Computer Networks Lab - Week 2

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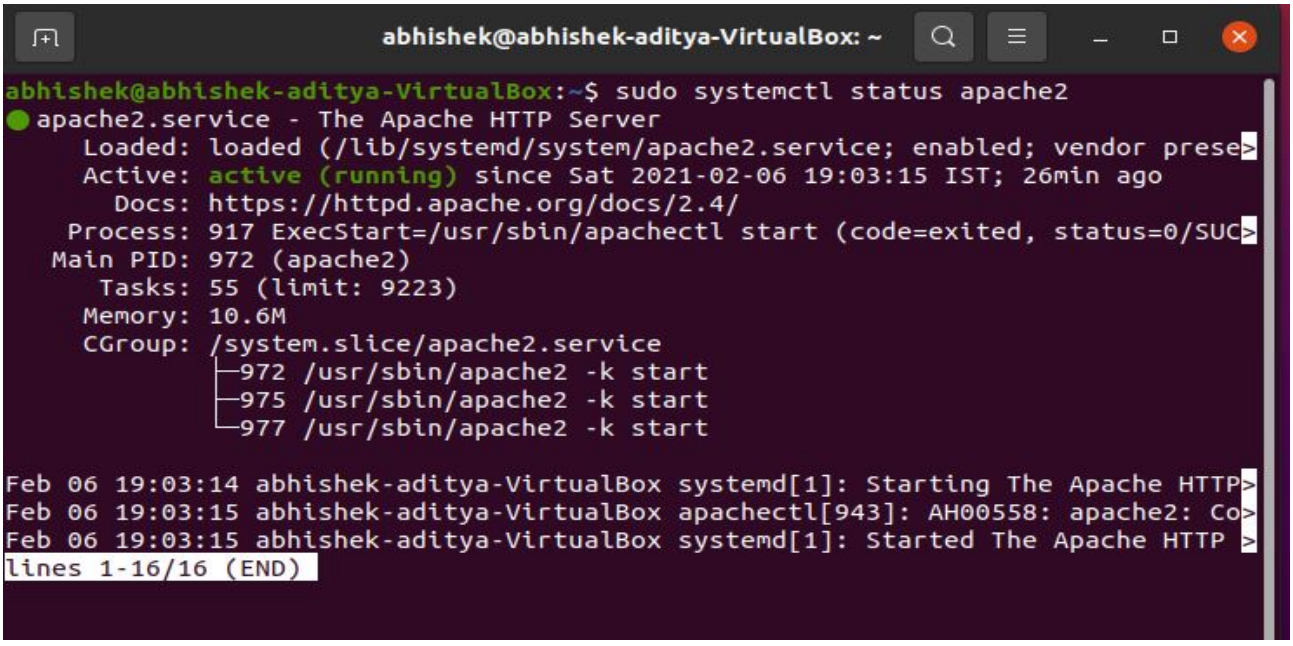
Section : A
Semester : 4

1.Configuration of Apache Server and Client Environment

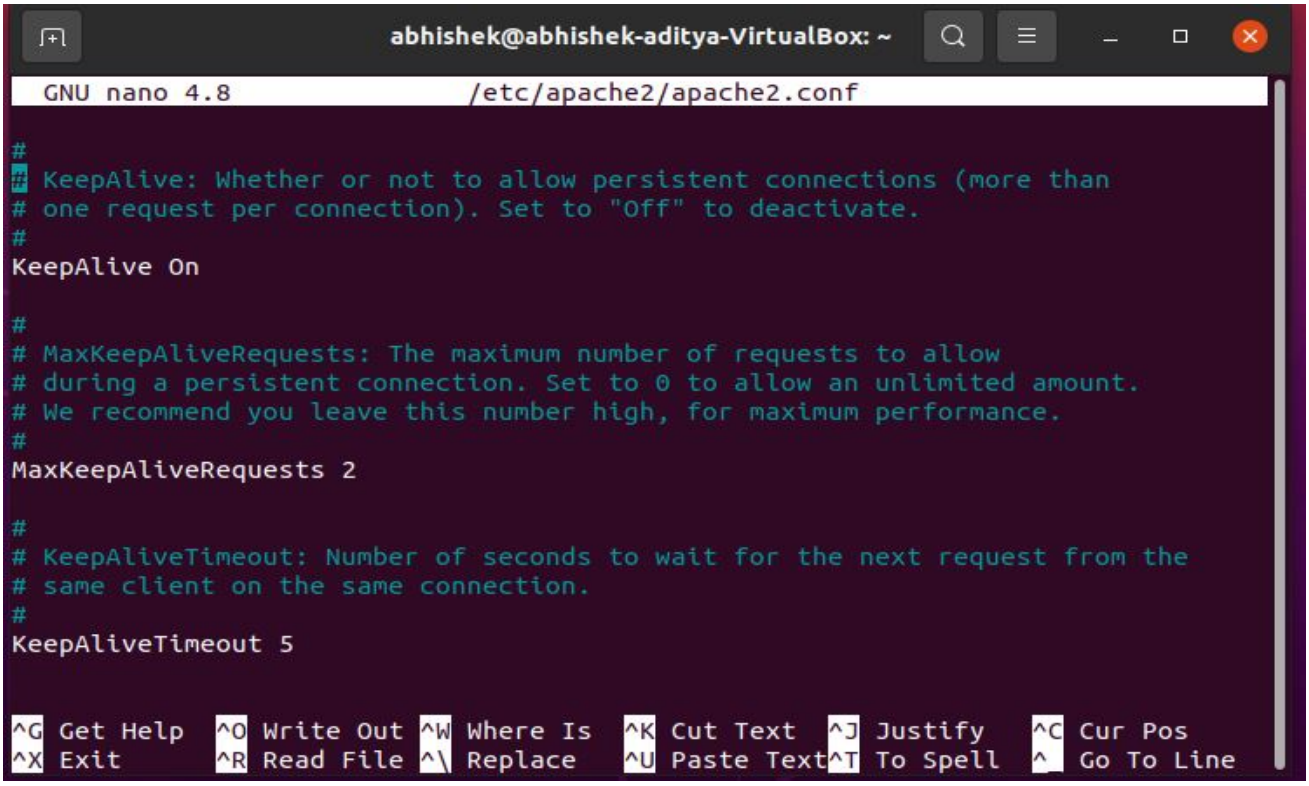
- ➔ To create a server – client architecture, two Virtual Machines were set up. The former is referred to as the server machine and the latter is the client machine.
- ➔ Apache Server was installed and configured on the server machine, and a static webpage consisting of 10 objects (images) was created and hosted on the local network between these machines.
- ➔ We need to observe and determine the effect of the number of persistent connections on the load time of this static webpage.

1.1 Setting up Apache Server

- The apache server is installed with the command
  `sudo apt-get install apache2`
- The status of the newly installed server can be verified using
  `sudo systemctl status apache2`

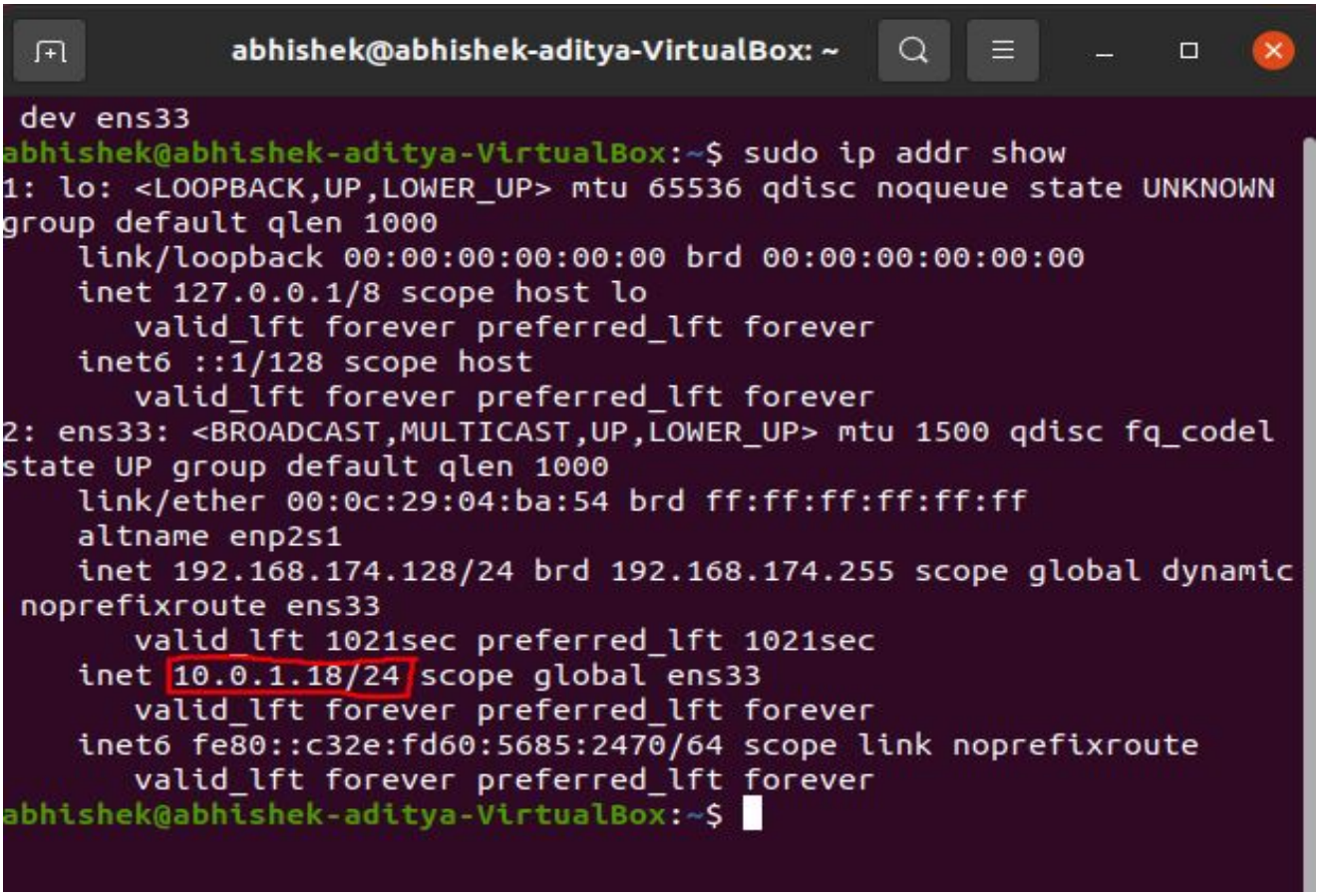


- The Apache Server also needs to be configured to allow persistent connections. This is done by editing the **apache2.conf** configuration file and setting the options
    - ➢ The **keepAlive** option was set (i.e. value was made **ON**)
    - ➢ The **MaximumKeepAliveRequests** were set to **2**



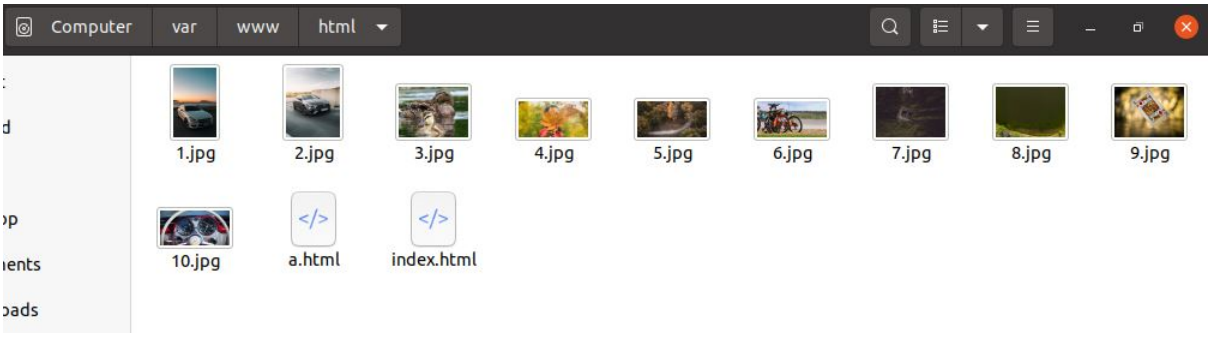
1.2 Adding Custom IP Addresses for Server and Client

- A custom IP Address was set for both the Server and Client machines
- The **Server IP Address** was set to **10.0.1.18** and the **Client IP Address** was set to **10.0.1.19** as per the serial number.
- The IP address were assigned using **`sudo ip addr add`**



1.3 Hosting the Webpage

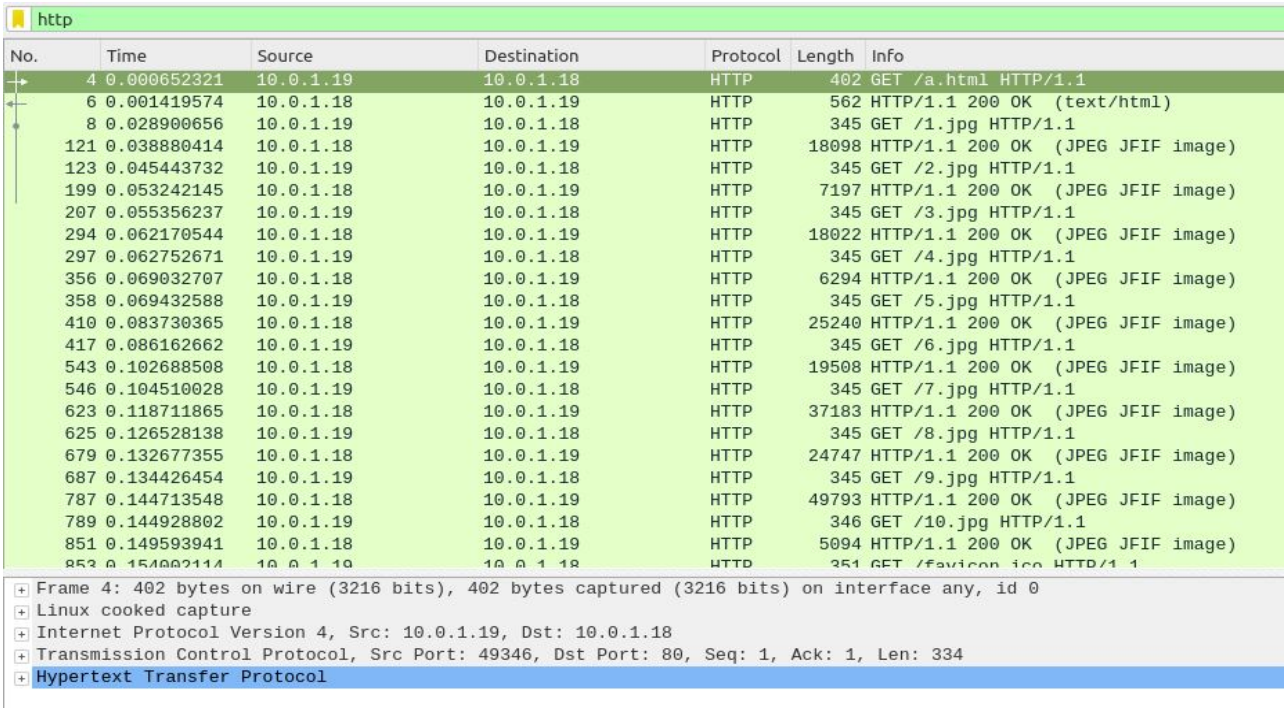
- The webpage can be hosted by moving the html script and the images to the server path
- The server path is **/var/www/html/**
- An HTML file was created which contains 10 images(1.jpg,2.jpg,...) each of 2 MB size and the file along with the images were placed at the server path **/var/www/html/**



2. Non-Persistent Connection

- To setup a non-persistent connection, we need to configure a few settings on our browser
- On Firefox, we set the **`max-persistent-connections-per-server`** to **0** and **`persistent-settings`** to **`false`**

Packet Capture Screenshot



Time taken to capture images

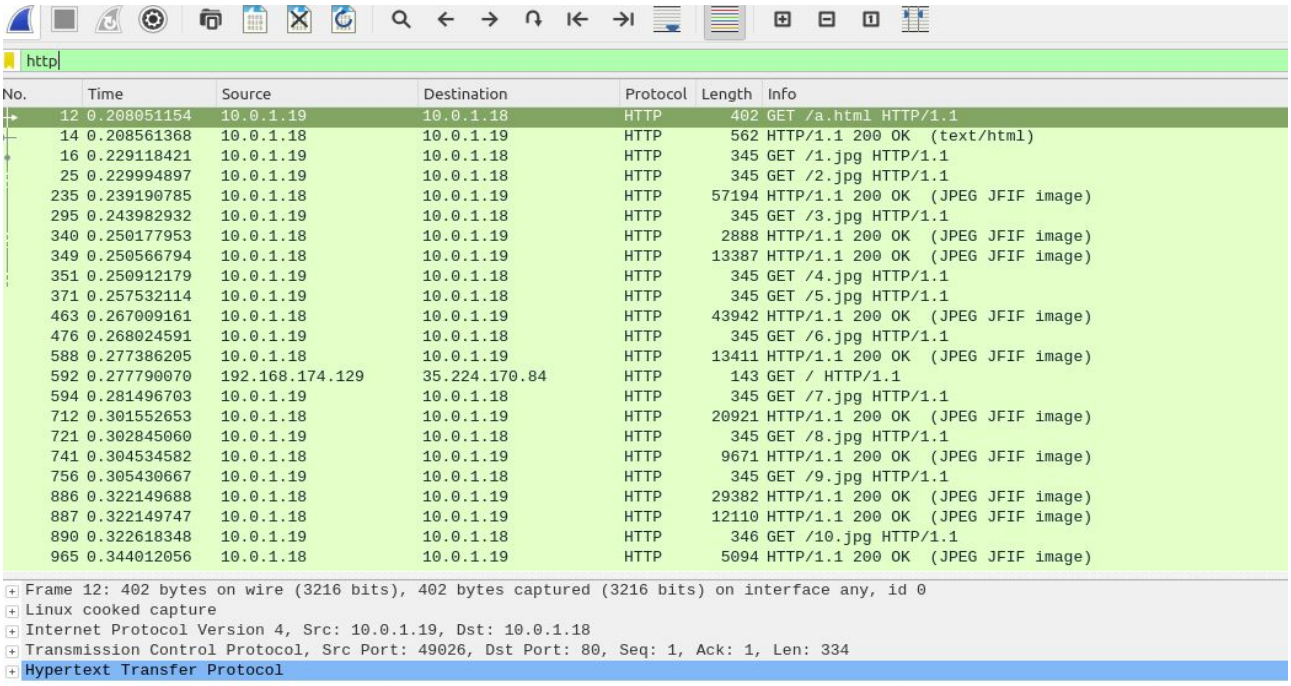
0.149593941 - 0.000652321 = 0.14894162

3. Persistent Connection

- To setup a persistent connection, we need to configure a few settings on our browser
- On Firefox, we set the **max-persistent-connections-per-server** to anything greater than **0** and **persistent-settings** to **true**

3.1 2 Persistent Connections

Packet Capture Screenshot



http

No.	Time	Source	Destination	Protocol	Length	Info
12	0.208051154	10.0.1.19	10.0.1.18	HTTP	402	GET /a.html HTTP/1.1
14	0.208561368	10.0.1.18	10.0.1.19	HTTP	562	HTTP/1.1 200 OK (text/html)
16	0.229118421	10.0.1.19	10.0.1.18	HTTP	345	GET /1.jpg HTTP/1.1
25	0.229994897	10.0.1.19	10.0.1.18	HTTP	345	GET /2.jpg HTTP/1.1
235	0.239190785	10.0.1.18	10.0.1.19	HTTP	57194	HTTP/1.1 200 OK (JPEG JFIF image)
295	0.243982932	10.0.1.19	10.0.1.18	HTTP	345	GET /3.jpg HTTP/1.1
340	0.250177953	10.0.1.18	10.0.1.19	HTTP	2888	HTTP/1.1 200 OK (JPEG JFIF image)
349	0.250566794	10.0.1.18	10.0.1.19	HTTP	13387	HTTP/1.1 200 OK (JPEG JFIF image)
351	0.250912179	10.0.1.19	10.0.1.18	HTTP	345	GET /4.jpg HTTP/1.1
371	0.257532114	10.0.1.19	10.0.1.18	HTTP	345	GET /5.jpg HTTP/1.1
463	0.267009161	10.0.1.18	10.0.1.19	HTTP	43942	HTTP/1.1 200 OK (JPEG JFIF image)
476	0.268024591	10.0.1.19	10.0.1.18	HTTP	345	GET /6.jpg HTTP/1.1
588	0.277386205	10.0.1.18	10.0.1.19	HTTP	13411	HTTP/1.1 200 OK (JPEG JFIF image)
592	0.277790070	192.168.174.129	35.224.170.84	HTTP	143	GET / HTTP/1.1
594	0.281496703	10.0.1.19	10.0.1.18	HTTP	345	GET /7.jpg HTTP/1.1
712	0.301552653	10.0.1.18	10.0.1.19	HTTP	20921	HTTP/1.1 200 OK (JPEG JFIF image)
721	0.302845060	10.0.1.19	10.0.1.18	HTTP	345	GET /8.jpg HTTP/1.1
741	0.304534582	10.0.1.18	10.0.1.19	HTTP	9671	HTTP/1.1 200 OK (JPEG JFIF image)
756	0.305430667	10.0.1.19	10.0.1.18	HTTP	345	GET /9.jpg HTTP/1.1
886	0.322149688	10.0.1.18	10.0.1.19	HTTP	29382	HTTP/1.1 200 OK (JPEG JFIF image)
887	0.322149747	10.0.1.18	10.0.1.19	HTTP	12110	HTTP/1.1 200 OK (JPEG JFIF image)
890	0.322618348	10.0.1.19	10.0.1.18	HTTP	346	GET /10.jpg HTTP/1.1
965	0.344012056	10.0.1.18	10.0.1.19	HTTP	5094	HTTP/1.1 200 OK (JPEG JFIF image)

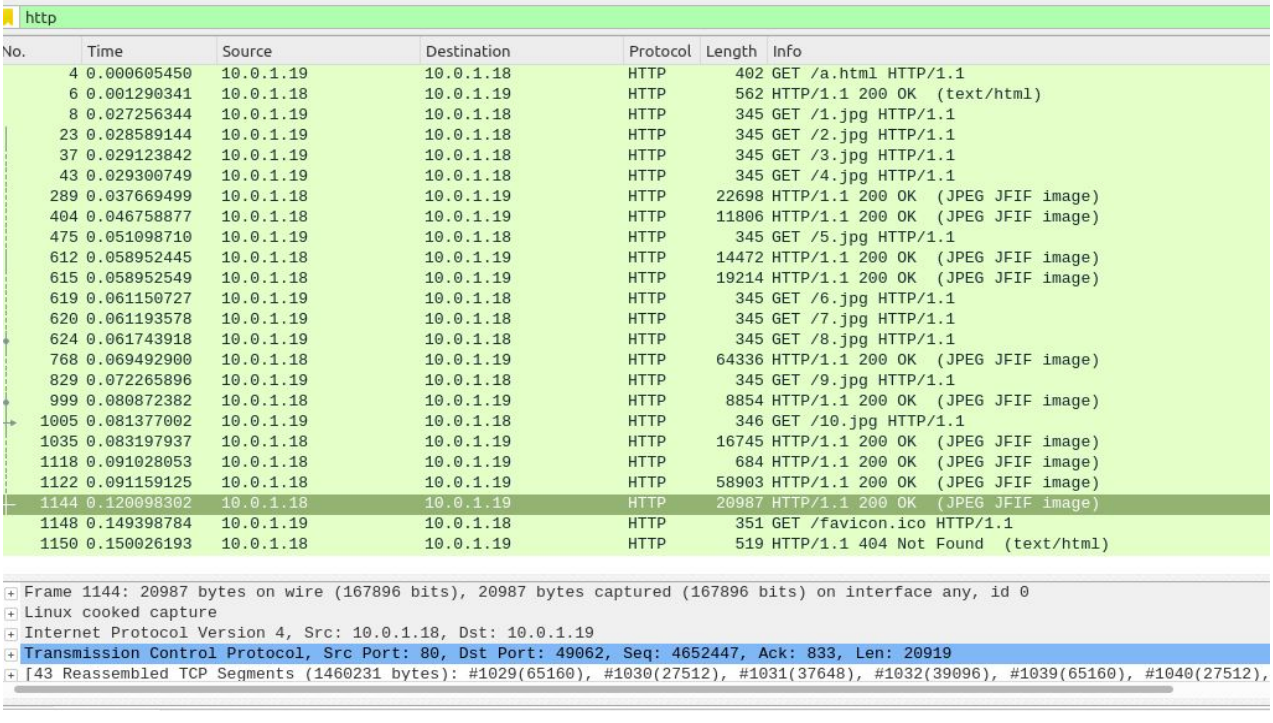
```
Frame 12: 402 bytes on wire (3216 bits), 402 bytes captured (3216 bits) on interface any, id 0
Linux cooked capture
Internet Protocol Version 4, Src: 10.0.1.19, Dst: 10.0.1.18
Transmission Control Protocol, Src Port: 49026, Dst Port: 80, Seq: 1, Ack: 1, Len: 334
Hypertext Transfer Protocol
```

Time taken to capture images

0.344012056-0.208051154 = 0.135960902

3.2 4 Persistent Connections

Packet Capture Screenshot



http

No.	Time	Source	Destination	Protocol	Length	Info
4	0.000605450	10.0.1.19	10.0.1.18	HTTP	402	GET /a.html HTTP/1.1
6	0.001290341	10.0.1.18	10.0.1.19	HTTP	562	HTTP/1.1 200 OK (text/html)
8	0.027256344	10.0.1.19	10.0.1.18	HTTP	345	GET /1.jpg HTTP/1.1
23	0.028589144	10.0.1.19	10.0.1.18	HTTP	345	GET /2.jpg HTTP/1.1
37	0.029123842	10.0.1.19	10.0.1.18	HTTP	345	GET /3.jpg HTTP/1.1
43	0.029300749	10.0.1.19	10.0.1.18	HTTP	345	GET /4.jpg HTTP/1.1
289	0.037669499	10.0.1.18	10.0.1.19	HTTP	22698	HTTP/1.1 200 OK (JPEG JFIF image)
404	0.046758877	10.0.1.18	10.0.1.19	HTTP	11806	HTTP/1.1 200 OK (JPEG JFIF image)
475	0.051098710	10.0.1.19	10.0.1.18	HTTP	345	GET /5.jpg HTTP/1.1
612	0.058952445	10.0.1.18	10.0.1.19	HTTP	14472	HTTP/1.1 200 OK (JPEG JFIF image)
615	0.058952549	10.0.1.18	10.0.1.19	HTTP	19214	HTTP/1.1 200 OK (JPEG JFIF image)
619	0.061150727	10.0.1.19	10.0.1.18	HTTP	345	GET /6.jpg HTTP/1.1
620	0.061193578	10.0.1.19	10.0.1.18	HTTP	345	GET /7.jpg HTTP/1.1
624	0.061743918	10.0.1.19	10.0.1.18	HTTP	345	GET /8.jpg HTTP/1.1
768	0.069492900	10.0.1.18	10.0.1.19	HTTP	64336	HTTP/1.1 200 OK (JPEG JFIF image)
829	0.072265896	10.0.1.19	10.0.1.18	HTTP	345	GET /9.jpg HTTP/1.1
999	0.080872382	10.0.1.18	10.0.1.19	HTTP	8854	HTTP/1.1 200 OK (JPEG JFIF image)
1005	0.081377002	10.0.1.19	10.0.1.18	HTTP	346	GET /10.jpg HTTP/1.1
1035	0.083197937	10.0.1.18	10.0.1.19	HTTP	16745	HTTP/1.1 200 OK (JPEG JFIF image)
1118	0.091028053	10.0.1.18	10.0.1.19	HTTP	684	HTTP/1.1 200 OK (JPEG JFIF image)
1122	0.091159125	10.0.1.18	10.0.1.19	HTTP	58903	HTTP/1.1 200 OK (JPEG JFIF image)
1144	0.120098302	10.0.1.18	10.0.1.19	HTTP	20987	HTTP/1.1 200 OK (JPEG JFIF image)
1148	0.149398784	10.0.1.19	10.0.1.18	HTTP	351	GET /favicon.ico HTTP/1.1
1150	0.150026193	10.0.1.18	10.0.1.19	HTTP	519	HTTP/1.1 404 Not Found (text/html)

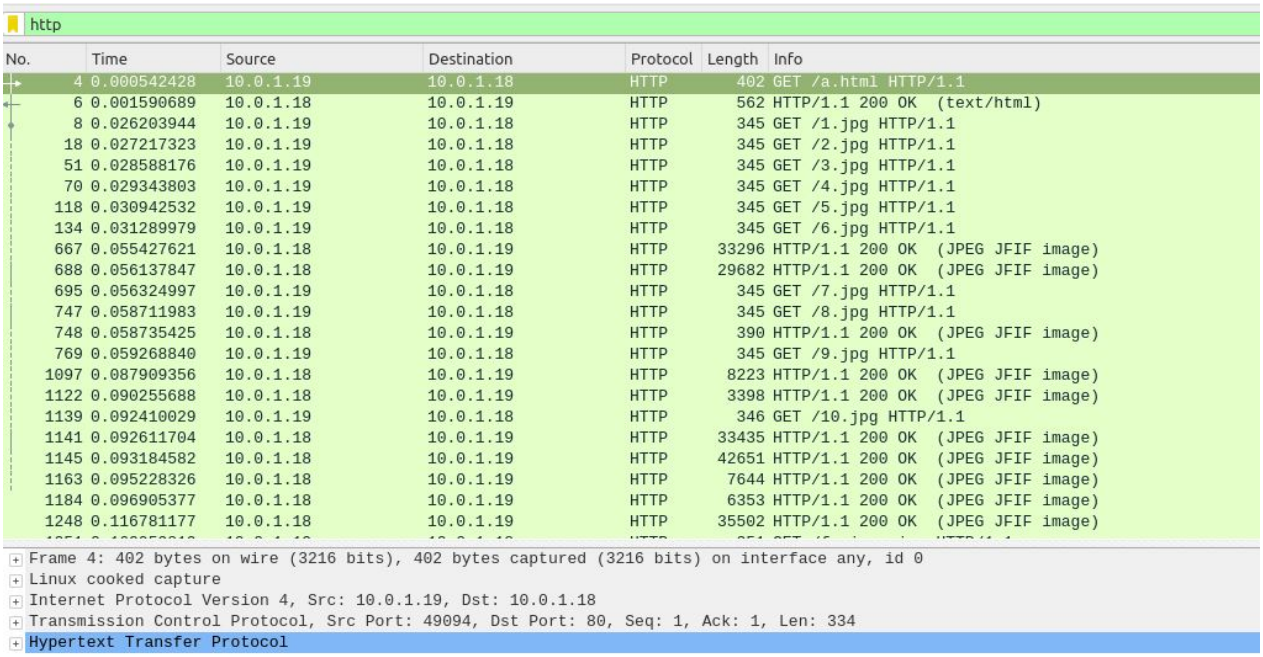
```
Frame 1144: 20987 bytes on wire (167896 bits), 20987 bytes captured (167896 bits) on interface any, id 0
Linux cooked capture
Internet Protocol Version 4, Src: 10.0.1.18, Dst: 10.0.1.19
Transmission Control Protocol, Src Port: 80, Dst Port: 49062, Seq: 4652447, Ack: 833, Len: 20919
[43 Reassembled TCP Segments (1460231 bytes): #1029(65160), #1030(27512), #1031(37648), #1032(39096), #1039(65160), #1040(27512),
```

Time taken to capture images

0.120098302-0.000605450 = 0.119492852

3.3 6 Persistent Connections

Packet Capture Screenshot



http

No.	Time	Source	Destination	Protocol	Length	Info
4	0.000542428	10.0.1.19	10.0.1.18	HTTP	402	GET /a.html HTTP/1.1
6	0.001590689	10.0.1.18	10.0.1.19	HTTP	562	HTTP/1.1 200 OK (text/html)
8	0.026203944	10.0.1.19	10.0.1.18	HTTP	345	GET /1.jpg HTTP/1.1
18	0.027217323	10.0.1.19	10.0.1.18	HTTP	345	GET /2.jpg HTTP/1.1
51	0.028588176	10.0.1.19	10.0.1.18	HTTP	345	GET /3.jpg HTTP/1.1
70	0.029343803	10.0.1.19	10.0.1.18	HTTP	345	GET /4.jpg HTTP/1.1
118	0.030942532	10.0.1.19	10.0.1.18	HTTP	345	GET /5.jpg HTTP/1.1
134	0.031289979	10.0.1.19	10.0.1.18	HTTP	345	GET /6.jpg HTTP/1.1
667	0.055427621	10.0.1.18	10.0.1.19	HTTP	33296	HTTP/1.1 200 OK (JPEG JFIF image)
688	0.056137847	10.0.1.18	10.0.1.19	HTTP	29682	HTTP/1.1 200 OK (JPEG JFIF image)
695	0.056324997	10.0.1.19	10.0.1.18	HTTP	345	GET /7.jpg HTTP/1.1
747	0.058711983	10.0.1.19	10.0.1.18	HTTP	345	GET /8.jpg HTTP/1.1
748	0.058735425	10.0.1.18	10.0.1.19	HTTP	390	HTTP/1.1 200 OK (JPEG JFIF image)
769	0.059268840	10.0.1.19	10.0.1.18	HTTP	345	GET /9.jpg HTTP/1.1
1097	0.087909356	10.0.1.18	10.0.1.19	HTTP	8223	HTTP/1.1 200 OK (JPEG JFIF image)
1122	0.090255688	10.0.1.18	10.0.1.19	HTTP	3398	HTTP/1.1 200 OK (JPEG JFIF image)
1139	0.092410029	10.0.1.19	10.0.1.18	HTTP	346	GET /10.jpg HTTP/1.1
1141	0.092611704	10.0.1.18	10.0.1.19	HTTP	33435	HTTP/1.1 200 OK (JPEG JFIF image)
1145	0.093184582	10.0.1.18	10.0.1.19	HTTP	42651	HTTP/1.1 200 OK (JPEG JFIF image)
1163	0.095228326	10.0.1.18	10.0.1.19	HTTP	7644	HTTP/1.1 200 OK (JPEG JFIF image)
1184	0.096905377	10.0.1.18	10.0.1.19	HTTP	6353	HTTP/1.1 200 OK (JPEG JFIF image)
1248	0.116781177	10.0.1.18	10.0.1.19	HTTP	35502	HTTP/1.1 200 OK (JPEG JFIF image)

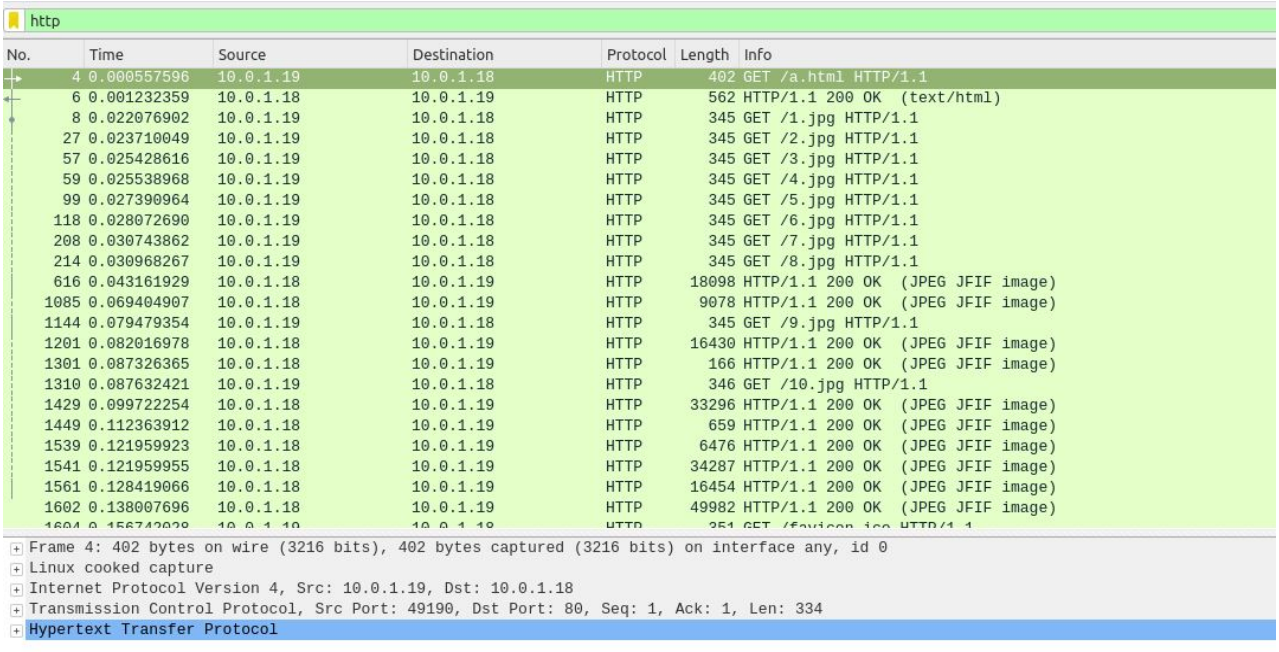
Frame 4: 402 bytes on wire (3216 bits), 402 bytes captured (3216 bits) on interface any, id 0
Linux cooked capture
Internet Protocol Version 4, Src: 10.0.1.19, Dst: 10.0.1.18
Transmission Control Protocol, Src Port: 49094, Dst Port: 80, Seq: 1, Ack: 1, Len: 334
Hypertext Transfer Protocol

Time taken to capture images

0.116781177-0.000542428 = 0.116238749

3.4 8 Persistent Connections

Packet Capture Screenshot



http

No.	Time	Source	Destination	Protocol	Length	Info
4	0.000557596	10.0.1.19	10.0.1.18	HTTP	402	GET /a.html HTTP/1.1
6	0.001232359	10.0.1.18	10.0.1.19	HTTP	562	HTTP/1.1 200 OK (text/html)
8	0.022076902	10.0.1.19	10.0.1.18	HTTP	345	GET /1.jpg HTTP/1.1
27	0.023710049	10.0.1.19	10.0.1.18	HTTP	345	GET /2.jpg HTTP/1.1
57	0.025428616	10.0.1.19	10.0.1.18	HTTP	345	GET /3.jpg HTTP/1.1
59	0.025538968	10.0.1.19	10.0.1.18	HTTP	345	GET /4.jpg HTTP/1.1
99	0.027390964	10.0.1.19	10.0.1.18	HTTP	345	GET /5.jpg HTTP/1.1
118	0.028072690	10.0.1.19	10.0.1.18	HTTP	345	GET /6.jpg HTTP/1.1
208	0.030743862	10.0.1.19	10.0.1.18	HTTP	345	GET /7.jpg HTTP/1.1
214	0.030968267	10.0.1.19	10.0.1.18	HTTP	345	GET /8.jpg HTTP/1.1
616	0.043161929	10.0.1.18	10.0.1.19	HTTP	18098	HTTP/1.1 200 OK (JPEG JFIF image)
1085	0.069404907	10.0.1.18	10.0.1.19	HTTP	9078	HTTP/1.1 200 OK (JPEG JFIF image)
1144	0.079479354	10.0.1.19	10.0.1.18	HTTP	345	GET /9.jpg HTTP/1.1
1201	0.082016978	10.0.1.18	10.0.1.19	HTTP	16430	HTTP/1.1 200 OK (JPEG JFIF image)
1301	0.087326365	10.0.1.18	10.0.1.19	HTTP	166	HTTP/1.1 200 OK (JPEG JFIF image)
1310	0.087632421	10.0.1.19	10.0.1.18	HTTP	346	GET /10.jpg HTTP/1.1
1429	0.099722254	10.0.1.18	10.0.1.19	HTTP	33296	HTTP/1.1 200 OK (JPEG JFIF image)
1449	0.112363912	10.0.1.18	10.0.1.19	HTTP	659	HTTP/1.1 200 OK (JPEG JFIF image)
1539	0.121959923	10.0.1.18	10.0.1.19	HTTP	6476	HTTP/1.1 200 OK (JPEG JFIF image)
1541	0.121959955	10.0.1.18	10.0.1.19	HTTP	34287	HTTP/1.1 200 OK (JPEG JFIF image)
1561	0.128419066	10.0.1.18	10.0.1.19	HTTP	16454	HTTP/1.1 200 OK (JPEG JFIF image)
1602	0.138007696	10.0.1.18	10.0.1.19	HTTP	49982	HTTP/1.1 200 OK (JPEG JFIF image)

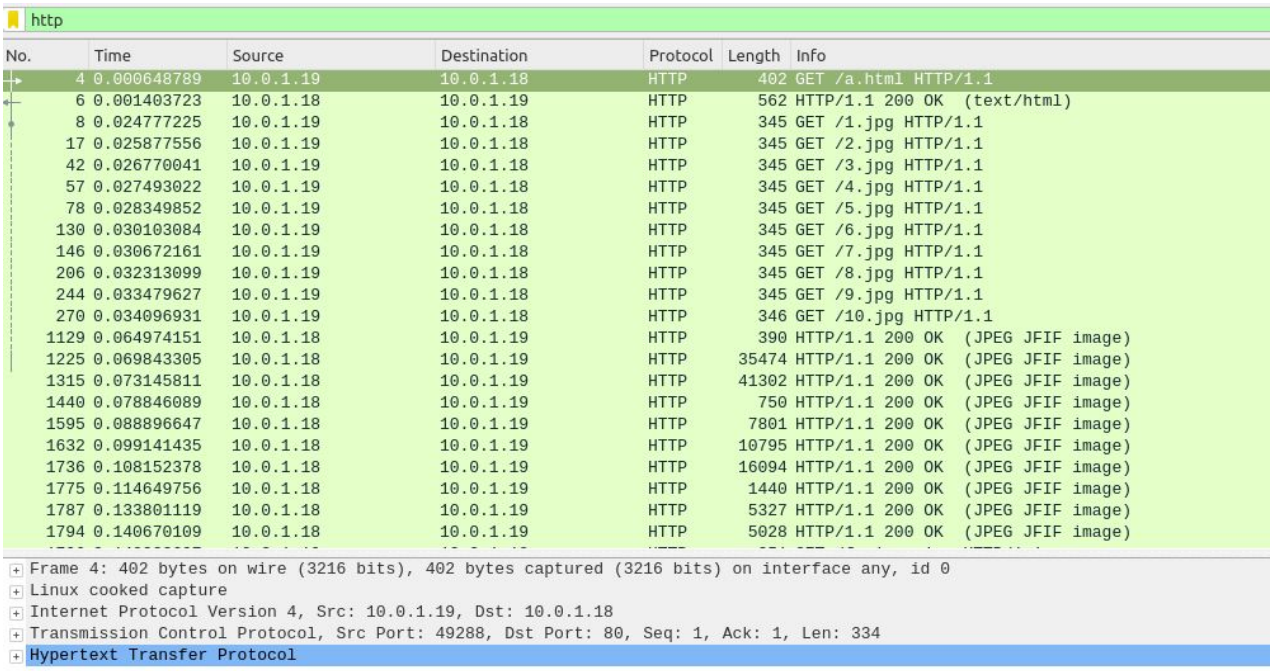
Frame 4: 402 bytes on wire (3216 bits), 402 bytes captured (3216 bits) on interface any, id 0
Linux cooked capture
Internet Protocol Version 4, Src: 10.0.1.19, Dst: 10.0.1.18
Transmission Control Protocol, Src Port: 49190, Dst Port: 80, Seq: 1, Ack: 1, Len: 334
Hypertext Transfer Protocol

Time taken to capture images

0.138007696-0.000557596 = 0.1374501

3.5 10 Persistent Connections

Packet Capture Screenshot



Time taken to capture images

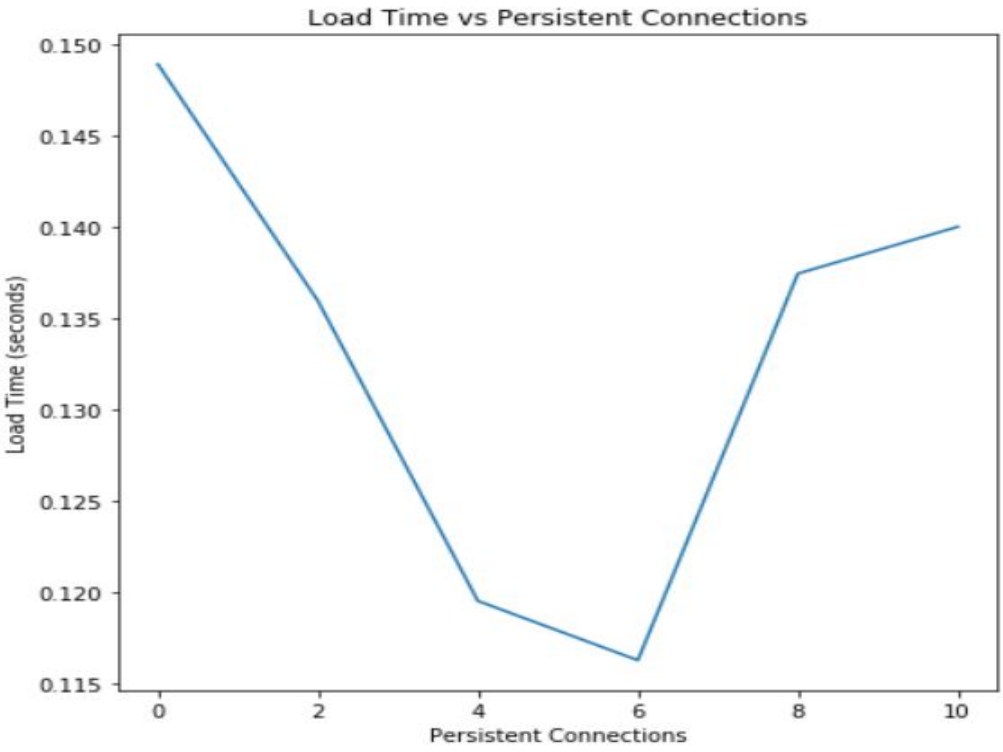
0.140670109-0.000648789 = 0.14002132

4. Observations

- We can calculate the total **load time** as the difference between the first GET time which corresponds to the time when the html page was requested and the last response time, which corresponds to when the last image was sent back.
- On doing so, we can construct the following observations table –

Persistent Connections	Time at first GET	Time at last Response	Load Time
0	0.000652321	0.149593941	0.14894162
2	0.208051154	0.344012056	0.135960902
4	0.000605450	0.120098302	0.119492852
6	0.000542428	0.116781177	0.116238749
8	0.000557596	0.138007696	0.1374501
10	0.000648789	0.140670109	0.14002132

- We can also plot the values of Load Time against the number of Persistent Connections to obtain the following visualisation.



- We can hence see that the **optimal number of persistent connections is 6**, since it corresponds to the lowest load time.
- Initially as the number of persistent connections increases, we can observe that the load time decreases gradually and then steeply. This occurs due to the parallelism and pipelining performed while processing and requesting for image objects.
- This allows for multiple images to be requested at the same time, hence decreasing the load time taken and is much lesser than requesting each individual image serially and individually.
- However, as the number of persistent connections increase, the load time again starts increasing. This is due to the decrease in throughput of each connection with the constant link capacity. Hence the load times increase with an increase in number of persistent connections above a certain threshold.
- It is therefore not suggested to keep an exceedingly high number of persistent connections.