Performance analysis of 802.11ax 2.4GHz (WiFi 6)

Group 6
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[1] K. Jirasukhanont, 2018.

CONTENTS

GOALS

1. Understand Innovations

Through this project we seek to understand significant changes added to WiFi 6 (802.11ax) from its previous versions

2. Find a WiFi 6 Simulator

Locate a WiFi 6 simulator ideally using ns-3 to work through and understand setup, focal points, and key variables

3. Change Current Simulation

Using the online ns-3 WiFi 6 simulator, edit the simulation parameters and compare results to expected increases from research

4. Visualize Variable Changes

Different people purchase various tiers of WiFI to meet their personal and financial needs, graphing this assists in understanding and can showcase errors more efficiently

PROBLEM DESCRIPTION

While we use WiFi on a daily basis, we don’t fully understand what makes it work or what exactly it does to allow uses to connect to the internet without a direct cable connection.

WiFi has had many iterations over the years, a newer model (802.11ax/WiFi 6) must have some improvements over the past versions; what was introduced and what does it do?

More specifically, basic WiFi terminology is widely unknown as well, what are the core components of WiFi 6 and what do they contribute to the whole?

OVERVIEW OF RELATED WORK

Wi-Fi 6 has proven to be superior to previous generations which has been attributed to these features:

Orthogonal Frequency Division Multiple Access (OFDMA): Improving both network efficiency and capacity by splitting frequency bands into orthogonal subcarriers, resulting in multiple users being able to use the same frequency band simultaneously

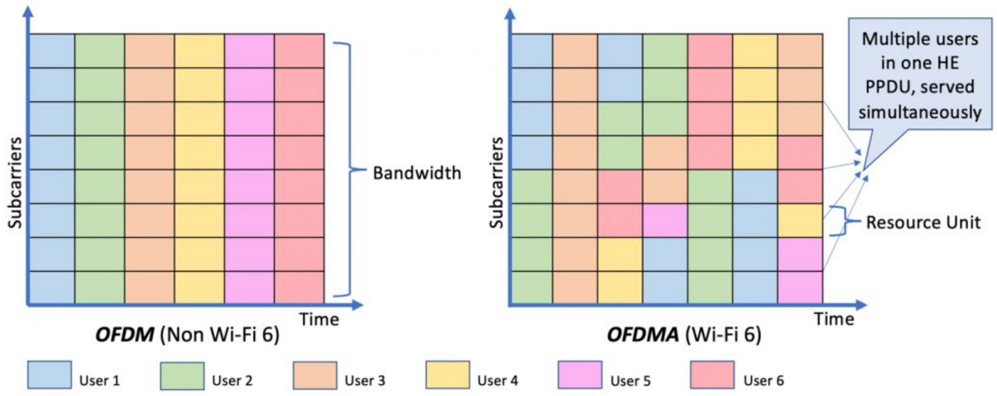


Fig. 1: OFDMA Overview
[2] S. Trivedi, 2020

OVERVIEW OF RELATED WORK

Wi-Fi 6 has proven to be superior to previous generations which has been attributed to these features:

Multi-User Multiple Input Multiple Output (MU-MIMO): Enables the router to simultaneously send data to multiple devices, reducing congestion and improving overall network performance

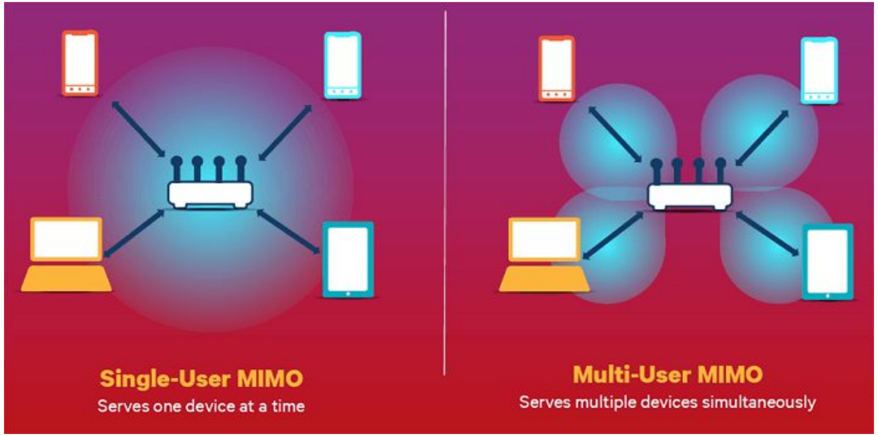


Fig. 2: MU-MIMO Overview
[3] everything RF, 2019

OVERVIEW OF RELATED WORK

Wi-Fi 6 has proven to be superior to previous generations which has been attributed to these features:

Basic Service Set (BSS) Coloring: A mechanism that improves performance and reduces interference in dense environments by assigning a colour to each BSS, allowing devices to differentiate between transmissions from their own and overlapping networks

Fig. 3: BSS Overview
[4] Memoona ans S.W. Kim, 2025

OVERVIEW OF RELATED WORK

OFDMA in Contention-Driven Scenarios [4]

- The paper highlighted the efficiency of improving throughput and reducing latency in congested environments
- Concluded that under contentious scenarios, the OFDMA was greater

Optimization of IEEE 802.11ax Dense Networks [5]

- Used ns-3 simulator with three different network topologies were analyzed and compared
- Highlighted that BSS coloring can bring up to a 15% increase in throughput for dense networks

OVERVIEW OF RELATED WORK

MU-MIMO Channel Sounding in ns-3 [6]

- In this study they implemented and evaluated IEEE 802.11ax's MU-MIMO in ns-3
- They found improvement in performance in multi-device scenarios

IEEE 802.11AX vs IEEE 802.11AC [7]

- Compared simulation performance of the their respective MIMO link features of WLANs
- Further, they show that 802.11AXs MIMO link outperformed 802.11ACs

SIMULATION OVERVIEW

The main simulation tool we used was Cisco's ns3-802.11ax-simulator [8]:

- Runs on ns-3.26
- Simulates clients running **VoIP**, **Video**, and **data transfer** loads
- Can modulate various parameters via command line inputs

For every client type, we measured the **latency** and **throughput**, depending on the value of the **MCS index** being used.

Functionally speaking, we made as few edits to the original Cisco codebase as possible under the assumption that it provided all the tools we needed.

SIMULATION OVERVIEW

				OFDM (802.11ax)											
MCS Index	Spatial Stream	Modulation	Coding	20MHz			40MHz			80MHz			160MHz		
				0.8us GI	1.6us GI	3.2us GI	0.8us GI	1.6us GI	3.2us GI	0.8us GI	1.6us GI	3.2us GI	0.8us GI	1.6us GI	3.2us GI
0	1	BPSK	1/2	8.6	8.1	7.3	17.2	16.3	14.6	36	34	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	58.5	144.1	136.1	122.5	288.2	272.2	245
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	58.5	137.6	130	117	288.2	272.2	245	576.5	544.4	490
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	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	175.5	432.4	408.3				
9	1	256-QAM	5/6	114.7	108.3	97.5	229.4	216.7	195	480.4	453.7				
10	1	1024-QAM	3/4	129	121.9	109.7	258.1	243.8	219.4	540.4	510.4				
11	1	1024-QAM	5/6	143.4	135.4	121.9	286.8	270.8	243.8	600.5	567.1				

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

Mbps

Number of Data Subcarriers (N_{SD}), *Number of Coded Bits per Subcarrier per Stream* (N_{BPSCS}), *Coding* (R), *Number of Spatial Streams* (N_{SS}), *OFDM Symbol Duration* (T_{DFT}), *Guard Interval Duration* (T_{GI})

Fig. 4: MCS Table (Data Rate)
[9] F. Vergès

SIMULATION OVERVIEW

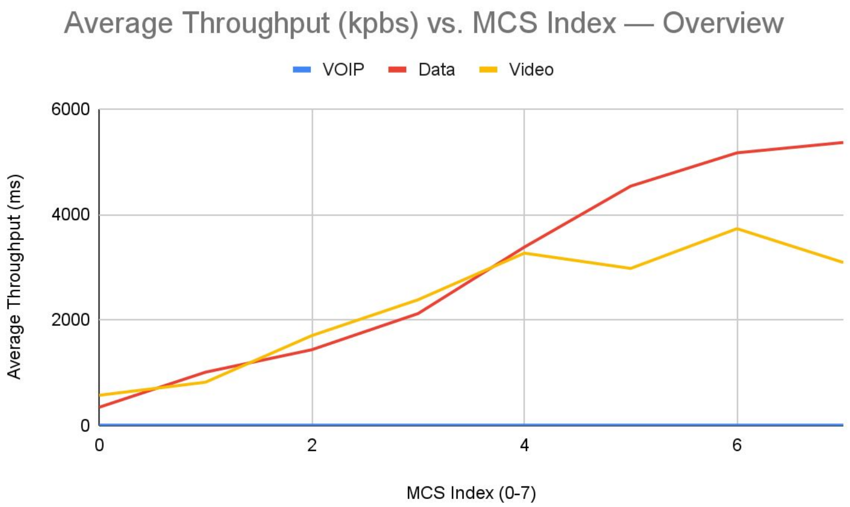
```
// Initialization: Provide a list of nodes in a text file and specify
// - Node type (Access Point, VoIP Client, Video Client, Data Client)
// - MAC Address
// - Node Position

Parse “scenario.txt” to initialize nodes
Determine MCS index from command line arguments

Set up WiFi 6 network using ns3 builtins

For every Node that is not an AP:
    Send the appropriate packet type to and from each Node
    Measure performance metrics: throughput, latency, jitter

Output results to another text file
```

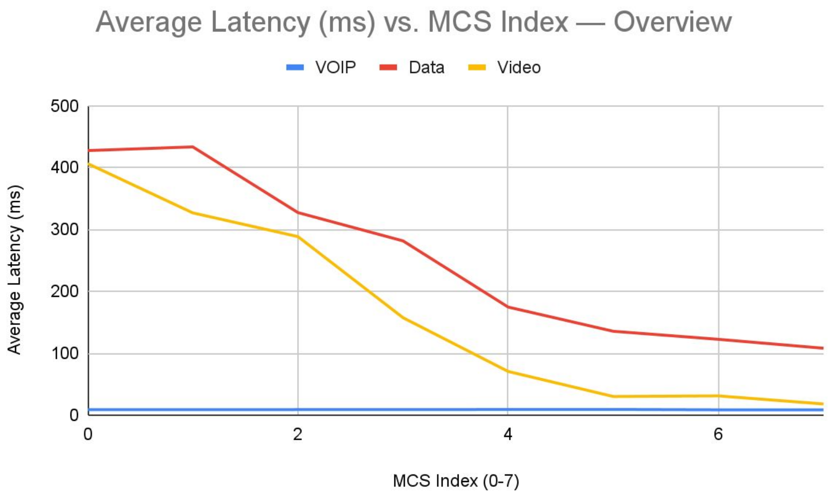
SIMULATION OVERVIEW

The simulation parameters were as follows:

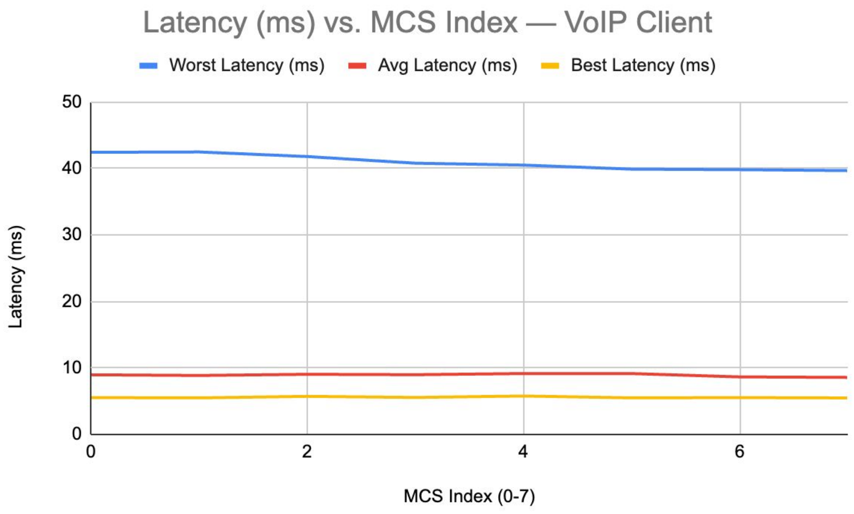
- 1 AP, 8 total clients
  - (2 VoIP, 3 Data, 3 Video)
  - Each client placed roughly equidistant from the AP
- Plot the average throughput and the best-case, worst-case, and average latency for each type of client

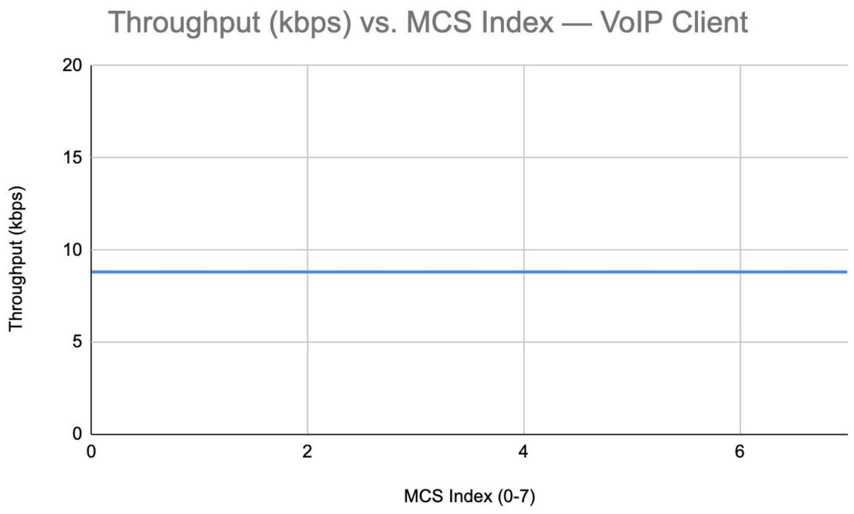
RESULTS — OVERVIEW



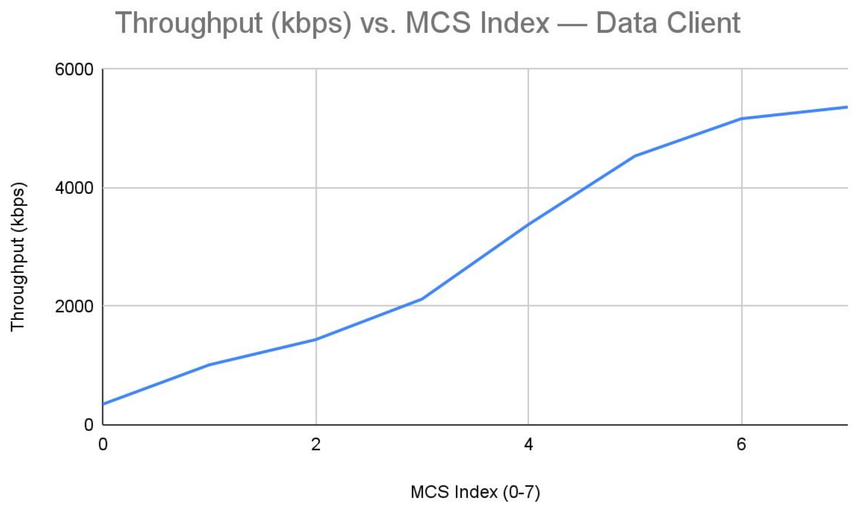


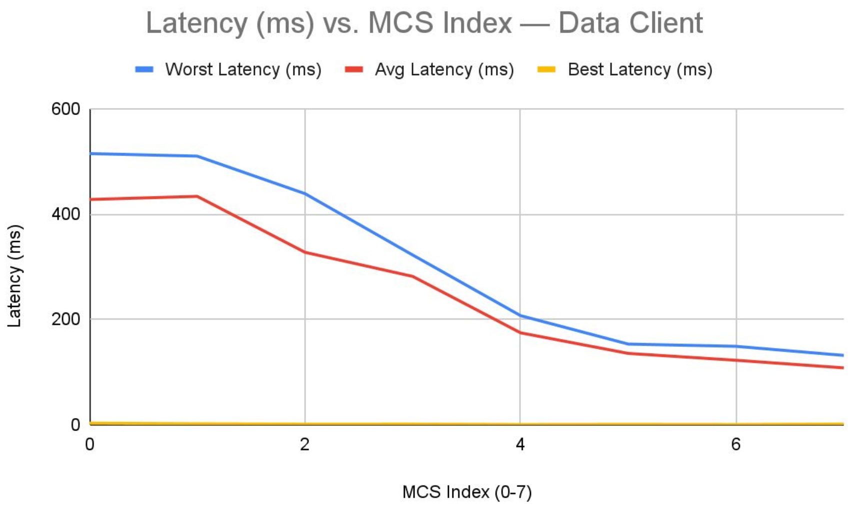
RESULTS — VoIP CLIENT



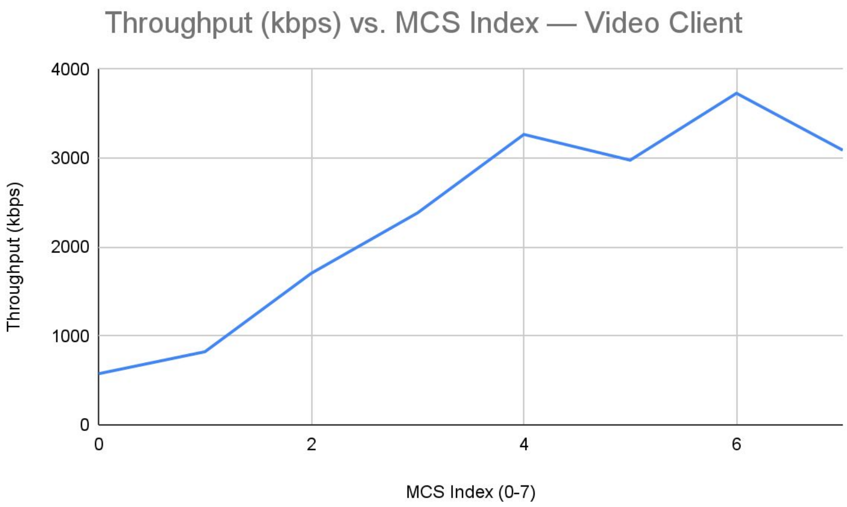


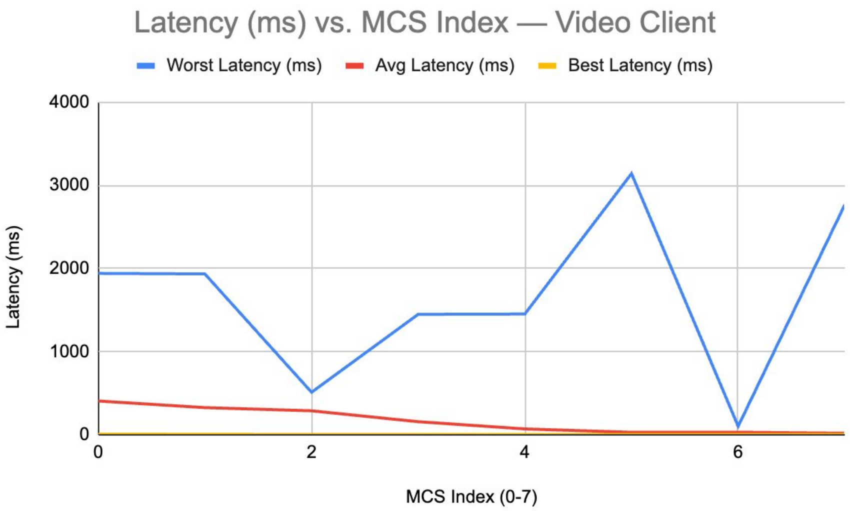
RESULTS — DATA CLIENT





RESULTS — VIDEO CLIENT





ANALYSIS

The results match what we expect from the Transport layer protocols [10]

VoIP: Throughput and latency does not change much with MCS index

- Realtime audio prioritizes robustness and reliability over speed

Data: Throughput and latency significantly increase and decrease respectively as MCS index increases

- File transfers have elastic throughput and latency is not a concern

Video: Throughput generally increases, latency is erratic

- Video streaming has elastic throughput and best-effort latency

DISCUSSION

In summary, the Cisco ns-3 WiFi 6 simulator provided a great framework for our throughput and latency measurements but was also limited by:

- No change in performance when channel bandwidth was changed
- Inability to change guard index

Setting up the existing simulator was difficult because:

- Install instructions were not complete
- OOP abstractions made it difficult to isolate the parameters of interest

Future work may include:

- Designing our own simulator
- Increasing the number of clients
- Modulating the packet size for different client types

CONTRIBUTIONS

- References and literature review
  33% Kurtis Lew - Provided multiple references and cited them accordingly, especially thorough investigation of Cisco Wi-Fi 6 simulation website
  33% Katherine Lee - Provided the most references and communicated details to groupmates for project development
  33% Owen Coukell - Provided multiple references and cited them in report
- Simulation scenarios, implementation, analysis, and discussion of simulation results
  55% Kurtis Lew - Performed various tests, shared output with team and proposed future edits to facilitate project development, Tested additional variables, Graphed output data
  12.5% Katherine Lee - Assisted in finding simulation code, Graphed outputted data
  32.5% Owen Coukell - Assisted in finding simulation code, Tested additional variables, Graphed output data
- Presentation
  33% Katherine Lee - Overview of Related Works, Problem Description
  33% Kurtis Lew - Simulation Overview, Results, Analysis, Discussion
  33% Owen Coukell - Introduction, Goals, Problem Statement, References

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