CS 739 Miniproject 1

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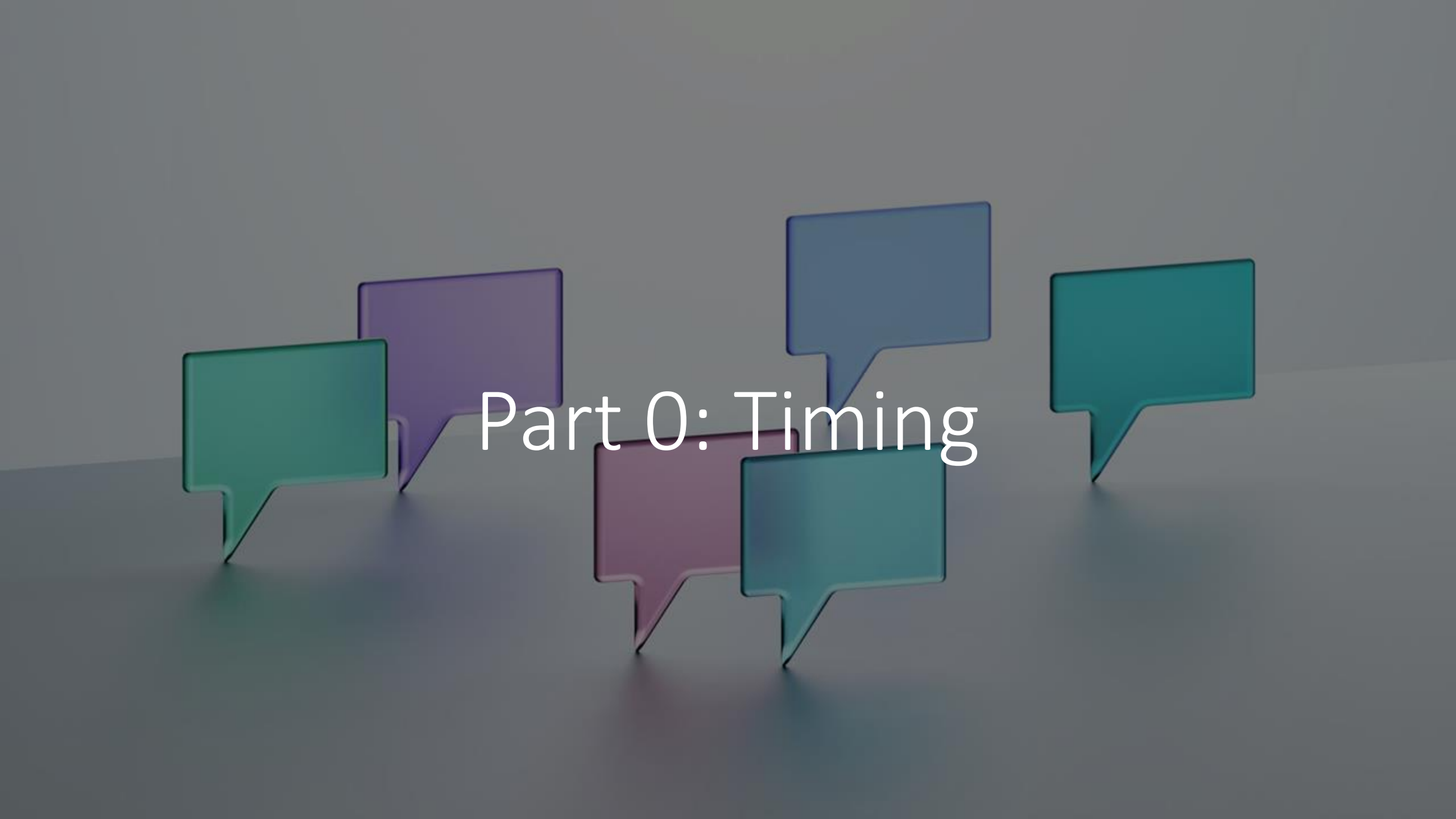
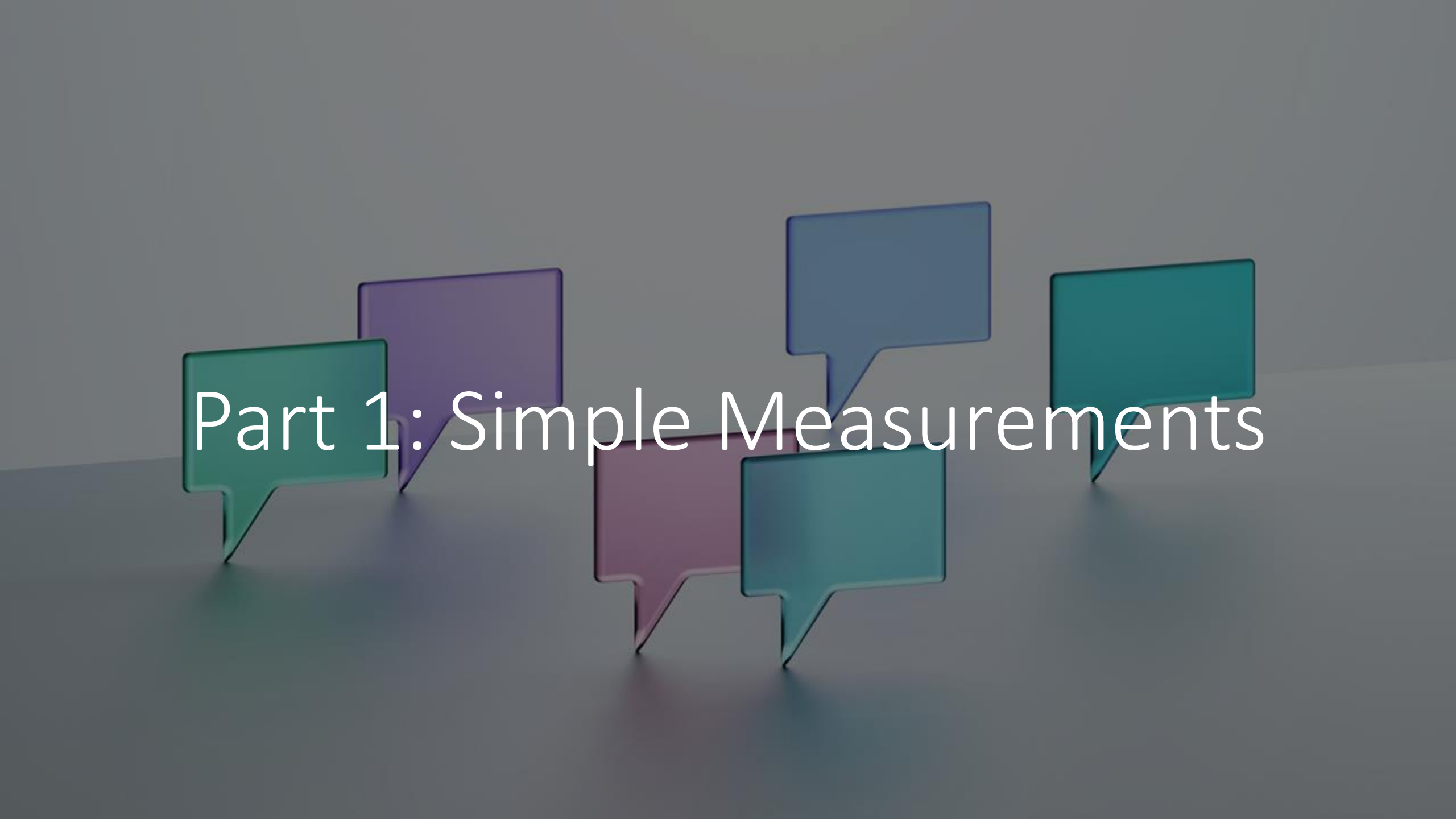


Part 0: Timing

Choosing a clock

- Both chrono's high_resolution_timer and clock_gettime have a resolution of ~1ns
- Two successive calls to clock_gettime() measures ~70ns, but ~20ns for the high_resolution_timer
- We chose the high_resolution timer as it is better suited for C++ and has lower overhead
- One iteration of for loop with only nop takes additional ~2ns



Part 1: Simple Measurements

Measurement Conditions

- Latency branch misprediction from online resources due to measurement difficulty
- Measurements for SSD and HDD read speeds are done on Cloudlab c220g2 machines
- All other measurements done from royal-12
  - If a server is required for network communication, server is royal-13
- Reported measurements are an average of 100 runs

Measurements

Measurement	Time	Notes
L1 Cache Reference	1 - 5ns	MOV instruction
Branch Misprediction	4-6ns	https://www.7-cpu.com/cpu/Haswell.html
L2 Cache Reference	2-10ns	MOV instruction
Mutex Lock/Unlock	10-20ns	
Main Memory Reference	100-120ns	MOVNTI instruction

Measurements Cont...

Measurement	Time	Notes
Compress 1k With Snappy	3us	Input from /dev/urandom
Send 1k Over 1Gbps Network	12us	From royal-12 to royal-13
Read 4K Randomly From SSD	2ms	16 random 256 byte reads from a 1GB file
Read 1MB Sequentially From Memory	97us	
Round Trip Time Within Datacenter	240us	ping -c 10 royal-13.cs.wisc.edu

Measurements Cont...

Measurement	Time	Notes
Read 1MB Sequentially From SSD	3.5ms	
Read 4K Randomly From Disk	65ms	16 random 256 byte reads from a 1GB file. Standin for Disk Seek
Read 1MB Sequentially From Disk	10ms	
Send packet from Madison -> Netherlands -> Madison	95ms	ping -c 10 government.nl

Part 2: Reliable Communication

Design

- Request packet

```
struct packet {
        int64_t seq;
        char data[max_data_size];
};
```

- Response packet

```
struct ack_packet {
        int64_t ack;
};
```

- Retry if no response in 1s

Overhead

- Measure using TCPDump
- Local/Client Machine: AMD Ryzen 5600x @3.7Ghz, 32G Ram
- Server: Intel I5-1135g7@2.4Ghz, 16G Ram
- Gigabit LAN
- *UDP packet break into fragment, measure from the last fragment received/sent

- Client:
  - T1 = In the beginning of library function
  - T2 = When tcpdump capture outgoing udp packet
  - T3 = When tcpdump capture incoming udp packet (ack)
  - T4 = Just before returning library function
  - Overhead = T2 – T1 + T4 – T3
- Server
  - S1 = When tcpdump capture incoming udp packet
  - S2 = Just before returning library function
  - Overhead = S2 – S1

	Local MAX packet	**LAN Max packet**	**Local 1400B packet**	**LAN 1400B packet**
Server	17.2 µs	83.7* µs	9.9 µs	95.7 µs
Client	24.6 µs	180.9* µs	8.4 µs	28.8 µs

Round trip

- Measure 1000 packets containing small data

Round trip time	Local	LAN	WAN
Mean	14.97 µs	68.25 µs	189.90 ms
Median	10 µs	64 µs	190.49 ms

Bandwidth

- Send 100 max size UDP packet (~65Kib)
- Total data size: 130998000 bytes ~= 124 MiB
- Average of 5 runs

	Local	**LAN**	**WAN**
Time	51.8 ms	1506.4 ms	x
Bandwidth	19294 Mib/s	663 Mib/s	x

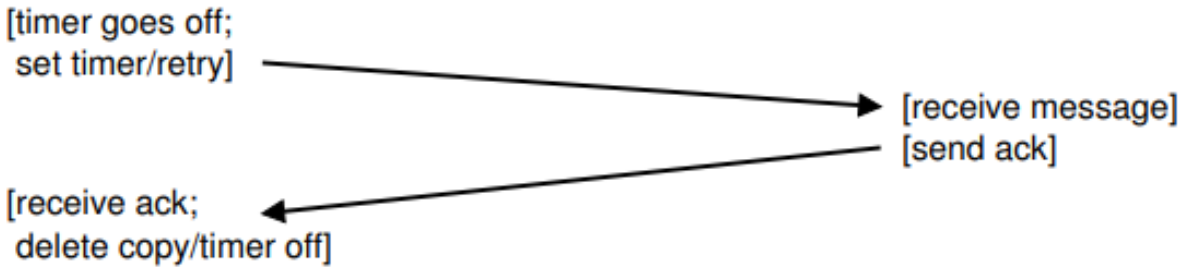
Bandwidth

- Send 100 UDP packet with size = 20000 bytes
- Total data size: 1999200 bytes ~= 2 MiB
- Average of 5 runs

	Local	**LAN**	**WAN**
Time	1.8 ms	246.2 ms	19009 ms
Bandwidth	8473 MiB/s	61.9 MiB/s	802 KiB/s

Bottleneck

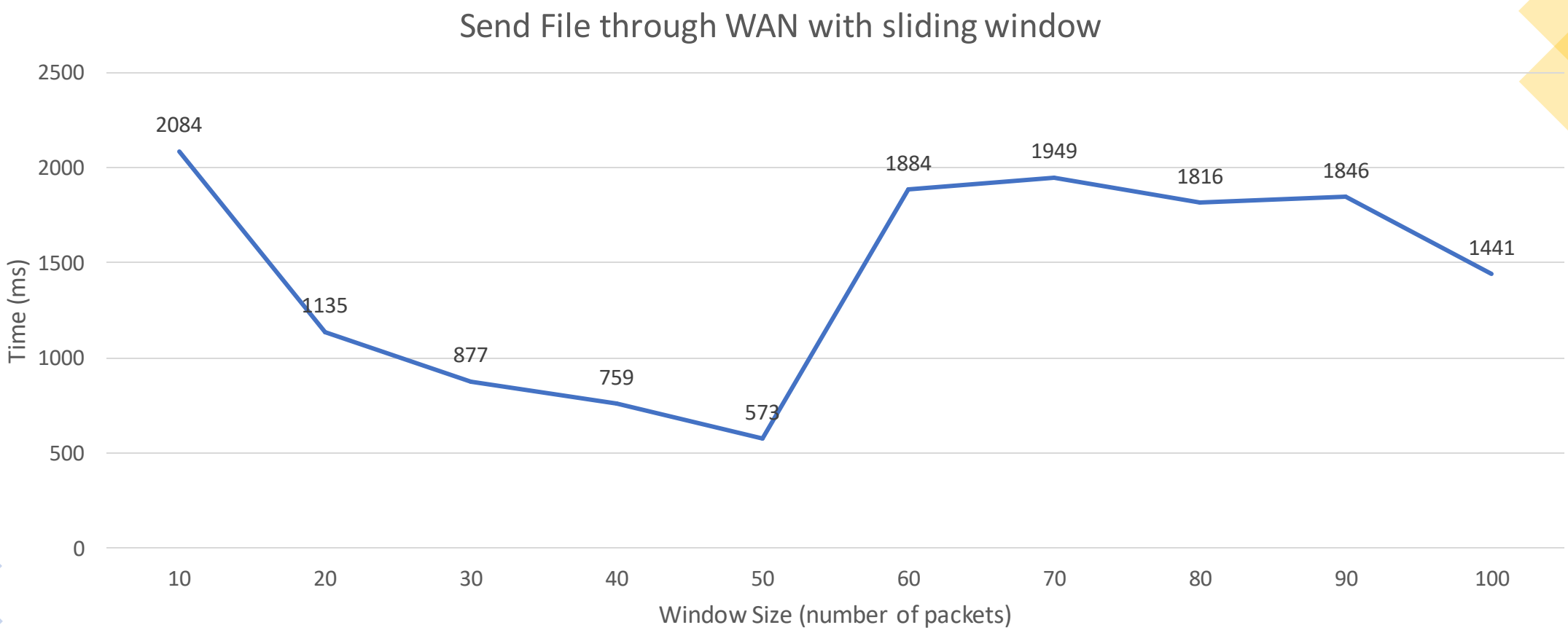
- Dominate by round trip time



Round trip time	**WAN**
Mean	189.90 ms

100 packets	**WAN**
Time	19009 ms
Bandwidth	802 KiB/s

Sliding Window

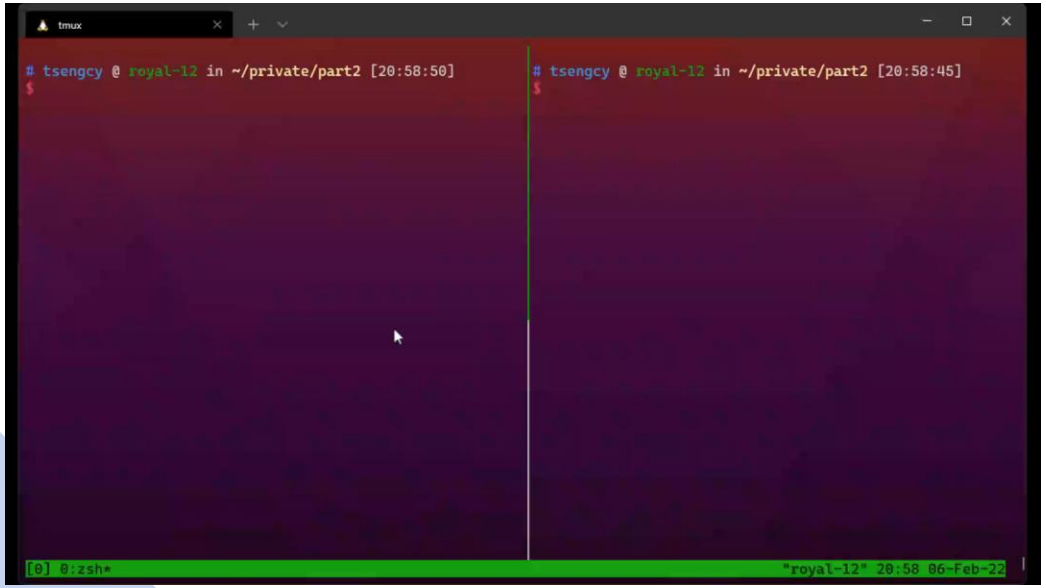


Bandwidth

	Local	**LAN**	**WAN**	**LAN Window**	**WAN Window**
Time	1.8 ms	246.2 ms	19009 ms	67 ms	573 ms
Bandwidth	8473 Mib/s	61.9 Mib/s	802 Kib/s	227.6 Mib/s	28.4 Mib/s

Packet Drop

- 100 packets



Drop Rate	# of packet with round trip time > 1s	Mean round trip time
0%	0	14.97 µs
10%	10	11 ms
20%	20	23 ms
30%	27	36 ms

Compiler Optimization

Round trip time	Local	Local No Optimization
Mean	14.97 µs	16 µs

Sending 2000 max size packet	Local	Local No Optimization
Time	51.8 ms	52 ms

Part 3: gRPC and Thrift

Mean RTT

*Thrift measured on Google Cloud machines

	Int	Double	Complex Structure	String 512	String 1024	String 2048
gRPC – Local	1113.3 us	1158.3 us	1239.1 us	1104.2 us	1291.4 us	1704.8 us
gRPC – LAN	1874.7 us	1944.8 us	1988.2 us	2100.2 us	2197.5 us	2678.9 us
gRPC - Local Compiler Optimization	897.6 us	872.2 us	1036.2us	982 us	1071.1 us	1328.4 us
gRPC - LAN Compiler Optimization	1474 us	1685.1 us	1649.2 us	1733.7 us	1753.8 us	1920.3 us
Thrift - Local	48.601 us	45.658 us	114.68 us	79.564 us	98.976 us	118.764 us
Thrift – LAN	21135.106 us	20954.037 us	22093.257 us	21913.437 us	21942.270 us	23032.465 us
Thrift – Local Compiler Optimization	33.586 us	39.579 us	82.567 us	68.957 us	81.469 us	105.736 us
Thrift – LAN Compiler Optimization	22458.56 us	21498.456 us	21494.576 us	20485.956 us	22486.356 us	22858.56 us
Pt2 Local Compiler Optimization	18 us	16 us	20 us	12 us	17 us	16 us
Pt2 Lan Compiler Optimization	60 us	57 us	56 us	63 us	56 us	63 us

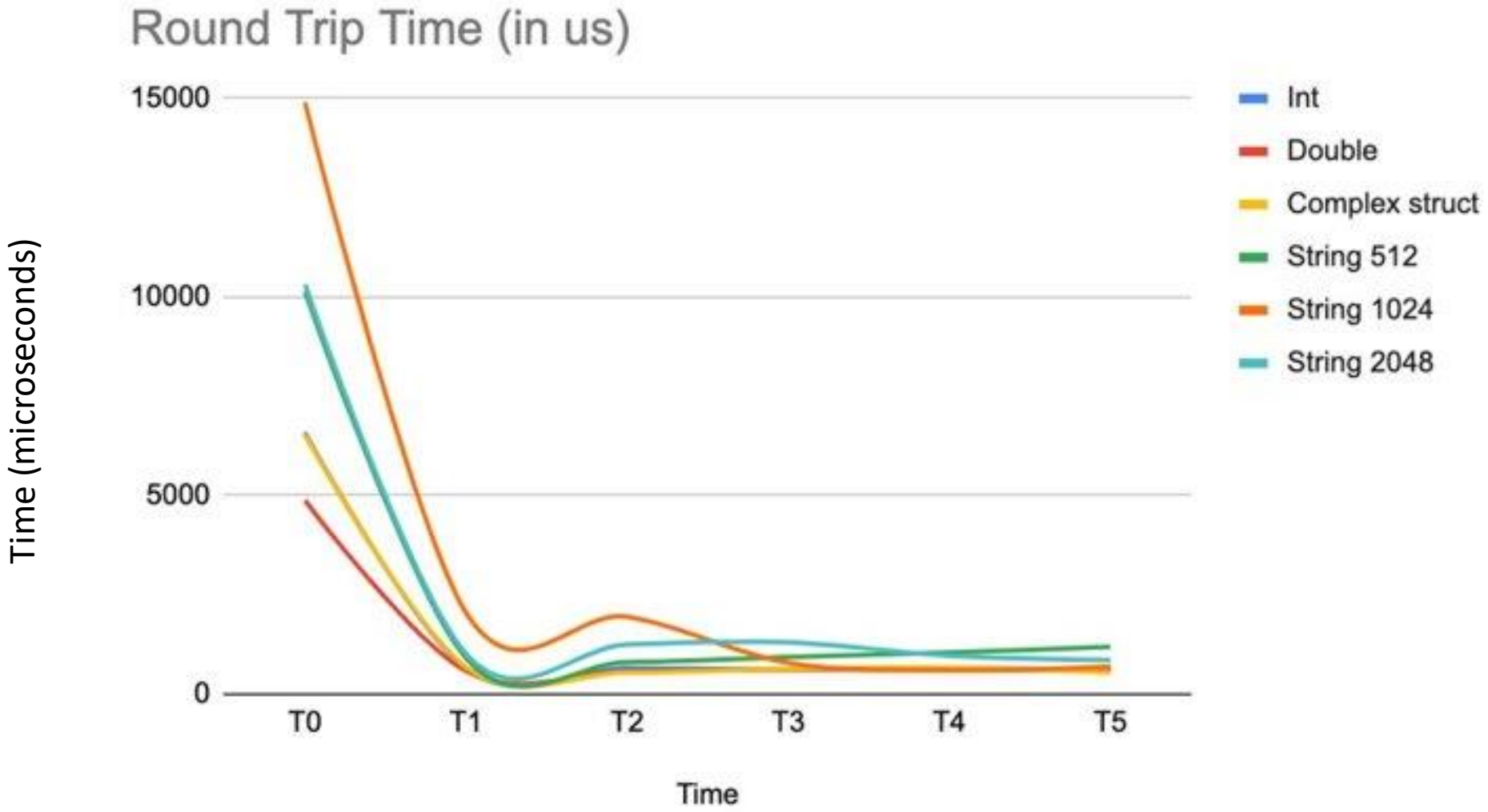
GRPC Mean RTT

RTT for the first request is large compared to subsequent requests irrespective of whether the client is on the same machine as the server or not.

All measurements are in microseconds.

Int	Double	Complex struct	String 512	String 1024	String 2048
6590.7	4884.6	6535.9	10141.1	14903.4	10320.2
640.4	584.6	677.2	911.6	2051.6	1012.6
660.1	575.4	550.1	809.2	1949.9	1253.5
616.9	623.5	638.5	937.1	789.6	1304.7
661.2	607.4	671.3	1050.9	604.8	969.9
599.6	624.8	547.4	1191.8	694.4	858.1

GRPC Mean RTT



Thrift Mean RTT

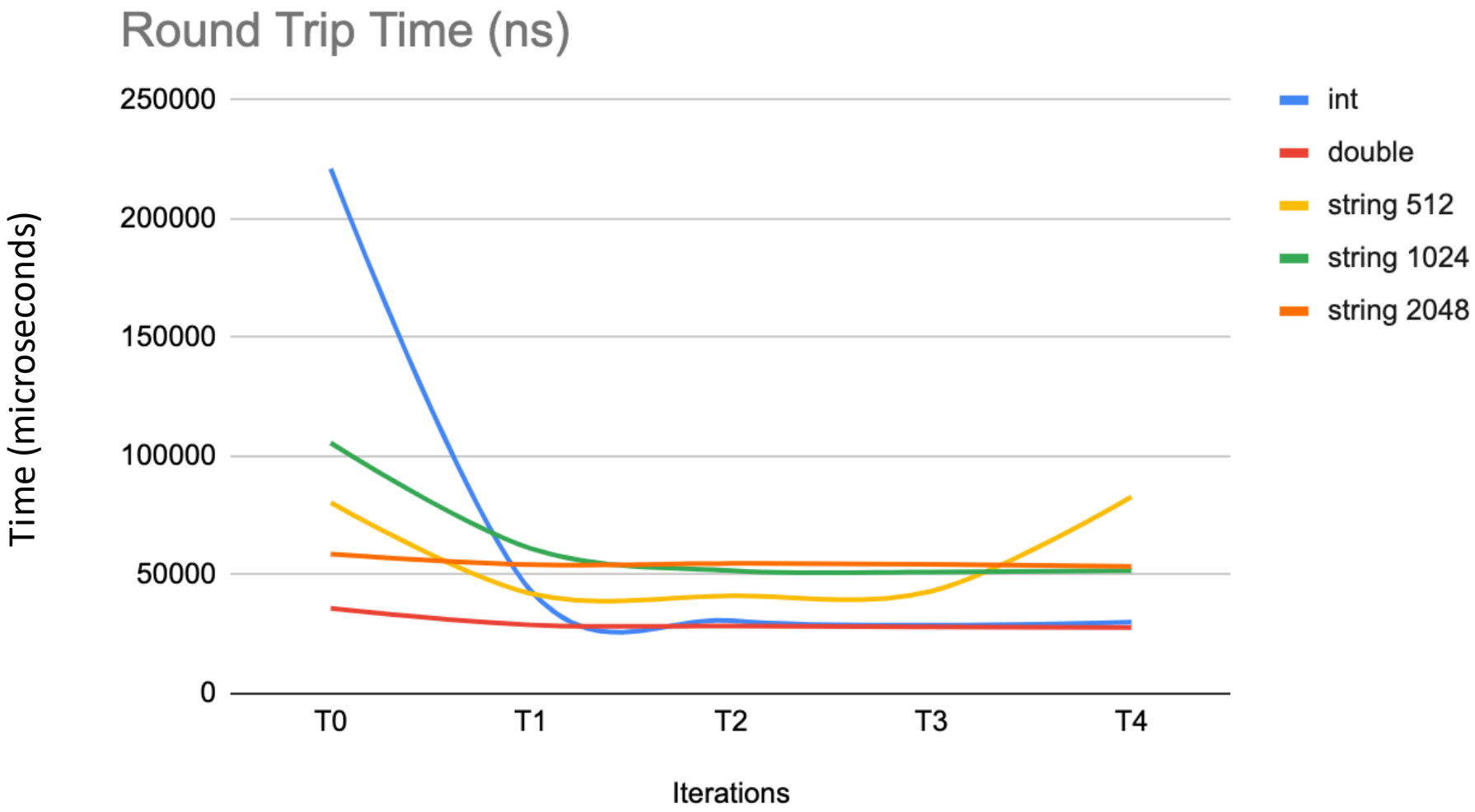
RTT for the first request is large compared to subsequent requests irrespective of whether the client is on the same machine as the server or not.

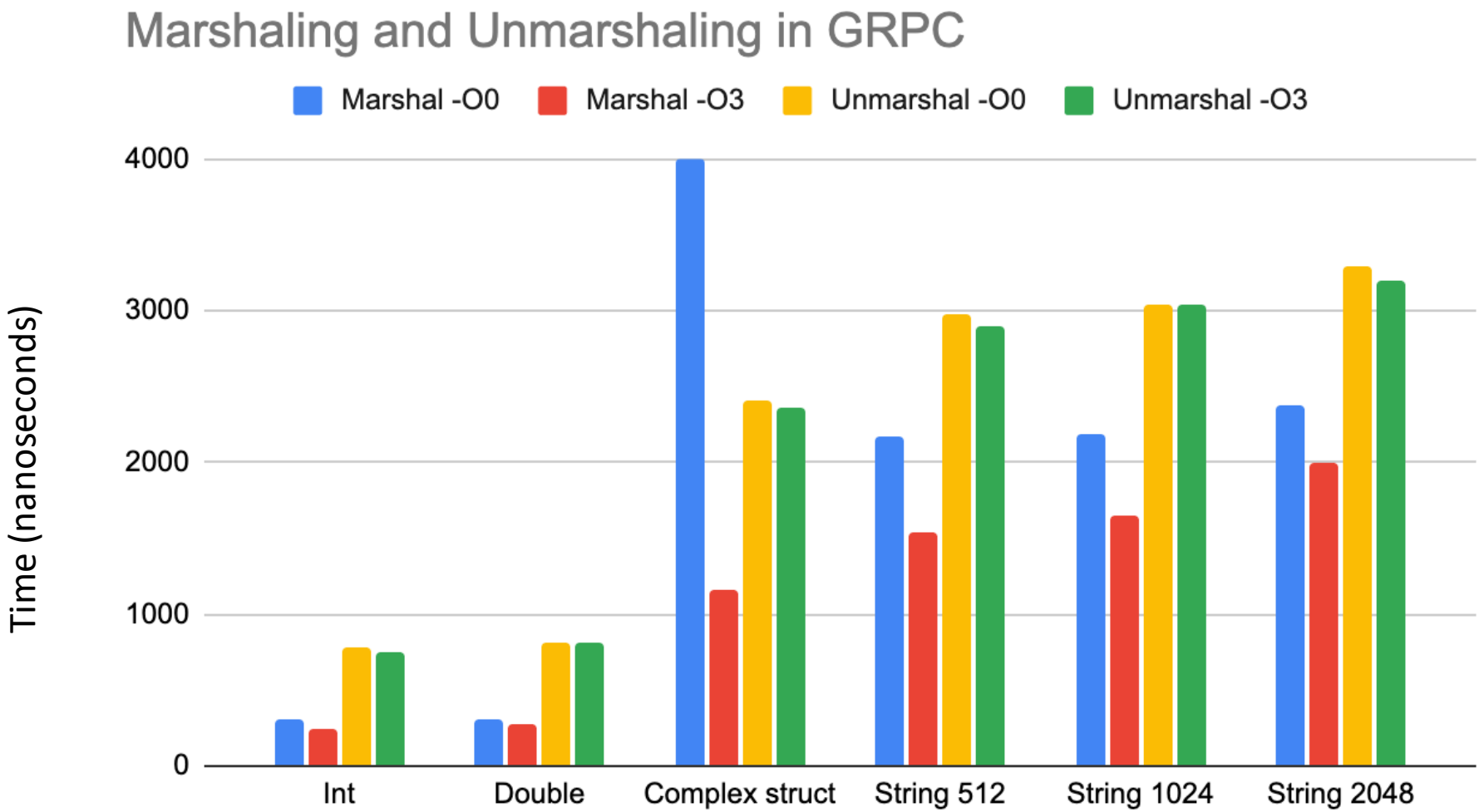
All measurements are in nanoseconds.

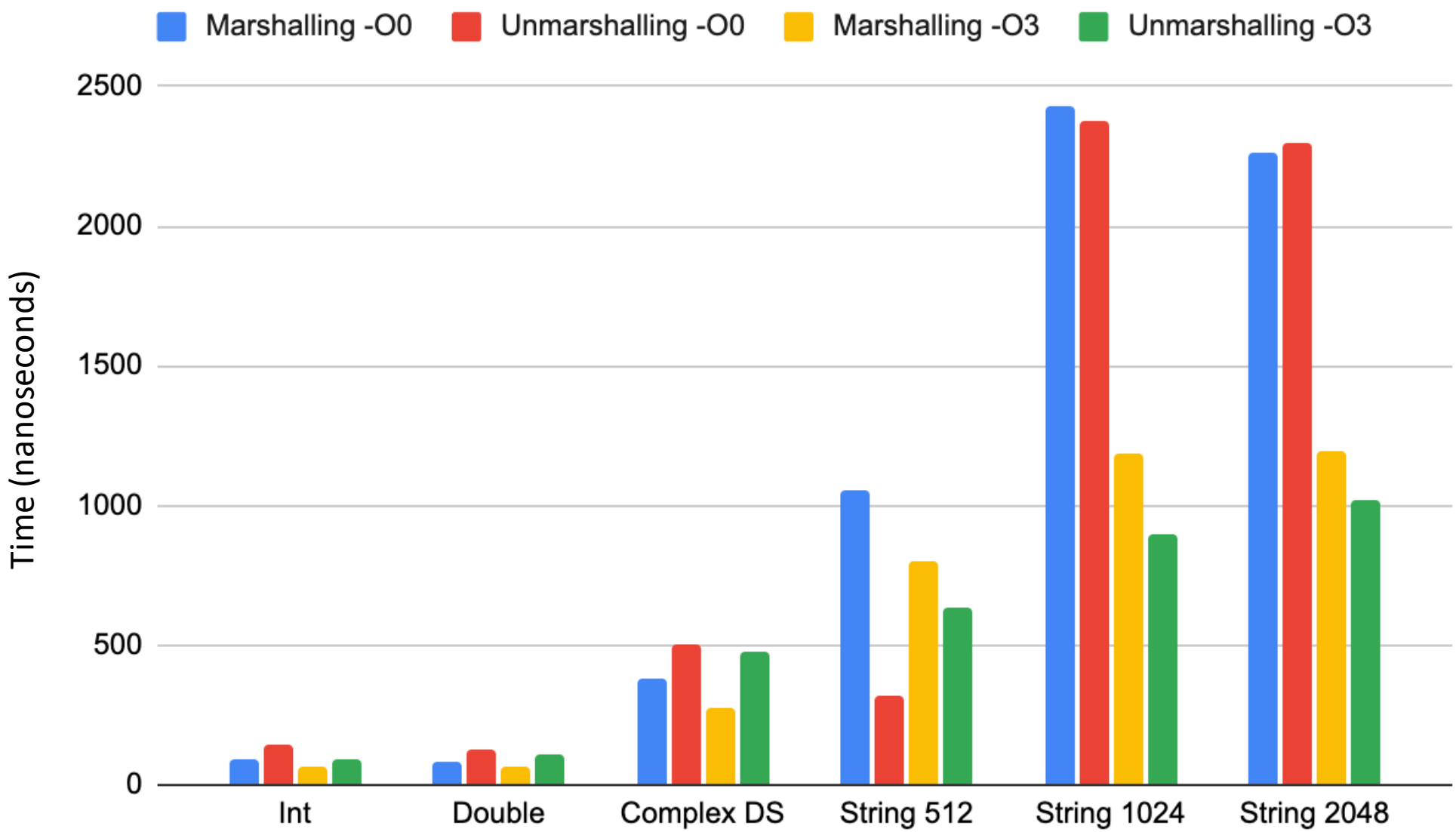
```
Round-trip time:

 *** TESTING INT ***
Time to marshall INT for iteration 0 : 221158 ns
Time to marshall INT for iteration 1 : 43351 ns
Time to marshall INT for iteration 2 : 30746 ns
Time to marshall INT for iteration 3 : 28834 ns
Time to marshall INT for iteration 4 : 30072 ns
avg rtt time : 25112.7 ns
```

Thrift Mean RTT

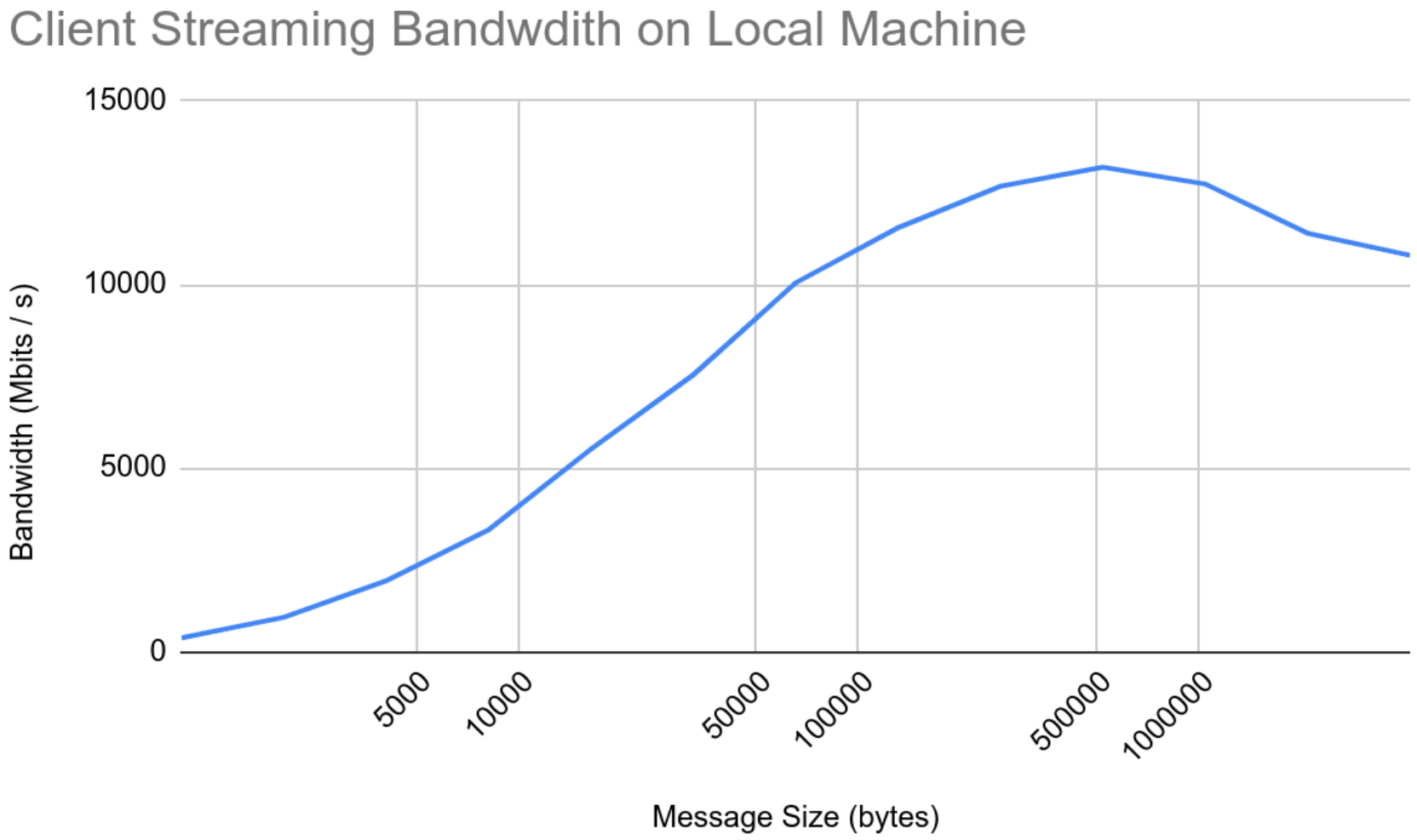



Marshaling and Unmarshaling in GRPC
Marshal -O0
Marshal -O3
Unmarshal -O0
Unmarshal -O3
Time (nanoseconds)
4000
3000
2000
1000
0
Int
Double
Complex struct
String 512
String 1024
String 2048


Marshalling -O0
Unmarshalling -O0
Marshalling -O3
Unmarshalling -O3
Time (nanoseconds)
2500
2000
1500
1000
500
0
Int
Double
Complex DS
String 512
String 1024
String 2048

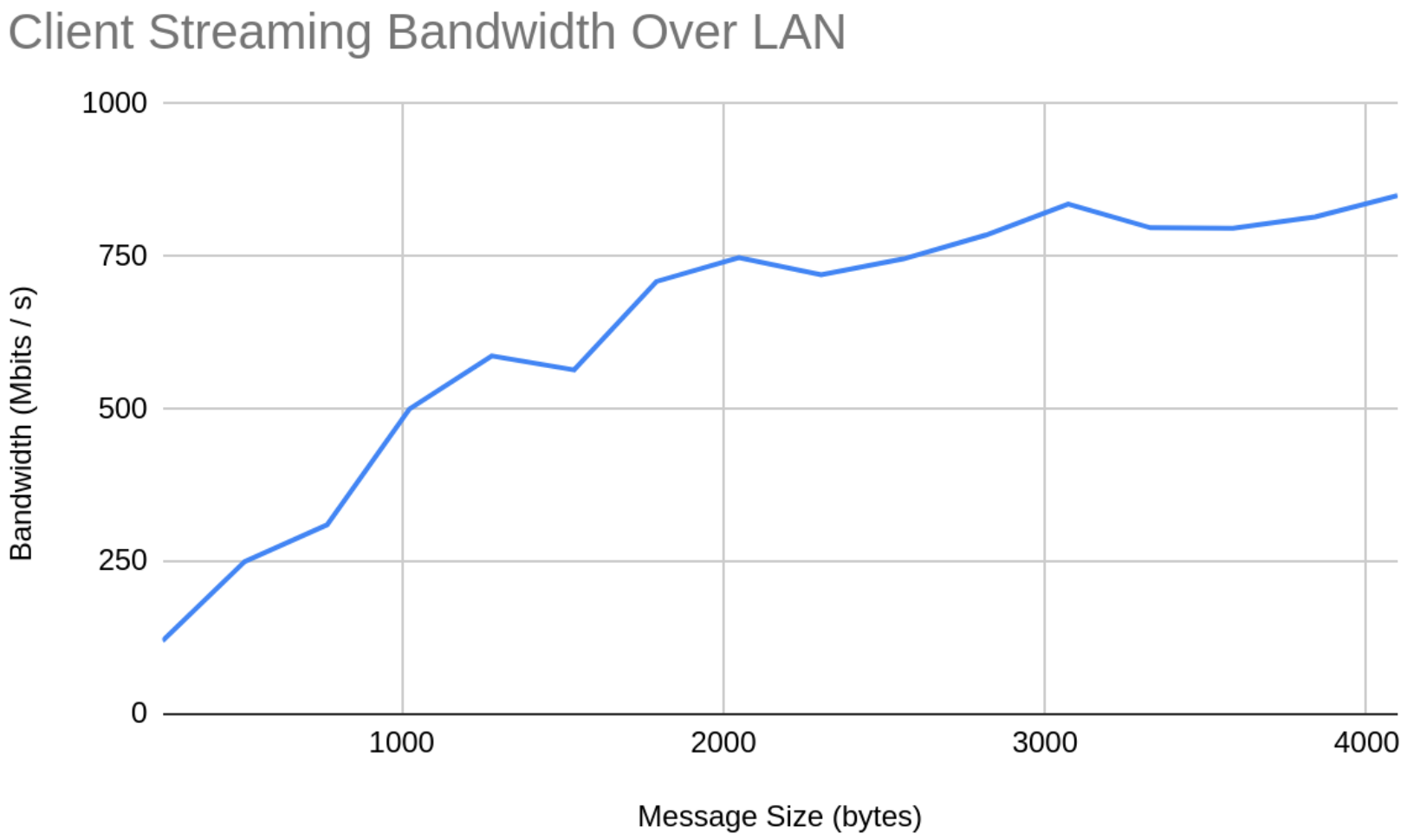
gRPC Client Streaming Bandwidth on Local Machine

Part2:
19284 Mbits/s



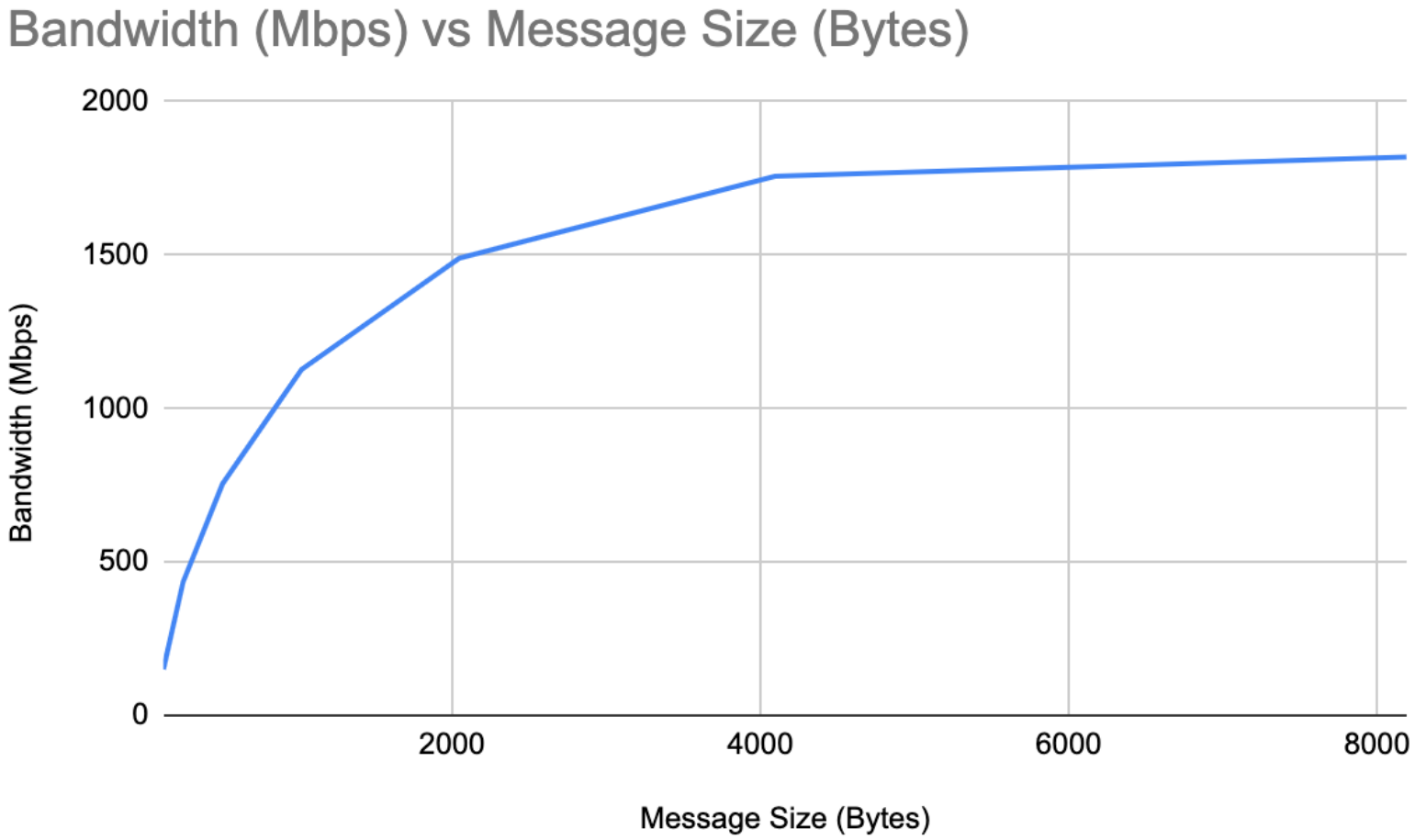
gRPC Client Streaming Bandwidth Over LAN

Part2:
663 Mbits/s



Thrift Client Streaming Bandwidth on Local Machine

Part2:
19284 Mbits/s



Thrift Client Streaming Bandwidth on LAN

Part2:
663 Mbits/s