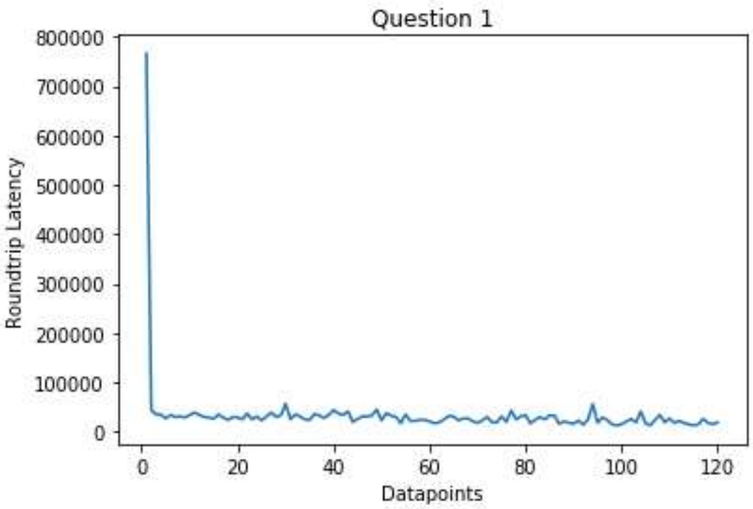
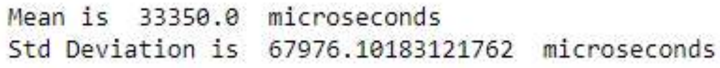
Programming Assignment 1 - Writeup :

1) Compute roundtrip latencies along with average and standard deviation for each scenario, and plot them in a graph. Provide an analysis of your results in terms of why there is a variation in latencies, which ones you expect to be more accurate, etc.

GRPC – Plotted graphs for round trip latencies:

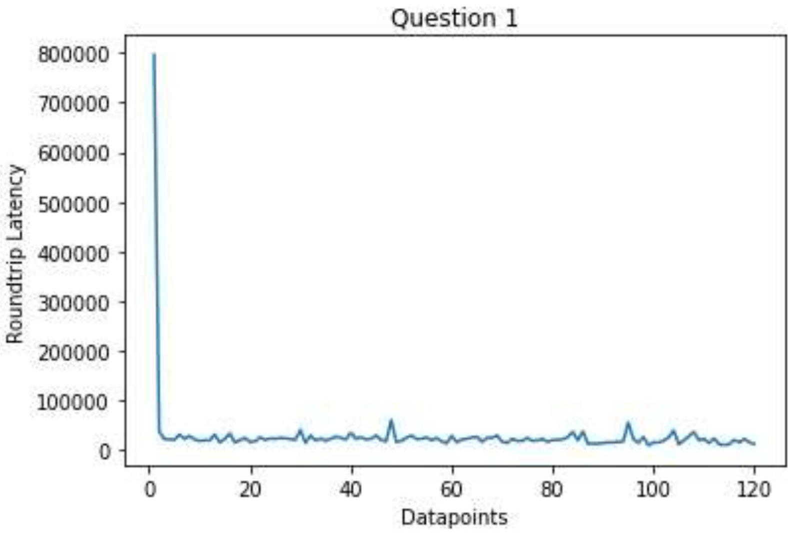
a) Same host

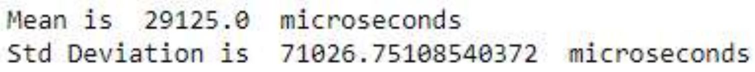




```
Mean is  33350.0  microseconds
Std Deviation is  67976.10183121762  microseconds
```

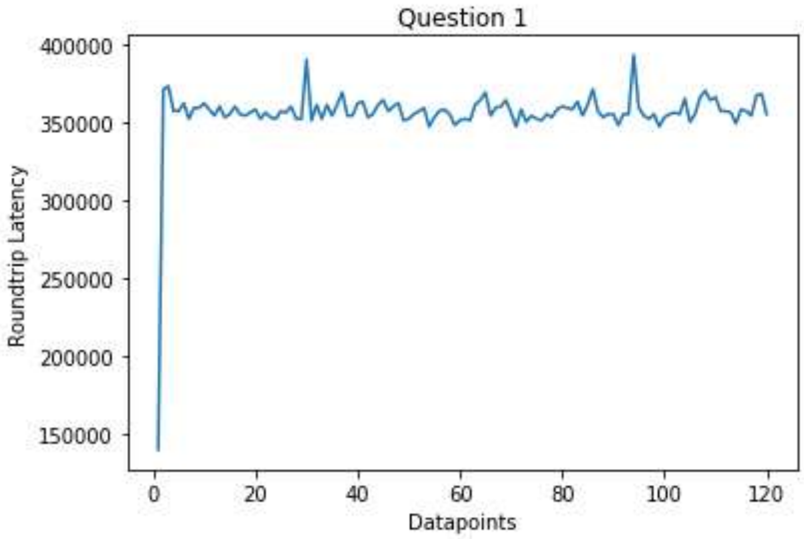
b) Same region, different host

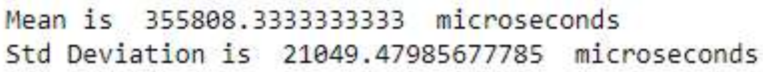




```
Mean is  29125.0  microseconds
Std Deviation is  71026.75108540372  microseconds
```

c) Different region, different host

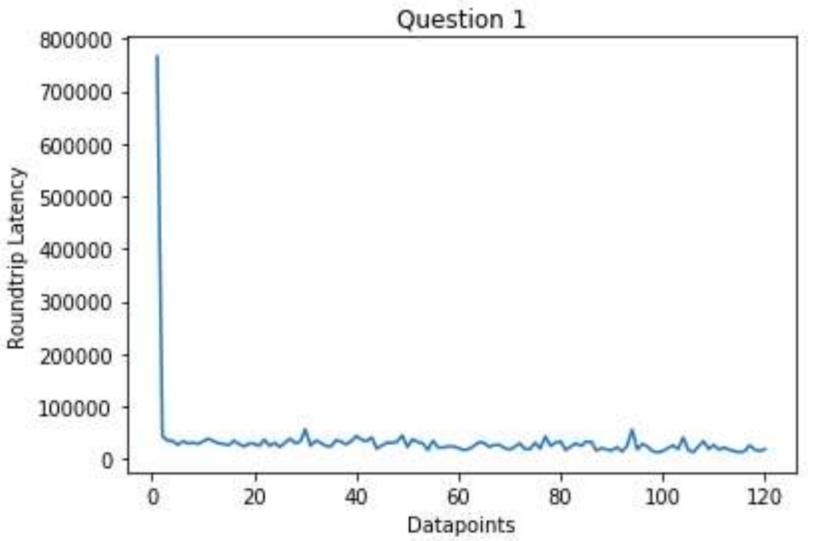


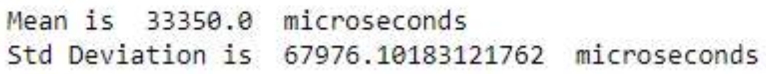


```
Mean is  355808.3333333333  microseconds
Std Deviation is  21049.47985677785  microseconds
```

UDP – Plotted graphs for round trip latencies:

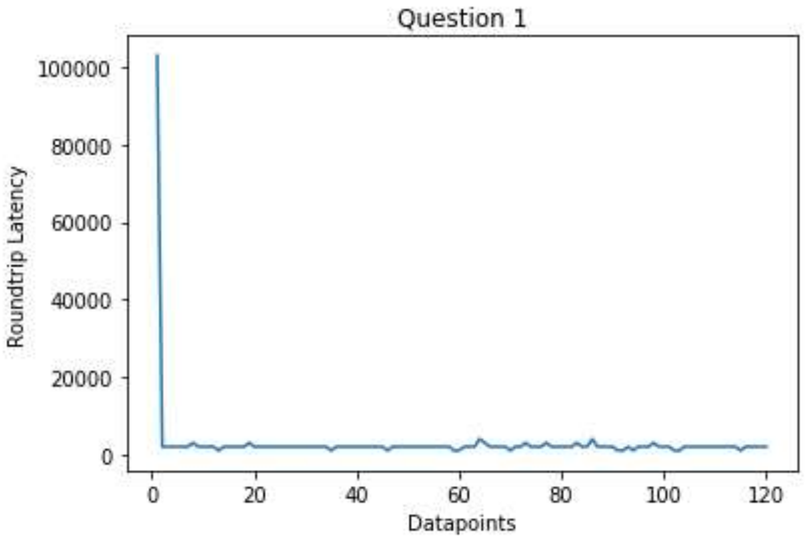
a) Same host:

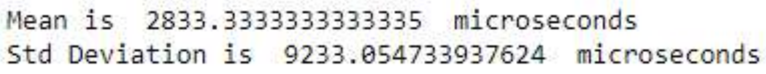




```
Mean is  33350.0  microseconds
Std Deviation is  67976.10183121762  microseconds
```

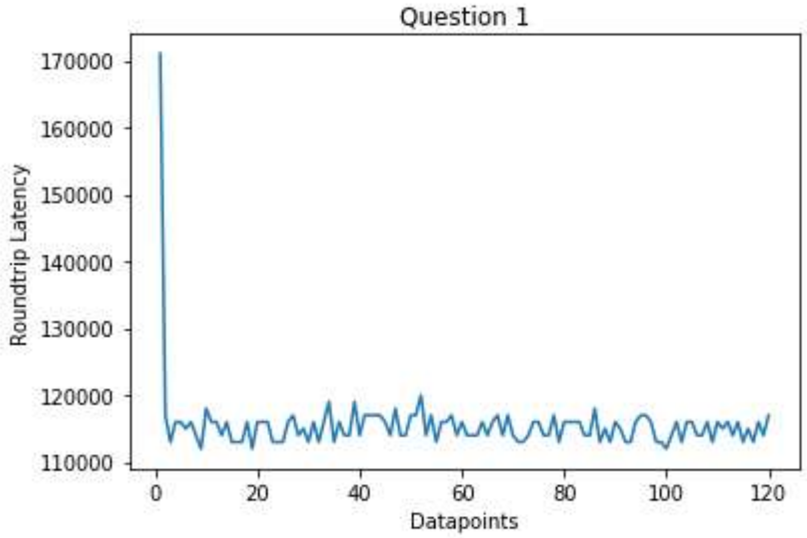
b) Same region, different host

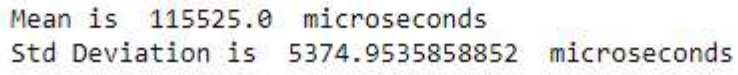




```
Mean is  2833.3333333333335  microseconds
Std Deviation is  9233.054733937624  microseconds
```

c) Different region, different host





```
Mean is  115525.0  microseconds
Std Deviation is  5374.9535858852  microseconds
```

Mean and standard deviation for GRPC and UDP are as follows:

Mean(in microseconds)

	Same host	Same region, Different host	Different region, Different host
UDP	2050	2833.33	115525
GRPC	33350	29125	355808.33

Standard Deviation (in microseconds)

	Same host	Same region, Different host	Different region, Different host
UDP	5129.99090	9233.05473	5374.9535
GRPC	67976.10180	71026.75108	21049.47985

Mean of Latencies is calculated in 2 different versions, it shows GRPC versions have more latencies than UDP for respective scenarios. Reason being UDP has no acknowledge packet. Whereas GRPC uses HTTP2 protocol which uses TCP which acknowledges packets.

Also, In UDP the latencies are consistent (increasing) based on scenarios (same machine, different machine, different region).

Since SD(standard deviations) are less for GRPC than UDP , therefore UDP makes more accurate protocol.

2) How much performance overhead does RPC incur under different scenarios? Provide an explanation of this overhead. Your answer must be based on the data you have collected.

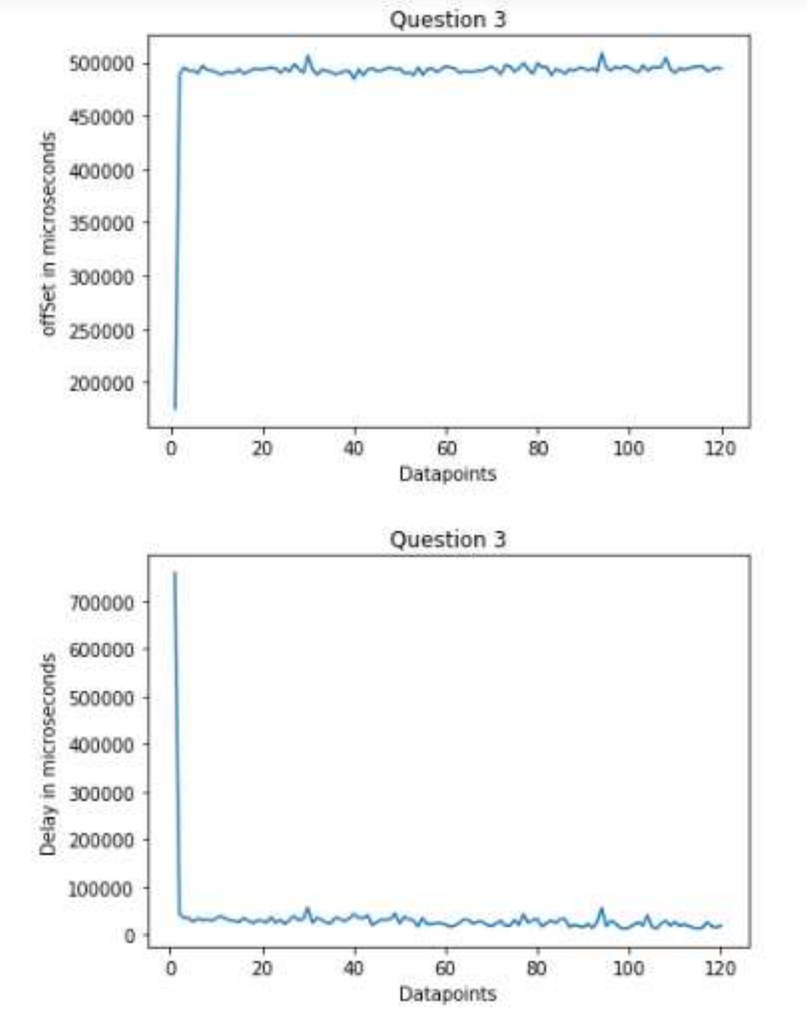
Difference of mean for UDP and GRPC in scenario 1 = 33350 – 2050 = 31300 microseconds
Difference of mean for UDP and GRPC in scenario 1 = 29125 – 2833 = 26292 microseconds
Difference of mean for UDP and GRPC in scenario 1 = 355808 – 115525 = 240283 microseconds

Performance overheads in all 3 scenarios for 2 versions is defined above.

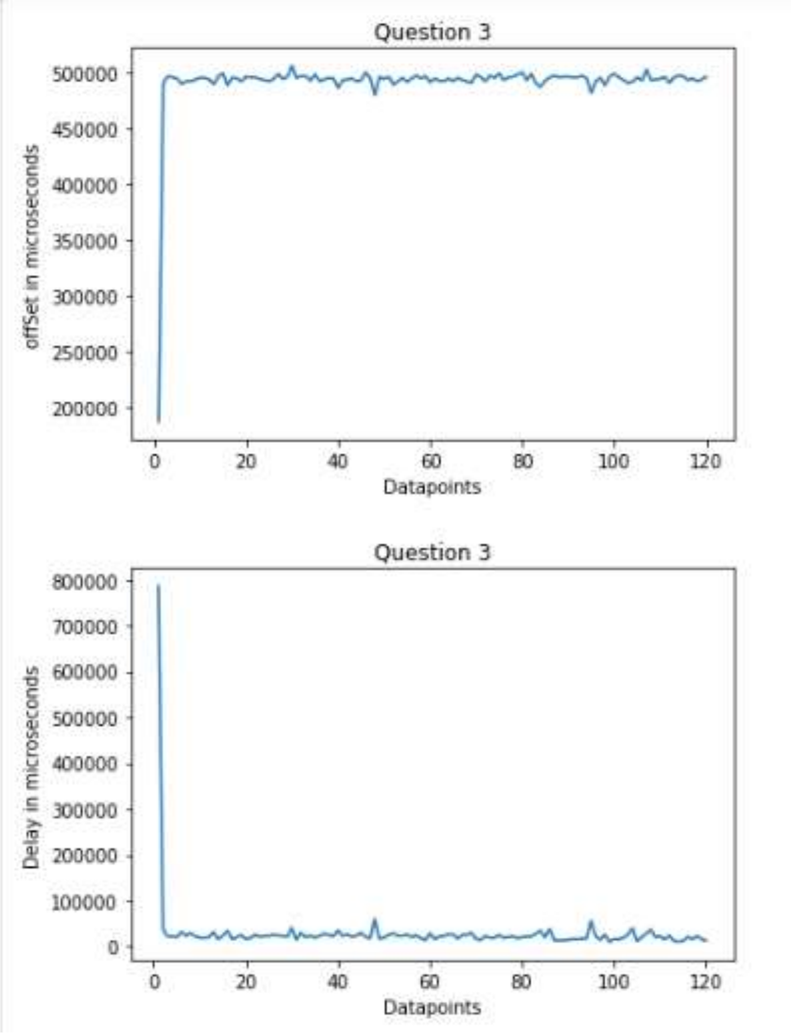
Reason being RPC having more performance overhead is dues to marshaling of data , wait time in acknowledgement, and for large data usually rpc breaks into packets then sequence it and assemble/re assemble them back. All these activites increase latencies for RPC decreasing it performance.

3) Compute the offset (oi) and delay (di) for each of the measurements for each scenario using the NTP formula and plot them in a graph (x-axis: measurement #; y-axis: oi or di). Provide an analysis of your results. What difference do you see in your estimates between the two versions of your program? Based on your data, can you justify the statement: The shorter and more symmetric the round-trip time is, the more accurate the estimate of the current time.

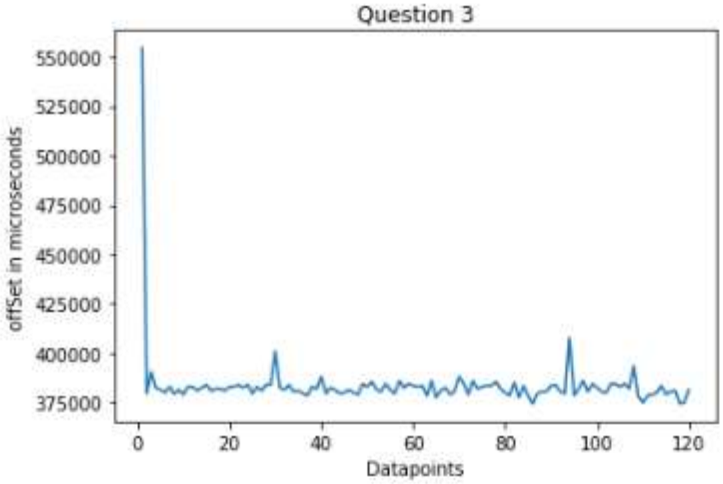
GRPC - Same host

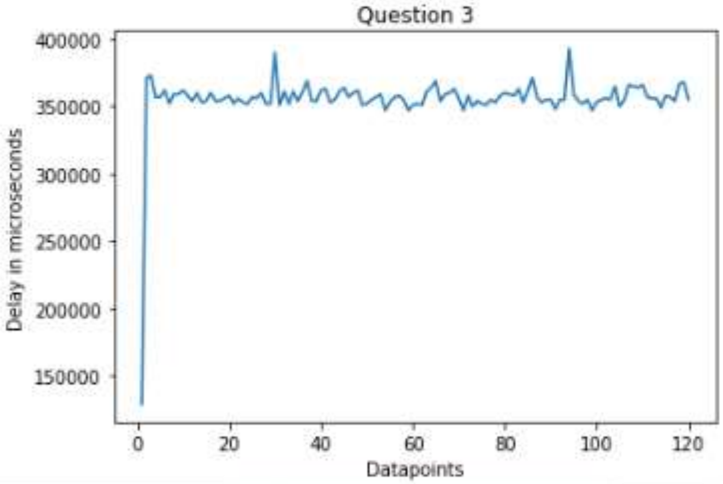


GRPC - Same Region, Different host

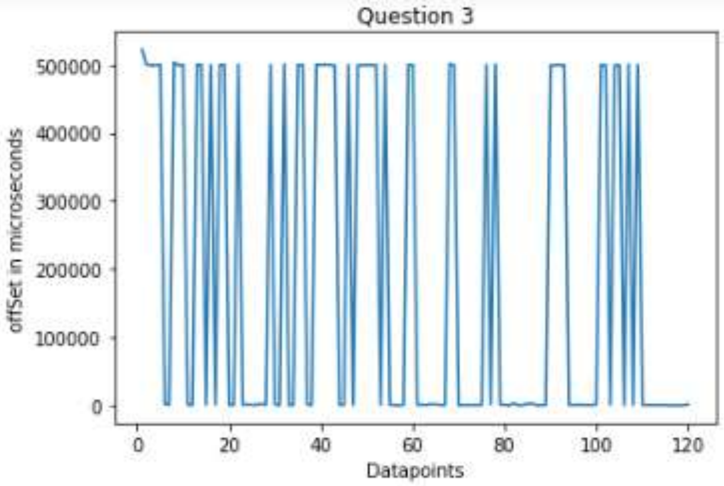


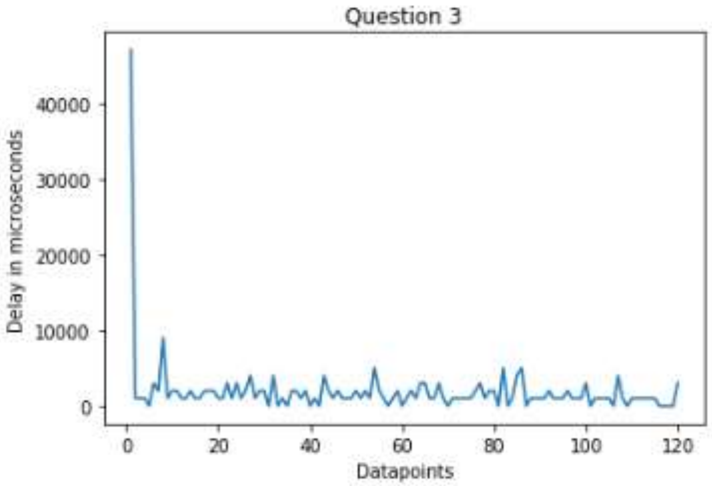
GRPC - Different Region, Different host



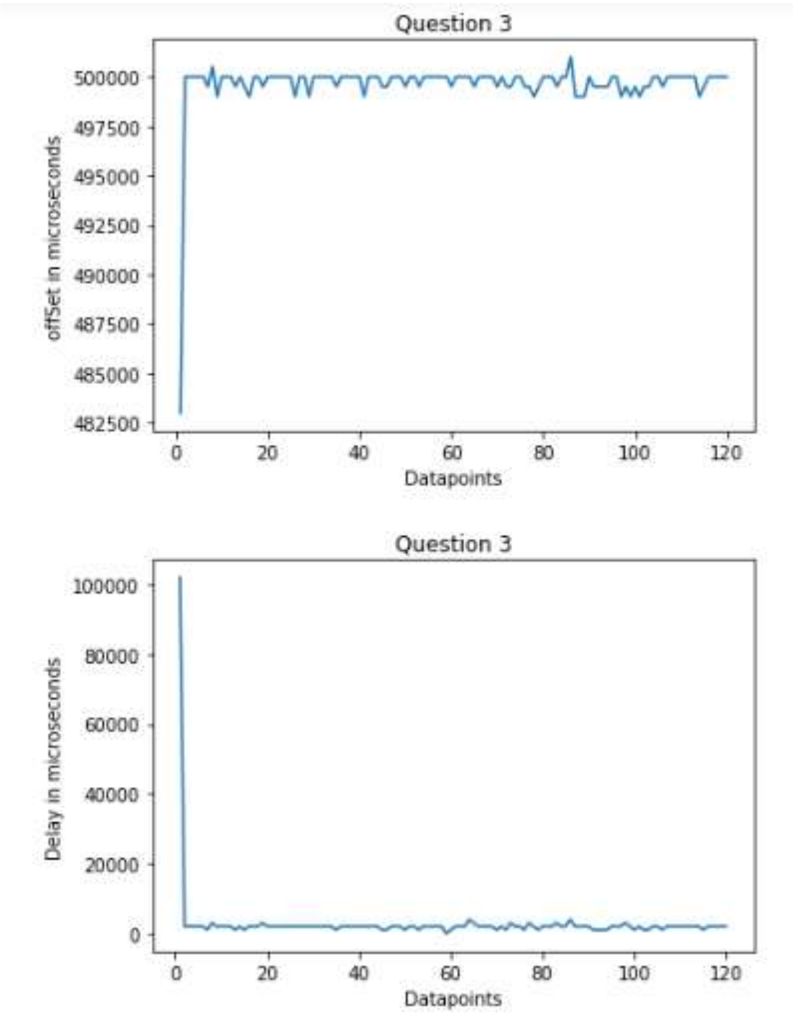


UDP - Same host

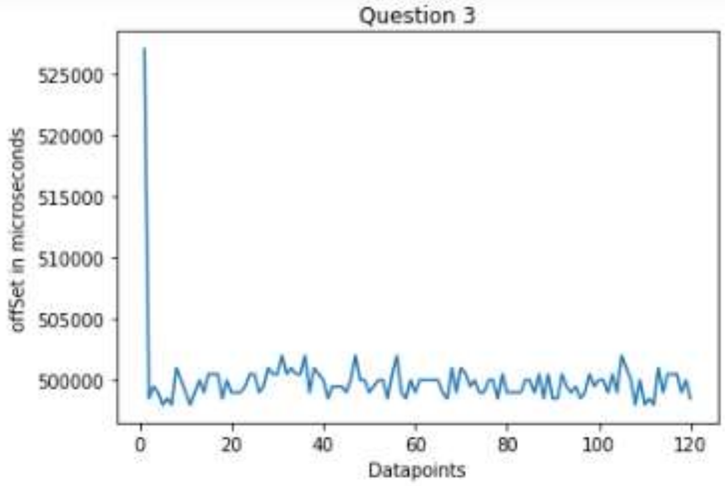


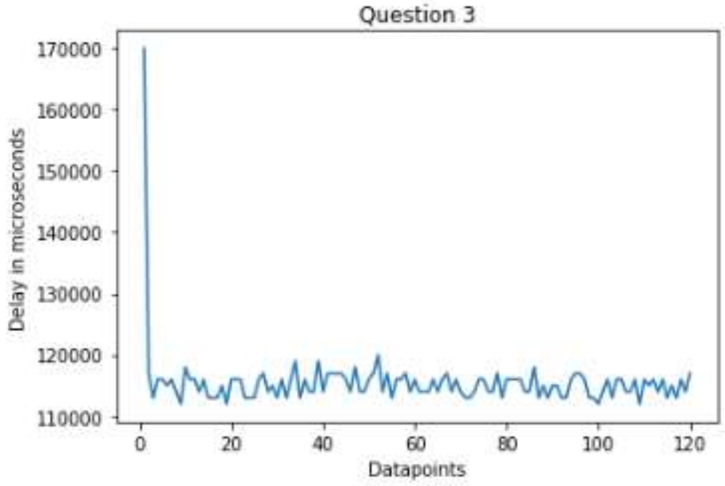


UDP - Same Region, Different host



UDP - Different Region, Different host





Below **is the aggregate of offset and delay in all scenarios of 2 versions.**

In microseconds

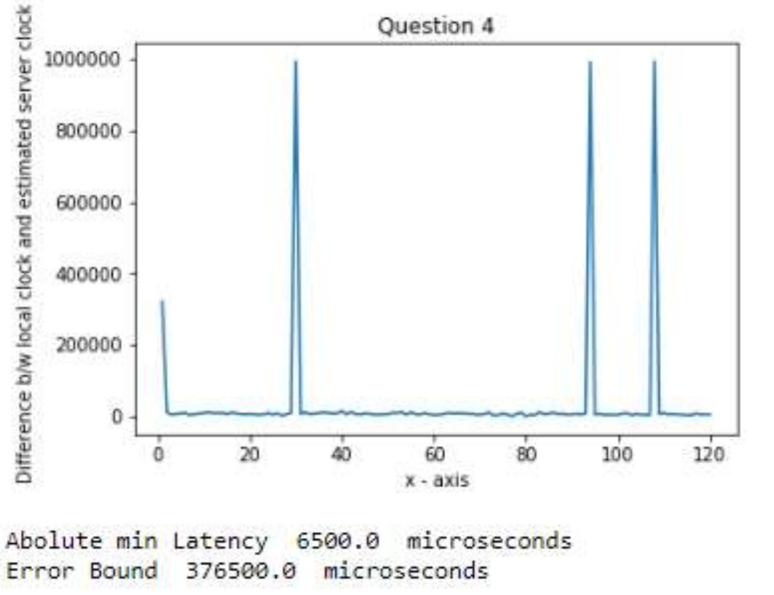
		Offset	**Delay**
UDP	Same Machine	192295.8	1875
	Differnet Machine	499645.8	2725
	Different Region	499912.5	115475
RPC	Same Machine	490862.5	33208.33
	Differnet Machine	383620.8	28958.33
	Different Region	491070.8	355625

It is clearly seen that , delays are more in RPC compared to UDP in their respective scenarios.

Also, if we compare delays and offset in both version, they are directly proportional. If delays are less then offsets are also less. Delay less means shorter round trip value, which means less offset value and more accurate the estimate of current time. So machine in same region has less offset which compared to machine in different region making estimate of current time more accurate in same machine.

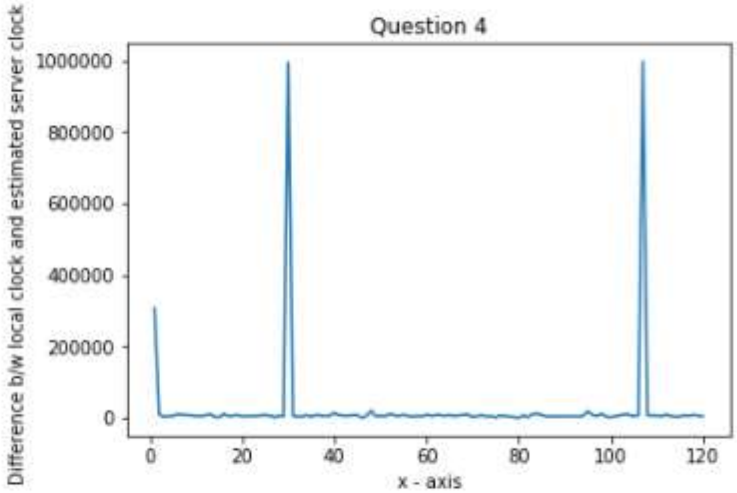
4) Compute server clock time estimate using the Cristian's clock synchronization algorithm, and plot the difference between the local clock and the estimated server clock values for each scenario. Based on your observations, what is a reasonable estimate of absolute minimum latency between the two machines you used for experiments for different scenarios. Using this estimate, calculate the error bounds for the synchronized time.

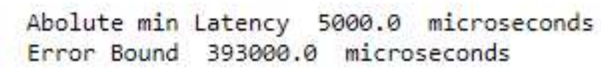
GRPC – Same Machine



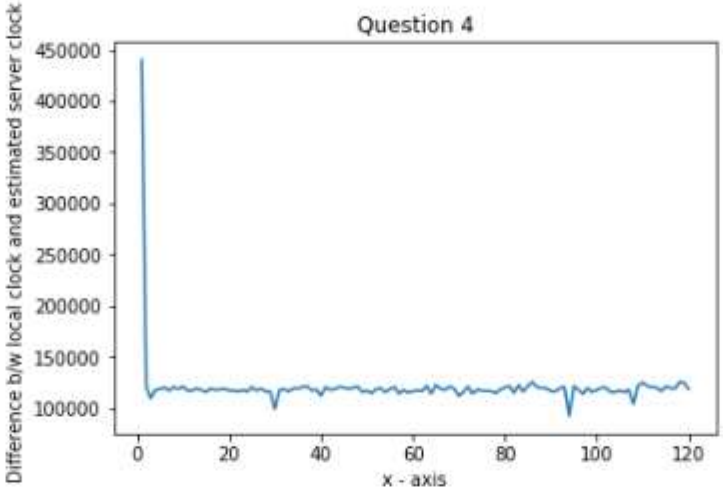
```
Abolute min Latency  6500.0  microseconds
Error Bound  376500.0  microseconds
```

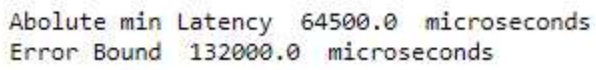
GRPC – Same Region, Different Machine



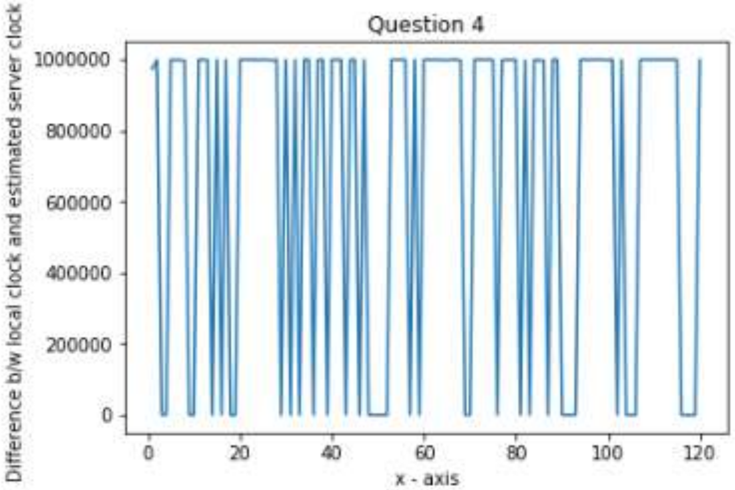

```
Abolute min Latency  5000.0  microseconds
Error Bound  393000.0  microseconds
```

GRPC – Different Region, Different Machine



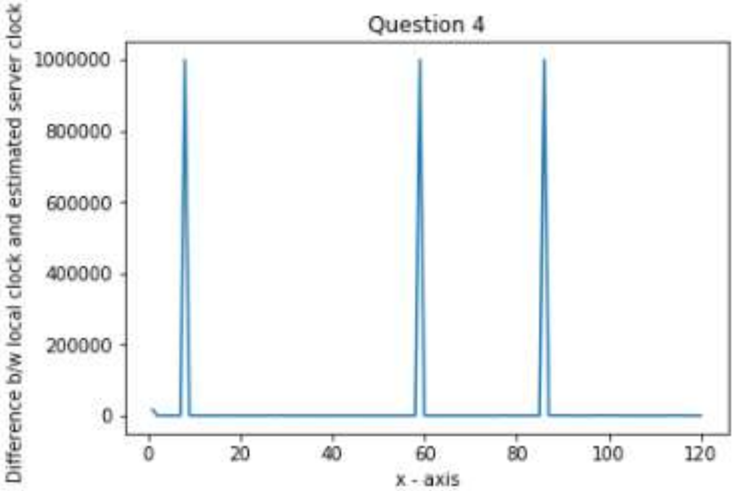

```
Abolute min Latency  64500.0  microseconds
Error Bound  132000.0  microseconds
```

UDP – Same Machine



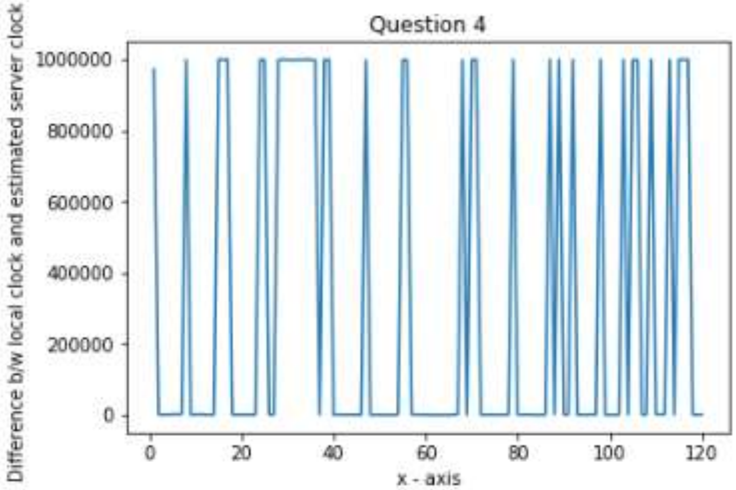
```
Abolute min Latency  0.0  microseconds
Error Bound  28000.0  microseconds
```

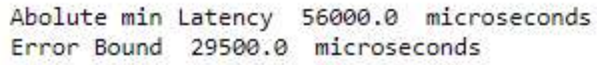
UDP – Different Machine



```
Abolute min Latency  0.0  microseconds
Error Bound  51500.0  microseconds
```

UDP – Different Region, Different Machine





```
Abolute min Latency  56000.0  microseconds
Error Bound  29500.0  microseconds
```

Minimum transport time and error bounds are present below the respective graphs.

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