Programming Assignment-1

Distributed Systems (CSCI/ECEN – 5673)

Spring – 2017

Due date: Tuesday, 14th February, 2017

Names:

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Programming Assignment-1 Report

Question 1:

- We have noted 4 timestamps values namely the client request time , server request time, server reply time and client reply time. These four timestamps gives us the idea about what is the delay present in the network. We have calculated the mean and standard deviation for pairwise latencies. Based on our results , we find that if both the client and the server are on the same machine, the delay and latency is less. So the standard deviation and the resulting mean values from the five iterations is also less.
- For Scenario 2, we are establishing connection between two CSEL servers and calculating the mean and standard deviation. We observe the fact that the mean and standard deviation for pairwise latencies increase slightly. This is due to the distance between two machines.
- For Scenario 3, we are establishing connection between two different machines on CU campus. The mean and standard devaiation of pairwise latencies are higher than Scenario 2
- For Scenario 4, we are establishing connection between machine in the CU campus a with another machine that is geographically located outside the CU campus. This can be done using VPN. The mean and standard deviation is large due to the distance

Scenario 1: A and B are the same machine

(A) A is server and B is client

```
C:\Python27>python client13.py
Client:
Connection established between client and server Client request time 2017-02-14 21:17:45.941000 Client reply time 2017-02-14 21:17:45.941000
Server:
Server request time,2017-02-14 21:17:45.941000,Server reply time,2017-02-14 21:17:45.941000
Round Trip Time:0:00:00
Client:
Connection established between client and server Client request time 2017-02-14 21:17:45.972000 Client reply time 2017-02-14 21:17:45.972000
Server:
Server request time,2017-02-14 21:17:45.972000,Server reply time,2017-02-14 21:17:45.972000
Round Trip Time:0:00:00
Client:
Connection established between client and server Client request time 2017-02-14 21:17:45.973000 Client reply time 2017-02-14 21:17:45.973000
Server:
Server request time,2017-02-14 21:17:45.973000,Server reply time,2017-02-14 21:17:45.973000
Round Trip Time:0:00:00
Client:
Connection established between client and server Client request time 2017-02-14 21:17:45.973000 Client reply time 2017-02-14 21:17:45.973000
Server:
Server request time,2017-02-14 21:17:45.973000,Server reply time,2017-02-14 21:17:45.973000
Round Trip Time:0:00:00
Client:
Connection established between client and server Client request time 2017-02-14 21:17:45.975000 Client reply time 2017-02-14 21:17:45.975000
Server:
Server request time,2017-02-14 21:17:45.975000,Server reply time,2017-02-14 21:17:45.975000
Round Trip Time:0:00:00
Mean of pairwise latencies: 0.0
Standard deviation of pairwise latencies: 0.0

C:\Python27>
```

(B) B is server and A is client

```
Client:
Connection established between client and server Client request time 2017-02-14 21:15:53.499000 Client reply time 2017-02-14 21:15:53.500000
Server:
Server request time,2017-02-14 21:15:53.500000,Server reply time,2017-02-14 21:15:53.500000
Round Trip Time:0:00:00.001000
Client:
Connection established between client and server Client request time 2017-02-14 21:15:53.537000 Client reply time 2017-02-14 21:15:53.538000
Server:
Server request time,2017-02-14 21:15:53.538000,Server reply time,2017-02-14 21:15:53.538000
Round Trip Time:0:00:00.001000
Client:
Connection established between client and server Client request time 2017-02-14 21:15:53.565000 Client reply time 2017-02-14 21:15:53.566000
Server:
Server request time,2017-02-14 21:15:53.566000,Server reply time,2017-02-14 21:15:53.566000
Round Trip Time:0:00:00.001000
Client:
Connection established between client and server Client request time 2017-02-14 21:15:53.601000 Client reply time 2017-02-14 21:15:53.602000
Server:
Server request time,2017-02-14 21:15:53.602000,Server reply time,2017-02-14 21:15:53.602000
Round Trip Time:0:00:00.001000
Client:
Connection established between client and server Client request time 2017-02-14 21:15:53.647000 Client reply time 2017-02-14 21:15:53.647000
Server:
Server request time,2017-02-14 21:15:53.647000,Server reply time,2017-02-14 21:15:53.647000
Round Trip Time:0:00:00
Mean of pairwise latencies: 0.0004
Standard deviation of pairwise latencies: 0.00154919333848
```

Scenario 2: A and B are different machines within the CS Department, eg. Two different CSEL servers

(A) A is server and B is client

```
hama5569@elra-03:~$ python client13.py
Client:
Connection established between client and server Client request time 2017-02-14
21:19:22.596501 Client reply time 2017-02-14 21:19:22.597842
Server:
Server Request Time:,2017-02-14 21:19:22.596439,Server Reply time:,2017-02-14 21
:19:22.596523
Round Trip Time:0:00:00.001341
Client:
Connection established between client and server Client request time 2017-02-14
21:19:22.601973 Client reply time 2017-02-14 21:19:22.602926
Server:
Server Request Time:,2017-02-14 21:19:22.601688,Server Reply time:,2017-02-14 21
:19:22.601729
Round Trip Time:0:00:00.000953
Client:
Connection established between client and server Client request time 2017-02-14
21:19:22.603071 Client reply time 2017-02-14 21:19:22.603955
Server:
Server Request Time:,2017-02-14 21:19:22.602722,Server Reply time:,2017-02-14 21
:19:22.602747
Round Trip Time:0:00:00.000884
Client:
Connection established between client and server Client request time 2017-02-14
21:19:22.604100 Client reply time 2017-02-14 21:19:22.604944
Server:
Server Request Time:,2017-02-14 21:19:22.603708,Server Reply time:,2017-02-14 21
:19:22.603733
Round Trip Time:0:00:00.000844
Client:
Connection established between client and server Client request time 2017-02-14
21:19:22.605088 Client reply time 2017-02-14 21:19:22.605888
Server:
Server Request Time:,2017-02-14 21:19:22.604677,Server Reply time:,2017-02-14 21
:19:22.604702
Round Trip Time:0:00:00.000800
Mean of pairwise latencies: 0.0004622
Standard deviation of pairwise latencies: 0.00172721591007
```

(B) B is server and A is client

```
hama5569@elra-02:~$ python client13.py
Client:
Connection established between client and server Client request time 2017-02-14
21:24:31.545795 Client reply time 2017-02-14 21:24:31.547050
Server:
Server Request Time:,2017-02-14 21:24:31.547231,Server Reply time:,2017-02-14 21
:24:31.547311
Round Trip Time:0:00:00.001255
Client:
Connection established between client and server Client request time 2017-02-14
21:24:31.567841 Client reply time 2017-02-14 21:24:31.568799
Server:
Server Request Time:,2017-02-14 21:24:31.568966,Server Reply time:,2017-02-14 21
:24:31.568993
Round Trip Time:0:00:00.000958
Client:
Connection established between client and server Client request time 2017-02-14
21:24:31.569047 Client reply time 2017-02-14 21:24:31.569924
Server:
Server Request Time:,2017-02-14 21:24:31.570194,Server Reply time:,2017-02-14 21
:24:31.570233
Round Trip Time:0:00:00.000877
Client:
Connection established between client and server Client request time 2017-02-14
21:24:31.570176 Client reply time 2017-02-14 21:24:31.570979
Server:
Server Request Time:,2017-02-14 21:24:31.571275,Server Reply time:,2017-02-14 21
:24:31.571299
Round Trip Time:0:00:00.000803
Client:
Connection established between client and server Client request time 2017-02-14
21:24:31.571225 Client reply time 2017-02-14 21:24:31.572040
Server:
Server Request Time:,2017-02-14 21:24:31.572355,Server Reply time:,2017-02-14 21
:24:31.572379
Round Trip Time:0:00:00.000815
Mean of pairwise latencies: 0.0004514
Standard deviation of pairwise latencies: 0.00166940624175
```

Scenario 3: A and B are different machines across the CU-Boulder campus

(A) A is server and B is client

```
C:\Python27>python client13.py
Client:
Connection established between client and server Client request time 2017-02-14 21:28:47.512000 Client reply time 2017-02-14 21:28:47.551000
Server:
Server request time:,2017-02-14 21:28:47.045734,Server Reply time:,2017-02-14 21:28:47.046519
Round Trip Time:0:00:00.039000
Client:
Connection established between client and server Client request time 2017-02-14 21:28:47.581000 Client reply time 2017-02-14 21:28:47.586000
Server:
Server request time:,2017-02-14 21:28:47.083719,Server Reply time:,2017-02-14 21:28:47.083746
Round Trip Time:0:00:00.005000
Client:
Connection established between client and server Client request time 2017-02-14 21:28:47.587000 Client reply time 2017-02-14 21:28:47.592000
Server:
Server request time:,2017-02-14 21:28:47.089177,Server Reply time:,2017-02-14 21:28:47.089195
Round Trip Time:0:00:00.005000
Client:
Connection established between client and server Client request time 2017-02-14 21:28:47.592000 Client reply time 2017-02-14 21:28:47.600000
Server:
Server request time:,2017-02-14 21:28:47.094994,Server Reply time:,2017-02-14 21:28:47.095012
Round Trip Time:0:00:00.008000
Client:
Connection established between client and server Client request time 2017-02-14 21:28:47.602000 Client reply time 2017-02-14 21:28:47.607000
Server:
Server request time:,2017-02-14 21:28:47.104620,Server Reply time:,2017-02-14 21:28:47.104635
Round Trip Time:0:00:00.005000
Mean of pairwise latencies: 0.0061137
Standard deviation of pairwise latencies: 1.57273795385
```

(B) B is server and A is client

```
engr2-16-200-dhcp:ProgrammingAssignment1 rajarshibasak$ python client13.py
Client:
Connection established between client and server Client request time 2017-02-14 22:17:59.234996 Client reply time 2017-02-14 22:17:59.279261
Server:
Server Request Time:,2017-02-14 22:17:59.762000,Server Reply time:,2017-02-14 22:17:59.762000
Round Trip Time:0:00:00.044265
Client:
Connection established between client and server Client request time 2017-02-14 22:17:59.499634 Client reply time 2017-02-14 22:17:59.507610
Server:
Server Request Time:,2017-02-14 22:17:59.994000,Server Reply time:,2017-02-14 22:17:59.994000
Round Trip Time:0:00:00.007976
Client:
Connection established between client and server Client request time 2017-02-14 22:17:59.507963 Client reply time 2017-02-14 22:17:59.513297
Server:
Server Request Time:,2017-02-14 22:17:59.994000,Server Reply time:,2017-02-14 22:17:59.994000
Round Trip Time:0:00:00.005334
Client:
Connection established between client and server Client request time 2017-02-14 22:17:59.513778 Client reply time 2017-02-14 22:17:59.520325
Server:
Server Request Time:,2017-02-14 22:18:00.010000,Server Reply time:,2017-02-14 22:18:00.010000
Round Trip Time:0:00:00.006547
Client:
Connection established between client and server Client request time 2017-02-14 22:17:59.520724 Client reply time 2017-02-14 22:17:59.526240
Server:
Server Request Time:,2017-02-14 22:18:00.010000,Server Reply time:,2017-02-14 22:18:00.010000
Round Trip Time:0:00:00.005516
Mean of pairwise latencies: 0.0069638
Standard deviation of pairwise latencies: 1.55499136568
```

Scenario 4: A and B are different machines, one in CU campus and the other at a different geographic location outside the CU campus

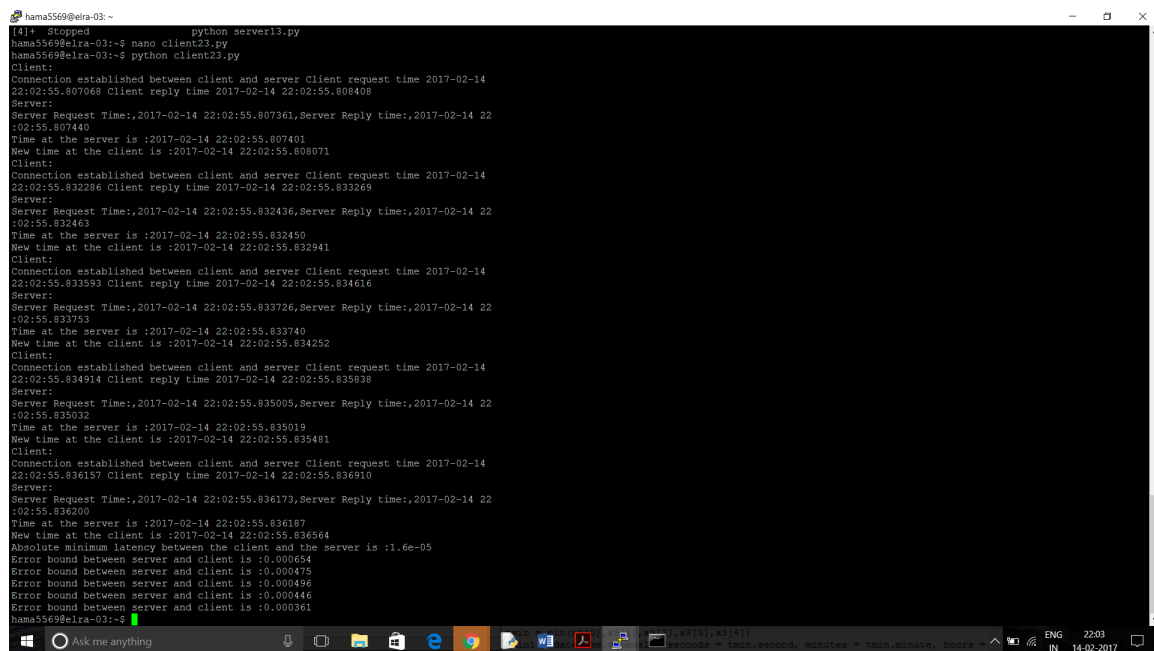### (A) A is server and B is client

```
C:\Python27>python client13.py
Client:
Connection established between client and server Client request time 2017-02-14 22:32:38.479000 Client reply time 2017-02-14 22:32:38.694000
Server:
Server request time:,2017-02-14 22:32:38.170649,Server Reply time:,2017-02-14 22:32:38.170665
Round Trip Time:0:00:00.215000
Client:
Connection established between client and server Client request time 2017-02-14 22:32:38.710000 Client reply time 2017-02-14 22:32:38.806000
Server:
Server request time:,2017-02-14 22:32:38.282612,Server Reply time:,2017-02-14 22:32:38.282637
Round Trip Time:0:00:00.096000
Client:
Connection established between client and server Client request time 2017-02-14 22:32:38.810000 Client reply time 2017-02-14 22:32:38.884000
Server:
Server request time:,2017-02-14 22:32:38.362792,Server Reply time:,2017-02-14 22:32:38.362810
Round Trip Time:0:00:00.074000
Client:
Connection established between client and server Client request time 2017-02-14 22:32:38.898000 Client reply time 2017-02-14 22:32:38.979000
Server:
Server request time:,2017-02-14 22:32:38.463163,Server Reply time:,2017-02-14 22:32:38.463191
Round Trip Time:0:00:00.081000
Client:
Connection established between client and server Client request time 2017-02-14 22:32:39.004000 Client reply time 2017-02-14 22:32:39.079000
Server:
Server request time:,2017-02-14 22:32:38.563074,Server Reply time:,2017-02-14 22:32:38.563098
Round Trip Time:0:00:00.075000
Mean of pairwise latencies: 0.0540889
Standard deviation of pairwise latencies: 1.47770763895
```

(B) B is server and A is client

```
engr2-16-200-dhcp:ProgrammingAssignment1 rajarshibasak$ python client13.py
Client:
Connection established between client and server Client request time 2017-02-14 22:27:35.586741 Client reply time 2017-02-14 22:27:35.664203
Server:
Server Request Time:,2017-02-14 22:27:36.112000,Server Reply time:,2017-02-14 22:27:36.112000
Round Trip Time:0:00:00.077462
Client:
Connection established between client and server Client request time 2017-02-14 22:27:35.717738 Client reply time 2017-02-14 22:27:35.847891
Server:
Server Request Time:,2017-02-14 22:27:36.228000,Server Reply time:,2017-02-14 22:27:36.228000
Round Trip Time:0:00:00.130153
Client:
Connection established between client and server Client request time 2017-02-14 22:27:35.848345 Client reply time 2017-02-14 22:27:35.923369
Server:
Server Request Time:,2017-02-14 22:27:36.359000,Server Reply time:,2017-02-14 22:27:36.359000
Round Trip Time:0:00:00.075024
Client:
Connection established between client and server Client request time 2017-02-14 22:27:35.923875 Client reply time 2017-02-14 22:27:36.003108
Server:
Server Request Time:,2017-02-14 22:27:36.440000,Server Reply time:,2017-02-14 22:27:36.440000
Round Trip Time:0:00:00.079233
Client:
Connection established between client and server Client request time 2017-02-14 22:27:36.003520 Client reply time 2017-02-14 22:27:36.083288
Server:
Server Request Time:,2017-02-14 22:27:36.517000,Server Reply time:,2017-02-14 22:27:36.517000
Round Trip Time:0:00:00.079768
Mean of pairwise latencies: 0.044164
Standard deviation of pairwise latencies: 1.49041439998
```

Question 2:

- We are determining the four timestamps across the client and server and we are finding the client's new time and the server's new time and the absolute minimum latency and the error bound between the client and the server.
- Time at the server, client and absolute minimum latency and error bound are found by using Cristian's algorithm.
  Tserver = (server reply time – server request time)/2 +(server request time)
  Tclient = Tserver + (T1 – T0)/2
- Minimum latency was found by comparing the minimum of all send latencies.
- Send latency = Server Request Time – Client Request Time
- Error bound is calculated by using the formula
- Error bound = (T1 –T0)/2 – Tmin,
  Where T1 = Client Reply Time
  T0 = Client Request Time
  Tmin = Minimum latency
- Based on our observations, we found that the error bound increases as the distance between two machines increases.

Scenario 1: A and B are the same machine
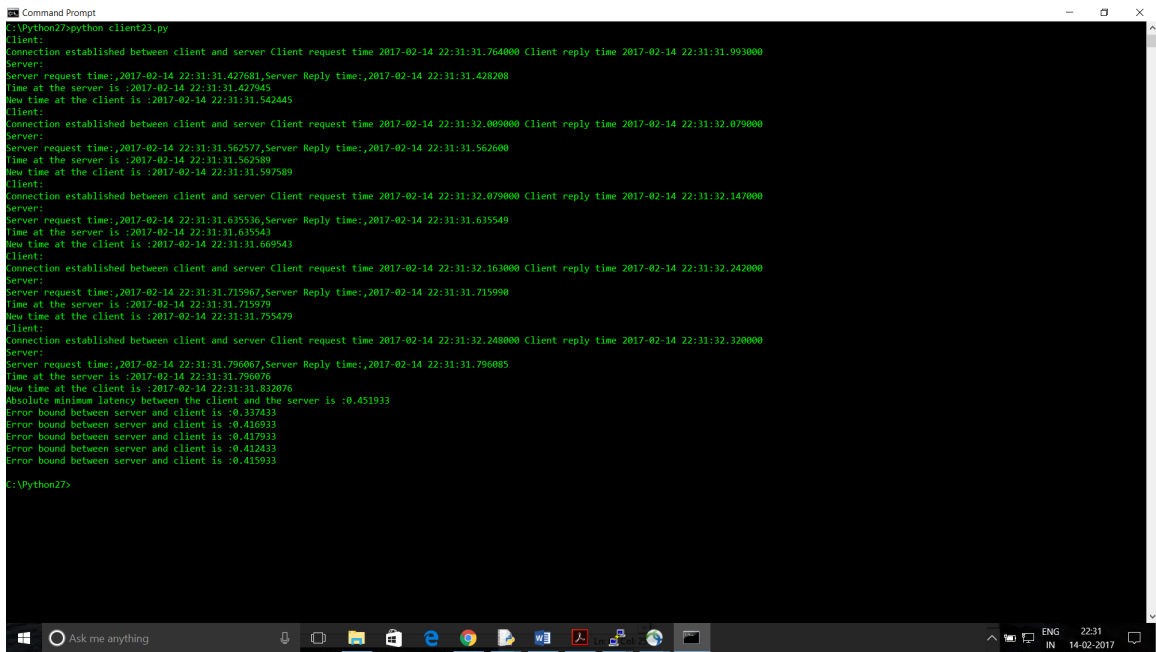
(A) A is server and B is client

```
C:\Python27>python client2.py
Client:
Connection established between client and server Client request time 2017-02-14 22:05:56.326000 Client reply time 2017-02-14 22:05:56.328000
Server:
Server request time,2017-02-14 22:05:56.327000,Server reply time,2017-02-14 22:05:56.327000
Time at the server is :2017-02-14 22:05:56.327000
New time at the client is :2017-02-14 22:05:56.328000
Client:
Connection established between client and server Client request time 2017-02-14 22:05:56.371000 Client reply time 2017-02-14 22:05:56.372000
Server:
Server request time,2017-02-14 22:05:56.371000,Server reply time,2017-02-14 22:05:56.371000
Time at the server is :2017-02-14 22:05:56.371000
New time at the client is :2017-02-14 22:05:56.371500
Client:
Connection established between client and server Client request time 2017-02-14 22:05:56.386000 Client reply time 2017-02-14 22:05:56.386000
Server:
Server request time,2017-02-14 22:05:56.386000,Server reply time,2017-02-14 22:05:56.386000
Time at the server is :2017-02-14 22:05:56.386000
New time at the client is :2017-02-14 22:05:56.386000
Client:
Connection established between client and server Client request time 2017-02-14 22:05:56.398000 Client reply time 2017-02-14 22:05:56.399000
Server:
Server request time,2017-02-14 22:05:56.398000,Server reply time,2017-02-14 22:05:56.398000
Time at the server is :2017-02-14 22:05:56.398000
New time at the client is :2017-02-14 22:05:56.398500
Client:
Connection established between client and server Client request time 2017-02-14 22:05:56.414000 Client reply time 2017-02-14 22:05:56.415000
Server:
Server request time,2017-02-14 22:05:56.414000,Server reply time,2017-02-14 22:05:56.414000
Time at the server is :2017-02-14 22:05:56.414000
New time at the client is :2017-02-14 22:05:56.414500
Absolute minimum latency between the client and the server is :0.0
Error bound between server and client is :0.001
Error bound between server and client is :0.0005
Error bound between server and client is :0.0
Error bound between server and client is :0.0005
Error bound between server and client is :0.0005
```

B is server and A is client

```
Client:
Connection established between client and server Client request time 2017-02-14 22:08:25.866000 Client reply time 2017-02-14 22:08:25.866000
Server:
Server request time,2017-02-14 22:08:25.866000,Server reply time,2017-02-14 22:08:25.866000
Time at the server is :2017-02-14 22:08:25.866000
New time at the client is :2017-02-14 22:08:25.866000
Client:
Connection established between client and server Client request time 2017-02-14 22:08:25.905000 Client reply time 2017-02-14 22:08:25.906000
Server:
Server request time,2017-02-14 22:08:25.905000,Server reply time,2017-02-14 22:08:25.905000
Time at the server is :2017-02-14 22:08:25.905000
New time at the client is :2017-02-14 22:08:25.905500
Client:
Connection established between client and server Client request time 2017-02-14 22:08:25.935000 Client reply time 2017-02-14 22:08:25.936000
Server:
Server request time,2017-02-14 22:08:25.936000,Server reply time,2017-02-14 22:08:25.936000
Time at the server is :2017-02-14 22:08:25.936000
New time at the client is :2017-02-14 22:08:25.936500
Client:
Connection established between client and server Client request time 2017-02-14 22:08:25.965000 Client reply time 2017-02-14 22:08:25.965000
Server:
Server request time,2017-02-14 22:08:25.965000,Server reply time,2017-02-14 22:08:25.965000
Time at the server is :2017-02-14 22:08:25.965000
New time at the client is :2017-02-14 22:08:25.965000
Client:
Connection established between client and server Client request time 2017-02-14 22:08:25.992000 Client reply time 2017-02-14 22:08:25.992000
Server:
Server request time,2017-02-14 22:08:25.992000,Server reply time,2017-02-14 22:08:25.992000
Time at the server is :2017-02-14 22:08:25.992000
New time at the client is :2017-02-14 22:08:25.992000
Absolute minimum latency between the client and the server is :0.0
Error bound between server and client is :0.0
Error bound between server and client is :0.0005
Error bound between server and client is :0.0005
Error bound between server and client is :0.0
Error bound between server and client is :0.0
```

Scenario 2: A and B are different machines within the CS Department, eg. Two different CSEL servers

(A) A is server and B is client

B is server and A is client

Scenario 3: A and B are different machines across the CU-Boulder campus

A is server and B is client

B is server and A is client

```
engr2-16-200-dhcp:ProgrammingAssignment1 rajarshibasak$ python client23.py
Client:
Connection established between client and server Client request time 2017-02-14 22:20:31.372156 Client reply time 2017-02-14 22:20:31.381493
Server:
Server Request Time:,2017-02-14 22:20:31.874000,Server Reply time:,2017-02-14 22:20:31.874000
Time at the server is :2017-02-14 22:20:31.874000
New time at the client is :2017-02-14 22:20:31.878669
Client:
Connection established between client and server Client request time 2017-02-14 22:20:31.480519 Client reply time 2017-02-14 22:20:31.485144
Server:
Server Request Time:,2017-02-14 22:20:31.978000,Server Reply time:,2017-02-14 22:20:31.978000
Time at the server is :2017-02-14 22:20:31.978000
New time at the client is :2017-02-14 22:20:31.980313
Client:
Connection established between client and server Client request time 2017-02-14 22:20:31.485529 Client reply time 2017-02-14 22:20:31.490320
Server:
Server Request Time:,2017-02-14 22:20:31.981000,Server Reply time:,2017-02-14 22:20:31.981000
Time at the server is :2017-02-14 22:20:31.981000
New time at the client is :2017-02-14 22:20:31.983396
Client:
Connection established between client and server Client request time 2017-02-14 22:20:31.490836 Client reply time 2017-02-14 22:20:31.494603
Server:
Server Request Time:,2017-02-14 22:20:31.981000,Server Reply time:,2017-02-14 22:20:31.981000
Time at the server is :2017-02-14 22:20:31.981000
New time at the client is :2017-02-14 22:20:31.982884
Client:
Connection established between client and server Client request time 2017-02-14 22:20:31.495060 Client reply time 2017-02-14 22:20:31.500185
Server:
Server Request Time:,2017-02-14 22:20:31.981000,Server Reply time:,2017-02-14 22:20:31.981000
Time at the server is :2017-02-14 22:20:31.981000
New time at the client is :2017-02-14 22:20:31.983563
Absolute minimum latency between the client and the server is :0.48594
Error bound between server and client is :0.481271
Error bound between server and client is :0.483627
Error bound between server and client is :0.483544
Error bound between server and client is :0.484056
Error bound between server and client is :0.483377
```

Scenario 4: A and B are different machines, one in CU campus and the other at a different geographic location outside the CU campus

A is server and B is client

B is server and A is client

```
engr2-16-200-dhcp:ProgrammingAssignment1 rajarshibasak$ python client23.py
Client:
Connection established between client and server Client request time 2017-02-14 22:29:05.660983 Client reply time 2017-02-14 22:29:05.743837
Server:
Server Request Time:,2017-02-14 22:29:06.189000,Server Reply time:,2017-02-14 22:29:06.189000
Time at the server is :2017-02-14 22:29:06.189000
New time at the client is :2017-02-14 22:29:06.230427
Client:
Connection established between client and server Client request time 2017-02-14 22:29:05.764284 Client reply time 2017-02-14 22:29:05.843280
Server:
Server Request Time:,2017-02-14 22:29:06.288000,Server Reply time:,2017-02-14 22:29:06.288000
Time at the server is :2017-02-14 22:29:06.288000
New time at the client is :2017-02-14 22:29:06.327498
Client:
Connection established between client and server Client request time 2017-02-14 22:29:05.843662 Client reply time 2017-02-14 22:29:05.923138
Server:
Server Request Time:,2017-02-14 22:29:06.368000,Server Reply time:,2017-02-14 22:29:06.368000
Time at the server is :2017-02-14 22:29:06.368000
New time at the client is :2017-02-14 22:29:06.407738
Client:
Connection established between client and server Client request time 2017-02-14 22:29:05.923724 Client reply time 2017-02-14 22:29:06.003246
Server:
Server Request Time:,2017-02-14 22:29:06.441000,Server Reply time:,2017-02-14 22:29:06.441000
Time at the server is :2017-02-14 22:29:06.441000
New time at the client is :2017-02-14 22:29:06.480761
Client:
Connection established between client and server Client request time 2017-02-14 22:29:06.003632 Client reply time 2017-02-14 22:29:06.083180
Server:
Server Request Time:,2017-02-14 22:29:06.521000,Server Reply time:,2017-02-14 22:29:06.521000
Time at the server is :2017-02-14 22:29:06.521000
New time at the client is :2017-02-14 22:29:06.560774
Absolute minimum latency between the client and the server is :0.517276
Error bound between server and client is :0.475849
Error bound between server and client is :0.477778
Error bound between server and client is :0.477538
Error bound between server and client is :0.477515
Error bound between server and client is :0.477502
```

Question 3:

- The offset and delay pairs are calculated for each iteration using the NTP formula.
- Delay is calculated by measuring the send and receive latencies for five iterations. Delay is the total of send and receive latencies.
- Offset is the drift in time between the server and client .
- Based on our observations, we found that the system with much lesser delay and offset has better accuracy than the system with higher delay and offset.
- This gives the relationship between delay and distance. As distance is large, delay is large, therefore the accuracy is less.

Scenario 1: A and B are the same machine

(A) A is server and B is client

```
C:\Python27>python client.py
Client:
Connection established between client and server Client request time 2017-02-13 17:41:45.611000 Client reply time 2017-02-13 17:41:45.612000
Server:
Server request time,2017-02-13 17:41:45.611000,Server reply time,2017-02-13 17:41:45.611000
Delay:0.001
Offset:0.0005
Client:
Connection established between client and server Client request time 2017-02-13 17:41:45.615000 Client reply time 2017-02-13 17:41:45.615000
Server:
Server request time,2017-02-13 17:41:45.615000,Server reply time,2017-02-13 17:41:45.615000
Delay:0.0
Offset:0.0
Client:
Connection established between client and server Client request time 2017-02-13 17:41:45.615000 Client reply time 2017-02-13 17:41:45.615000
Server:
Server request time,2017-02-13 17:41:45.615000,Server reply time,2017-02-13 17:41:45.615000
Delay:0.0
Offset:0.0
Client:
Connection established between client and server Client request time 2017-02-13 17:41:45.631000 Client reply time 2017-02-13 17:41:45.631000
Server:
Server request time,2017-02-13 17:41:45.631000,Server reply time,2017-02-13 17:41:45.631000
Delay:0.0
Offset:0.0
Client:
Connection established between client and server Client request time 2017-02-13 17:41:45.646000 Client reply time 2017-02-13 17:41:45.646000
Server:
Server request time,2017-02-13 17:41:45.646000,Server reply time,2017-02-13 17:41:45.646000
Delay:0.0
Offset:0.0
```

<u>B is server and A is client</u>

```
Client:
Connection established between client and server Client request time 2017-02-14 13:41:07.758000 Client reply time 2017-02-14 13:41:07.759000
Server:
Server request time,2017-02-14 13:41:07.759000,Server reply time,2017-02-14 13:41:07.759000
Delay:0.001
Offset:0.0005
Client:
Connection established between client and server Client request time 2017-02-14 13:41:07.930000 Client reply time 2017-02-14 13:41:07.931000
Server:
Server request time,2017-02-14 13:41:07.930000,Server reply time,2017-02-14 13:41:07.930000
Delay:0.001
Offset:0.0005
Client:
Connection established between client and server Client request time 2017-02-14 13:41:07.979000 Client reply time 2017-02-14 13:41:07.979000
Server:
Server request time,2017-02-14 13:41:07.979000,Server reply time,2017-02-14 13:41:07.979000
Delay:0.0
Offset:0.0
Client:
Connection established between client and server Client request time 2017-02-14 13:41:08.030000 Client reply time 2017-02-14 13:41:08.030000
Server:
Server request time,2017-02-14 13:41:08.030000,Server reply time,2017-02-14 13:41:08.030000
Delay:0.0
Offset:0.0
Client:
Connection established between client and server Client request time 2017-02-14 13:41:08.058000 Client reply time 2017-02-14 13:41:08.058000
Server:
Server request time,2017-02-14 13:41:08.058000,Server reply time,2017-02-14 13:41:08.058000
Delay:0.0
Offset:0.0
```

Scenario 2: A and B are different machines within the CS Department, eg. Two different CSEL servers

<u>(A) A is server and B is client</u>

B is server and A is client

Scenario 3: A and B are different machines across the CU-Boulder campus

A is server and B is client

```
C:\Python27>python client3.py
Client:
Connection established between client and server:
Client request time 2017-02-14 22:14:47.746000
Client reply time 2017-02-14 22:14:47.904000
Server:
Server request time:,2017-02-14 22:14:47.357216,Server Reply time:,2017-02-14 22:14:47.418348
Delay:0.096868
Offset:0.437218
Client:
Connection established between client and server:
Client request time 2017-02-14 22:14:47.957000
Client reply time 2017-02-14 22:14:47.973000
Server:
Server request time:,2017-02-14 22:14:47.475211,Server Reply time:,2017-02-14 22:14:47.475227
Delay:0.015984
Offset:0.489781
Client:
Connection established between client and server:
Client request time 2017-02-14 22:14:47.973000
Client reply time 2017-02-14 22:14:47.973000
Server:
Server request time:,2017-02-14 22:14:47.482082,Server Reply time:,2017-02-14 22:14:47.482095
Delay:-1.3e-05
Offset:0.490911
Client:
Connection established between client and server:
Client request time 2017-02-14 22:14:47.973000
Client reply time 2017-02-14 22:14:47.989000
Server:
Server request time:,2017-02-14 22:14:47.491257,Server Reply time:,2017-02-14 22:14:47.491270
Delay:0.015987
Offset:0.489736
Client:
Connection established between client and server:
Client request time 2017-02-14 22:14:47.989000
Client reply time 2017-02-14 22:14:48.004000
Server:
Server request time:,2017-02-14 22:14:47.508206,Server Reply time:,2017-02-14 22:14:47.508229
Delay:0.014977
Offset:0.488282

C:\Python27>
```

B is server and A is client

```
engr2-16-200-dhcp:Downloads rajarshibasak$ python client.py
Client:
Connection established between client and server:
Client request time 2017-02-14 22:23:21.236567
Client reply time 2017-02-14 22:23:21.292064
Server:
Server Request Time:,2017-02-14 22:23:21.773000,Server Reply time:,2017-02-14 22:23:21.773000
Delay:0.055497
Offset:0.508685
Client:
Connection established between client and server:
Client request time 2017-02-14 22:23:21.426663
Client reply time 2017-02-14 22:23:21.430927
Server:
Server Request Time:,2017-02-14 22:23:21.913000,Server Reply time:,2017-02-14 22:23:21.913000
Delay:0.004264
Offset:0.484205
Client:
Connection established between client and server:
Client request time 2017-02-14 22:23:21.431278
Client reply time 2017-02-14 22:23:21.435519
Server:
Server Request Time:,2017-02-14 22:23:21.913000,Server Reply time:,2017-02-14 22:23:21.913000
Delay:0.004241
Offset:0.479602
Client:
Connection established between client and server:
Client request time 2017-02-14 22:23:21.435856
Client reply time 2017-02-14 22:23:21.440786
Server:
Server Request Time:,2017-02-14 22:23:21.928000,Server Reply time:,2017-02-14 22:23:21.928000
Delay:0.00493
Offset:0.489679
Client:
Connection established between client and server:
Client request time 2017-02-14 22:23:21.441295
Client reply time 2017-02-14 22:23:21.445897
Server:
Server Request Time:,2017-02-14 22:23:21.935000,Server Reply time:,2017-02-14 22:23:21.935000
Delay:0.004602
Offset:0.491404
```

Scenario 4: A and B are different machines, one in CU campus and the other at a different geographic location outside the CU campus

A is server and B is client

B is server and A is client

```
engr2-2-80-92-dhcp:Downloads rajarshibasak$ python client.py
Client:
Connection established between client and server:
Client request time 2017-02-14 15:50:07.113758
Client reply time 2017-02-14 15:50:07.875838
Server:
Server Request Time:,2017-02-14 15:50:08.236000,Server Reply time:,2017-02-14 15:50:08.236000
Delay:0.76208
Offset:0.741202
Client:
Connection established between client and server:
Client request time 2017-02-14 15:50:07.968546
Client reply time 2017-02-14 15:50:08.397380
Server:
Server Request Time:,2017-02-14 15:50:08.636000,Server Reply time:,2017-02-14 15:50:08.636000
Delay:0.428834
Offset:0.453037
Client:
Connection established between client and server:
Client request time 2017-02-14 15:50:08.397745
Client reply time 2017-02-14 15:50:08.711461
Server:
Server Request Time:,2017-02-14 15:50:09.052000,Server Reply time:,2017-02-14 15:50:09.052000
Delay:0.313716
Offset:0.497397
Client:
Connection established between client and server:
Client request time 2017-02-14 15:50:08.711840
Client reply time 2017-02-14 15:50:09.130071
Server:
Server Request Time:,2017-02-14 15:50:09.408000,Server Reply time:,2017-02-14 15:50:09.408000
Delay:0.418231
Offset:0.487045
Client:
Connection established between client and server:
Client request time 2017-02-14 15:50:09.130520
Client reply time 2017-02-14 15:50:09.442042
Server:
Server Request Time:,2017-02-14 15:50:09.830000,Server Reply time:,2017-02-14 15:50:09.830000
Delay:0.311522
Offset:0.543719
```

Note:

Scenario 4 was executed using VPN architecture where one system used the mobile hotspot to connect to the VPN, and for the other system we connected to the wireless network in the University (UCB Wireless).

The architecture of VPN is given below: