ECE466 Computer Networks II

Lab 4 Bandwidth Estimation

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Part 1. Generating and Time-stamping Packet Trains

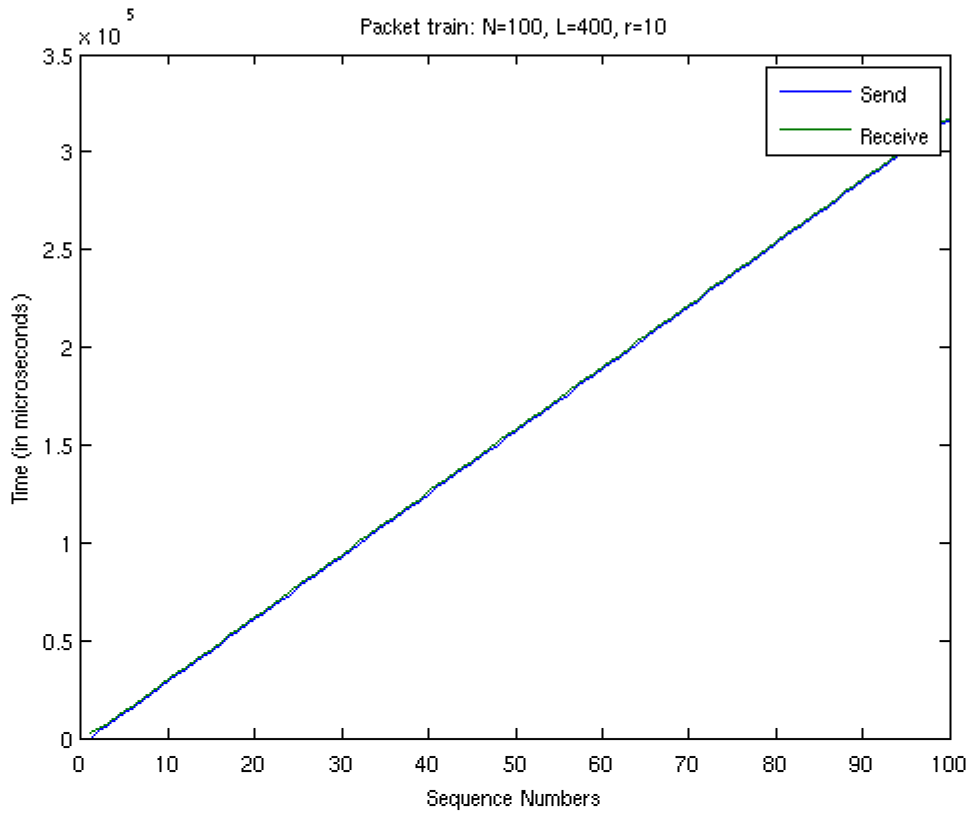
Lab Report:

The source code for the Estimator that was used can be found in part1:

TrafficEstimator.java
TrafficGenerator.java
TrafficSink.java
Timestamp.java

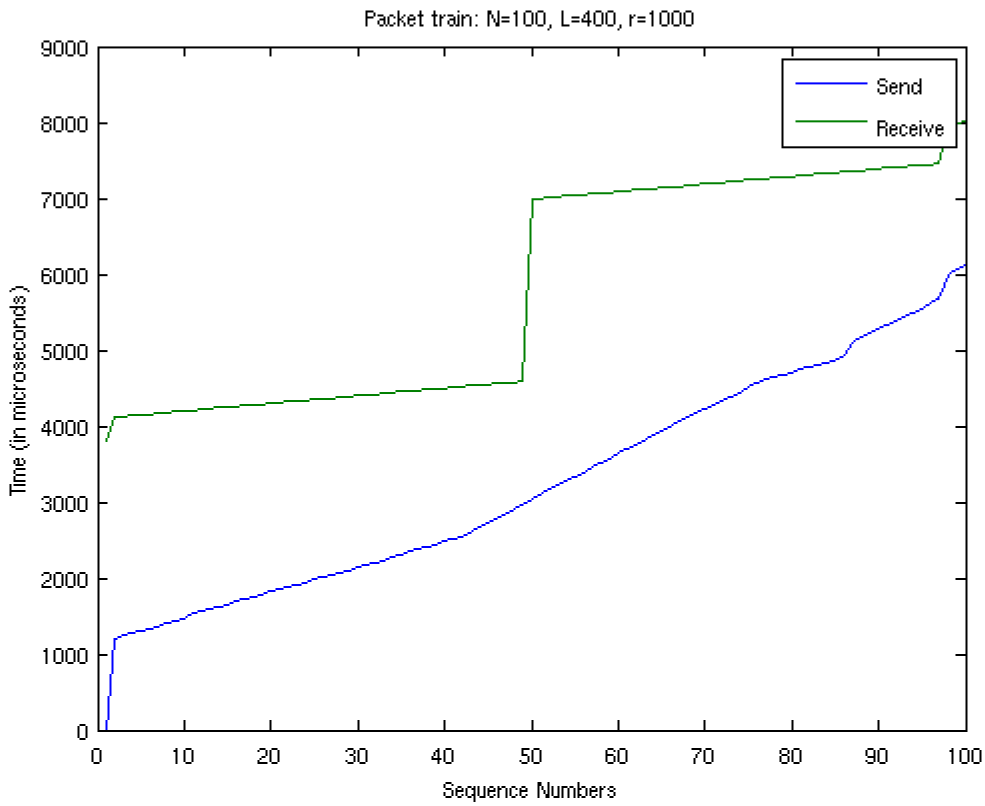
Exercise 1.5 Evaluation

1. Packet train: N=100, L=400, r=10



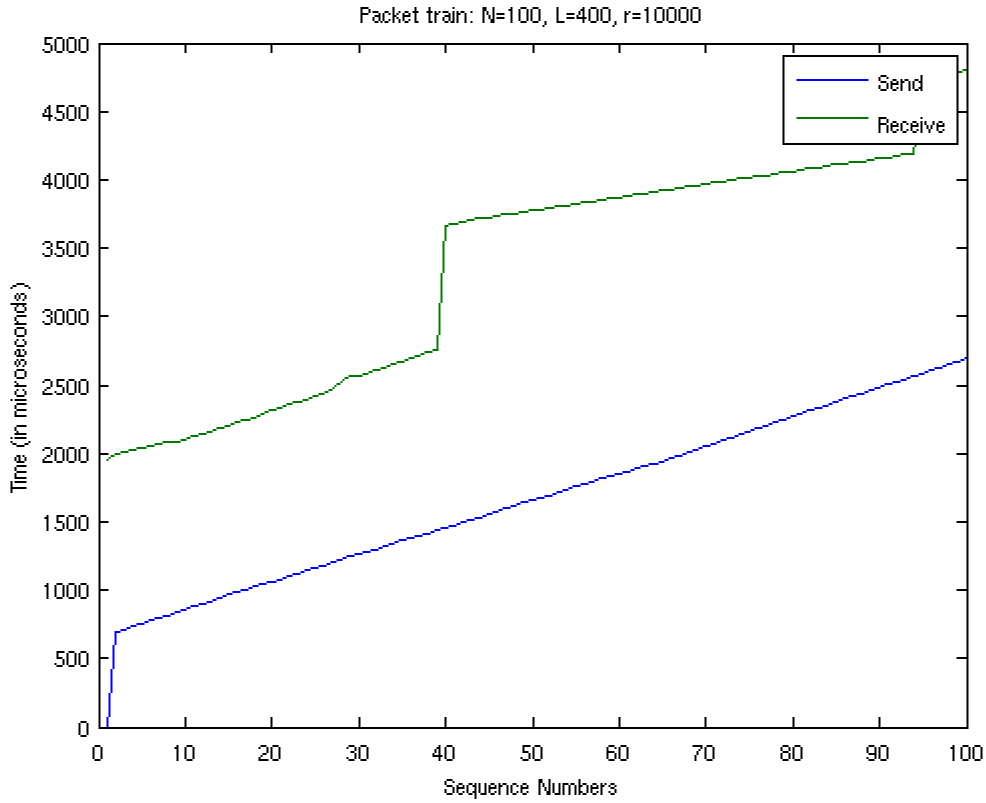
We can see from the two overlapping curves that the BlackBox is able to efficiently send back the packets that it received from the Estimator. The interval between two packets are nearly the same for both the sender and the received packet, however the data and the plot shows a slight delay due to the TConstant set to 1000 microseconds near the very beginning.

2. Packet train: N=100, L=400, r=1000



We can see that the BlackBox quickly gets backlogged due to the increased in rate of the packet train, and then the packets are sent back to the Estimator at a faster rate than it was received, lowering the backlog quickly. The sharp slope shows a window of time in which it is the backlog is empty and it is sending out its received packets.

3. Packet train: N=100, L=400, r=10000



We can see a similar plot to the previous packet train. However, we can see that other than those sharp slopes, the two curves are almost parallel representing a similar rate of departure of packets. Again, there is a backlog that is introduced by the packet train's rate, which is eventually emptied, causing new packets to depart at the sharp slopes.

Part 2. Bandwidth Estimation of Black Boxes

Exercise 2.1 Implement and test the probing methodology

Since our Estimator could not transfer at a rate of 100 Mbps, it is not possible to figure out the service curve of a BlackBox with R=100 Mbps through the probing methodology. For this experiment to show results, the parameter for the BlackBox was reduce to R=1 instead of 100 so that the Estimator can apply the probing methodology to determine the service curve.

We begin our Estimators with N = 1000, L = 100,000 so we will send 1000 packets with each at size 100 Bytes. r will be set to a value greater than R so that we can derive the equation:

$B_{max}(r) = A - D - burst$

where $A = rt$ and $D = R(t-T)$

then determine the service curve:

$S(t) = rt - B_{max}(r)$

BlackBox 1: $b=L_{max}$, R = 1, T = 10000:

With the given parameters to the BlackBox, b = 11840 bits, R = 1000 kbps, T = 10000 ms, we have an ideal service curve of S(t) = 1000(t - 10) + 11840

1. Determining service curves using the probing methodology

experiment 1

r = 1400

B_{max} = 228018 at t = 571 ms

D (t) = 1000(t-29)

$B_{max}(r)$ = A - D - burst

228018 = 1400(571) - 1000(571 - 29) - burst

burst = 29382

S(t) = 1000(t-29) + 29382

experiment 2

r = 1200

B_{max} = 134450 at t = 665 ms

D (t) = 1000(t-11.6)

$B_{max}(r)$ = A - D - burst

134450 = 1200(655) - 1000(655 - 11.6) - burst

burst = 8150

S(t) = 1000(t-11.6) + 8150

experiment 3

r = 1100

B_{max} = 72868 at t = 724 ms

D (t) = 1000(t-11.2)

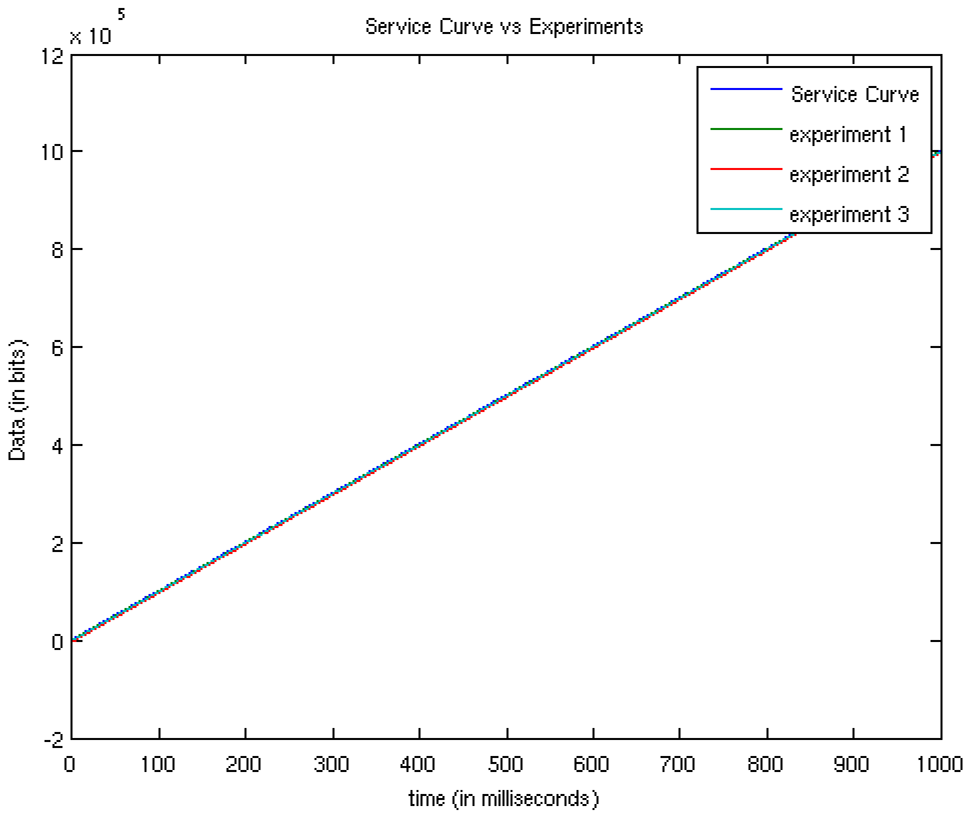
$B_{max}(r)$ = A - D - burst

72868 = 1100(724) - 1000(724 - 11.2) - burst

burst = 10732

S(t) = 1000(t-11.2) + 10732

2. Comparing the plots of the service curves to the ideal service curve



As we can see from the plot that the experiments are overlapping the ideal service curve, the BlackBox was able appear to serve traffic and the Estimator was able to collect the departure packets at the rate at which it was sending. Closer inspection to the estimated service curve for experiment 3 shows us it is nearest to the ideal service curve.

3. Repeat experiments with double the size of N and L

N = 2000, L = 200,000,

<u>experiment 4</u>

r = 1400

B_{max} = 455965 at t = 1142 ms

D (t) = 1000(t-10.9)

$B_{max}(r)$ = A - D - burst

455965 = 1400(1142) - 1000(1142 - 10.9) - burst

burst = 11735

S(t) = 1000(t-10.9) + 11735

<u>experiment 5</u>

r = 1200

B_{max} = 267546 at t = 1331 ms

D (t) = 1000(t-11.2)

$B_{max}(r)$ = A - D - burst

267546 = 1200(1331) - 1000(1331 - 11.2) - burst

burst = 9854

$S(t) = 1000(t-11.2) + 9854$

experiment 6

$r = 1100$

$B_{max} = 144757$ at $t = 1455$ ms

$D(t) = 1000(t-11.2)$

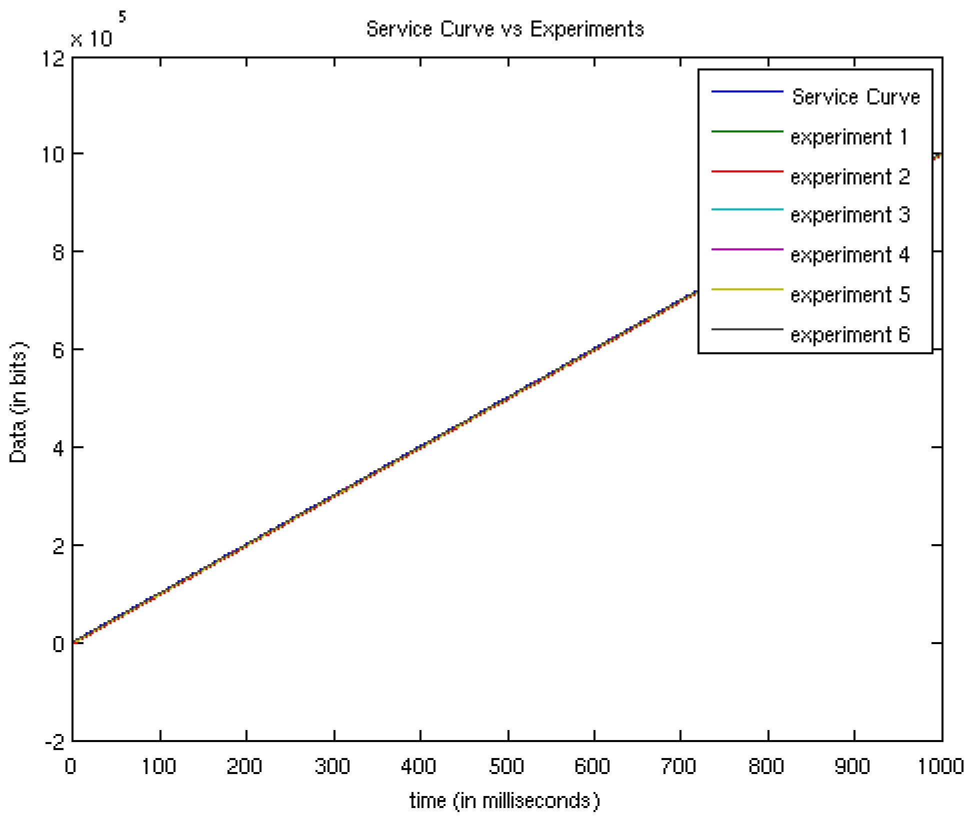
$B_{max}(r) = A - D - burst$

$144757 = 1100(1455) - 1000(1455 - 11.2) - burst$

$burst = 11943$

$S(t) = 1000(t-11.2) + 11943$

4. Findings for repeated measurement experiments



After repeating the experiment with the values of N and L doubled, it appears similar in the sense that they are still overlapping the ideal service curve. The increased in data shows estimated service curves very close to the ideal service curves.

BlackBox 2: b=10000, R = 1, T = 100,000:

With the given parameters to the BlackBox, b = 10000 bits, R = 1000 kbps, T = 10000 ms, we have an ideal service curve of $S(t) = 1000(t - 100) + 10000$

1. Determining service curves using the probing methodology

experiment 1

$r = 1400$

$B_{max} = 319894$ at $t = 570$ ms

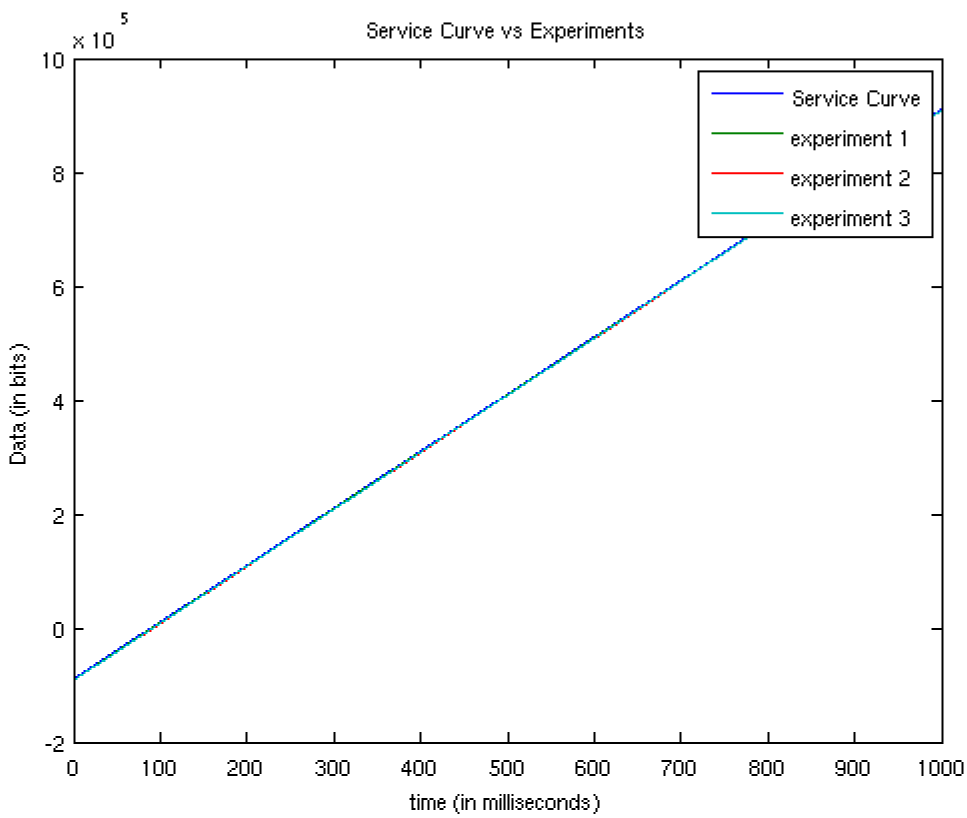
$D(t) = 1000(t-101)$

burst = 1400(570) - 1000(570-101) - 319894
S(t) = 1000(t-101) + 9106

<u>experiment 2</u>
r = 1200
B_{max} = 225850 at t = 665 ms
burst = 1200(665) - 1000(665-101) - 225850
S(t) = 1000(t-101) + 8150

<u>experiment 3</u>
r = 1100
B_{max} = 165045 at t = 726 ms
D (t) = 1000(t-101)
burst = 1100(726) - 1000(726-101) - 165045
S(t) = 1000(t-101) + 8555

2. Comparing the plots of the service curves to the ideal service curve



Since the only difference between the service curve of this BlackBox compared to the previous BlackBox, BlackBox1, is the increase in T and slightly decrease in b, the curves are still overlapping, however, we can see in the service curves from both the ideal and estimates that there is a delay T in the plot.

3. Repeat experiments with double the size of N and L

N = 2000, L = 200,000

<u>experiment 4</u>

r = 1400

B_{max} = 549369 at t = 1140 ms

D (t) = 1000(t-101)

burst = 1400(1140) - 1000(1140-101) - 549369

S(t) = 1000(t-101) + 7631

<u>experiment 5</u>

r = 1200

B_{max} = 350127 at t = 1339 ms

D (t) = 1000(t-101)

burst = 1200(1339) - 1000(1339-101) - 350127

S(t) = 1000(t-101) + 18673

<u>experiment 6</u>

r = 1100

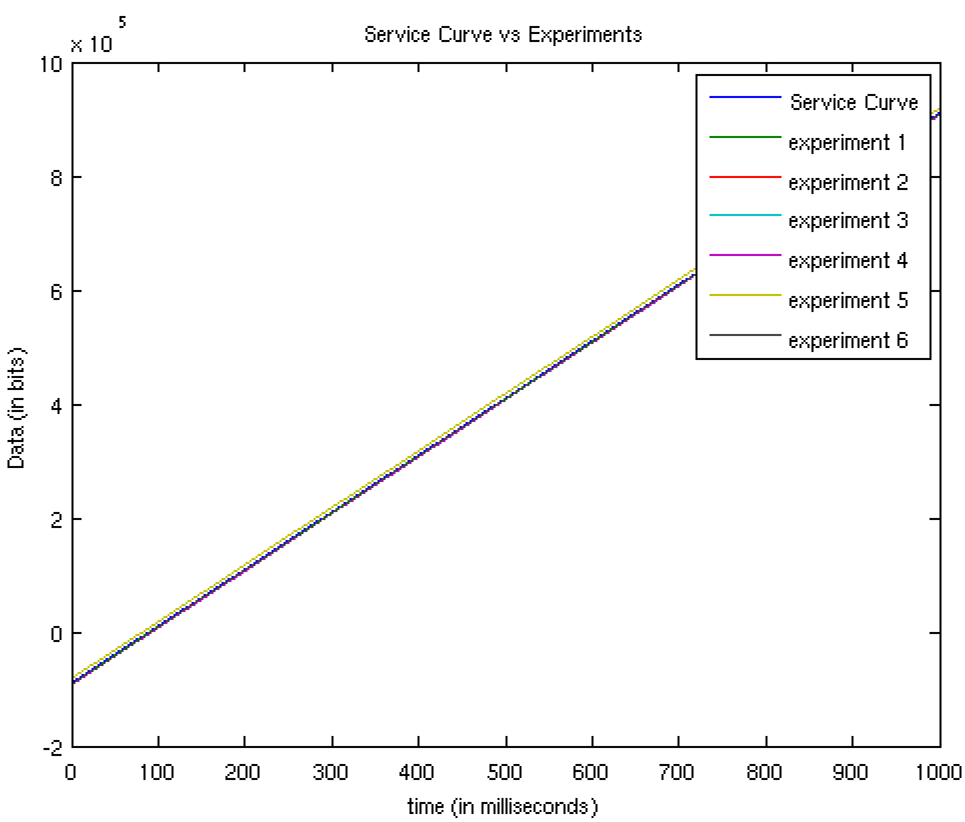
B_{max} = 237564 at t = 1453 ms

D (t) = 1000(t-101)

burst = 1100(1453) - 1000(1453-101) - 237564

S(t) = 1000(t-101) + 8736

4. Findings for repeated measurement experiments



Again, the repeated experiments with increase in N and L shows similar results as they are also overlapping.

BlackBox 3: b=L_{max}, R = 10, T = 20000:

With the given parameters to the BlackBox, b = 11840 bits, R = 10000 kbps, T = 10000 ms, we have an ideal service curve of S(t) = 10000(t - 20) + 11840

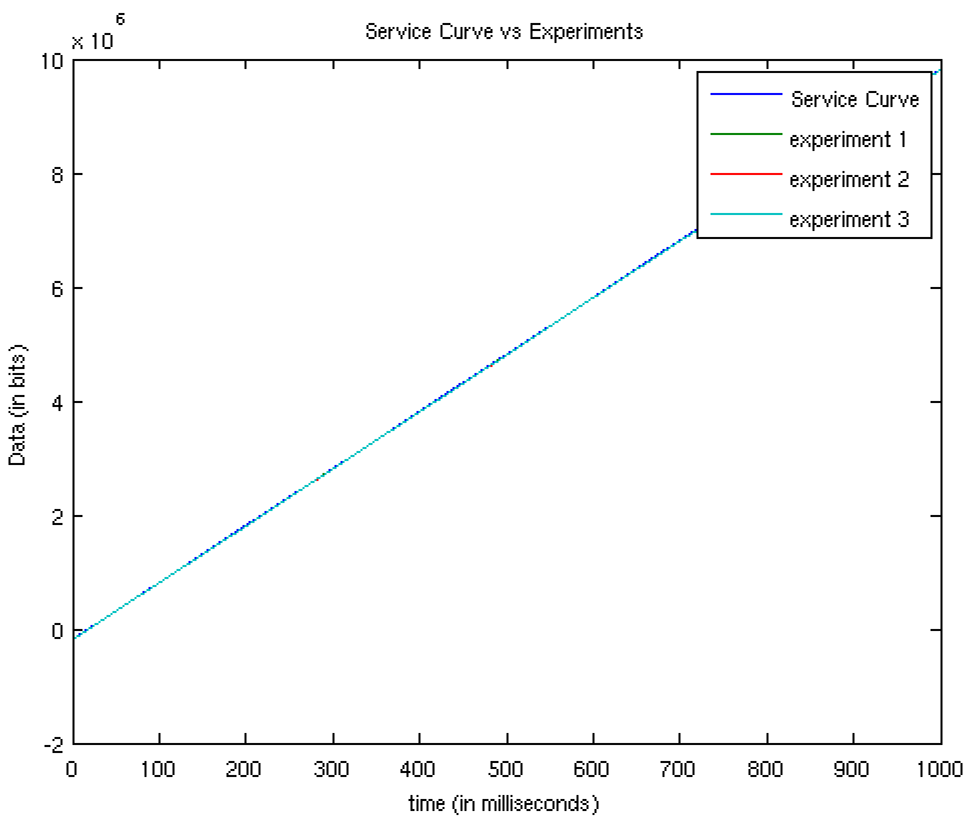
1. Determining service curves using the probing methodology

experiment 1
r = 14000
S(t) = 10000(t-21) + 11851

experiment 2
r = 12000
S(t) = 10000(t-21) + 11573

experiment 3
r = 11000
S(t) = 10000(t-21) + 11583

2. Comparing the plots of the service curves to the ideal service curve



With this BlackBox, the significant change is the increase in R to 10 instead of 1, we have our estimates closely resembling the ideal service curve as seen in the plot above.

3. Repeat experiments with double the size of N and L

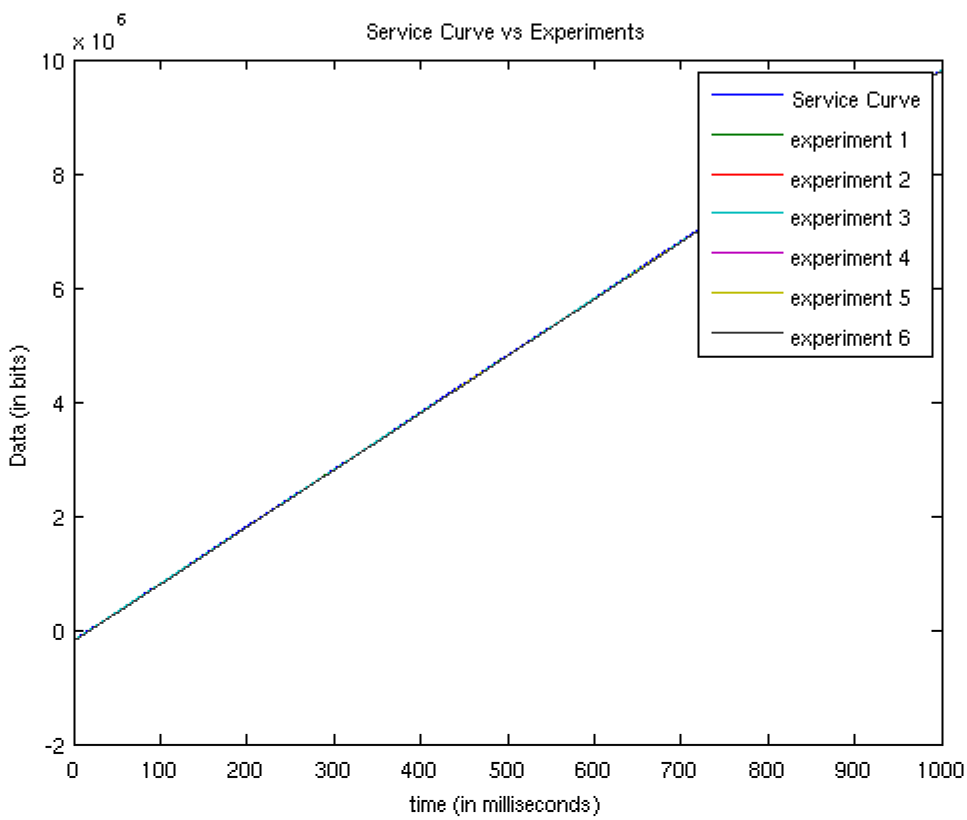
N = 2000, L = 200,000

<u>experiment 4</u>
r = 14000
S(t) = 10000(t-22) + 11682

<u>experiment 5</u>
r = 12000
S(t) = 10000(t-22) + 11594

<u>experiment 6</u>
r = 11000
S(t) = 10000(t-22) + 10432

4. Findings for repeated measurement experiments



The repeated estimation with longer packet trains and larger packet size shows similar results such that they are still overlapping the ideal service curve.

Exercise 2.2 Evaluation of Black Boxes with unknown parameters

We begin our Estimator with the same values as before, N=1000 and L = 100000. Our estimated values for T is in ms, b in bits, and R in kbps.

BlackBox1.jar

experiment 1

r = 500

S(t) = 370(t-100) + 3529

experiment 2

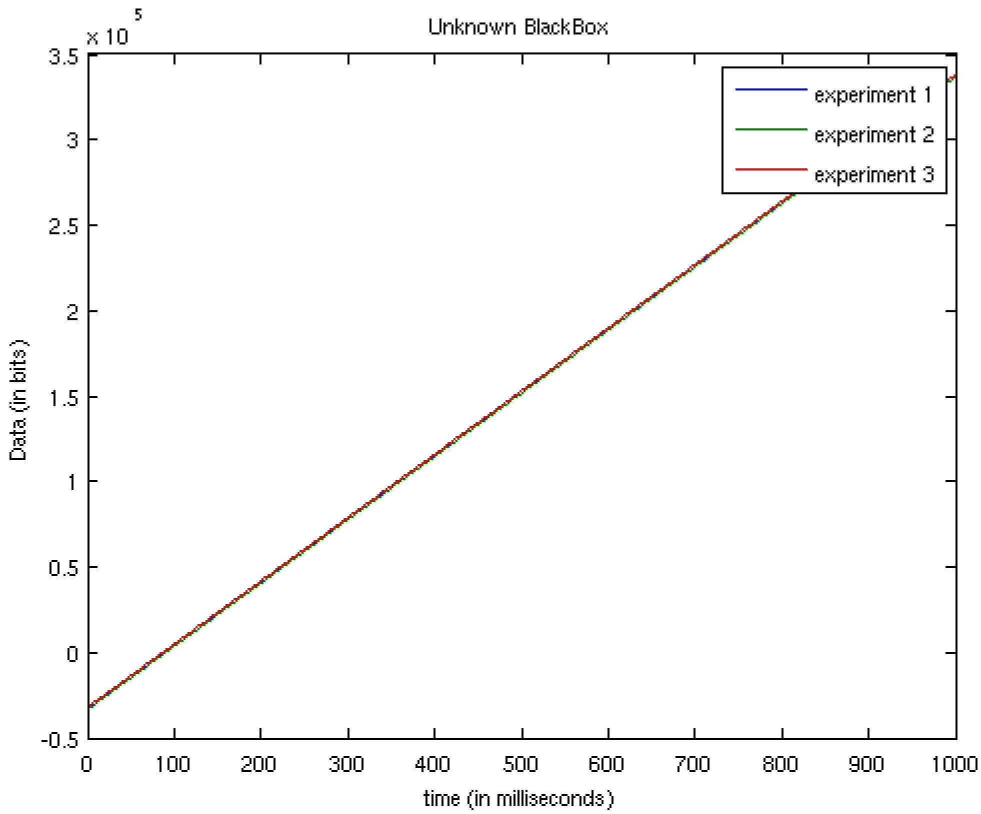
r = 600

S(t) = 370(t-100) + 3456

experiment 3

r = 700

S(t) = 370(t-100) + 4821



From our experiment, we can provide an estimation for the values of b, R, and T. Since they are overlapping each other for the various values of r, and the r values are picked to be close to each other, the values of the b, R, T can be seen from the estimated service curves themselves. Since S(t) has the form of S(t) = R(t-T) +b, then we can see that R = 370 kbps, T=100 ms, and can be the average of the three experiments, b= 3935 bits.

BlackBox2.jar

experiment 1

r = 50

S(t) = 50(t-1.5) + 2589

experiment 2

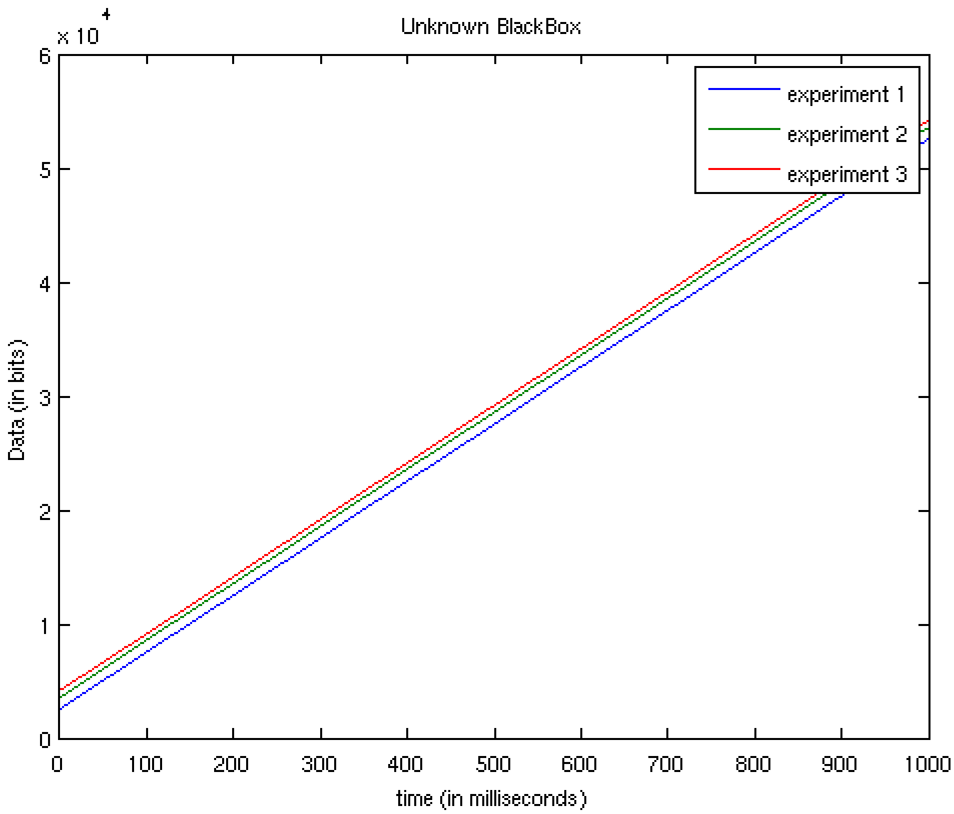
r = 100

S(t) = 50(t-1.5) + 3628

experiment 3

r = 150

S(t) = 50(t-1.5) + 4197



Similar to the previous experiment, our BlackBox appears to have a service curve with T=1.5 ms, R = 50 kbps, and b = 3471 (the average of the three b's from the experiment).

BlackBox3.jar

experiment 1

r = 200

S(t) = 170(t-100) + 944

experiment 2

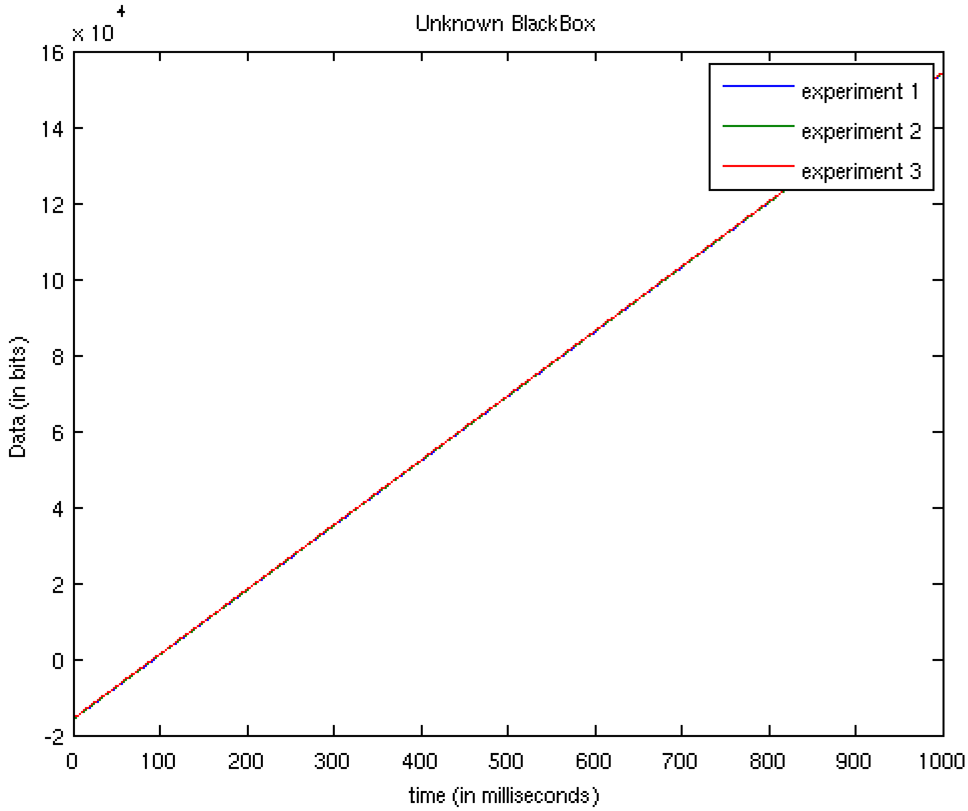
r = 250

S(t) = 170(t-100) + 1032

experiment 3

r = 300

S(t) = 170(t-100) + 1232

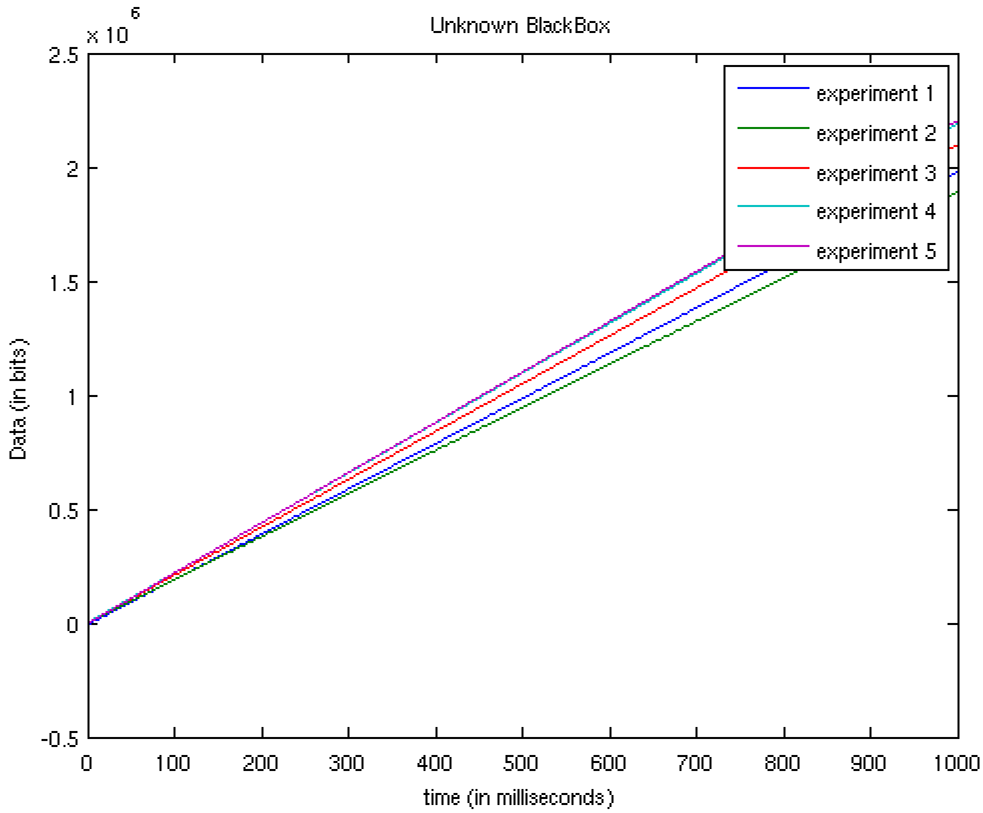


Similar to the previous experiment, our BlackBox appears to have a service curve with T=100 ms, R = 170 kbps, and b = 1069 (the average of the three b's from the experiment).

Part 3. Bandwidth Estimation of the Internet

Using the same values for N and L, we will estimate the remotely running instance of the Black Box.

Experiments
r=2000 B_{max} = 21574 at t = 386 ms D (t) = 1986(t-4.5) burst = 2000(386) - 1986(386-4.5) - 21574 **S(t) = 1986(t-4.5)**
r=2250 B_{max} = 124256 at t = 345 ms D (t) = 1890(t-4.4) burst = 2250(345) - 1890(345-4.4) - 124256 **S(t) = 1986(t-4.5) + 8260**
r=2500 B_{max} = 128762 at t = 318 ms D (t) = 2099(t-4.5) burst = 2500(318) - 2099(318-4.5) - 128762 **S(t) = 2099(t-4.5) + 8260**
r=2750 B_{max} = 163485 at t = 291 ms D (t) = 2190(t-4.8) burst = 2750(291) - 2190(291-4.8) - 163485 **S(t) = 2190(t-4.8) + 9987**
r=3000 B_{max} = 215323 at t = 267 ms D (t) = 2206(t-3.1) burst = 3000(267) - 2206(267-3.1) - 215323 **S(t) = 2206(t-3.1) +3514**



From our experiments, we can see that the above experiments were provided consistent results for the service curve as they are close to overlapping. If we take the average R, T, and b from the estimates we have from the experiments, we can provide an overall estimate for the service curve of the BlackBox. We can exclude experiment 1 from our calculation below since it's r should be less than the R of the BlackBox.

R = (1986 + 2099 + 2190 + 2206) / 4
R = 2120 kbps
T = (4.5 + 4.5 + 4.8 + 3.1) / 4
T = 4.2 ms
b = (8260 + 8260 + 9987 + 3514) /4
b = 7505 bits

We have our estimated service curve of the remote BlackBox to be:
S(t) = 2120(t-4.2) + 7505