# Department of Computer Science, Electrical and Space Engineering

# Advanced Wireless Networks

## Lab 3 - Measuring Performance of WiFi network in Different Scenarios

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## Scenario 1 – Application throughput using WiFi network.

You have to measure the average application throughput over time, i.e., the amount of useful information from the application layer, which you could send through the network. The throughput is measured in bits/sec. The MAC settings should be set in agreement with the IEEE 802.11b specification. Traffic type is UDP. Initial payload size is 1000B.

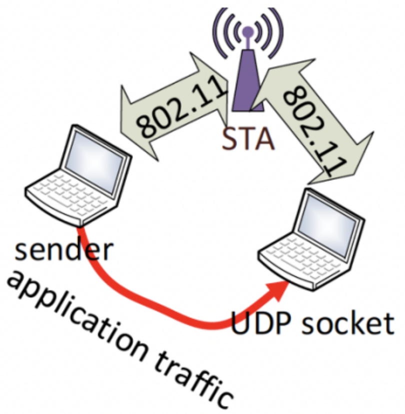

Figure 1. Topology for the first part of Scenario 1.

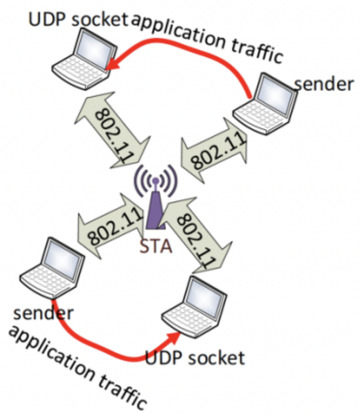

Figure 2. Topology for the second part of Scenario 1.

## Tasks:

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

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

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

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 a topology similar to one depicted in Figure 2 (two equilateral triangles opposite to each other, Access Point is in the middle).

5. For both parts of Scenario 1 and for each bit rate run 2 experiments with different seeds for the random generator (Note, that the provided simulation script does not contain the randomization procedure. Therefore, you should implement it by yourself). For randomization of your simulations make use of RngSeedManager. In each experiment measure the application–layer

throughput for each application and total throughput for the whole network (basically, the sum of independent applications throughputs)

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

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

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In Scenario 1, 2 nodes and 1 access point are set up. 1 node sends UDP traffic to the other node via AP. Packets are captured on all the nodes which are later used to calculate the throughput. Experiments are done to analyze change in throughput rate by changing the transmission rate at the physical layer.

| Bitrate (Mbps) | Random Seed | Throughput (Kb/s) | Throughput 1/2 | Application Throughput (Kb/s) |
|---|---|---|---|---|
| 1 | 1 | 893 | 446.5 | 419.64 |
| | 5 | 887 | 443.5 | 416.82 |
| | 10 | 884 | 442 | 415.41 |
| 5.5 | 1 | 3696 | 1848 | 1736.84 |
| | 5 | 3685 | 1842.5 | 1731.67 |
| | 10 | 3670 | 1835 | 1724.62 |
| 11 | 1 | 5675 | 2837.5 | 2666.82 |
| | 5 | 5640 | 2820 | 2650.38 |
| | 10 | 5631 | 2815.5 | 2646.15 |

Figure 3: Scenario 1 - Part 1 Experiments

| | | Throughput (Kb/s) - Down Layer | | | | |
|---|---|---|---|---|---|---|
| Bitrate | Random Se | App1 (10.1.1.2) | App1 (10.1.1.4) | Total DL | Application | Application / 2 |
| 1 | 1 | 455 | 443 | 898 | 427.63 | 213.82 |
| | 5 | 451 | 455 | 906 | 423.87 | 211.94 |
| | 10 | 567 | 377 | 944 | 532.89 | 266.45 |
| 5.5 | 1 | 1866 | 1825 | 3691 | 1753.76 | 876.88 |
| | 5 | 1825 | 1845 | 3670 | 1715.23 | 857.61 |
| | 10 | 2100 | 1821 | 3921 | 1973.68 | 986.84 |
| 11 | 1 | 2852 | 2808 | 5660 | 2680.45 | 1340.23 |
| | 5 | 2839 | 2841 | 5680 | 2668.23 | 1334.12 |
| | 10 | 3145 | 2865 | 6010 | 2955.83 | 1477.91 |

Figure 4: Scenario 1 - Part 2 Experiments

| | | Throughput (Kb/s) - Upper Layer | | | | |
|---|---|---|---|---|---|---|
| Bitrate | Random Se | App1 (10.1.1.2) | App1 (10.1.1.4) | Total | Application | Application / 2 |
| 1 | 1 | 446 | 463 | 909 | 435.15 | 217.58 |
| | 5 | 439 | 463 | 902 | 435.15 | 217.58 |
| | 10 | 558 | 387 | 945 | 363.72 | 181.86 |
| 5.5 | 1 | 1858 | 1826 | 3684 | 1716.17 | 858.08 |
| | 5 | 1820 | 1851 | 3671 | 1739.66 | 869.83 |
| | 10 | 2097 | 1825 | 3922 | 1715.23 | 857.61 |
| 11 | 1 | 2852 | 2808 | 5660 | 2639.10 | 1319.55 |
| | 5 | 2839 | 2841 | 5680 | 2670.11 | 1335.06 |
| | 10 | 3145 | 2865 | 6010 | 2692.67 | 1346.33 |

Figure 5: Scenario 1 - Part 2 Experiments

In the above experiments (figure 3 to 5), Bitrate (in Mbps) was varied to observe the changes in the application throughput. Random seeds were used to get statistical performance metrics across all the runs.

To get the actual throughput, throughput from the PCAP traces is divided by 2. Beaucase PCAP traces are being taken in promiscuous mode, e.g., the receiver hears the packets from the sender even if the packets are not for the receiver (for Access Point).

To get the application throughput following formula is used:

$$\text{Application throughput} = \frac{throughput * payload\ size}{payload\ size + header\ size}$$

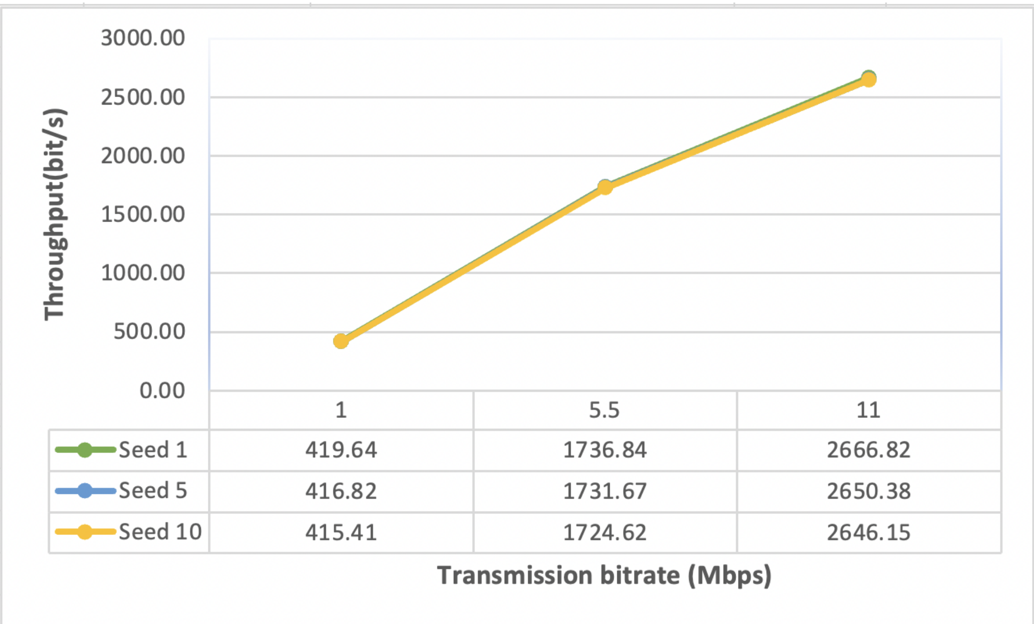


Figure 6: Scenario 1 - Part 1 Graph

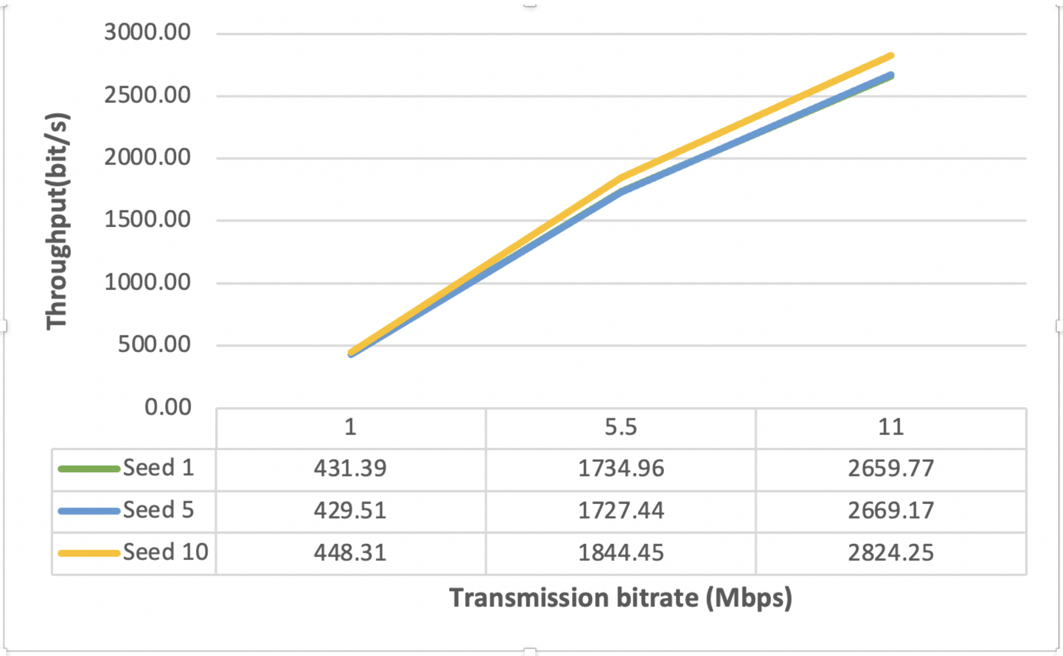


Figure 7: Scenario 1 - Part 7 Graph

Comparing Figure 6 (Scenario 1 - Part 1) and Figure 7 (Scenario 1 - Part 2) there is very little difference between both the graphs. Within both the graphs there is very little difference due to the seed values.

Since the graph for both parts is similar, this shows that the transmission medium is saturated as even after adding more nodes network throughput remains almost the same. However, as the figure 4 and figure 5 shows that application throughput between two nodes (node 1 to node 2 and node 3 to node 4) is halved as compared to throughput in figure 3 as the same transmission medium is used by four nodes now.

## 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 $d_i$ 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}.

**Tasks:**

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

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?

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).

4. Explain the observed behavior.

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.

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

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For this task $d_i$ is taken as 251.1 meters.

| Bitrate | UDP Payload (Bytes) | Throughput (Kb/s) | Throuput/2 (Kb/s) |
|---|---|---|---|
| 1 | 400 | 415 | 207.5 |
| 1 | 700 | 444 | 222 |
| 1 | 1000 | 456 | 228 |
| 5.5 | 400 | 1360 | 680 |
| 5.5 | 700 | 1692 | 846 |
| 5.5 | 1000 | 1897 | 948.5 |
| 11 | 400 | 1808 | 904 |
| 11 | 700 | 2452 | 1226 |
| 11 | 1000 | 2908 | 1454 |

Figure 8: Scenario 2 - Experiments

| Physical layer transmission rate (Kbps) | 1000 | 5500 | 11000 |
|---|---|---|---|
| Measured Throughput (Kbps) | 456 | 1897 | 2908 |

The table above shows that maximum transmission rate was not achieved. This is due to headers overheader which reduces the amount of useful data being sent for the application layers, hence application layer throughput is decreased. Moreover, with increased distance, throughput decreases as well due to increased errors, interference and collisions.

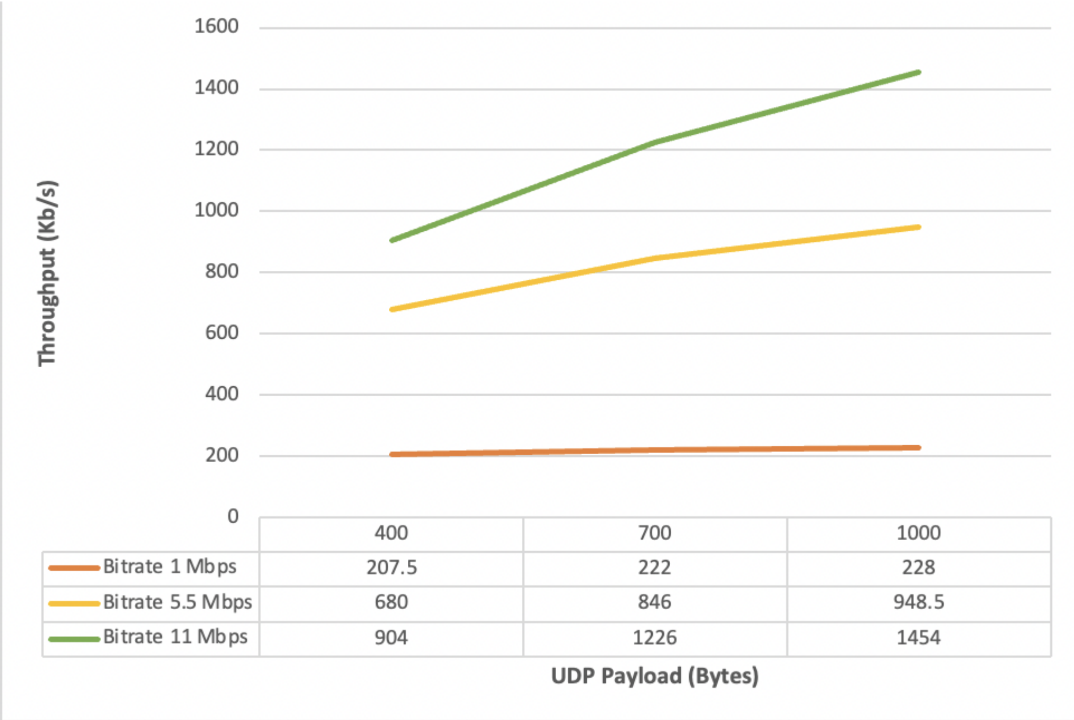


Figure 9: Scenario 2 - Graph

The graph above shows that as the payload size is increased throughput increases accordingly. With an increase in payload size, overall header overhead is reduced as more data can be sent in larger chunks. Similarly, if data needs to be retransmitted, with larger payload size, a lesser number of packets needs to be sent again, hence lesser overhead.

**Transmission rate calculation for task 5:**

Transmission rate = $\frac{464 * 8}{(0.142483 - 0.139056) * 10^6} = \frac{\textit{Packet Size}}{\textit{Transmission Time}}$ =1.083 Mbps

Calculation above shows that the transmission rate is not 11 Mbps. Transmission is not close to maximum transmission rate because packet is sent via AP to the receiving node which increases the transmission time. Moreover, due to packet buffering further transmission time is increased. Lastly, due to the distance between the nodes, theoretical transmission rate is not achieved due to medium limitations.

## Scenario 2. Part 2. Hidden terminal problem

Run the experiments when RTS/CTS is enabled and then when it is disabled. Measure the throughput at the receiver (Node 1) and the packet delivery ratio for both sessions (node(0)->node(1), node(2)->node(1)).

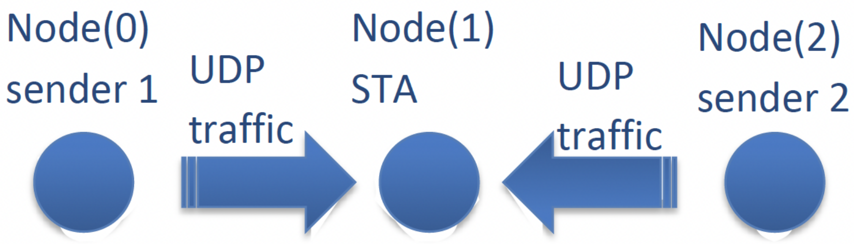


Figure 10: Scenario 2 - Part

**Tasks:**

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

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.

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| | Bitrate (Mbps) | STA1 throughput (Kbps) | STA2 throughput (Kbps) | STA1 Packet Delivery Ratio | STA2 Packet Delivery Ratio |
|---|---|---|---|---|---|
| **Disabled** | 1 | 215 | 304 | 0.289705882 | 0.412042503 |
| **Enabled** | 1 | 506 | 330 | 0.982935154 | 0.989637306 |

RTS (Ready to Send) and CTS (Clear to Send) provides a carrier sensing mechanism as defined in the WiFi 802.11 standard. The above table shows that when RTS/CTS is disabled throughput is significantly lower with low packet delivery ratio.

This is due to the hidden terminal problem as both the terminals can't see each other and hence when they try to send data, there is a lot of collision due to which there is low packet delivery ratio. By using RTS/CTS this problem is solved as it provides a coordinating mechanism between the terminals and they send data such that the collisions are reduced as shown in the table above.