Assignment No. 02:

Factory Simulation

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CS433: Performance Evaluation

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I. INTRODUCTION

A. Purpose

In this assignment, basic simulation techniques has been used to analyze and evaluate the performance of a factory. The factory consists of a machining center and inspection station in series. Unfinished parts arrive at the factory with exponential interarrival times with a mean of 1 minute. Processing times at the machining center are uniform on the interval [0.65, 0.70] minute, and subsequent inspection times are uniformly distributed as [0.75, 0.80] minute. Ten percent of the parts are bad and are sent back to the machine for rework (i.e. 90inspected parts are good and are sent to shipping).

The machining center is subject to randomly occurring breakdowns. In particular, a new (or a freshly-repaired) machine will break down after an exponential amount of time with a mean of 6 hours. Repair times are uniform on the interval [8, 12] minutes. If a part is being processed when the machine breaks down, then the machine continues where it left off upon the completion of repair. The factory is initially empty and idle, and is working continuously without any breaks periods.

B. Measurement Tool

In this assignment, The Iperf tool has been used to collect the required data. Iperf is a tool for measuring TCP and UDP performance over a network.

C. Procedure

1. TCP Connection

a. LAN Network

1. Connect two machines using a network cable.
2. Choose one machine as a **server** and the other as a **client**.
3. At the server machine run *ipconfig command* to obtain server IP address.
4. Run Iperf on server machine with a predefined port number *e.g. 5001.*
5. Run Iperf on client machine with the predefined port number and the server IP address.
6. repeat the above step n times where n bigger than 30

b. WLAN Connection

1. Setup wireless ad hoc network between two machines.
2. Choose one machine as a **server** and the other as a **client**.
3. At the server machine run *ipconfig command* to obtain server IP address.
4. Run Iperf on server machine with a predefined port number *e.g. 5001.*
5. Run Iperf on client machine with the predefined port number and the server IP address.
6. repeat the above step n times where n bigger than 30

c. ADSL Connection

1. Configure port forwarding on the server machine `http://www.portforward.com/`.
2. Get the external IP address of the server machine using: `http://www.whatismyip.com/`
3. Run Iperf on server machine with a predefined port number *i.e. the port configured in step 1.*
4. Run Iperf on client machine with the predefined port number and the server IP address.
5. repeat the above step n times where n bigger than 30

d. Dail up Connection

1. Connect server machine to a dail up network
2. Get the external IP address of the server machine using: `http://www.whatismyip.com/`.
3. Run Iperf on server machine with a predefined port number .
4. repeat step 1 for client machine.
5. repeat the above step n times where n bigger than 30

2. UDP Connection

Same procedures as TCP. However, the data rate has been changed to measure different throughput values. For each data rate, the experiment has been run for three times and the average results was recorded. This is done to avoid any noise in the resulting data. The packets loss ratio has also been recorded for UDP connections.

II. PERFORMANCE ANALYSIS PROCEDURE

A. TCP Connection

This section will describe the analytical steps done on the experiment data of the TCP connection
Definitions:

1. x = sample collected data
2. n = sample size of collected data
3. $\bar{x}$ = sample mean
4. s = sample deviation
5. r = accuracy of number of samples required to follow normal distribution
6. CI = confedence IntervaL

1. The mean bandwidth over several trials

$$\bar{x} = \sum_{i=1}^{n} \frac{x_i}{n}$$

2. The 95% confidence intervals for the mean bandwidth

$$n > 30$$

$$\bar{x} \sim N(\mu, \frac{s}{\sqrt{n}})$$

$$z_{1-\frac{\alpha}{2}} = z_{0.975} = 1.96 \cdots NormalTable$$

$$s = \frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2$$

$$CI = \bar{x} \mp z_{1-\frac{\alpha}{2}} \frac{s}{\sqrt{n}}$$

3. the number of samples required to obtain the mean bandwidth with 1% accuracy

$$r = 1$$

$$z = z_{1-\frac{\alpha}{2}} = 1.96$$

$$N_{sample} = \lceil (\frac{100 * z * s}{r * \bar{x}})^2 \rceil$$

III. EXPERIMENT DATA

This section will consist of the actual analysis of the collected data.

A. TCP Connection

This matlab script is used to generate the required data in the analysis of TCP connection

```
%lan
x = [81.8125 82.2265625 78.1953125 74.734375 75.78125 75.625 77.5390625 75.6015625 74.1484375 75.40625 76.7890625
     76.78125 74.8984375 74.8984375 77.65625 77.296875 75.0078125 76.0625 75.8203125 74.03125 76.65625 77.2109375
     75.578125 82.078125 76.9140625 75.2734375 76.578125 76.5390625 76.328125 76.0703125 76.640625 75.3125 75.3125
     76.5234375 75.9296875 76.3671875 74.1484375 75.484375 74.7578125 73.5];
%wifi
x2=[10.9 11.4 10.7 10.9 10.8 10.8 10.7 10.5 10.6 10.6 10.6 10.5 11.1 12.1 11.7 11.7 11.5 11.7 11.5 10.7 10.4 10.6
    10.5 11 10.8 12.1 10.4 12 10.9 10.6 11 11.7 12.2 11.4 12 11.7 12.3 11.9 12.1 12.2 ];
%DSL
x3=[0.123046875 0.094140625 0.1064453125 0.111328125 0.10546875 0.09541015625 0.1103515625 0.1103515625 0.109375
    0.1142578125 0.109375 0.1103515625 0.1162109375 0.0830078125 0.111328125 0.1005859375 0.09736328125
    0.0939453125 0.1044921875 0.1103515625 0.1142578125 0.1083984375 0.10546875 0.1005859375 0.1240234375
    0.1064453125 0.1162109375 0.1083984375 0.1123046875 0.1005859375 0.1083984375 0.0912109375 0.1044921875
    0.1083984375 0.103515625 0.099609375 0.1123046875 0.10546875 0.1142578125 0.111328125];
%dailup
x4 = [0.08583984375 0.0849609375 0.09716796875 0.103515625 0.091015625 0.06328125 0.0986328125 0.103515625
    0.0986328125 0.09765625 0.103515625 0.0919921875 0.0912109375 0.09765625 0.111328125 0.08779296875
    0.0681640625 0.09765625 0.1025390625 0.1015625 0.1025390625 0.1064453125 0.08740234375 0.092578125 0.099609375
     0.1025390625 0.06318359375 0.006328125 0.008974609375 0.09609375 0.109375 0.021484375 0.0560546875
    0.06533203125 0.069921875 0.10546875 0.0462890625 0.0580078125 0.0408203125 0.03212890625 ];

%clac mean
n = length(x);
mean = sum(x)/n;
fprintf('mean = %d\n',mean);

%calc sample variance
sTemp = 0;
for i = 1:n
    sTemp = sTemp + (x(i)-mean)^2;
end
s = sqrt( (1 / (n-1) ) * sTemp );
fprintf('s = %d\n',s);

%calc CI
z = 1.96; %from normal table
ciLow = mean - (z * ( s/sqrt(n) ) );
ciHigh = mean + (z * ( s/sqrt(n) ) );
fprintf('CI = [ %d , %d ]\n',ciLow,ciHigh);

%calc number of samples required
r = 1;
nReq = ceil( ( ( 100*z*s )/( r*mean ) )^2 );
fprintf('number of samples = %d\n',nReq);

%drawing Quantile-quantile plot
qqplot(x);

%drawing probability plot
probplot('normal',[rot90(x) rot90(x2) rot90(x3) rot90(x4)]);
legend('LAN','WIFI','ADSL','Dail_Up','Location','N')

%drawing histogram plot
hist(x,30);
h = findobj(gca, 'Type','patch');
set(h(1), 'FaceColor','k', 'EdgeColor','r')

%drawing box plot
boxplot([rot90(x) rot90(x2) rot90(x3) rot90(x4)]);
```

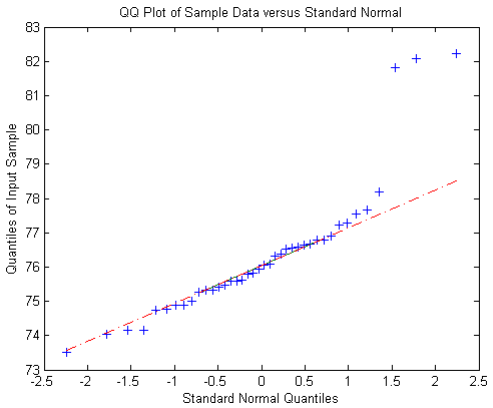
1. *LAN Network*

a. Readings

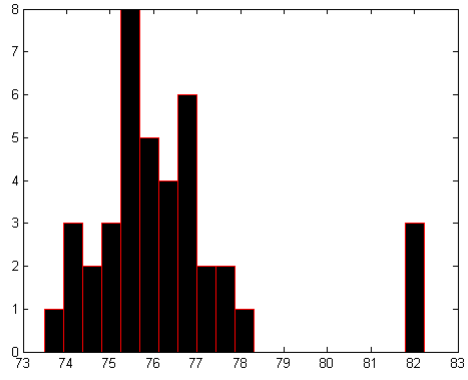
Trial number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Bandwidth(Mbps)	81.8	82.2	78.1	74.7	75.7	75.6	77.5	75.6	74.1	75.4	76.7	76.7	74.8	74.8	77.6
Trial number	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Bandwidth(Mbps)	77.2	75.0	76.0	75.8	74.0	76.6	77.2	75.5	82.0	76.9	75.2	76.5	76.5	76.3	76.0
Trial number	31	32	33	34	35	36	37	38	39	40					
Bandwidth(Mbps)	76.6	75.3	75.3	76.5	75.9	76.3	74.1	75.4	74.7	73.5					

b. Results

- $\bar{x} = 76.3Mbps$
- $s = 1.94$
- $Confidence\ interval = (75.7, 76.9)$
- $N_{normal} = 26$



(a)Qunatiltle quantile plot



(b)Histogram plot

c. Observations

- Bandwidth is faster than usual DSL
- according quantile quantile plot the sample data follow noraml distribution
- packet Delay is minimal *i.e.* ad hoc network is used which eliminates the need of a router and therefore the queuing delay and processing delay

$$d_{nodal} = d_{processing} + d_{queue} + d_{transmission} + d_{propagation}$$

$$d_{processing} = 0, d_{queue} = 0$$

- When packet size increase results become more accurate
- the material of the connecting wire affects the limit of the bandwidth

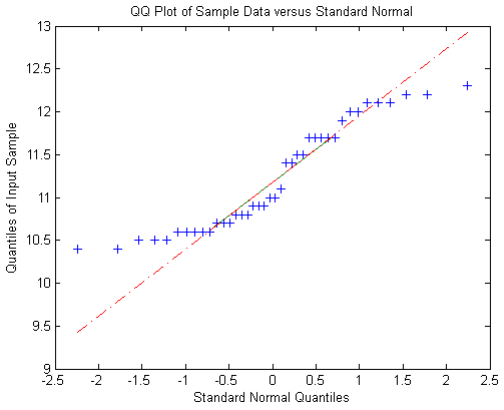
2. *WLAN Network*

a. Readings

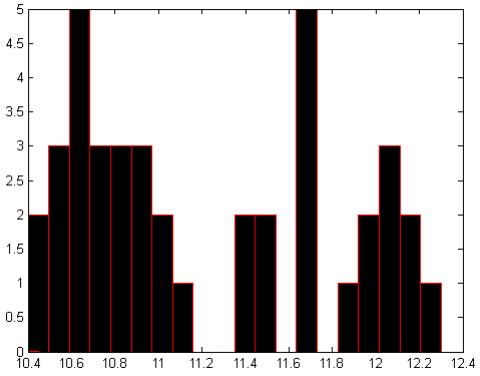
Trial number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Bandwidth(Mbps)	10.9	11.4	10.7	10.9	10.8	10.8	10.7	10.5	10.6	10.6	10.6	10.5	11.1	12.1	11.7
Trial number	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Bandwidth(Mbps)	11.7	11.5	11.7	11.5	10.7	10.4	10.6	10.5	11	10.8	12.1	10.4	12	10.9	10.6
Trial number	31	32	33	34	35	36	37	38	39	40					
Bandwidth(Mbps)	11	11.7	12.2	11.4	12	11.7	12.3	11.9	12.1	12.2					

b. Results

- $\bar{x} = 11.2Mbps$
- $s = 0.62$
- $Confidence\ interval = (11.027, 11.41)$
- $N_{normal} = 181$



(c)Qunatiltle quantile plot



(d)Histogram plot

c. Observations

- Bandwidth is slower than that on lan network
- According quantile quantile plot the sample data roughly follow noraml distribution
- There exist some noise in the data and this may be due to external factor as the transfer medium
- The results makes more sense when using a wireless ad hoc network rather than that of traditional wifi network

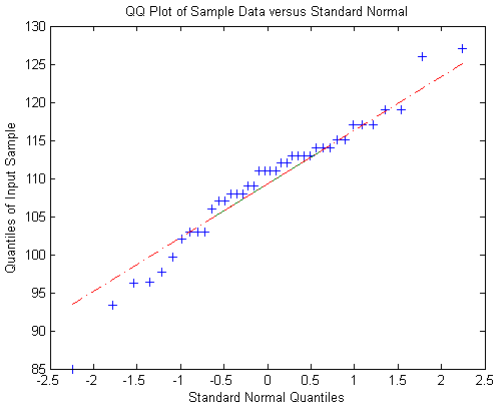
3. *ADSL Network*

a. Readings

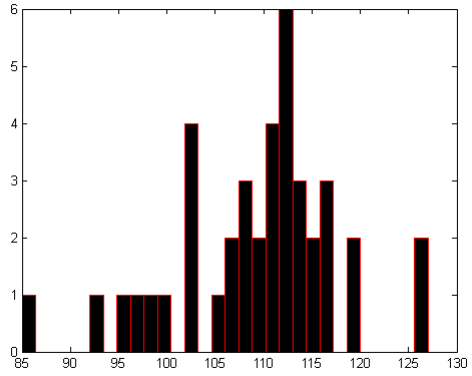
Trial number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Bandwidth(Kbps)	126	96.4	109	114	108	97.7	113	113	112	117	112	113	119	85	114
Trial number	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Bandwidth(Kbps)	99.7	96.2	107	113	117	111	108	103	127	109	119	111	115	103	111
Trial number	31	32	33	34	35	36	37	38	39	40					
Bandwidth(Kbps)	107	111	106	102	115	108	117	93.4	114	103					

b. Results

- $\bar{x} = 109.3Kpbs$
- $s = 8.43$
- $Confidence\ interval = (106.7, 112)$
- $N_{normal} = 229$



(e)Qunatiltle quantile plot



(f)Histogram plot

c. Observations

- Bandwidth is slower than both of lan and wlan nerworks
- According quantile quantile plot the sample data roughly follow noraml distribution
- Readings depends on the router of the server machine and its max bandwidth and whether its over-loaded or not

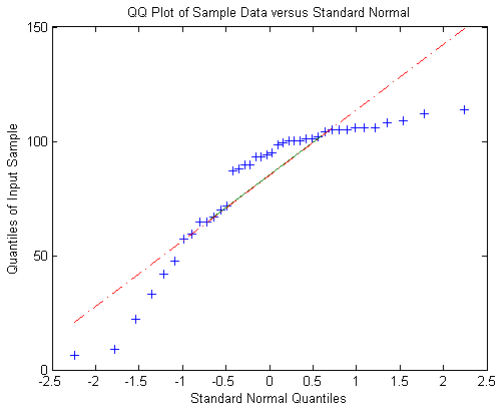
4. *Dial up Network*

a. *Readings*

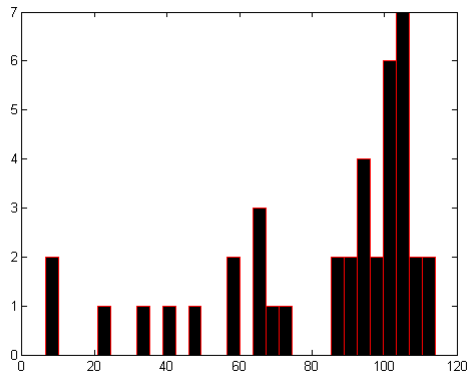
Trial number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Bandwidth(Kbps)	87.9	87.0	99.5	106.0	93.2	64.8	101.0	106.0	101.0	100.0	106.0	94.2	93.4	100.0	114.0
Trial number	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Bandwidth(Kbps)	89.9	69.8	100.0	105.0	104.0	105.0	109.0	89.5	94.8	102.0	105.0	64.7	6.48	9.19	98.4
Trial number	31	32	33	34	35	36	37	38	39	40					
Bandwidth(Kbps)	112.0	22.0	57.4	66.9	71.6	108.0	47.4	59.4	41.8	32.9					

b. *Results*

- $\bar{x} = 83.1 Kpbs$
- $s = 28.9$
- $Confidence\ interval = (74.2, 92.1)$
- $N_{normal} = 4632$



(g)Qunatiltle quantile plot



(h)Histogram plot

c. *Observations*

- Bandwidth is slowest among other networks
- According quantile quantile plot we can assume that the sample data doesn't perfectly follow normal distribution

B. UDP Connection

This batch script is used to collect the required data for UDP analysis using iperf

```
FOR /L %%i in (2 2 20) DO (
FOR /L %%j IN (1 1 3) DO (
    iperf.exe -c 169.254.124.96 -u -P 1 -i 1 -p 5001 -f m -b %%iM -t 10 -T 1 >> wireless-udp.txt
    :sleep for 1 sec
    ping 127.0.0.1 -n 11 -w 1000
)
)
```

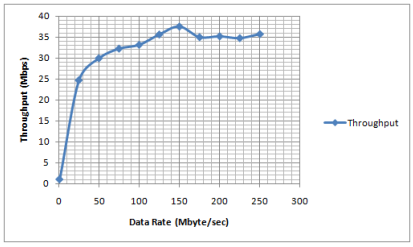
1. LAN Network

a. Readings The following table includes the data collected for carrying out the analysis phase for the UDP connection on local area network (LAN). The data rates have been changed from 1 MBytes/sec up to 250 MBytes/sec with a step of 25 MBytes/sec in each iteration. For each data rate, three samples have been collected and the average throughput and loss rate has been recorded.

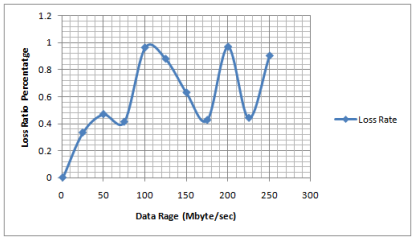
Data Rate (Mbyte/sec)	Throughput 1 (Mbit/sec)	Loss Rate 1	Throughput 2 (Mbit/sec)	Loss Rate 2	Throughput 3 (Mbit/sec)	Loss Rate 3	Throughput	Loss Rate
1	1	0	1	0	1	0	1	0
25	24.5	0.42	24.8	0.22	24.8	0.36	24.7	0.333333
50	29.7	0.45	29.6	0.58	30.6	0.38	29.9666667	0.47
75	31.9	0.26	32.1	0.48	32.8	0.5	32.2666667	0.413333
100	33.1	1.1	32.7	1.3	33.7	0.49	33.1666667	0.963333
125	33.7	0.4	33.3	1.3	39.9	0.94	35.6333333	0.88
150	35.8	0.45	36.2	0.34	40.6	1.1	37.5333333	0.63
175	34.6	0.2	36.2	0.4	34.2	0.68	35	0.426667
200	35.3	0.51	35.4	1.3	34.9	1.1	35.2	0.97
225	34.8	0.44	35	0.71%	34.5	0.88	34.7666667	0.442367
250	35.2	0.56	36	1.4	36	0.75	35.7333333	0.903333

(i)Readings for UDP Connection in LAN Network

b. Results The figures below illustrate the realation between the data rate in MBytes/sec and the acheived throughput and loss rate over a local area network (LAN).



(j)Data Rate (MByte/sec) vs Throughput (Mbps)



(k)Loss Rate Percentage

c. Observations

- Knee Point:
  - Throughput: 25 Mbps
  - Data Rate: 30 MBytes/sec
- Maximum Throughput: 37 Mbps

- Compared to TCP (76.3 Mbps), it was expected that UDP acheives heigher throughput than TCP. However, due to the default packet size (1470 Bytes / datagram). By increasing the data packet size, the throughput for UDP was improved. Note however that differing nature of UDP and TCP flows means that it their measurements should not be directly compared. Iperf sends UDP datagrams are a constant steady rate, whereas TPC tends to send packet trains. This means that TCP is likely to suffer from congestion effects at a lower data rate than UDP. (`http://kb.pert.geant.net/PERTKB/IperfTool`)
- The error rate remains within the expected bound (Less than 1 percent). For the error rate below the knee point (30 MBytes/sec), the error increases with the increase in data rate. After the knee point, the error rate behavior tend to be unpredicted but remains heigher than 0.4 percent.
- By changing the direct cable used to connect the two computer devices in the LAN, the UDP and TCP throughput was changed depending on the wire used. Higher quality wires achevied better results reaching up to 90.5 Mbps for TCP and 65 Mbps for UDP.

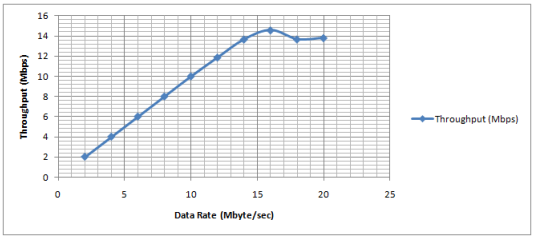
2. *WLAN Network*

a. Readings The following table includes the data collected for carrying out the analysis phase for the UDP connection on Wireless local area network (WLAN). The data rates have been changed from 2 MBytes/sec up to 20 MBytes/sec with a step of 2 MBytes/sec in each iteration. For each data rate, three samples have been collected and the average throughput and loss rate has been recorded.

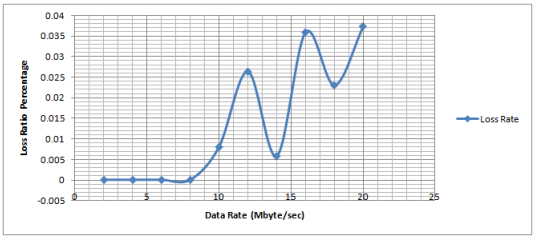
Data Rate (Mbyte/sec)	Throughput1 (Mbps)	Loss Rate1	Throughput 2 (Mbps)	Loss Rate 2	Throughput 3 (Mbps)	Loss Rate 3	Throughput (Mbps)	Loss Rate
2	2	0	2	0	2	0	2	0
4	4	0	4	0	4	0	4	0
6	6	0	6	0	6	0	6	0
8	8	0	8	0	8	0	8	0
10	9.99	0	10	0	10	0.024	9.996666667	0.008
12	12	0.069	12	0	11.6	0.01	11.86666667	0.026333
14	13.8	0.0085	13.8	0	13.4	0.0088	13.66666667	0.005767
16	14.2	0.025	14.2	0.075	15.3	0.0077	14.56666667	0.0359
18	13.5	0.026	13.3	0.018	14.2	0.025	13.66666667	0.023
20	14.2	0.025	13.8	0.017	13.4	0.07	13.8	0.037333

(l)Readings for UDP Connection in WLAN Network

b. Results The figures below illustrate the realation between the data rate in MBytes/sec and the acheived throughput and loss rate over a wireless local area network (WLAN).



(m)Data Rate (MByte/sec) vs Throughput (Mbps)



(n)Loss Rate Percentage

c. Observations

- Knee Point:
  - Throughput: 14.5 Mbps
- Maximum Throughput: 14.5 Mbps
- Compared to TCP (11.2 Mbps), The UDP connection acheived higher throughput compared to TCP (14.5 Mbps)
- The error rate remains within the expected bound (Less than 0.4 percent). It's also clear that the loss rate increases with the increase in the data rate.

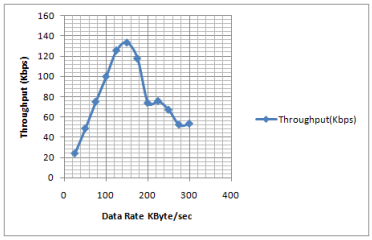
3. *ADSL Network*

a. Readings The following table includes the data collected for carrying out the analysis phase for the UDP connection using ADSL connection. The data rates have been changed from 25 KBytes/sec up to 300 KBytes/sec with a step of 25 KBytes/sec in each iteration. For each data rate, three samples have been collected and the average throughput and loss rate has been recorded.

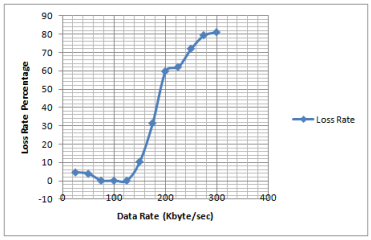
Data Rate (Kbyte/sec)	Throughput 1 (Kbps)	Loss Rate 1	Throughput 2 (Kbps)	Loss Rate 2	Throughput 3 (Kbps)	Loss Rate 3	Throughput(Kbps)	Loss Rate
25	23.8	4.8	25.2	0	22.9	8.7	23.96666667	4.5
50	46.4	6.8	51.8	0	47.9	4.5	48.7	3.766667
75	75	0	75.2	0	75	0	75.06666667	0
100	100	0	100	0	100	0	100	0
125	128	0	125	0	125	0	126	0
150	131	11	130	13	140	7	133.6666667	10.33333
175	105	36	128	27	121	31	118	31.33333
200	76.6	60	84.8	52	60.6	67	74	59.66667
225	98.3	51	67.5	65	61.6	70	75.8	62
250	73.5	70	72.5	70	55.5	76	67.16666667	72
275	56.2	77	42.7	84	58.5	77	52.46666667	79.33333
300	61.1	79	53.1	81	46.2	83	53.46666667	81

(o)Readings for UDP Connection in DSL Network

b. Results The figures below illustrate the realation between the data rate in MBytes/sec and the acheived throughput and loss rate over a wireless local area network (WLAN).



(p)Data Rate (KByte/sec) vs Throughput (Kbps)



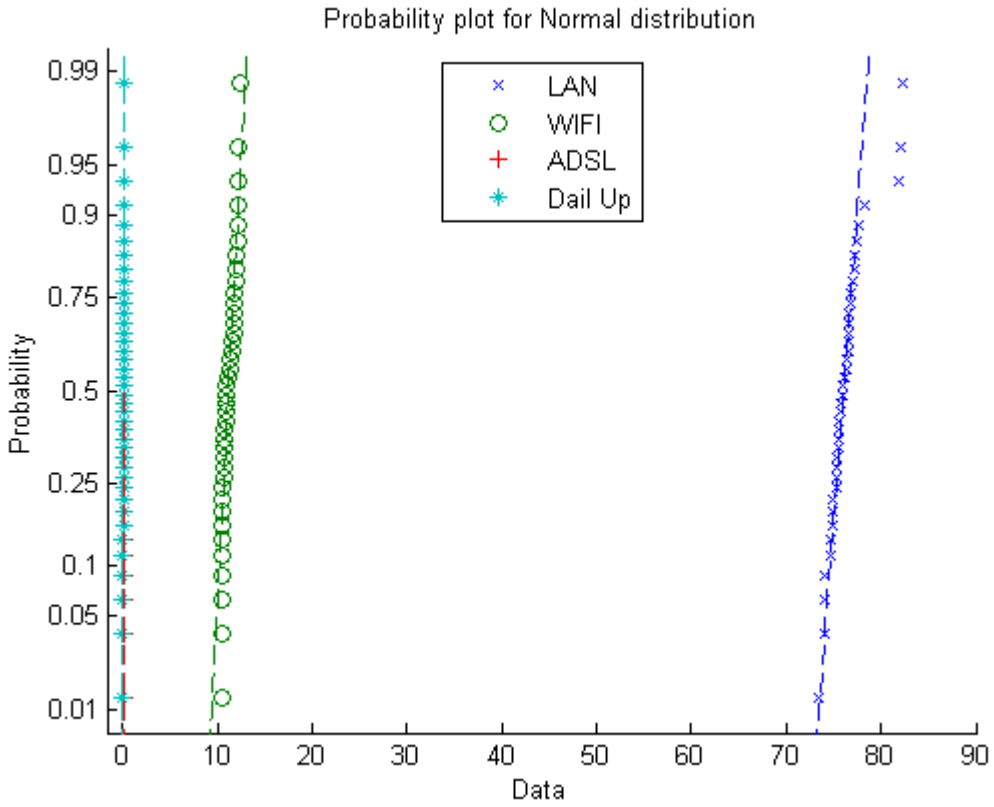
(q)Loss Rate Percentage

c. Observations

- Knee Point:
  - Throughput: 135 Kbps
- Maximum Throughput: 135 Kbps
- Compared to TCP (109.3 Kbps), The UDP connection acheived higher throughput compared to TCP (135 Kbps)
- It's clear that the loss rate increases with the increase in the data rate. The error reaches 80 Percent for high data transmission rates (300 KBytes/sec)

IV. CONCLUSION

A. TCP



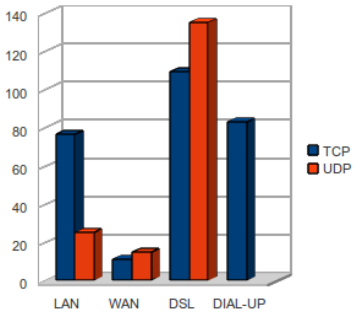
(r)Probability plot

- Performance of wired network is better than that of wireless network
-

$$Bandwidth_{LAN} > Bandwidth_{WLAN} > Bandwidth_{ADSL} > Bandwidth_{Dailup}$$

- The distribution of the Dail up sample data follows the same ditribution as that of ADSL sample data which is not expected but the reason may be that during taking the readings of ADSL experiment the network was congested which cause this low results

B. UDP



(s)Comparison between UDP and TCP

- Performance of UDP connection is better than TCP connection. Although the data collected for the LAN network showed that TCP is faster than UDP, this is not the expected case. This could be due to the packet size assigned for the datagrams and several other different factors.
- $$Bandwidth_{LAN} > Bandwidth_{WLAN} > Bandwidth_{ADSL} > Bandwidth_{Dailup}$$
- The packet loss ratio increases when the data rate increases.
- It was quite difficult to measure the performance of UDP network over dial-up connection. This is due to the high loss ratio and failure to receive the final server report for the received datagram and loss rate.