

TCP throughput over LANs and the Internet

Wireless Networks and Mobile Communications

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1 Introduction

The goal of the project is the development of a server and a client for mobile or desktop devices as well as conducting various experiments when transmitting fragments of a large file. Two server instances are used to request fragments from, each one hosting the same 160 fragments of the large file. Via a request, each instance is asked for a set of files identified by their filename.

1.1 Desktop Version

For the purpose of the experiments, a desktop version of a TCP server and client was developed using the Java programming language¹. Dependencies and compilation is handled through **MAVEN** .

The client creates a series of TCP requests to each server instance concurrently. In more detail, a thread is created to handle the communication and the metadata produced for each server. Each thread is responsible for sending requests, receiving fragments and measuring the amount of time it took to save the fragments. A request is essentially a **JSON** array containing the identifiers for the desired fragments. After the request is sent by the client, the thread proceeds to block awaiting a server response. A response contains the following data from the server:

- the desired files for the specific request.
- the file name, in order to save the file with the appropriate name.
- the file size; since the files are received in chunks².

Each thread is shut down **only** after the client has sent all the requests that correspond to the server. Consequently, this also means the termination of the TCP connection with the server. Therefore, the TCP connection is persistent and thus used for full duplex communication between the client and the server.

The server receives the **JSON** request containing the desired fragments and sends them to the client. When a server receives a request, a thread is assigned from a *thread pool* to handle the request. The thread is responsible for parsing the **JSON** request, extracting the file identifiers and reading the file using a **FileInputStream**. The aforementioned metadata is sent to client. While reading a segment, a **DataOutputStream** sends the segment in chunks depending on buffer size³. Finally, the thread is shut down after the client connection is terminated by the client or when an error occurs.

1.2 Mobile Version

For mobile devices, a mobile version of the TCP server and client mentioned in section 1.1 was developed for Android using Android Studio⁴. Unlike the desktop version, where the server and the client are two separate processes, the mobile version bundles the two in the same app as independent threads. The user can access the two interchangeably by the provided *Tab View* as shown in figures 1 and 2.

2 Experiments

The experimentation process revolves around measuring the time to transmit a large amount of data (apprx. 1.04GB) between several different setups. In each scenario, two server instances were assigned a specific set of fragments that they had to send to the client. Thus the load distribution could be altered between test runs, resulting in different observations regarding the total transfer time. We represent load

¹<https://github.com/FotiosBistas/Tcp-Throughput-Different-Server-Implementations>

²Used for subtracting the file size with the chunk size received to determine if the whole file was received or just a chunk.

³4096B in the current implementation.

⁴<https://github.com/gsiros/TCP3wput-app>

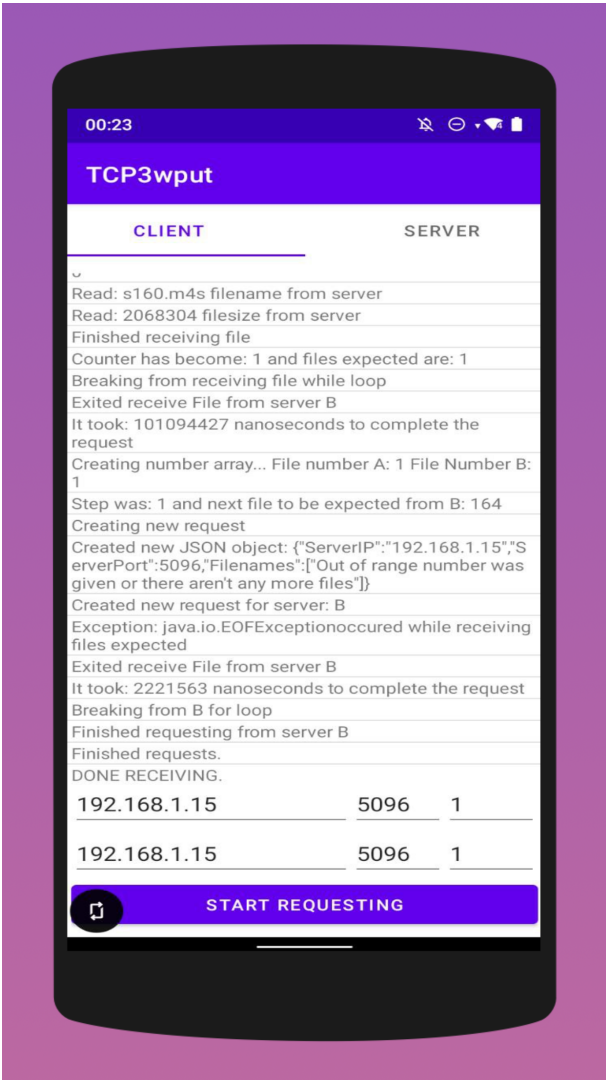


Figure 1: Server tab.

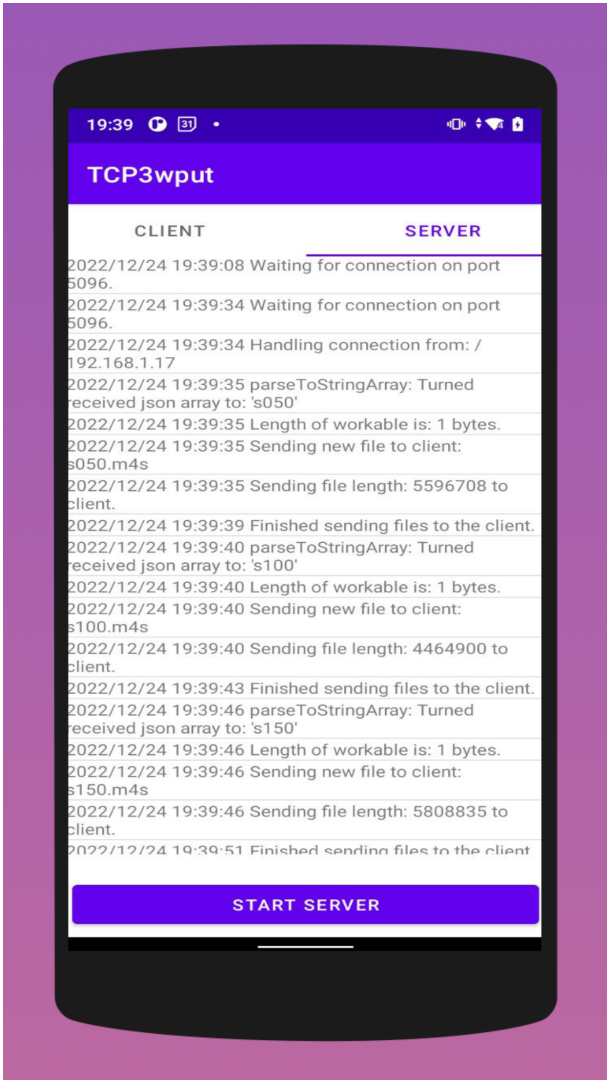


Figure 2: Client tab.

distribution ratios (*LDRs*) as $a:b$, where a corresponds to server instance A and b to server instance B. For example, let $1:2$ be a *LDR*. This means that for each file requested from server A two are requested from server B.

For each scenario, 9 different *LDRs* were used: $1:5$, $1:4$, $1:3$, $1:2$, $1:1$, $2:1$, $3:1$, $4:1$ and $5:1^5$. The three components that make up the file exchange (Client, Server A & Server B), are arranged in a different way, swapping device type (laptop/smartphone/remote machine), connection type (wired/wireless), and location relative to the Access Point (AP). A visual representation of the layout of the devices for each scenario can be observed in figure 8.

2.1 Scenario 1

For this scenario, the Client is represented by a laptop connected to the (AP) via Gigabit Ethernet. Server A is a laptop with wireless connection, stationed in close proximity to the AP throughout the run of the tests. Finally, Server B runs in a smartphone, which is placed in three locations during the test: one close to the AP, one far from the AP, and one in between the first two.

According to the measurements in table 2, latency is minimized both A and B are located close to the AP. Despite A and B being both close to the AP, it seems as A has the edge over B by a margin of 10sec.

⁵:' represented as '1' in figures.

Device name	Signal Strength(dBm)	TCP Throughput(Mbps)
Server A	-39	164
Server B (short)	-36	169
Server B (medium)	-55	135
Server B (long)	-68	85

Table 1: (Scenario 1) Signal Strength & TCP Throughput details

Load Distribution	Distance		
	Short	Medium	Long
1_5	50.91	55.55	59.04
1_4	53.35	58.34	62.20
1_3	57.08	58.13	61.91
1_2	58.87	59.40	61.52
1_1	55.76	60.09	61.43
2_1	52.19	55.36	66.44
3_1	47.42	47.34	54.93
4_1	42.79	40.84	42.32
5_1	41.10	43.10	42.81

Table 2: (Scenario 1) Transfer latency per measuring distance and load distribution.

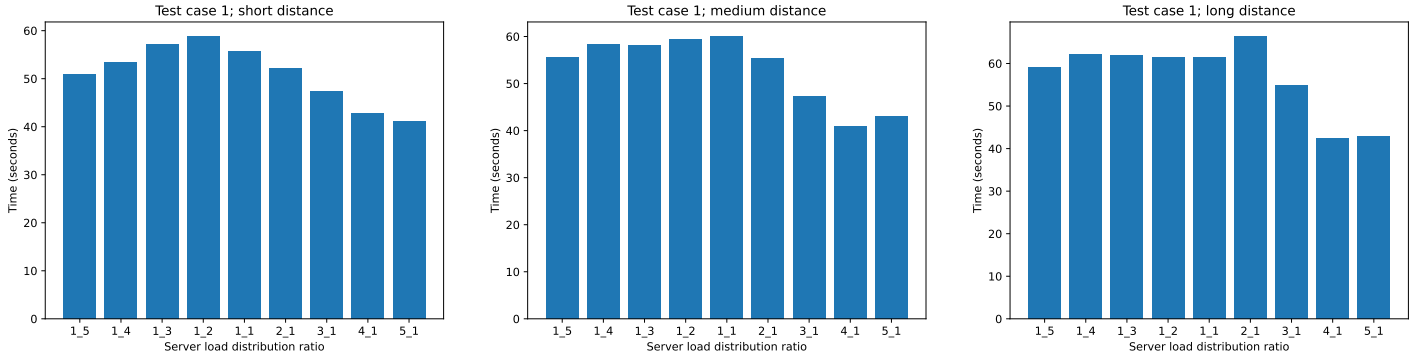


Figure 3: (Scenario 1) Transfer latency for short, medium and long distance from AP.

A possible explanation is the fact that A, being a laptop computer, possesses more processing power than the smartphone. Thus, less delay is added to the total latency due to file processing. On the contrary, the worst case is observed when the LDR is set to 1:1. In this case, the scheduling delay dominates the total latency as time is lost due to the excessive requests being sent to the servers. I.e. the servers spend more time idle while waiting for the client to request the next fragment.

Our hypothesis is also in accordance with the `iperf3` findings in table 1 where we observe that server A has one of the highest TCP throughput along with one of the highest signal strengths. Server B **only** matches server A's throughput when located in close proximity to the AP. Accordingly, the measurements for the short distance are the lowest across all LDRs.

2.2 Scenario 1*

This scenario is identical to Scenario 2.1, with the exception of Server A, which now runs on a remote machine, sending the data to the Client over the internet. As before, the Client runs on a laptop connected to the AP via Gigabit Ethernet and Server B runs on a smartphone, changing location between the

scenario’s test runs.

Device name	Signal Strength(dBm)	TCP Throughput(Mbps)
Server A	-	5.03
Server B (short)	-39	162
Server B (medium)	-53	140
Server B (long)	-69	93

Table 3: (Scenario 1*) Signal Strength & TCP Throughput details

Load Distribution	Distance		
	Short	Medium	Long
1_5	78.16	86.09	103.80
1_4	79.78	107.36	110.66
1_3	94.83	123.07	137.13
1_2	106.63	132.54	136.89
1_1	129.06	139.01	156.49
2_1	149.41	160.50	165.59
3_1	156.26	165.45	166.80
4_1	164.31	182.05	175.78
5_1	161.46	176.13	176.44

Table 4: (Scenario 1*) Transfer latency per measuring distance and load distribution.

From table 4 the lowest total latency occurs when the load assigned to server A is the lowest possible and server B is place in the closest proximity to the AP. As the load increases for A, the overall latency increases similarly across all distances. This indicates A’s transfer medium, i.e. the *Internet*, introduces a major bottleneck to the system.

As observed in 3, the higher the throughput of server B, the lower the total transfer latency. This can only be observed with LDRs 1:4 and 1:5, as with higher LDRs the benefit of the higher throughput for server B is masked by latency introduced by A.

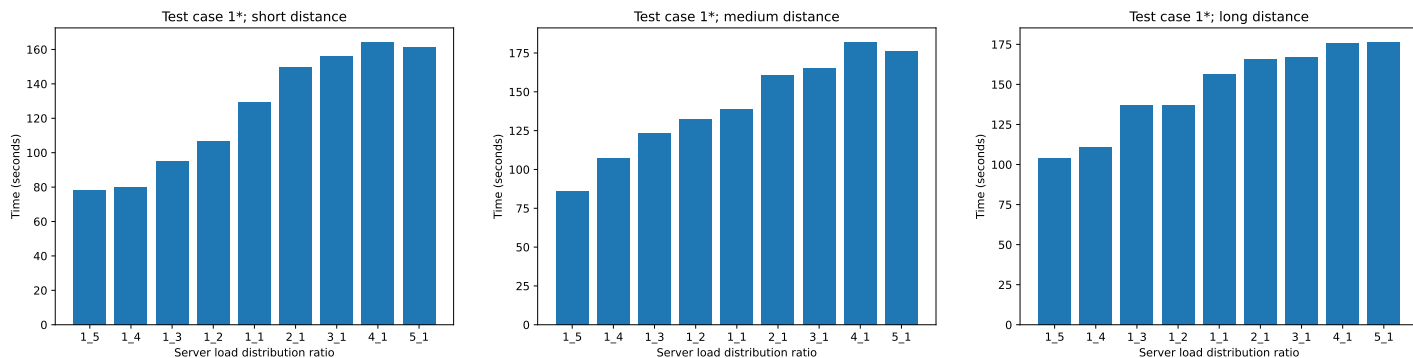


Figure 4: (Scenario 1*) Transfer latency for short, medium and long distance from AP.

2.3 Scenario 2

For this scenario, the Client runs on a laptop connected wirelessly to the AP. Server A is also a laptop, this time connected to the AP via Ethernet. Finally, as with Scenario 2.1, Server B runs on a smartphone,

which this time is placed in close proximity to the AP and remains stationary throughout the scenario. The device that changes location during this scenario is the laptop that hosts the Client. As with Scenario 2.1 the tests were ran for three different locations: one close to the AP, one far from the AP, and one in between the first two.

Client distance	Device name	Signal Strength(dBm)	TCP Throughput(Mbps)
Short	Server A	-	301
	Server B	-41	154
Medium	Server A	-	264
	Server B	-43	143
Long	Server A	-	207
	Server B	-42	125

Table 5: (Scenario 2) Signal Strength & TCP Throughput details

Load Distribution	Distance		
	Short	Medium	Long
1_5	71.69	94.77	105.93
1_4	82.89	90.23	103.83
1_3	79.69	93.84	106.89
1_2	89.94	108.09	120.01
1_1	93.98	112.67	125.91
2_1	79.77	90.49	105.12
3_1	79.73	87.35	100.70
4_1	72.02	78.78	98.29
5_1	63.59	80.24	95.51

Table 6: (Scenario 2) Transfer latency per measuring distance and load distribution.

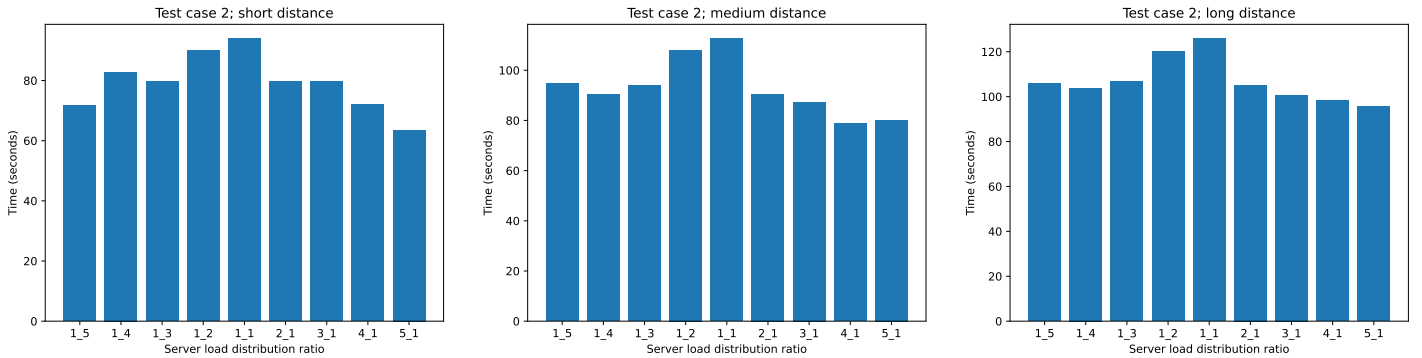


Figure 5: (Scenario 2) Transfer latency for short, medium and long distance from AP.

According to the measurements in table 6, the lowest latency is observed when the Client is situated closest to the AP. In that setting, the fastest scenario occurs when the LDR is set to 5:1, assigning the majority of the load to Server A. This complies with our logic, as Server A is connected to the AP via Gigabit Ethernet, vastly outclassing Server B, which is connected wirelessly, in terms of Throughput. Something that also warrants pointing out, is that the latency in this scenario is overall higher than the latency observed in Scenario 2.1. This is likely due to the fact that the Client is no longer connected to the AP via Ethernet, and therefore its connection to it presents a likely bottleneck to the entire set-up.

Moving the client farther away from the wireless access point, the time it takes for the file to be sent from the server to the client is expected to increase. This is due to the decreased signal strength and increased latency caused by the increased distance from the wireless access point. Additionally, if there are any obstacles between the client and the wireless access point, such as walls or other electronic devices, this can also contribute to decreased signal strength and increased latency.

Again, our hypothesis is in accordance with the `iperf3` findings in table 5. The highest TCP Throughput occurs when the Client is positioned closest to the AP. This is also the setup that yields the best results in terms of overall latency. As the Client is moved further away from the AP and TCP throughput decreases, the total latency of the tests increases. Therefore the typical positive correlation between TCP Throughput and transferring performance (i.e. low total latency) can be clearly observed.

2.4 Scenario 2*

This scenario is similar to Scenario 2.3, with the exception of the Client and Server A. Server A now runs on a remote machine, sending the data to the Client over the internet. The Client now runs on a smartphone instead of a laptop, changing location between the test runs of the scenario. Server B continues to run on a smartphone placed close to the AP for the entirety of the scenario.

As before, the Client runs on a laptop connected to the AP via Gigabit Ethernet and Server B runs on a smartphone, changing location between the scenario’s test runs.

Client distance	Device name	Signal Strength(dBm)	TCP Throughput(Mbps)
Short	Server A	-	5.01
	Server B	-39	154
Medium	Server A	-	5.05
	Server B	-40	136
Long	Server A	-	5.01
	Server B	-40	99

Table 7: (Scenario 2*) Signal Strength & TCP Throughput details

Load Distribution	Distance		
	Short	Medium	Long
1_5	72.72	85.52	84.84
1_4	74.13	93.00	100.55
1_3	87.50	109.17	120.21
1_2	98.60	109.59	129.54
1_1	123.14	134.21	146.14
2_1	144.86	145.65	149.72
3_1	160.19	156.78	162.70
4_1	176.76	176.50	168.76
5_1	167.46	164.29	170.64

Table 8: (Scenario 2*) Transfer latency per measuring distance and load distribution.

As per section 2.2 and per the data presented in table 8, it can be seen that the overall latency is at its lowest when the load assigned to Server A is at its minimum level and Server B is placed in the closest proximity to the Access Point (AP). As the load assigned to Server A increases, it becomes apparent that the overall latency similarly increases across all distances. Again, this is a clear indication that the Internet is a significant bottleneck in the system. As previously observed in the data presented in table 7, it is evident that the higher the throughput of Server B, the lower the overall transfer latency. However, similar

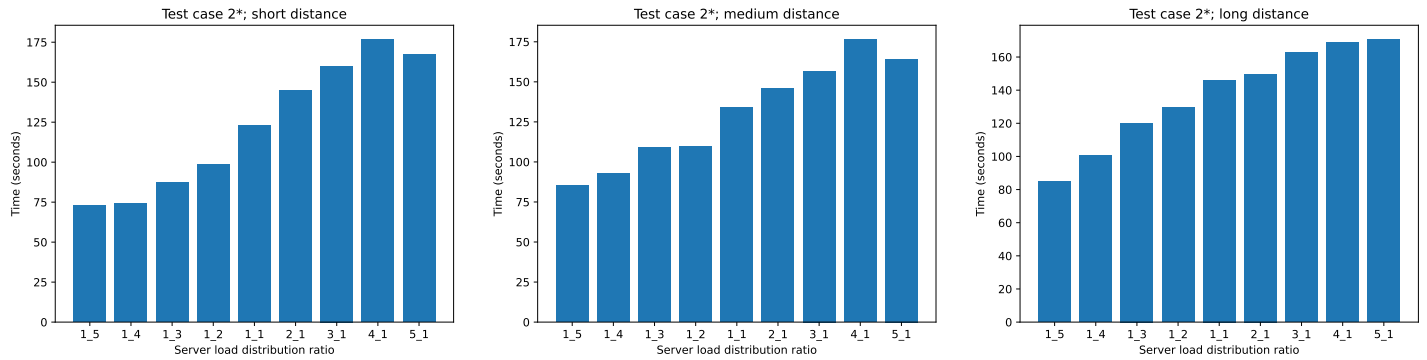


Figure 6: (Scenario 2*) Transfer latency for short, medium and long distance from AP.

to section 2.2, this correlation can only be observed in the cases of Load Distribution Ratios (LDRs) 1:5 through 1:2. As the LDRs increase, the benefit of the higher throughput for Server B is obscured by the latency introduced by Server A.

One last point of comparison with section 2.2, is that the lowest latency observed in both scenarios is very similar. In contrast, when comparing section 2.1 and section 2.3, we found that the total latency in Scenario 1 was lower than that of Scenario 2 across all tests. This was attributed to the fact that the lack of an Ethernet connection for the Client in section 2.3 created a bottleneck for the entire system, and thus it performed unfavorably when compared to section 2.1. However in this case, due to the very low throughput of Server A, being housed remotely, the total amount of data directed to the Client is not enough to overwhelm its remote connection, therefore no benefit is observed in section 2.2, where the Client was connected via Ethernet.

3 Appendix

The following appendix provides additional information on the experiments conducted in this study. Specifically, we include line graphs showing the transmission latency at different distances from the wireless access point, as well as topological layouts of the experimental setup for each trial. These figures serve to supplement the data presented in the main body of the report and provide a more comprehensive understanding of the results.

3.1 IP Address & Device Details

Name	Device	IP Address
Client	Laptop	192.168.1.9
Server A	Laptop	192.168.1.14
Server B	Smartphone	192.168.1.3

Table 9: (Scenario 1) Devices & IP addresses of scenario components.

Name	Device	IP Address
Client	Laptop	192.168.1.9
Server A	Remote Machine	13.93.51.1
Server B	Smartphone	192.168.1.3

Table 10: (Scenario 1*) Devices & IP addresses of scenario components.

Name	Device	IP Address
Client	Laptop	192.168.1.9
Server A	Laptop	192.168.1.14
Server B	Smartphone	192.168.1.3

Table 11: (Scenario 2) Devices & IP addresses of scenario components.

Name	Device	IP Address
Client	Smartphone	192.168.1.3
Server A	Remote Machine	13.93.51.1
Server B	Smartphone	192.168.1.4

Table 12: (Scenario 2*) Devices & IP addresses of scenario components.

3.2 Transmission Latency Graphs & Topological Layouts

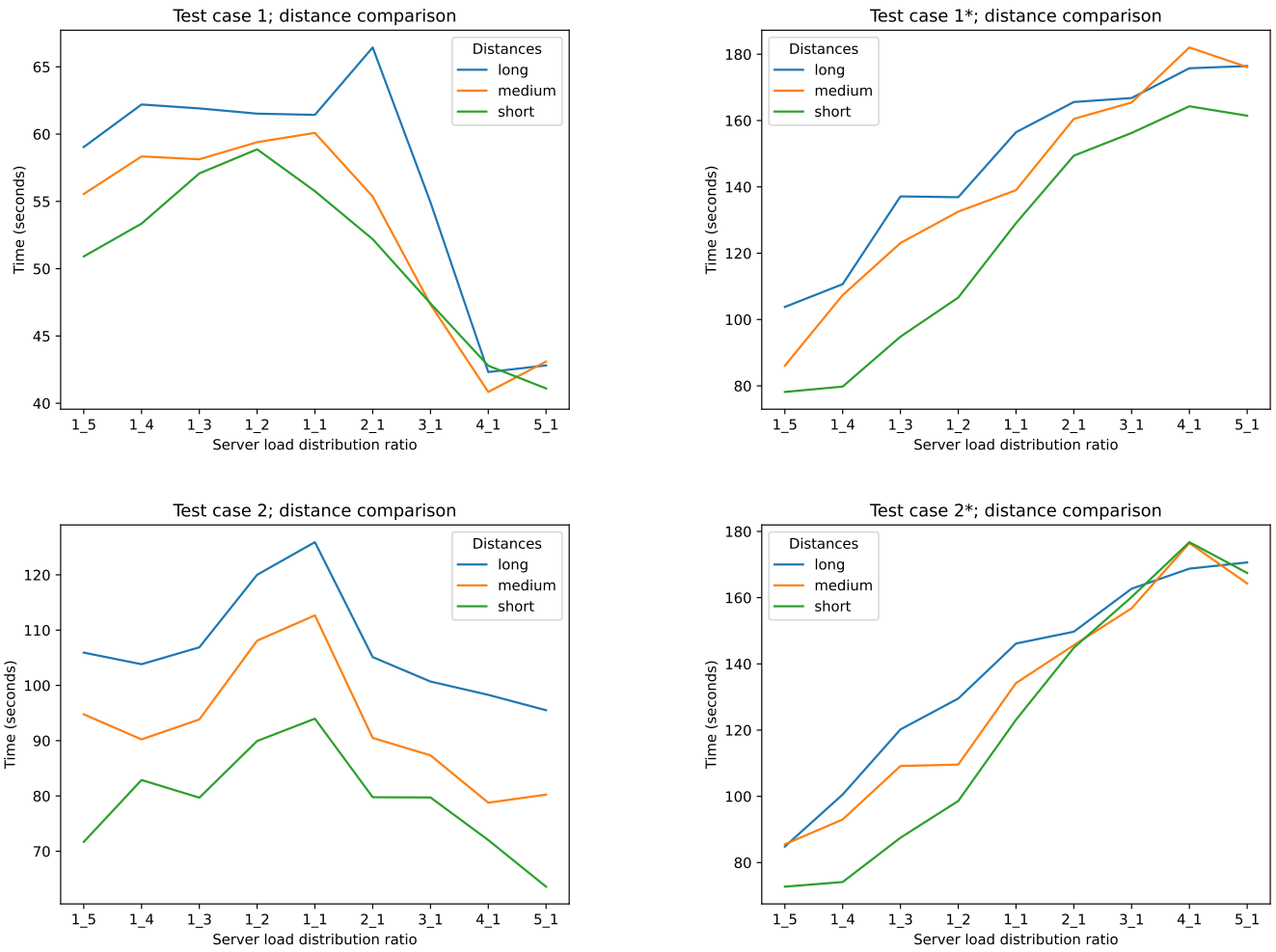
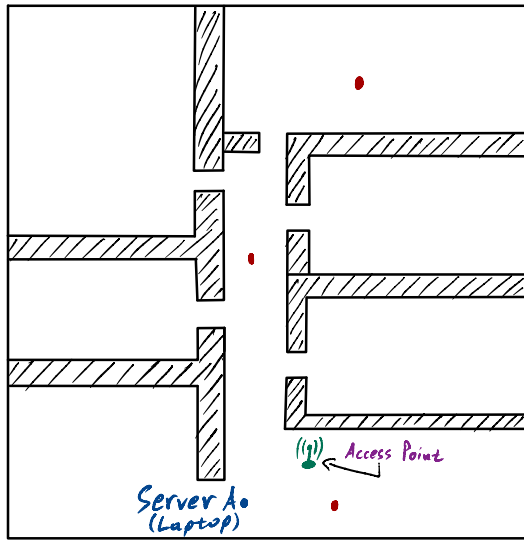


Figure 7: Combined transfer times for short, medium and long distance from AP for each scenario.

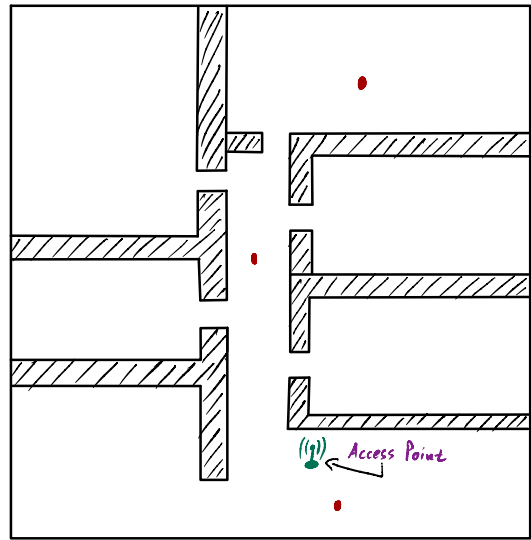
Layout (Test Case 1)



Laptop Client:
• ethernet

• Wireless AP
• Server B (Smartphone)
test Locations

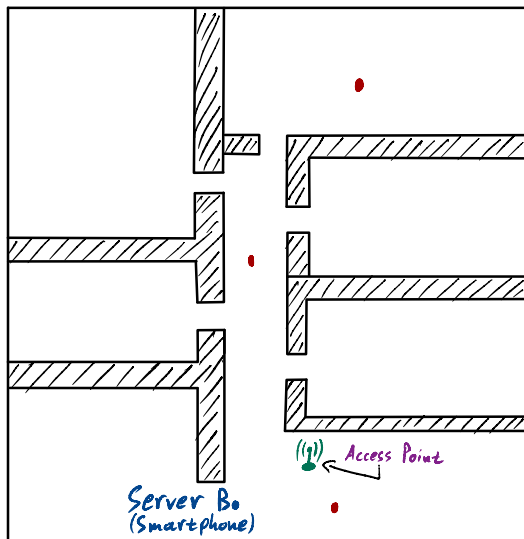
Layout (Test Case 1*)



Laptop Client:
• ethernet
Server A:
• cloud

• Wireless AP
• Server B (Smartphone)
test Locations

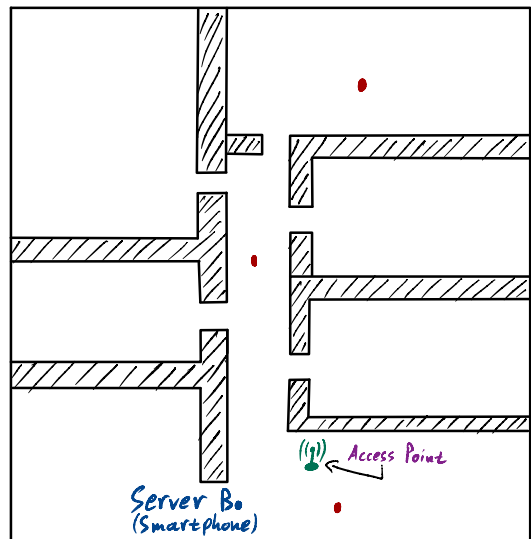
Layout (Test Case 2)



Server A (laptop)
• ethernet

• Wireless AP
• Client (Laptop)
test Locations

Layout (Test Case 2*)



Server A:
• cloud

• Wireless AP
• Client (Smartphone)
test Locations

Figure 8: Measurement layouts for each experiment scenario.