QAM	5/6	114.7	108.3	97.5
10	1	1024-QAM	3/4	129.0	121.9	109.7
11	1	1024-QAM	5/6	143.4	135.4	121.9

MCS	20MHz		
	800 ns	1600 ns	3200 ns
0	7.2	6.8	6.1
1	14.6	13.8	12.4
2	21.9	20.7	18.6
3	29.4	27.7	24.9
4	44.0	41.5	37.3
5	58.7	55.3	49.8
6	65.8	62.2	56.0
7	72.6	68.9	62.3
8	86.0	81.5	73.9
9	94.6	89.8	81.4
10	105.3	99.9	90.7
11	115.9	110.1	100.1

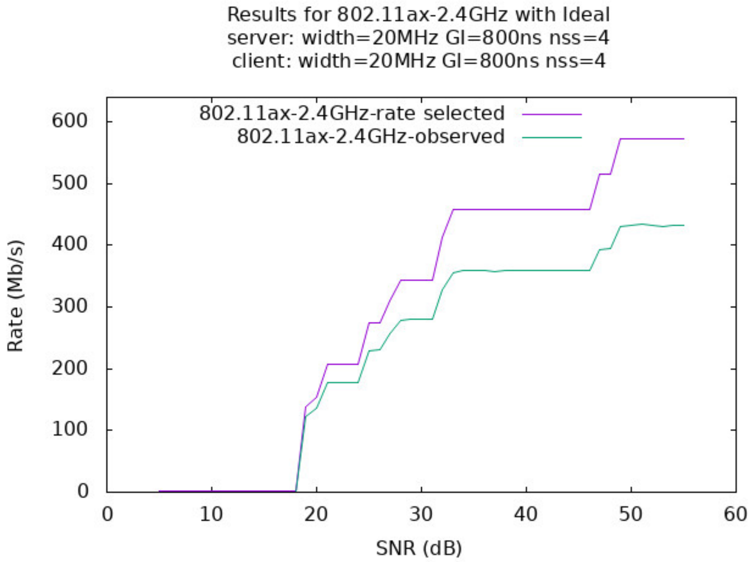
test case:

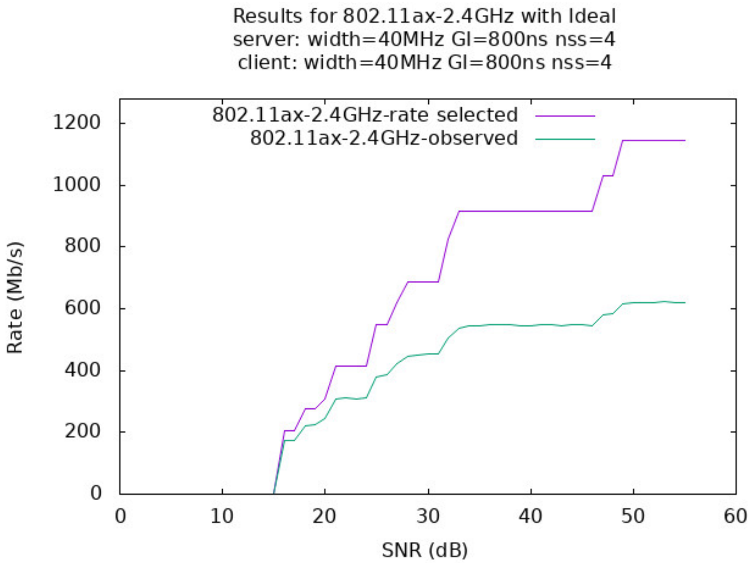
```
// The simulation assumes a configurable number of stations in an infrastructure network:
//
//  STA(10)      AP
//    *           *
//    |           |
//   n1-10       n11
//
// NO-OFDMA
// Freq = 6G
// Throughput Range set enabled
// ExtendedBlockAck enabled
// Packets in this simulation belong to BestEffort Access Class (AC_BE).
```



Test output

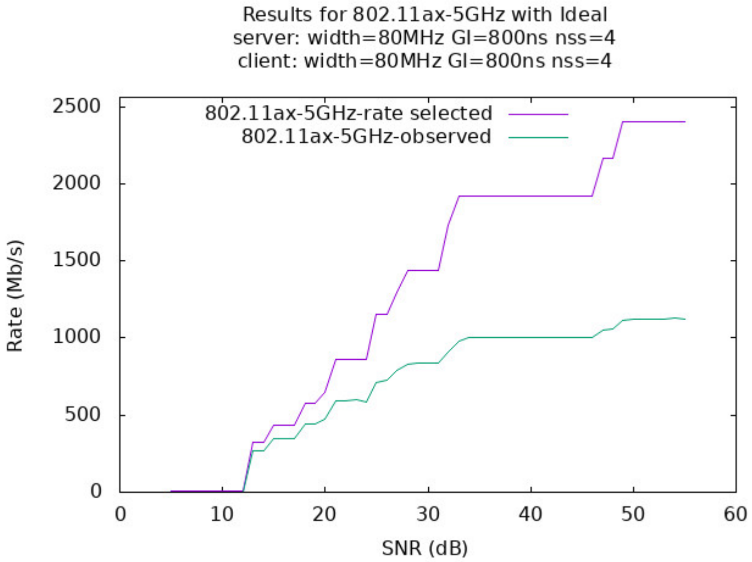
test case:
// This simulates point to point transmission and
// measures the Actual Throughput vs Ideal
// Throughput as RSSI (Received Signal Strength
// Indicator) is reduced which in turn reduces
// Signal to Noise Ratio (SNR):
//
// STA(1) AP
// * *
// | |
// n1 n0
//
// Number Spatial Streams (NSS) = 4 (AP/STA)
// Guard Interval = 800ns (lowest)
// Freq = **2.4GHz**
// Channel BW = default(20MHz)/Max(40MHz)
// Manager Model = Ideal

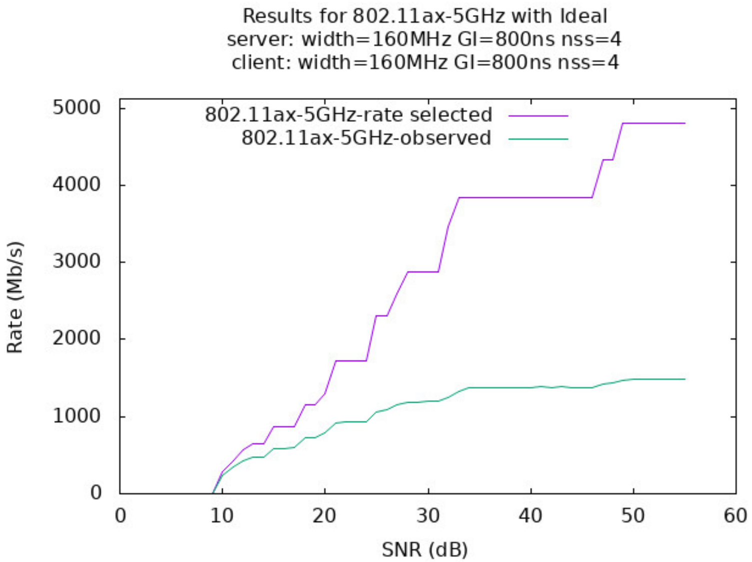




Test output

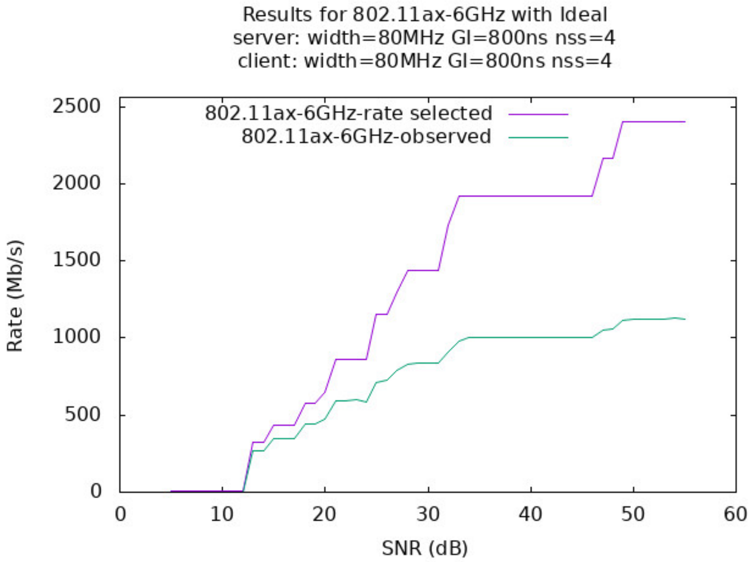
test case:
// This simulates point to point transmission and
// measures the Actual Throughput vs Ideal
// Throughput as RSSI (Received Signal Strength
// Indicator) is reduced which in turn reduces
// Signal to Noise Ratio (SNR):
//
// STA(1) AP
// * *
// | |
// n1 n0
//
// Number Spatial Streams (NSS) = 4(AP/STA)
// Guard Interval = 800ns (lowest)
// Freq = **5GHz**
// Channel BW = default(80MHz)/Max(160MHz)
// Manager Model = Ideal

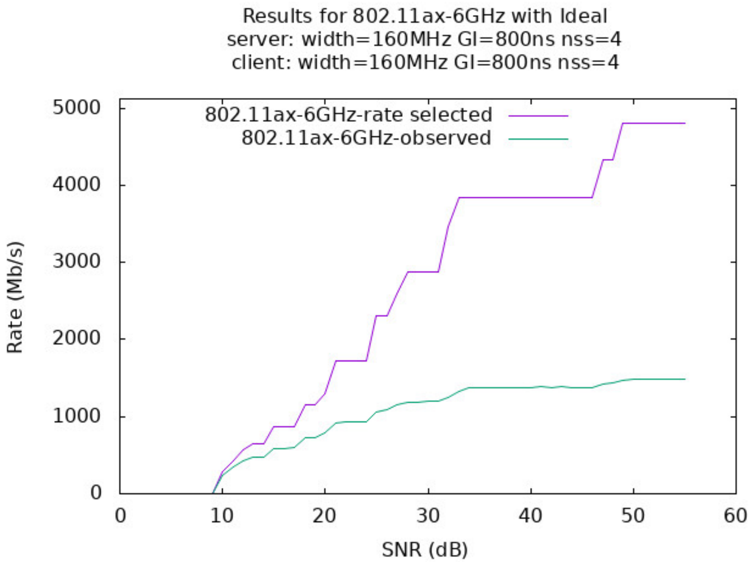




Test output

test case:
// This simulates point to point transmission and
// measures the Actual Throughput vs Ideal
// Throughput as RSSI (Received Signal Strength
// Indicator) is reduced which in turn reduces
// Signal to Noise Ratio (SNR):
//
// STA(1)   AP
//   *   *
// | |
//   n1   n0
//
// Number Spatial Streams (NSS) = 4(AP/STA)
// Guard Interval = 800ns (lowest)
// Freq = **6GHz**
// Channel BW = default(80MHz)/Max(160MHz)
// Manager Model = Ideal





DISCUSSION

Conclusion :

Although Wi-Fi 6 has been implemented and adopted in ns-3, and has a number of examples and papers and examples utilizing the Wi-Fi 6 implementation, since it is a relatively new technology the number of simulations papers are still limited compared to that of other technologies implemented in ns-3. There are still very few papers exploring the results of **MCS** and its self-adaptive function dealing with **user-intense environment.**

Remaining Work :

- Implement **OFDMA** signalling for the **Multi-User** case
- Complete final simulation topology for tests showing effects of throughput when increasing the number of Stations on the network

Future Work:

- **Latency Measurements** to determining the improvement in Wi-Fi 6 for low latency applications
- Investigate **Spatial Stream reuse** for **Multi-User** operation in Wi-Fi 6
- Investigate **BSS Coloring** for reduced interference between APs

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THANK YOU.
QUESTIONS?