

Saif Omeis 0192330

Mohannad Al-Badarneh 21908080

Table-0

Link Delay = 0 ms	
Link Data Rate (Mbps)	Throughput (Mbps)
9	8.16
12	10.88
15	13.6
18	16.32
21	19.12
24	21.76(not included in the screenshot)

```
vboxuser@ubuntu: ~/Desktop/ns3/ns-allinone-3.41/ns-3.41
vboxuser@ubuntu:~/Desktop/ns3/ns-allinone-3.41/ns-3.41$ ./ns3 run hw2_1
Consolidate compiler generated dependencies of target scratch_hw2_1
[ 0%] Building CXX object scratch/CMakeFiles/scratch_hw2_1.dir/hw2_1.cc.o
[ 0%] Linking CXX executable ../../build/scratch/ns3.41-hw2_1-default
Total Bytes Received: 23838248
vboxuser@ubuntu:~/Desktop/ns3/ns-allinone-3.41/ns-3.41$ ./ns3 run hw2_1
Consolidate compiler generated dependencies of target scratch_hw2_1
[ 0%] Building CXX object scratch/CMakeFiles/scratch_hw2_1.dir/hw2_1.cc.o
[ 0%] Linking CXX executable ../../build/scratch/ns3.41-hw2_1-default
Total Bytes Received: 20437056
vboxuser@ubuntu:~/Desktop/ns3/ns-allinone-3.41/ns-3.41$ ./ns3 run hw2_1
Consolidate compiler generated dependencies of target scratch_hw2_1
[ 0%] Building CXX object scratch/CMakeFiles/scratch_hw2_1.dir/hw2_1.cc.o
[ 0%] Linking CXX executable ../../build/scratch/ns3.41-hw2_1-default
Total Bytes Received: 17033544
vboxuser@ubuntu:~/Desktop/ns3/ns-allinone-3.41/ns-3.41$ ./ns3 run hw2_1
Consolidate compiler generated dependencies of target scratch_hw2_1
[ 0%] Building CXX object scratch/CMakeFiles/scratch_hw2_1.dir/hw2_1.cc.o
[ 0%] Linking CXX executable ../../build/scratch/ns3.41-hw2_1-default
Total Bytes Received: 13626728
vboxuser@ubuntu:~/Desktop/ns3/ns-allinone-3.41/ns-3.41$ ./ns3 run hw2_1
Consolidate compiler generated dependencies of target scratch_hw2_1
[ 0%] Building CXX object scratch/CMakeFiles/scratch_hw2_1.dir/hw2_1.cc.o
[ 0%] Linking CXX executable ../../build/scratch/ns3.41-hw2_1-default
Total Bytes Received: 10219912
vboxuser@ubuntu:~/Desktop/ns3/ns-allinone-3.41/ns-3.41$
```

Table-1

Link Data Rate = 24 Mbps	
Link Delay (ms)	Throughput (Mbps)
0	21.76
50	9.92
100	4.72
150	2.96
200	2.08

```
vboxuser@ubuntu: ~/Desktop/ns3/ns-allinone-3.41/ns-3.41
/usr/bin/cmake --build /home/vboxuser/Desktop/ns3/ns-allinone-3.41/ns-3.41/cmake
-cache -j 7
vboxuser@ubuntu:~/Desktop/ns3/ns-allinone-3.41/ns-3.41$ ./ns3 run hw2_1
Total Bytes Received: 27239728
vboxuser@ubuntu:~/Desktop/ns3/ns-allinone-3.41/ns-3.41$ ./ns3 run hw2_1
[ 0%] Building CXX object scratch/CMakeFiles/scratch_hw2_1.dir/hw2_1.cc.o
[ 0%] Linking CXX executable ../../build/scratch/ns3.41-hw2_1-default
Total Bytes Received: 12371992
vboxuser@ubuntu:~/Desktop/ns3/ns-allinone-3.41/ns-3.41$ ./ns3 run hw2_1
Consolidate compiler generated dependencies of target scratch_hw2_1
[ 0%] Building CXX object scratch/CMakeFiles/scratch_hw2_1.dir/hw2_1.cc.o
[ 0%] Linking CXX executable ../../build/scratch/ns3.41-hw2_1-default
Total Bytes Received: 5916160
vboxuser@ubuntu:~/Desktop/ns3/ns-allinone-3.41/ns-3.41$ ./ns3 run hw2_1
Consolidate compiler generated dependencies of target scratch_hw2_1
[ 0%] Building CXX object scratch/CMakeFiles/scratch_hw2_1.dir/hw2_1.cc.o
[ 0%] Linking CXX executable ../../build/scratch/ns3.41-hw2_1-default
Total Bytes Received: 3704832
vboxuser@ubuntu:~/Desktop/ns3/ns-allinone-3.41/ns-3.41$ ./ns3 run hw2_1
Consolidate compiler generated dependencies of target scratch_hw2_1
[ 0%] Building CXX object scratch/CMakeFiles/scratch_hw2_1.dir/hw2_1.cc.o
[ 0%] Linking CXX executable ../../build/scratch/ns3.41-hw2_1-default
Total Bytes Received: 2647040
vboxuser@ubuntu:~/Desktop/ns3/ns-allinone-3.41/ns-3.41$
```

Q0-

The effect of the link delay on throughput is more significant

Q1-

It's the same, because the filesizeb in hw2_0 had the same size as what was printed in hw2_1

```
int fileSizeB = 27239728; // File size in Bytes
```

Theory

Q0-

To prove Shannon-Hartly Capacity theorem we need to define received signal as sum of signal power and noise power as in the below formula:

$$\text{Received signal} = \text{Signal power } (S) + \text{Noise Power } (N)$$

$$\sqrt{(\text{Received signal})} = \sqrt{(S + N)}$$

Then we need to find the number of data information levels that can be separated without errors as :

$$m = \sqrt{(S + N)} / \sqrt{(N)}$$

$$m = \sqrt{1 + S/N}$$

then digital information will be :

$$I = \log_2 m$$

$$I = \log_2 \sqrt{1 + S/N}$$

$$= \frac{1}{2} \log_2 (1 + S/N)$$

If the channel transmits k pulses per second then the channel capacity is:

$$C = I * k$$

$$C = k/2 * \log_2 (1 + S/N)$$

According to Nyquist theorem $k = 2B$, then the capacity is :

$$C = B * \log_2 (1 + S/N)$$

To demonstrate the validity of Shannon's equation, let's consider a simple example. Imagine we have a communication channel with a bandwidth of 10 kHz (10,000 Hz), a signal power of 1 mW (milliwatt), and a noise power of 0.1 mW. Using the Shannon Capacity Formula:

$$C = 10,000 \times \log_2(1 + 0.0010.0001)$$

$$C = 10,000 \times \log_2(1 + 10)$$

$$C = 10,000 \times \log_2(11)$$

$$C \approx 10,000 \times 3.4594$$

$$C \approx 34,594$$

This means that in this scenario, the maximum achievable data rate over the channel is approximately 34,594 bits per second, given the specified bandwidth, signal power, and noise power. This demonstrates the application and validity of the Shannon Capacity Formula.

Q1-The Sampling Theorem states that a continuous signal can be perfectly reconstructed from its samples if the sampling frequency f_s is greater than twice the maximum frequency component of the signal f_{\max} . This is expressed as:

$$f_s > 2 \text{ times } f_{\max}$$

On the other hand, the Bandpass Sampling Theorem applies to band-limited signals. It states that a band-limited signal can be perfectly reconstructed from its samples if the sampling frequency f_s is greater than twice the bandwidth of the signal B . This is expressed as:

$$f_s > 2 \text{ times } B$$

While the Sampling Theorem applies to any signal, the Bandpass Sampling Theorem specifically addresses signals that have a limited frequency range.