**The question:** The data transfer latency measured can be decomposed into two components: (1) data size and bandwidth dependent transmission delay (which is approximated by data size divided by network link bandwidth), and (2) data size and bandwidth independent delay caused by the time it takes for data to physically propagate over the length of network links, the time overhead of making software function calls, etc.; this bandwidth independent delay exists no matter how high the underlying network link bandwidth is.

For this part of the assignment, design and write up a method for measuring this bandwidth independent delay across two CLEAR servers as accurately as possible using only the ping-pong client/server software you have developed; no change to the software is allowed. Because you are limited by the ping-pong client/server's design, you will not be able to obtain a perfect answer; instead, the goal is to estimate the bandwidth independent delay as closely as possible. You should then perform the corresponding measurements according to your method using your ping-pong client/server, and report your estimate of this bandwidth independent delay. Finally, use this estimated bandwidth independent delay to adjust your estimate of the true bandwidth of the network link. You must clearly show your measurement results and calculations in your write-up

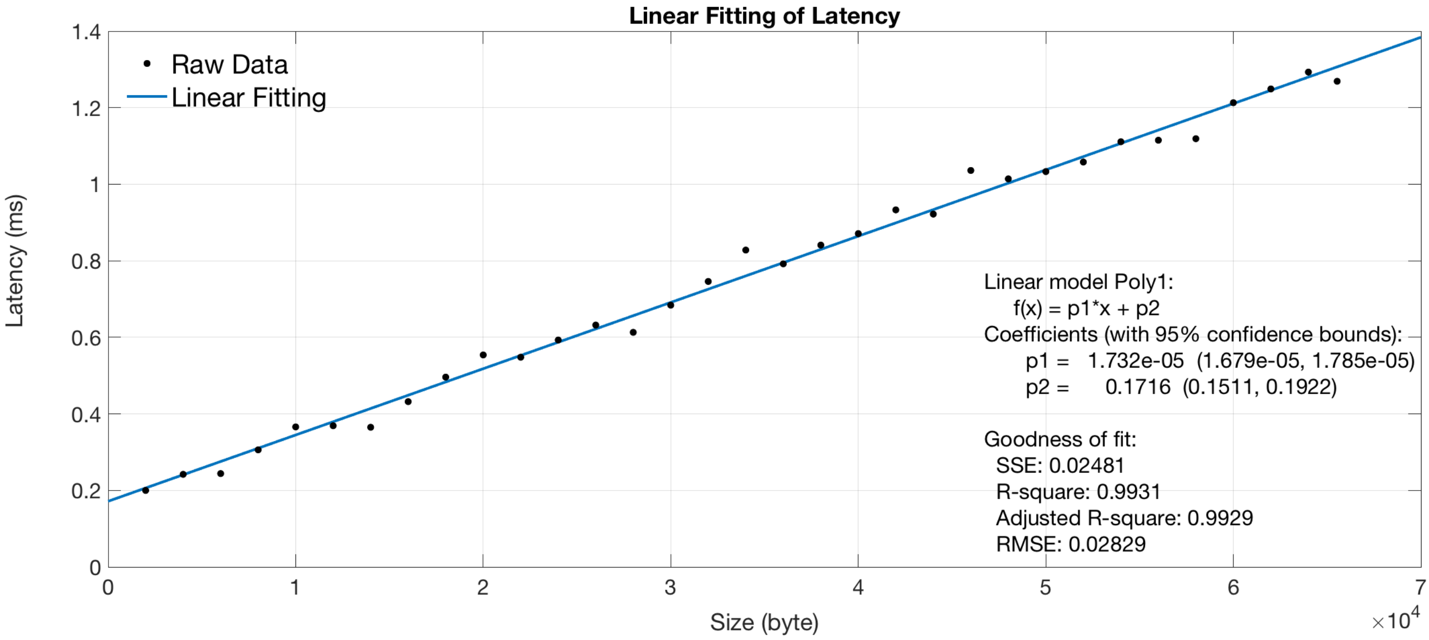
**Method Design:** Since the bandwidth dependent transmission are approximately equals to data size divided by network bandwidth, so we can model this total latency as: Latency = Data Size / Network Link Bandwidth + Independent Delay. We assume network link bandwidth and independent delay are constant and our goal is to calculate them. So the question became a linear equation: Latency = Data Size * (constant) + (constant). With Ping-Pong client/server software we developed, we can customise the data size then receive the latency, so we did experiments with following 33 data points, each data size we transmitted 10000 times then calculate the arithmetic mean.

Our experiments results (on water and glass):

| Data Size (bytes) | Latency (millisecond) | Data Size (bytes) | Latency (millisecond) |
|---|---|---|---|
| 2000 | 0.200 | 36000 | 0.792 |
| 4000 | 0.242 | 38000 | 0.841 |
| 6000 | 0.244 | 40000 | 0.871 |
| 8000 | 0.306 | 42000 | 0.933 |
| 10000 | 0.366 | 44000 | 0.922 |
| 12000 | 0.369 | 46000 | 1.036 |
| 14000 | 0.365 | 48000 | 1.014 |
| 16000 | 0.432 | 50000 | 1.033 |

| | | | |
|---|---|---|---|
| 18000 | 0.496 | 52000 | 1.058 |
| 20000 | 0.554 | 54000 | 1.111 |
| 22000 | 0.548 | 56000 | 1.115 |
| 24000 | 0.593 | 58000 | 1.119 |
| 26000 | 0.632 | 60000 | 1.213 |
| 28000 | 0.613 | 62000 | 1.249 |
| 30000 | 0.684 | 64000 | 1.293 |
| 32000 | 0.746 | 65535 | 1.269 |
| 34000 | 0.828 | | |

Linear Regression result:




So we can see the slope p1 equals to 1.732e-05, intercept p2 equals to 0.1716.

Bandwidth independent delay = intercept = 0.1716 millisecond.

Network bandwidth = 2 * 8 * $slope^{-1}$ = 924 Mbps.

In additional, we can still do some correction to the results when we take header into consideration. Because each packet can only have 1500 bytes, and the first 40 are header. So approximately the bandwidth we calculated is 1460/1500 of the real bandwidth. So we can update the bandwidth:

Corrected network bandwidth: 924 Mbps * 1500/1460 = 949 Mbps