LAB 3 Measuring performance of a WiFi network in different scenarios

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D7030E Advanced Wireless Networks

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by

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Scenario 1 –Application throughput using WiFi network

1.1. Study the provided script for the scenario in Figure 1. Be able to explain the details of this simulation.

This will be explained in detail during the Lab Assessment. An AP and two STAs were created following the WIFI protocols.

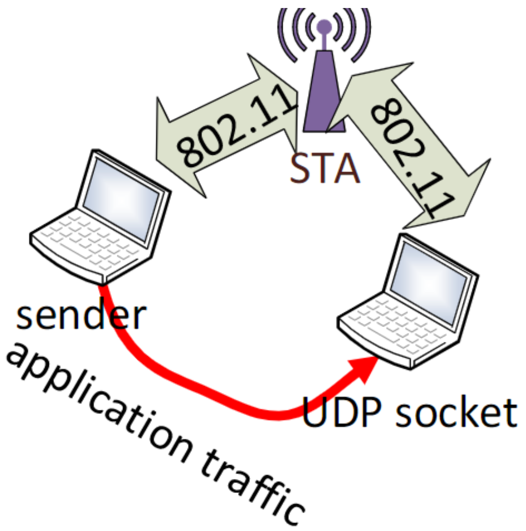

Figure 1.1: Figure 1

1.2. Based on the script for the first part of Scenario 1 implement the second part as illustrated in Figure 2.

This was implemented by changing the code in 3 different places. 4 STAs were created to support the 4 nodes according to Figure 2. The distance was set for the 4 STAs in relation to the AP. Afterwards, two applications were created to service two of the topologies.

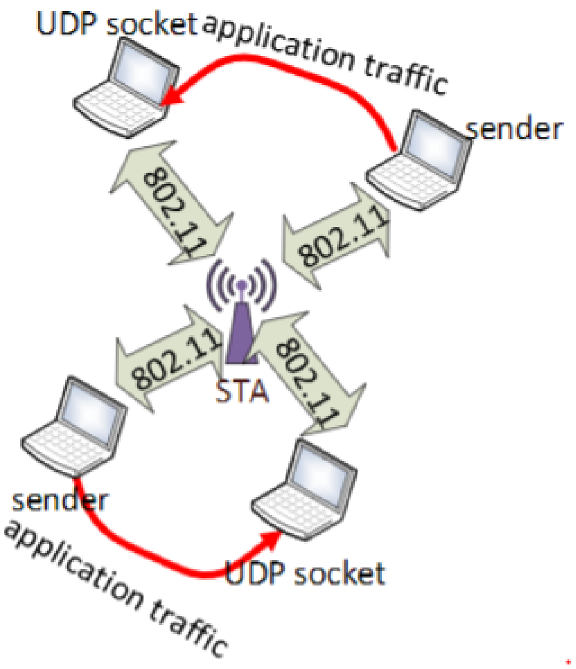

Figure 1.2: Figure 2

1.3. In your experiments you will vary the transmission rate at the physical layer in the range 1 Mbps, 5.5 Mbps and 11 Mbps.

The transmission rate was varied using the following: wifi.SetRemoteStationManager ("ns3::ConstantRateWifiManager", "DataMode",StringValue ("DsssRate5_5Mbps"), "ControlMode",StringValue ("DsssRate5_5Mbps"));

The result of this will be demonstrated in the later questions.

1.4. For the first part of Scenario 1 keep the distances between sender, receiver, and Access Point equal to 10 meters (equilateral triangle). For the second scenario create topology similar to one depicted in Figure 2 (two equilateral triangles opposite to each other, Access Point is in the middle).

The coordinates for the Figure 1 were set as follows:

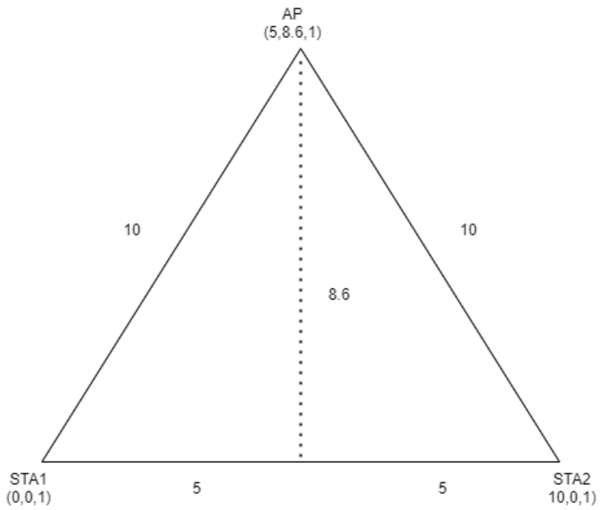

Figure 1.3: Coordinates for Figure 1

Using the Pythagoras equation, the vertical height for the equilateral triangle, that is the AP is found as follows: $\sqrt{10^2 - 5^2} = 8.66$.

Similarly, the coordinates for figure 2 were also set in the following manner - by setting the coordinates according the to the previous logic for 4 STAs.

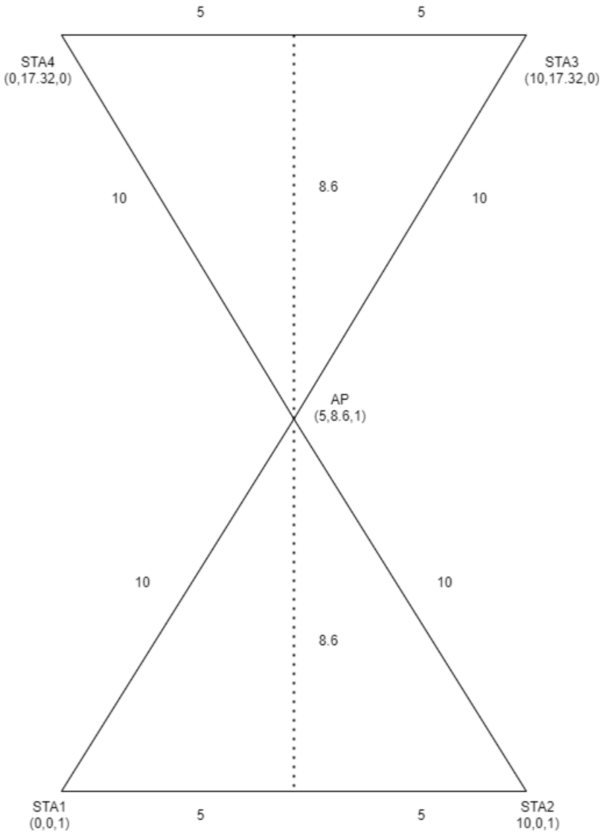

Figure 1.4: Coordinates for Figure 2

1.5. For both parts of Scenario 1 and for each bit rate run 2 experiments with different seeds for the random generator. In each experiment measure the application–layer throughput for each application and total throughput for the whole network.

Random seed value of 1 is the default and two random seeds are chosen at increments of 5. The throughput is viewed from wireshark statistics (from the capture file properties) and divided by 2 because half of the data comes from the AP. The application throughput is calculated using the following formula $throughput * \frac{1000}{1064}$ where 1000B is the payload size and 1064B is the payload size including the headers.

The random seed was set using the following: RngSeedManager::SetSeed (5);

1.5.1. For Figure 1

Table 1.1: Throughput for 1 Mbps for Figure 1

Random Seed	Throughput (kbps)	Throughput/2 (kbps)	Application throughput (kbps)
1	893	446.5	419.6428571
5	887	443.5	416.8233083
10	884	442	415.4135338

Table 1.2: Throughput for 5.5 Mbps for Figure 1

Random Seed	Throughput (kbps)	Throughput/2 (kbps)	Application throughput (kbps)
1	3696	1848	1736.842105
5	3685	1842.5	1731.672932
10	3670	1835	1724.62406

Table 1.3: Throughput for 11 Mbps for Figure 1

Random Seed	Throughput (kbps)	Throughput/2 (kbps)	Application throughput (kbps)
1	5675	2837.5	2666.823308
5	5640	2820	2650.37594
10	5631	2815.5	2646.146617

Table 1.4: Mean APP. Throughput and Std Deviation for Figure 1

Bitrate (Mbps)	Mean App. Throughput (Kbps)	Std dev
1	417.2932	2.153466
5.5	1731.046	6.133074
11	2654.449	10.92344

1.5.2. For Figure 2

For this scenario, there are two applications, the downlink and the uplink for each bitrate.

Table 1.5: Throughput for 1 Mbps downlink for Figure 2

Random Seed	Throughput (10.1.1.2) (kbps)	Throughput (10.1.1.4) (kbps)	Total DL (kbps)	App. Throughput (kbps)
1	455	443	898	213.8157895
5	451	455	906	211.9360902
10	567	377	944	266.4473684

Table 1.6: Throughput for 1 Mbps uplink for Figure 2

Random Seed	Throughput (10.1.1.2) (kbps)	Throughput (10.1.1.4) (kbps)	Total UL (kbps)	App. Throughput (kbps)
1	446	463	909	217.575188
5	439	463	902	217.575188
10	558	387	945	181.8609023

Table 1.7: Throughput for 5.5 Mbps downlink for Figure 2

Random Seed	Throughput (10.1.1.2) (kbps)	Throughput (10.1.1.4) (kbps)	Total DL (kbps)	App. Throughput (kbps)
1	1866	1825	3691	876.8796992
5	1825	1845	3670	857.612782
10	2100	1821	3921	986.8421053

Table 1.8: Throughput for 5.5 Mbps uplink for Figure 2

Random Seed	Throughput (10.1.1.2) (kbps)	Throughput (10.1.1.4) (kbps)	Total UL (kbps)	App. Throughput (kbps)
1	1858	1826	3684	858.0827068
5	1820	1851	3671	869.8308271
10	2097	1825	3922	857.612782

Table 1.9: Throughput for 11 Mbps downlink for Figure 2

Random Seed	Throughput (10.1.1.2) (kbps)	Throughput (10.1.1.4) (kbps)	Total DL (kbps)	App. Throughput (kbps)
1	2852	2808	5660	1340.225564
5	2839	2841	5680	1334.116541
10	3145	2865	6010	1477.913534

Table 1.10: Throughput for 11 Mbps uplink for Figure 2

Random Seed	Throughput (10.1.1.2) (kbps)	Throughput (10.1.1.4) (kbps)	Total UL (kbps)	App. Throughput (kbps)
1	2852	2808	5660	1319.548872
5	2839	2841	5680	1335.056391
10	3145	2865	6010	1346.334586

Table 1.11: Mean APP. Throughput and Std Deviation for Figure 2 DL

Bitrate (Mbps)	Mean App. Throughput (Kbps)	Std dev
1	230.7331	30.94375
5.5	907.1115	69.71748
11	1384.085	81.3151

Table 1.12: Mean APP. Throughput and Std Deviation for Figure 2 UL

Bitrate (Mbps)	Mean App. Throughput (Kbps)	Std dev
1	205.6704	20.61965
5.5	861.8421	6.922425
11	1333.647	13.44839

1.6. Plot the application throughput for each seed versus the bit rate for both parts of the scenario(one figure per part).

The general conclusion can be that as bitrate increases, throughput increases.

1.6.1. Individual Plots For Figure 1

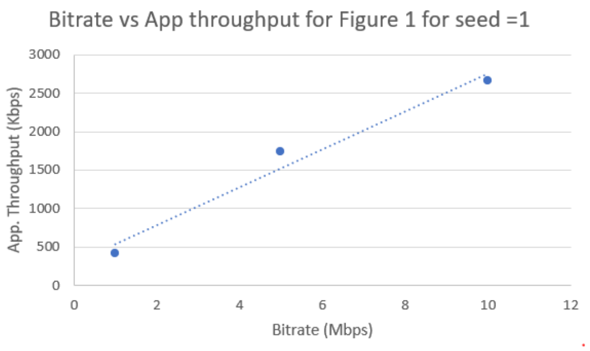

Figure 1.5: Bitrate vs App throughput for Figure 1 for seed= 1

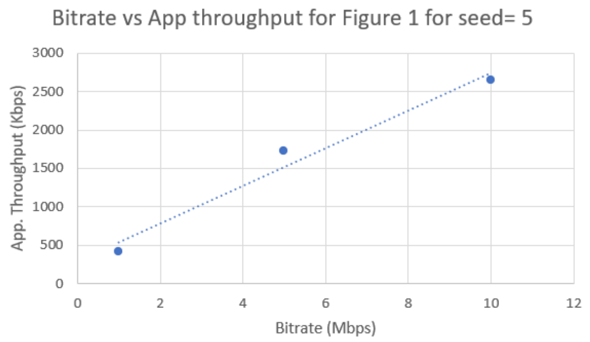

Figure 1.6: Bitrate vs App throughput for Figure 1 for seed= 5

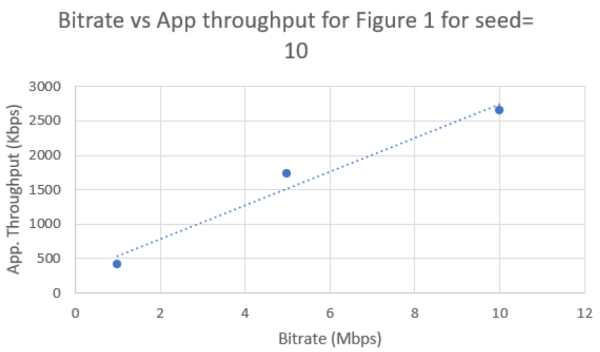

Figure 1.7: Bitrate vs App throughput for Figure 1 for seed= 10

1.6.2. Individual Plots For Figure 2

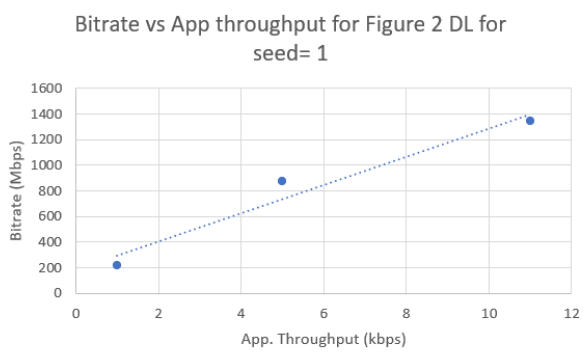

Figure 1.8: Bitrate vs App throughput for Figure 2 DL for seed= 1

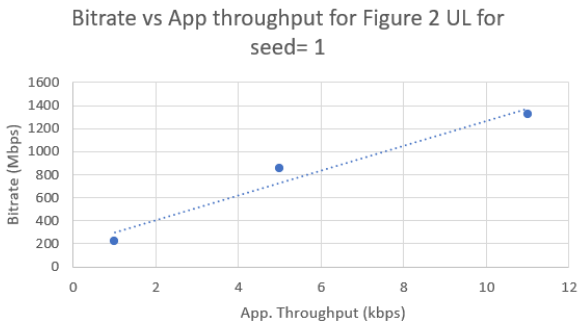

Figure 1.9: Bitrate vs App throughput for Figure 2 UL for seed= 1

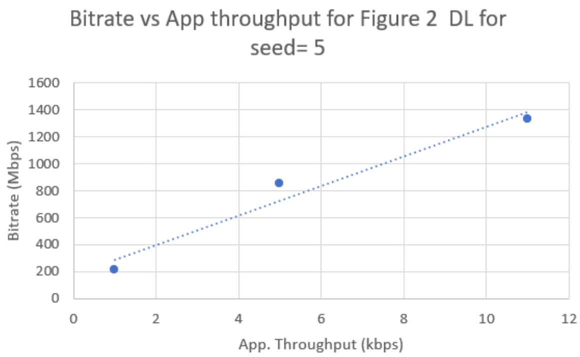

Figure 1.10: Bitrate vs App throughput for Figure 2 DL for seed= 5

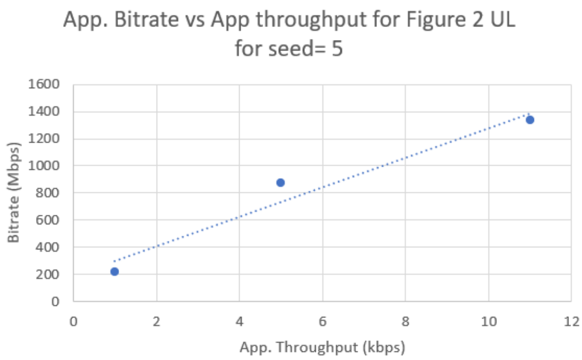

Figure 1.11: Bitrate vs App throughput for Figure 2 UL for seed= 5

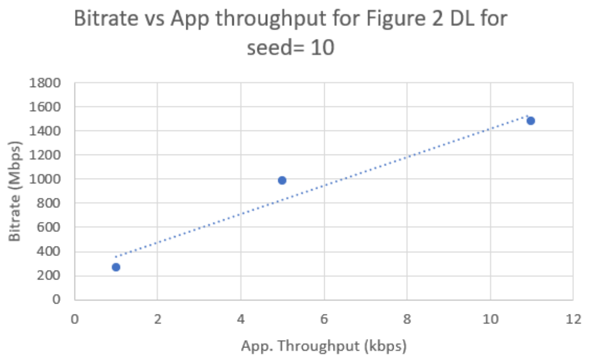

Figure 1.12: Bitrate vs App throughput for Figure 2 DL for seed= 10

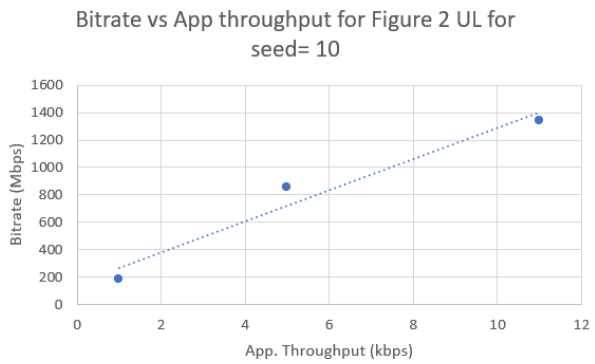

Figure 1.13: Bitrate vs App throughput for Figure 2 UL for seed= 10

1.7. Compare how application throughput for the whole network varies for Figure 1 and Figure 2.

The table below summarizes the result of the whole section. The table compares the Application Throughput for transmission in the downlink for both the figures. It can be observed that the Figure 1 receives double the throughput of Figure 2. This is because Figure 2 has to supply half of the throughput to the uplink communication. This behaviour is demonstrated below.

Table 1.13: Comparison of App. Throughput for Figure 1 & 2 for transmission in the downlink

Random Seed	Fig1_1Mbps	Fig2_1Mbps	Fig1_5.5Mbps	Fig2_5.5Mbps	Fig1_11Mbps	Fig2_11Mbps
1	419.6429	213.8158	1736.842	876.8797	2666.823	1340.226
5	416.8233	211.9361	1731.673	857.6128	2650.376	1334.117
10	415.4135	266.4474	1724.624	986.8421	2646.147	1477.914
Mean	417.2932	230.7331	1731.046	907.1115	2654.449	1384.085
Std.dev	2.153466	30.94375	6.133074	69.71748	10.92344	81.3151

2

Scenario 2.Part 1.The effect of different packet sizes on the application level throughput

In this scenario you will use the topology as depicted in Figure 1. Use Two-Ray Ground propagation model. Place the nodes(sender –Access Point –receiver)at distance di/2, where di you have calculated in the previous lab. In this scenario you will use UDP traffic. In your experiments you will vary the transmission rate at the physical layer in the range 1Mbps, 5.5 Mbps and 11 Mbps. You will also vary the UDP payload in the range 400B, 700B, 1000B.

2.1. For EACH transmission rate in the range of transmission rates run one experiment with EVERY packet size(3x3=9 experiments).

From previous lab experiments, it is determined that the maximum or the initial distance for two ground propagation model is 251.2 metres. Therefore the nodes are placed accordingly (sender –Access Point –receiver) at distance 251.1/2 = 125.6. The experiment is then repeated for various bitrates with various UDP payload.

The payload was varied using the following: onOffHelper.SetAttribute("PacketSize", UintegerValue(1000));

Table 2.1: Comparison of different packet sizes on the application level throughput

Bitrate (Mbps)	UDP Payload (B)	Throughput (kbps)	Throuput/2 (kbps)	App. Throughput (kbps)
1	400	415	207.5	178.8793103
1	700	444	222	203.4031414
1	1000	456	228	214.2857143
5.5	400	1360	680	586.2068966
5.5	700	1692	846	775.1308901
5.5	1000	1897	948.5	891.4474
11	400	1808	904	779.3103448
11	700	2452	1226	1123.298429
11	1000	2908	1454	1366.541

2.2. Select measurements when packet size equals 1000 bytes. Fill in a table where in the upper row you list the physical layer transmission rate and in the lower row you write the measured throughput. Did you achieve the absolute maximum transmission rate?

Table 2.2: Comparison of transmission rate and the corresponding throughput

Categories	1 Mbps	5.5 Mbps	11 Mbps
Physical (kbps)	1000	5500	11000
Measured (kbps)	456	1897	2908
Measured /2 (kbps)	228	948.5	1454

As it can be observed, the absolute maximum throughput is not reached.

2.3. Plot a graph showing the dependency of the average throughput versus packet size for each physical layer transmission rate in the range (3 graphs).

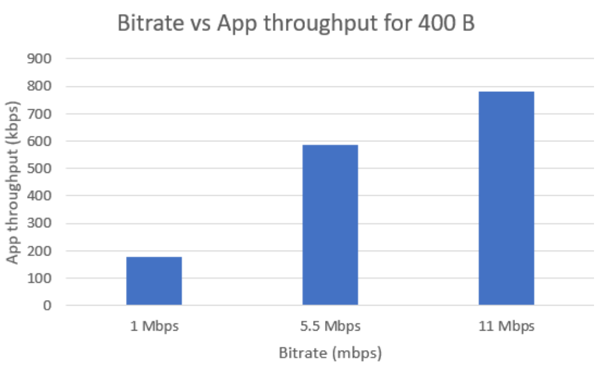

Figure 2.1: Bitrate vs App throughput for 400 B

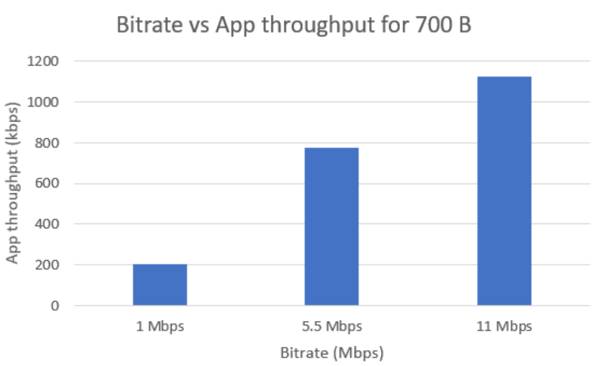

Figure 2.2: Bitrate vs App throughput for 700 B

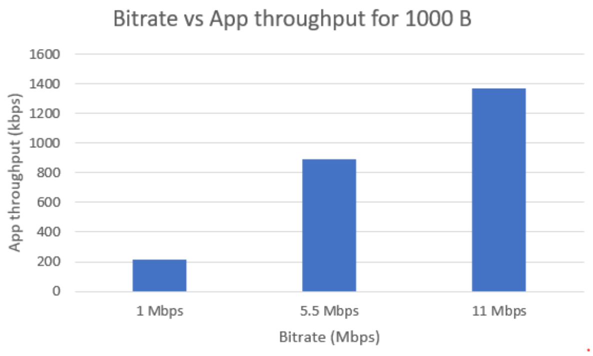

Figure 2.3: Bitrate vs App throughput for 1000 B

2.4. Explain the observed behavior.

The graphs above illustrate that greater the payload size, greater the throughput. For smaller packets size, the overall number of bytes sent will be larger because the a large portion of the packet is for packet headers, and therefore packets have to be sent more often. This will be demonstrated mathematically now. Let us assume that we want to send 3000B and then calculate individually the the number of packets required to transmit this message.

For 400 Bytes

$$\text{Number of Packets} = \frac{\text{Data Size}}{PayloadSize}$$

$$\text{Number of Packets} = \frac{3000}{400} = 8$$

For 700 Bytes

$$\text{Number of Packets} = \frac{\text{Data Size}}{PayloadSize}$$

$$\text{Number of Packets} = \frac{3000}{700} = 5$$

For 1000 Bytes

$$\text{Number of Packets} = \frac{\text{Data Size}}{PayloadSize}$$

$$\text{Number of Packets} = \frac{3000}{1000} = 3$$

2.5. Select the simulation trace for 11Mb/s transmission rate and 400B payload size. Measure the time for transmission of a SINGLE packet. Taking the packet's TOTAL size (including headers on all layers) in bits calculate the transmission rate.

To calculate the throughput the following equation is used:

$$Throughput = \frac{\text{Packet size in bits}}{\text{receiver time} - \text{sender time}}$$

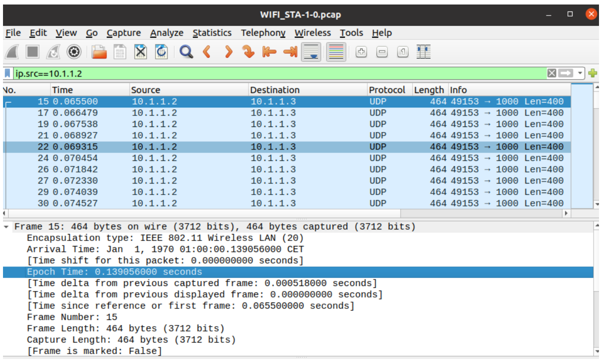

Figure 2.4: Epoch time for sender captured from wireshark

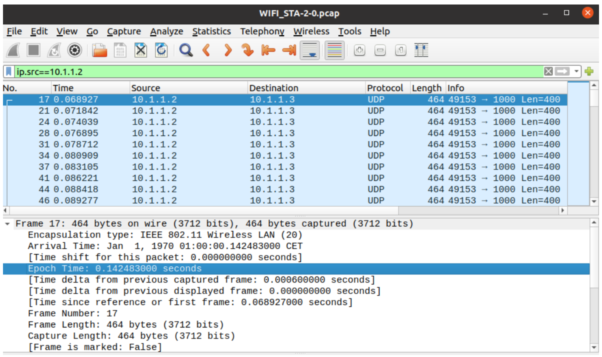

Figure 2.5: Epoch time for receiver captured from wireshark

From the above mentioned images, the sender and receiver time is captured and the throughput is calculated:

$$Throughput = \frac{464 * 8}{0.142483 - 0.139056}$$

$$Throughput = 1083163bps = 1Mbps$$

2.6. Is it equal to 11Mb/s? If not why?

The transmission is not equal to 11 Mbps. This is because the access point can only transmit it further after it has received the packets causing an additional delay (due to the re-transmission of packets by AP). From the equation used to derive throughput, it can be observed that an increase in transmission time will lead to a decrease in throughput since they are inversely related. So it can be concluded that due to to increased transmission time, the throughput experiences a reduction.

3

Scenario 2. Part 2.Hidden terminal problem

3.1. Run experiments for both modes and calculate the throughput and the packet delivery ratio.

The hidden terminal problem occurs when a terminal is visible from a wireless access point (APs), but not from other nodes communicating with AP (ques10, 2021).

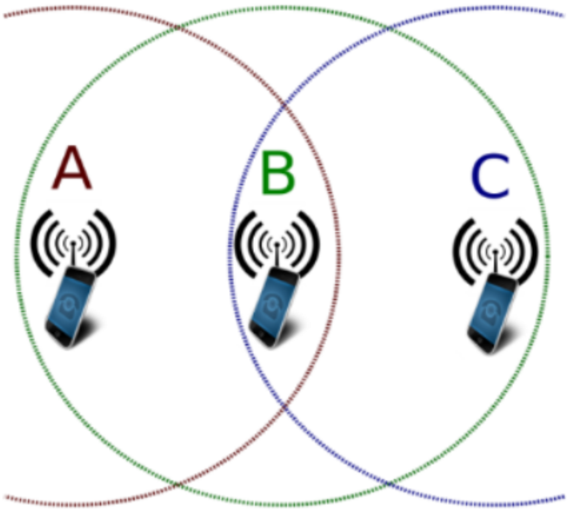

Figure 3.1: Hidden terminal problem

The experiment is set up as follows:

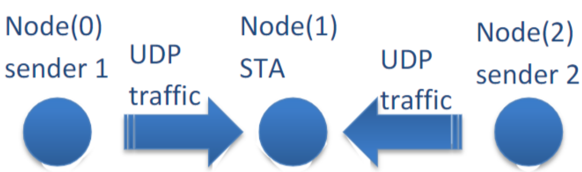

Figure 3.2: Experimental Hidden terminal problem

with a distance of 250 metres between each node, packet's payload size of 1000B, bitrate of 1Mbps and using the two ground propagation model. The experiment is repeated with RTS/CTS enabled and disabled to see the effect of RTS/CTS on the hidden terminal problem.

Table 3.1: Comparison of transmission rate and the corresponding throughput

RTS/CTS Mode	Bitrate (Mbps)	STA1 throughput (kbps)	STA2 throughput (kbps)	STA1 Packet Del.	STA2 Packet Del.
Disabled	1	215	304	0.289706	0.412043
Enabled	1	506	330	0.982935	0.989637

3.2. Study the PCAP traces for both modes: Do you observe any difference between the measured throughput at the receiver with and without using RTS/CTS. Motivate your answer.

The PCAP traces (demonstrated in table 3.1) reveals that the enabling the RTS/CTS protocol assists in avoiding collisions leading to less packet loss and therefore less retransmission. This leads to increased throughput and packet delivery ratio (almost double in comparison to when there is no RTS/CTS enabled).

Bibliography

ques10. (2021). *Explain Hidden and Exposed Terminal Problem*. Retrieved October 9, 2021, from https://www.ques10.com/p/30462/explain-hidden-and-exposed-terminal-problem/