Project 2: HTTP CLI Web Client

CS513 - Computer Networks

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Introduction

For this assignment, a simple command-line (CLI) tool has been developed in Python to function as an HTTP web client. The tool allows users to: send HTTP GET requests to a specified server, retrieve web content to a file, and measure and display the round-trip time (RTT) for the request as well as individual packet sizes and times. The client supports HTTP/1.0 and includes additional enhancements for verbose output. The code can be found in the GitHub repository: `https://github.com/javiervela/http_cli_webclient`. The repository includes a README file with instructions on how to run the client and details about its features.

1 Measuring RTT around the World

In the first exercise, we measure the RTT to various universities around the world. Table 1 shows the university names, domains, and locations. The RTT measurements were taken from Worcester Polytechnic Institute (WPI) in the United States. For each university, we recorded the minimum, maximum, median, and mean RTT values (see Table 2). Additionally, we calculated the geographical distance from WPI to each university and to the resolved IP address of each university's domain (see Table 3). The distances were computed using the Haversine formula based on latitude and longitude coordinates.

On Table 3 we can observe that most non-US universities have their domains resolved to US-based IP addresses. This is likely due to the use of Content Delivery Networks (CDNs) or other hosting services that distribute content closer to the end-users. This phenomenon is reflected in Figure 1, which shows the relationship between RTT and distance to the university. The universities with US-based IP addresses tend to have lower RTTs regardless of their actual geographical distance from WPI. For example, the National University of Singapore and Kyoto University (found in the lower-right corner of the figure) are geographically distant from WPI, but their RTT is relatively low because their domain resolves to a US-based IP address.

Table 1: List of universities and their locations.

University	Domain	Latitude	Longitude	Country
ETH Zurich	www.ethz.ch	47.413218	8.537491	Schweiz
Gonzaga University	www.gonzaga.edu	47.667102	-117.403055	United States
Harvard University	www.harvard.edu	42.365743	-71.122214	United States
Harvey Mudd College	www.hmc.edu	34.106140	-117.708728	United States
Indian Institute of Technology Madras	www.iitm.ac.in	12.994156	80.236683	India
Kyoto University	www.kyoto-u.ac.jp	35.022930	135.777149	Japan
National Autonomous University of Mexico	www.unam.mx	19.321597	-99.184926	México
National University of Singapore	www.nus.edu.sg	1.296202	103.776898	Singapore
Sorbonne University	www.sorbonne-universite.fr	48.846900	2.357449	France
Tsinghua University	www.tsinghua.edu.cn	40.002291	116.320963	China
University of Barcelona	www.ub.edu	41.386860	2.163478	España
University of British Columbia	www.ubc.ca	49.257891	-123.242976	Canada
University of California, Los Angeles	www.ucla.edu	34.019832	-118.278064	United States
University of Cambridge	www.cam.ac.uk	52.210946	0.092005	United Kingdom
University of Melbourne	www.unimelb.edu.au	-37.824137	144.917089	Australia
University of North Dakota	www.und.edu	47.926541	-97.072121	United States
University of Toronto	www.toronto.edu	43.663462	-79.397760	Canada
University of Zaragoza	www.unizar.es	41.634557	-0.899798	España
Victoria University of Wellington	www.vuw.ac.nz	-36.848242	174.767756	New Zealand
Worcester Polytechnic Institute	www.wpi.edu	42.274315	-71.808457	United States

Table 2: University RTT statistics.

Domain	Country	RTT min	RTT max	RTT median	RTT mean
www.cam.ac.uk	United Kingdom	15	21	17	17.35
www.ethz.ch	Switzerland	85	314	86	99.90
www.gonzaga.edu	United States	81	109	84	86.35
www.harvard.edu	United States	17	35	20	21.60
www.hmc.edu	United States	77	95	80	82.15
www.iitm.ac.in	India	300	378	340	341.05
www.kyoto-u.ac.jp	Japan	18	36	19	21.00
www.nus.edu.sg	Singapore	16	31	17	17.95
www.sorbonne-universite.fr	France	17	21	19	19.10
www.toronto.edu	Canada	21	26	23	22.95
www.tsinghua.edu.cn	China	256	310	258	264.55
www.ub.edu	España	104	165	106	110.45
www.ubc.ca	Canada	15	31	19	19.30
www.ucla.edu	United States	16	52	18	19.60
www.unam.mx	México	18	28	19	20.55
www.und.edu	United States	45	54	49	48.85
www.unimelb.edu.au	Australia	16	23	18	18.45
www.unizar.es	España	96	135	97	99.40
www.vuw.ac.nz	New Zealand	214	323	239	243.05
www.wpi.edu	United States	16	21	17	17.70

Table 3: University RTT and distance statistics.

Domain	Country	IP Country	WPI to Uni	WPI to IP	Uni to IP
www.cam.ac.uk	United Kingdom	US	5309	4273	8567
www.ethz.ch	Schweiz	CH	6072	6075	5
www.gonzaga.edu	United States	US	3583	3732	153
www.harvard.edu	United States	US	57	4275	4328
www.hmc.edu	United States	US	4062	4023	1338
www.iitm.ac.in	India	IN	13238	13231	8
www.kyoto-u.ac.jp	Japan	US	10973	599	11098
www.nus.edu.sg	Singapore	US	15150	4276	13613
www.sorbonne-universite.fr	France	US	5588	4274	8955
www.toronto.edu	Canada	CA	636	637	5
www.tsinghua.edu.cn	China	CN	10830	10840	12
www.ub.edu	España	ES	5924	5942	86
www.ubc.ca	Canada	US	3985	608	3765
www.ucla.edu	United States	US	4113	608	3656
www.unam.mx	México	US	3623	4274	3041
www.und.edu	United States	US	2069	2066	3
www.unimelb.edu.au	Australia	AU	16875	16178	717
www.unizar.es	España	ES	5683	5732	144
www.vuw.ac.nz	New Zealand	NZ	14422	14641	494
www.wpi.edu	United States	US	0	599	599

If we look at the distance to the university IP address (Figure 2), we can see a clearer correlation between RTT and distance. Universities with IP addresses located closer to WPI generally have lower RTTs, while those with IP addresses located farther away tend to have higher RTTs. There is still an "anomalous" point in the lower-right corner, which corresponds to the University of Melbourne. This university's domain resolves to an IP address in Australia, which is geographically distant from WPI, but it has a relatively low RTT. This could be due to various factors, such as efficient routing paths or the presence of high-speed undersea cables that connect Australia to the US.

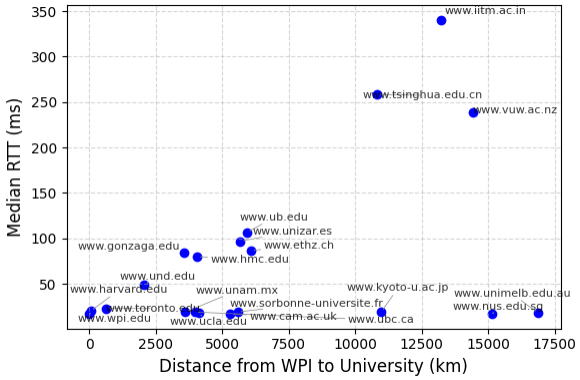

Figure 1: RTT vs. distance to university.

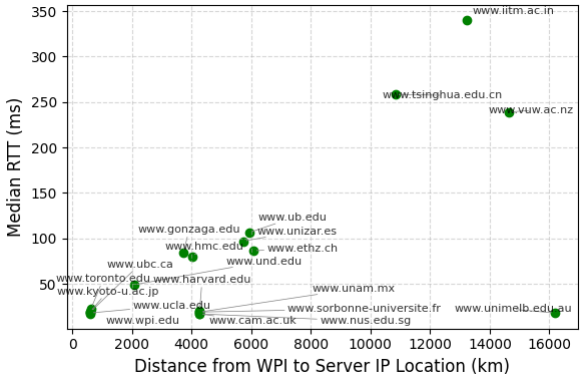

Figure 2: RTT vs. distance to university IP.

2 Measuring Packet Sizes

In the second exercise, we measure the size of each chunk read from the socket as data is received. For every chunk, we record both its size and the time it was received. This enables us to analyze the distribution of packet sizes and their timing for different universities (Table 4). The Python code in Listing 1 shows how the client collects this information.

Table 4: Packet Statistics per University

Domain	Total Bytes	Packet Min	Packet Max	Packet Mode	Packet Median
www.ethz.ch	163	163	163	163	163
www.fu-berlin.de	442	442	442	442	442
www.gonzaga.edu	415	415	415	415	415
www.harvard.edu	349	349	349	349	349
www.hmc.edu	432	432	432	432	432
www.iitm.ac.in	79	79	79	79	79
www.kcl.ac.uk	208	208	208	208	208
www.kyoto-u.ac.jp	401	401	401	401	401
www.unam.mx	659	659	659	659	659
www.nus.edu.sg	107	107	107	107	107
www.sorbonne-universite.fr	382	382	382	382	382
www.tsinghua.edu.cn	316	316	316	316	316
www.ub.edu	444	444	444	444	444
www.ubc.ca	700	700	700	700	700
www.ucla.edu	557	557	557	557	557
www.cam.ac.uk	433	433	433	433	433
www.unimelb.edu.au	799	799	799	799	799
www.und.edu	119	119	119	119	119
www.ox.ac.uk	246	246	246	246	246
www.toronto.edu	537	537	537	537	537
www.unizar.es	379	379	379	379	379
www.vuw.ac.nz	122	122	122	122	122
www.wpi.edu	653	653	653	653	653

```
def _receive_all(self, sock):
    response = b""
    buffer_size = 10240  # 10K bytes
    while True:
        chunk = sock.recv(buffer_size)
        read_time = time.time()
        if not chunk:
            break
        response += chunk
        self.packet_sizes.append(len(chunk))
        self.packet_times.append(read_time)
    return response.decode(errors="ignore")
```

Listing 1: Receiving all data and tracking packet sizes and times

Because the universities' websites do not host large files, and most of them do not answer to our HTTP requests, we selected four public mirrors that host large files for downloading. For our measurements, we chose files with sizes between 200K and 500K bytes from each mirror. These mirrors are `ubuntu.cs.wpi.edu` (WPI, USA), `ftp.debian.org` (USA), `mirror.junda.nl` (Netherlands), and `mirrors.dotsrc.org` (Denmark).

Table 5 shows the packet statistics for each mirror, including total bytes received, minimum, maximum, mode, and median packet sizes. For these mirrors, we observe that the maximum chunk size is 10K bytes. Expected because for each read operation, we request up to 10K bytes from the socket. The mode and median values are also 10K bytes for most mirrors, indicating that the majority of chunks are of maximum size.

Table 5: Packet Statistics per Mirror

Mirror	Total Bytes	Packet Min	Packet Max	Packet Mode	Packet Median
ubuntu.cs.wpi.edu	484786	70	10240	10240	10240
ftp.debian.org	322035	1280	10240	10240	10240
mirror.junda.nl	230598	578	10240	10240	10240
mirrors.dotsrc.org	287808	70	10240	2740	2740

Figure 3 illustrates the cumulative bytes received over time for all mirrors. We can visually identify the differences in download speeds and patterns among the mirrors. Both US-based mirrors show significantly faster download speeds compared to the European mirrors. We can visually identify the "flights" of packets, where multiple packets are received in quick succession, followed by periods of lower activity. We can especially see this in the EU-based mirrors, where the packet arrivals are more spread out over time. The number of chunks read per each of these "flights" varies.

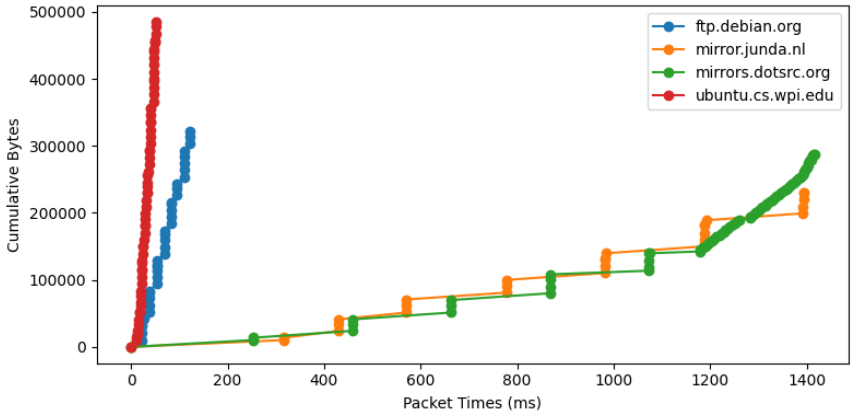

Figure 3: Cumulative bytes vs packet times for all mirrors.

3 Measuring RTT with `TCP_INFO`

Besides using the RTT measurements obtained with the `-ping` option, we retrieve the RTT estimates using the `TCP_INFO` socket option. Table 6 shows our mean RTT estimates alongside the RTT values obtained from `TCP_INFO`. Figure 4 shows a scatter plot comparing the mean RTT values with the RTT values from `TCP_INFO`. Both RTT measurement methods show a positive correlation, with values clustered near the diagonal. This suggests that the `-ping` option and `TCP_INFO` provide similar network latency estimates.

Table 6: University RTT statistics using `TCP_INFO`.

Domain	RTT_mean	RTT (TCP_INFO)	RTT_var (TCP_INFO)
www.ethz.ch	99.90	84	32
www.fu-berlin.de	114.40	114	63
www.gonzaga.edu	86.35	80	30
www.harvard.edu	21.60	15	6
www.hmc.edu	82.15	74	29
www.iitm.ac.in	341.05	399	152
www.kcl.ac.uk	87.60	78	29
www.kyoto-u.ac.jp	21.00	15	6
www.unam.mx	20.55	15	5
www.nus.edu.sg	17.95	13	5
www.sorbonne-universite.fr	19.10	15	5
www.tsinghua.edu.cn	264.55	281	111
www.ub.edu	110.45	150	72
www.ubc.ca	19.30	15	5
www.ucla.edu	19.60	15	5
www.cam.ac.uk	17.35	13	5
www.unimelb.edu.au	18.45	15	5
www.und.edu	48.85	41	16
www.ox.ac.uk	17.45	15	6
www.toronto.edu	22.95	23	9
www.unizar.es	99.40	93	35
www.vuw.ac.nz	243.05	285	112
www.wpi.edu	17.70	13	5

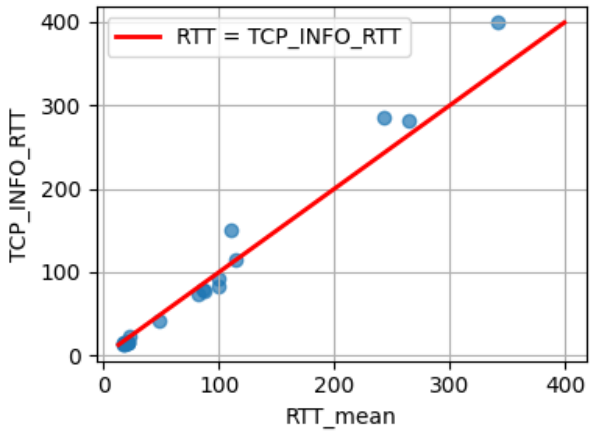

Figure 4: RTT mean vs RTT (TCP_INFO) for universities.