Department of Computer Science, Electrical and Space Engineering

D7030E: Advanced wireless networks

Lab 2: Measuring performance of a Wi-Fi network

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➢ Part 1 – Application throughput using WiFi network

In this scenario there is one Access Point and several devices connected to the Access Point. During all experiments node(0) is a sender and node(1) is a receiver (denoted as UDP socket in Figures 1 and 2). 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.

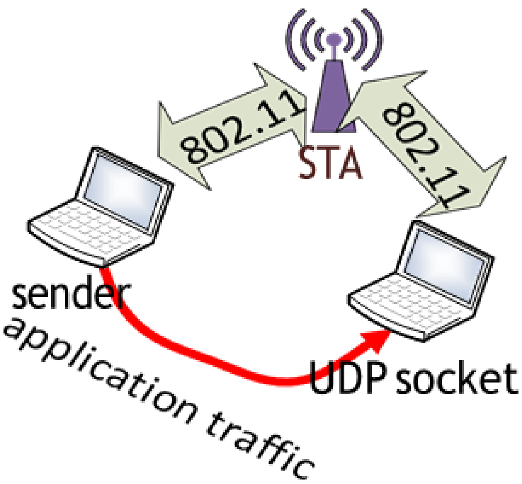

Figure 1. Topology for the first Scenario 1

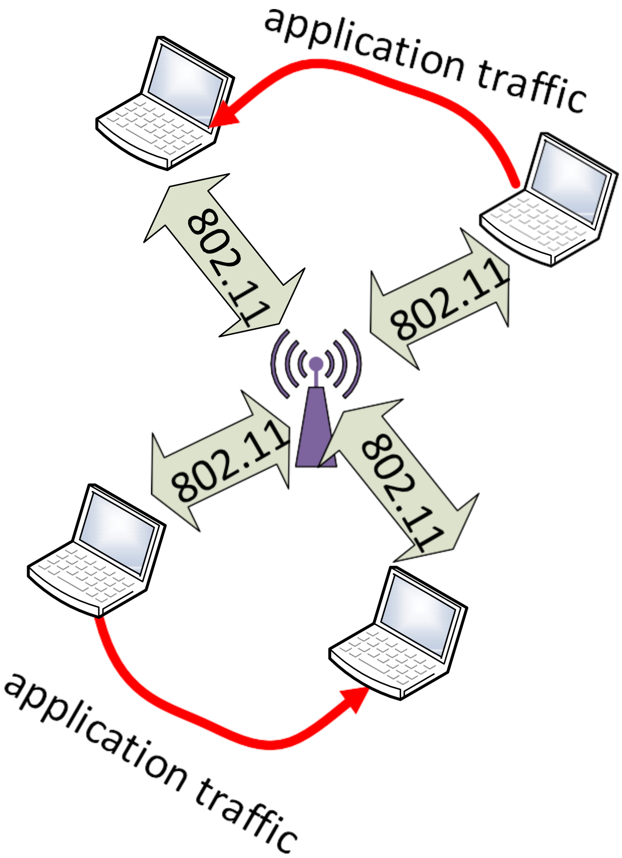

Figure 2. Topology for the second Scenario 2

Tasks:

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

The provided script for the wifi lab implements the scenario shown in figure 1. Two ray ground loss model was used for the wireless signal propagation, the transmission power for antennas the transmission channel was set to 16 dBm, and the receiver sensitivity is -80dBm. IEEE802.11b wifi standard was used. The nodes were located 10 meters from each other (equilateral triangle). Network ID 10.1.1.0/24 was configured for all nodes in this scenario.

In the application part, the on/off application class was used to generate UDP traffic between the sender and receiver through an access point. The application data rate was set to 20 Mbps while the physical throughput varied in our experiments from 1 Mbps to 11 Mbps. Traffic traces are then generated in .pcap files for all nodes to be analyzed to calculate the application throughput.

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 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 ~~http://www.nsnam.org/doxygen/classns3_1_1_rng_seed_manager.html~~. 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)

The following tables show the readings from our experiments for both scenarios at different physical bitrates and random seeds:

Total throughput (kb/s): is the data rate shown in the .pcap file at the receiver side.

Application Throughput (kb/s): is the application layer throughput.

$$Application\ Throughput = \frac{total\ throughput * payload\ size}{2 * (Payload\ size + header\ size)}$$

Scenario 1:

Table 1. Readings for scenario 1 with 2 nodes

Physical Bitrate (Mb/s)	Random Seed	Total Thorughput (kb/s)	Thorughput/2 (kb/s)	App Throughput (Kb/s)
1	10	888	444	417.29
	20	888	444	417.29
5.5	10	3699	1849.5	1738.25
	20	3692	1846	1734.96
11	10	5669	2834.5	2664
	20	5676	2838	2667.29

Scenario 2:

Table 2. Readings for the first application in scenario 2 (4 nodes)

Physical Bitrate (Mb/s)	Random Seed	Total Thorughput (kb/s) (Sender 10.1.1.2)	Thorughput/2 (kb/s)	App1 Throughput (Kb/s)
1	10	473	236.5	222.27
	20	532	266	250
5.5	10	1796	898	843.98
	20	1898	949	891.92
11	10	2867	1433.5	1347.27
	20	2965	1482.5	1393.33

Table 3. Readings for the second application in scenario 2 (4 nodes)

Physical Bitrate (Mb/s)	Random Seed	Total Thorughput (kb/s) (Sender 10.1.1.4)	Thorughput/2 (kb/s)	App2 Throughput (Kb/s)
1	10	452	226	212.41
	20	436	218	204.89
5.5	10	1908	954	896.62
	20	1819	909.5	854.79
11	10	2861	1430.5	1344.45
	20	2761	1380.5	1297.46

Table 4. Total applications throughput for scenario 2

Physical Bitrate(Mb/s)	Random Seed	Total Apps Throughput
1	10	434.68
	20	454.89
5.5	10	1740.6
	20	1746.71
11	10	2691.73
	20	2690.79

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

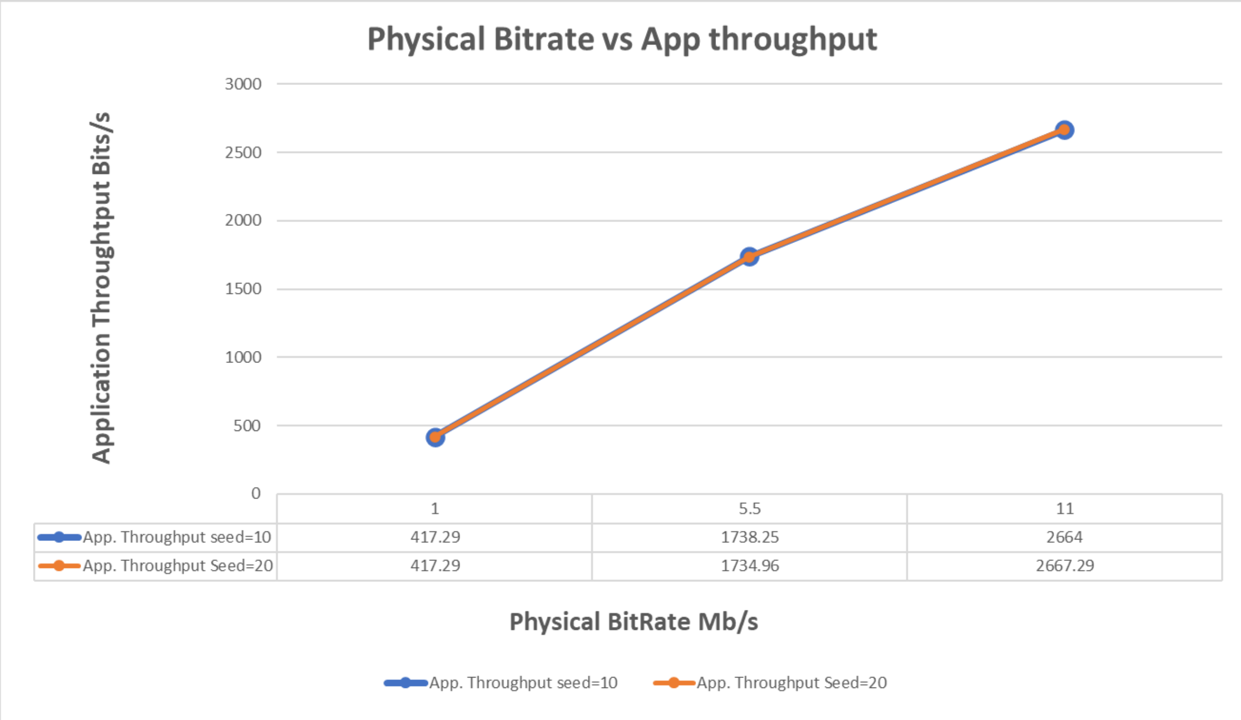

Figure 3. Physical bitrate vs Application throughput for scenario 1 (2 nodes)

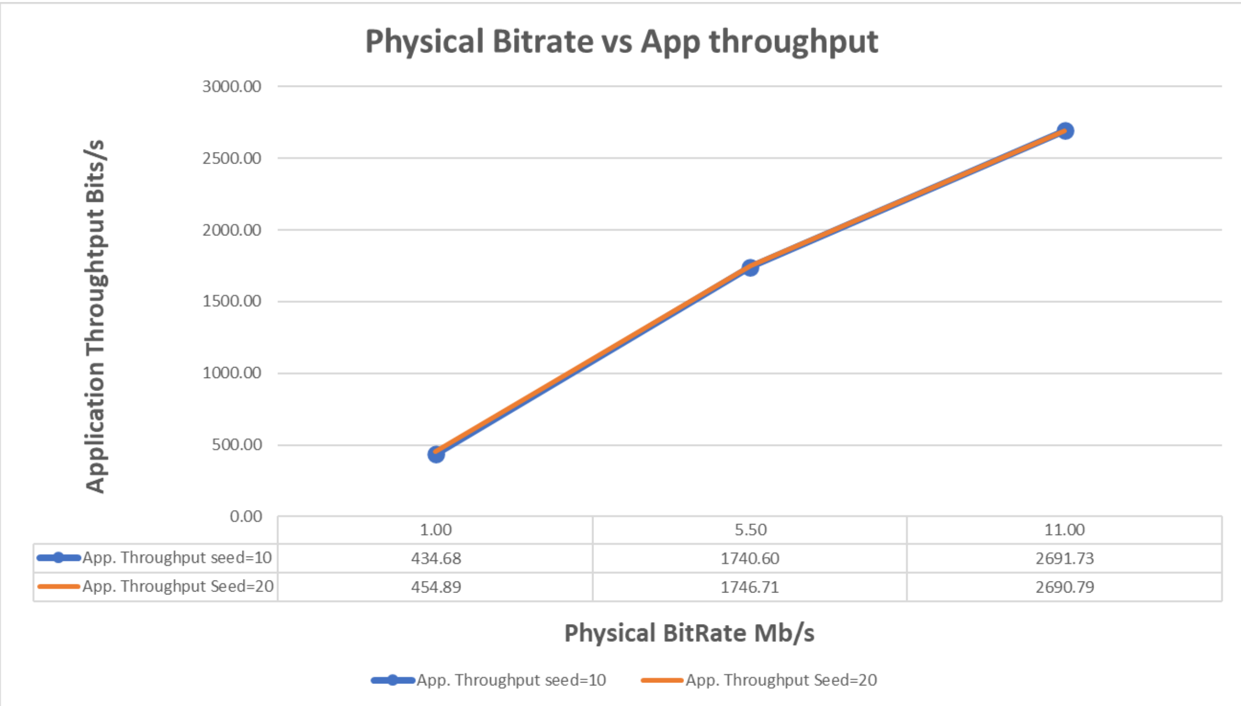

Figure 4. Physical bitrate vs Application throughput for scenario 2 (4 nodes)

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

Since the application data rate was set at 20Mbps in the script, as we were increasing the physical throughput from 1 to 5.5 to 11 Mbps, the measured application throughput increased accordingly for both scenarios. There is no significant difference in throughput values for different seeds.

In the first scenario, there was only one application (one sender and one receiver) to occupy the wireless channel and achieved 417 kb/s. However, in the second scenario, two applications shared the wireless channel which resulted in a lower throughput of 212 kb/s per application - half of the first scenario-

➢ Part 2.1: 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 *d_i/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).

The nodes were placed at 125.55 meters from each other = d/2 for the two-ray ground propagation model from lab 1. The following table shows the measurements for this scenario.

Table 5. Readings for various packet sizes and transmission rates for part 2 scenario 1

Physical Bitrate (Mb/s)	Random Seed	Total Thorughput (kb/s)	Thorughput/2 (kb/s)	App Throughput (Kb/s)
1	400	807	403.5	347.8448276
	700	861	430.5	394.4371728
	1000	887	443.5	416.8233083
5.5	400	2653	1326.5	1143.534483
	700	3306	1653	1514.528796
	1000	3696	1848	1736.842105
11	400	3544	1772	1527.586207
	700	4793	2396.5	2195.746073
	1000	5678	2839	2668.233083

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?

The following table shows the Physical throughput compared to the application throughput:

Physical Layer Transmission rate (Kbps)	1000	5500	11000
Measured Throughput (Kbps)	887	3696	5678
Application Throughput (kbps)	443.5	1848	2839

The maximum transmission rate was not achieved due to the following factors:

- Issues related to the propagation environment that affect the transmitted signal characteristics.
- In shared wireless media, packet collisions & retransmissions occur resulting in consuming bandwidth to retransmit lost packets.
- The absolute maximum physical throughput is not achievable in real situations due to hardware limitations in stations and access points.

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).

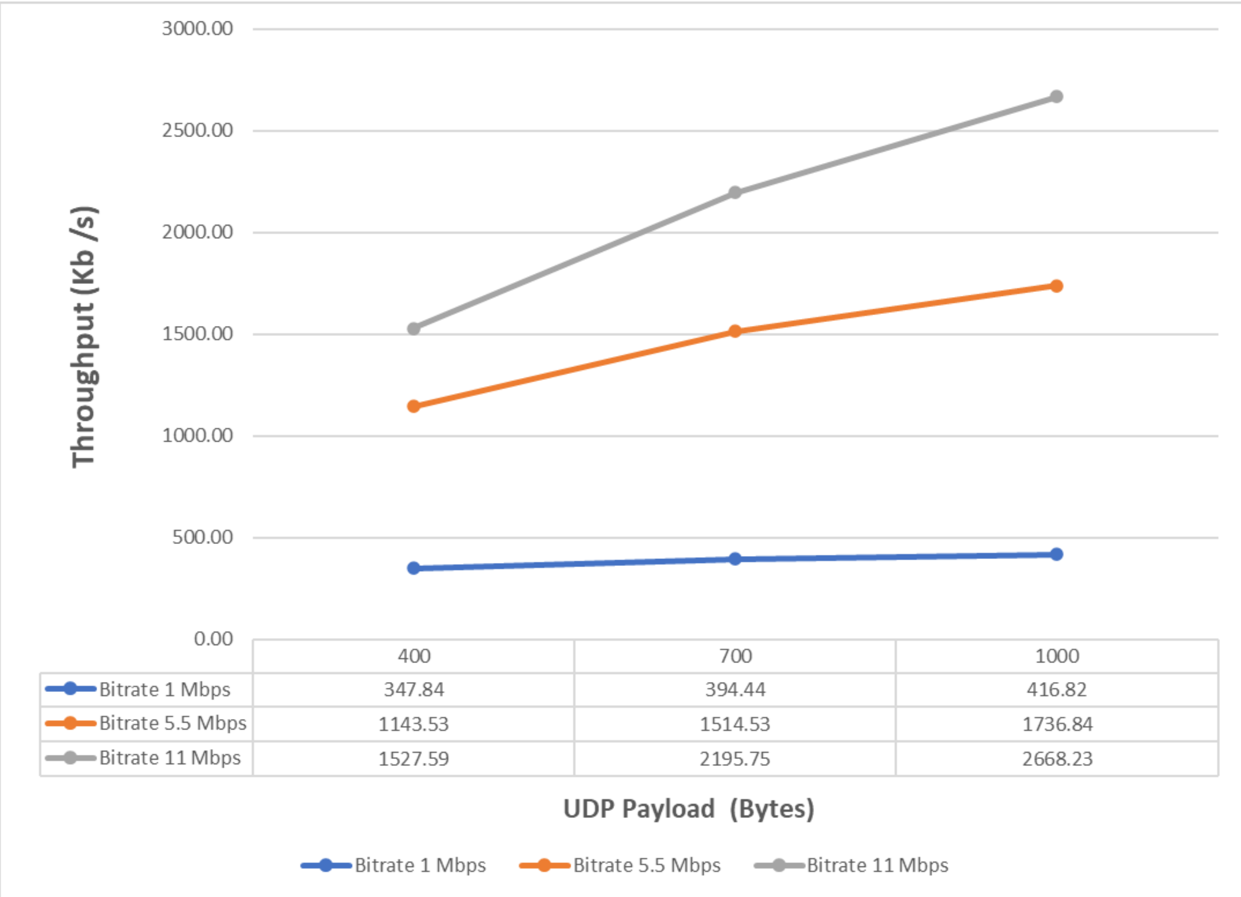

Figure 5. Application throughput vs payload size

4. Explain the observed behavior.

In the previous graph, the application throughput was plotted for different physical data rates and different packet sizes. The observed behavior is that as the payload size increase, the application throughput increases.

This is due to the header size of 64 bytes which is a considerable length for short packets. Therefore, as the packet size increases, the ratio between packet payload and packet header becomes higher which increases the percentage of useful data being sent.

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.

The epoch time for the first packet sent from 10.1.1.1 is: 0.1382020 seconds
The epoch time for the first packet received at 10.1.1.3 is: 0.138733 seconds

The data rate (bps) = payload size (bits) / time for transmission (seconds)

Data rate = (464*8) / (0.138733- 0.1382020) = 6.9 Mbps

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

The data rate is less than 11Mb/s. The absolute transmission rate isn't achievable due to collisions, retransmissions, interferences, channel propagation constraints, & hardware limitations.

➢ Part 2.2: The Hidden terminal problem

The RTS/CTS virtual carrier sensing mechanism is implemented as an option in the IEEE 802.11 standards. It mitigates the effect of the hidden terminal and the exposed terminal problems. Here you will study the impact of using RTS/CTS on the network performance.

As it is shown in Figure 3, you need to setup a network of three nodes: the senders (located at Node(0) and Node(2)) and the access point (Node(1) between them). Access point should implement 2 opened receiving sockets. Note, that it is safer to have different ports for senders' applications. Use the simulation script for Scenario 1 as the starting point for this experiment. This time, however, enable the RTS/CTS mode and change distances between senders, so they would not hear each other. The size of packet's payload is 1000B, the bitrate is 1Mbps. The distances between node(0) - node(1) and node(1) - node(2) should both be equal to di (see LAB 1) for TwoRayGround propagation model. Traffic type: UDP. 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)). For this purpose think whether the FlowMonitor will help in this scenario (see the following script as an example: /examples/wireless/wifi-hidden-terminal.cc)

Tasks:

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

Node 0 & node 2 were placed 251.1 meters away from node 1 to create the hidden terminal scenario.

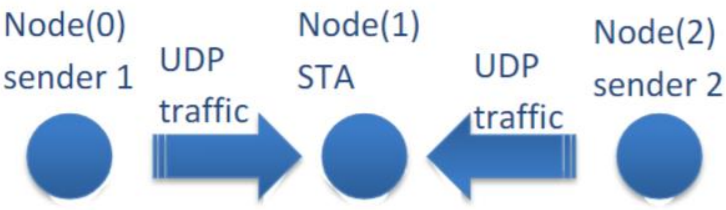

Figure 6. Hidden Terminal Topology

Table 6. Throughput and Packet delivery ratio for the experiment without CTS/RTS

Without CTS/RTS	**App 1 Source: 10.1.1.2**	**App 2 Source: 10.1.1.3**
Total Throughput (kb/s)	171	596
Application throughput (kb/s)	160.7142857	560.1503759
No. of Sent Packets	3670	9713
No. of Received Packets	913	6999
Packet delivery rate	24.88%	72.06%

Table 7. Throughput and Packet delivery ratio for the experiment with CTS/RTS

With CTS/RTS	**App 1 Source: 10.1.1.2**	**App 2 Source: 10.1.1.3**
Total Throughput (kb/s)	419	416
Application throughput (kb/s)	393.7969925	390.9774436
No. of Sent Packets	4912	4944
No. of Received Packets	4859	4887
Packet delivery rate	98.92%	98.85%

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.

Request to Send/Clear to send is a mechanism used in wireless communications to solve the issue of data collisions over the air interface introduced by hidden nodes.

Wireless nodes perform physical channel sensing before transmitting to avoid collisions.

However, in the hidden terminal situations where nodes are far away from each other ranges the physical sensing doesn't work and collisions appear. This is demonstrated in table 6, where the packet delivery ratio for both nodes reflects the number of packet collisions and losses.

When Implementing the RTS/CTS, the sessions between wifi nodes are managed by RTS/CTS acknowledgments to avoid collisions, as clearly shown in the higher packet delivery rates for both applications in table 7.