

Investigations into the Structure and Performance of the Internet: ---The Role of the DNS

1. Experiment Objectives

When a user sends a request to a server via its hostname rather than an IP address, the client must have to obtain its IP address from a local DNS before contacting the intended server. The experiment tests and compares the time to contact a DNS and the time to contact the intended server with an IP.

The programming code is in the current directory named after “DNSTest.java”. It can repeatedly receive a hostname from standard input and print to standard output the processed information, including name resolution time ($t_2 - t_1$), and the remaining server response time ($t_3 - t_2$). Beyond the major java program, I write a shell script that running every thirty minutes, and redirect the standard output to a textual file, in CSV format. The data analysis is done in Excel.

2. Experiment Information

The 27 URLs I tested are stored in a separate text file (URLs.txt). They are:

www.unc.edu	www.unimelb.edu.au
www.google.com	www.auckland.ac.nz
www.wikipedia.org	www.alaska.edu
www.harvard.edu	www.colorado.edu
www.stanford.edu	www.umn.edu
www.youtube.com	wustl.edu
www.facebook.com	www.ksu.edu.sa
www.ox.ac.uk	www.msu.ru
www.cam.ac.uk	www.u-tokyo.ac.jp
www.bbc.co.uk	www.nankai.edu.cn
www.unicamp.br	www.unisa.ac.za
www2.planalto.gov.br	www.shenyang.gov.cn
www.unam.mx	(removed due to partial data missing)
sydney.edu.au	english.dl.gov.cn

They include the major regions of the world and all four time zones across the United States. They include both well-known addresses and obscure ones. E.g.

- US Eastern: www.unc.edu,
- US Central: www.umn.edu, www.wustl.edu,
- US Mountain: www.colorado.edu,
- US Western: www.stanford.edu,
- Europe: www.ox.ac.uk, www.cam.ac.uk, www.bbc.co.uk,
- South America: www.unicamp.br,

- Asia: www.nankai.edu.cn, english.dl.gov.cn, www.u-tokyo.ac.jp,
- Oceania: www.unimelb.edu.au, sydney.edu.au, www.auckland.ac.nz,
- Africa: www.unisa.ac.za,

The testing time is categorized as it states:

- Early morning (7-9am)
- Mid-morning (10am-12pm)
- Mid-afternoon (2-5pm)
- Evening (6 – 8pm)
- Night (10pm – 6am)

My sample data is obtained from two periods, i.e.

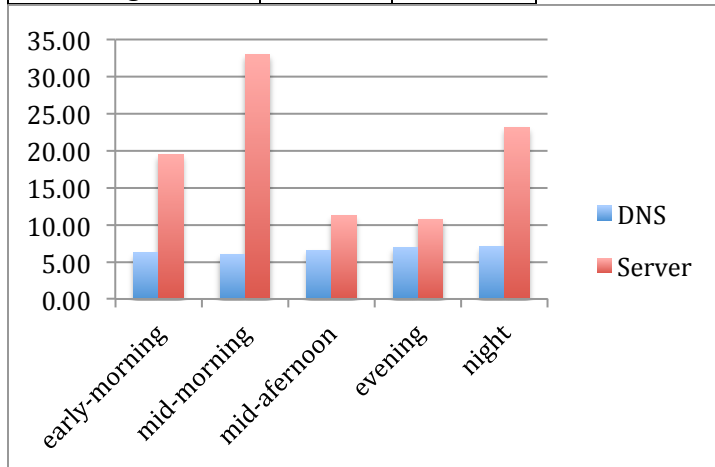
- 10 am, 3/25/2012 ~ 10 am, 3/26/2012
- 10 am, 3/28/2012 ~ 10 am, 3/29/2012

The 24-hour gap is from 3/26/2012 8:54:34 AM ~ 3/27/2012 8:58:30 AM. No experiment is running during the period. Data from the period other than the above is for verification and correction. All qualified sample data is averaged in the analysis, and the raw data is available in the file (log.csv).

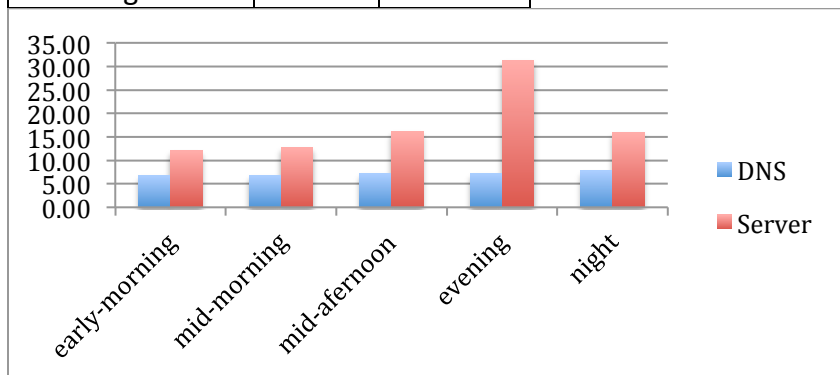
3. Data Analysis

3.1 UNC (www.unc.edu)

3.25~3.26		
Time	DNS	Server
Early-morning	6.25	19.50
Mid-morning	6.00	33.00
Mid-afternoon	6.60	11.20
Evening	7.00	10.75
Night	7.06	23.19



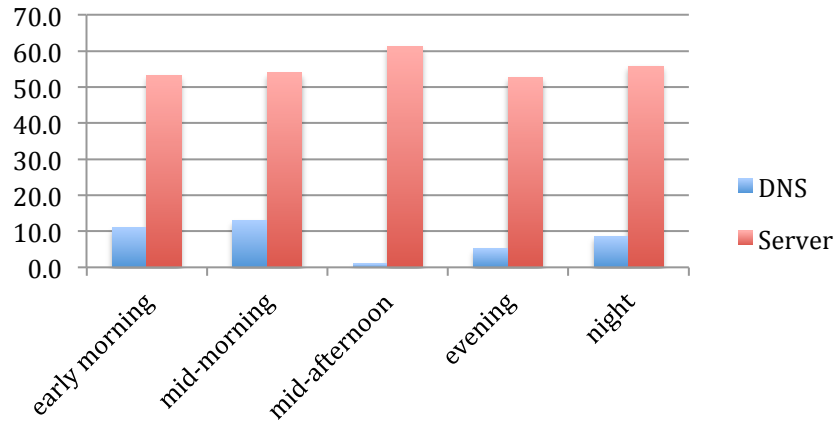
3.28~3.29		
Time	DNS	Server
Early-morning	6.75	12.00
Mid-morning	6.75	12.75
Mid-afternoon	7.17	16.17
Evening	7.25	31.25
Night	7.73	15.93



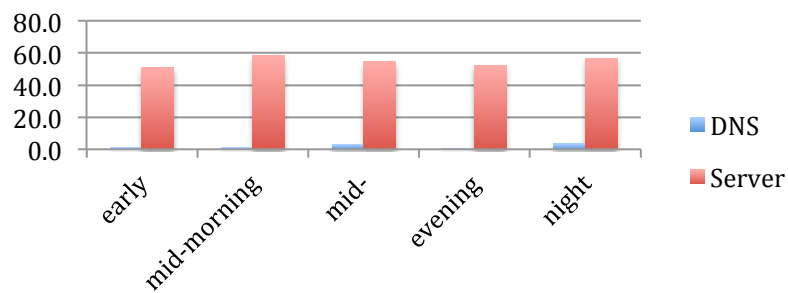
From the above two sets of data, we see that the DNS response time are almost constantly small around 6~7 milliseconds, it may suggest the local DNS service is stable or even may be cached in lots for most computer systems.

3.2 Google (www.google.com)

3.25~3.26		
Time	DNS	Server
Early morning	11.0	53.3
Mid-morning	13.0	54.0
Mid-afternoon	1.0	61.2
Evening	5.3	52.8
Night	8.6	55.8



3.28~3.29		
Time	DNS	Server
Early morning	1.0	51.0
Mid-morning	1.0	58.3
Mid-afternoon	3.2	54.5
Evening	0.8	52.5
Night	3.6	56.7

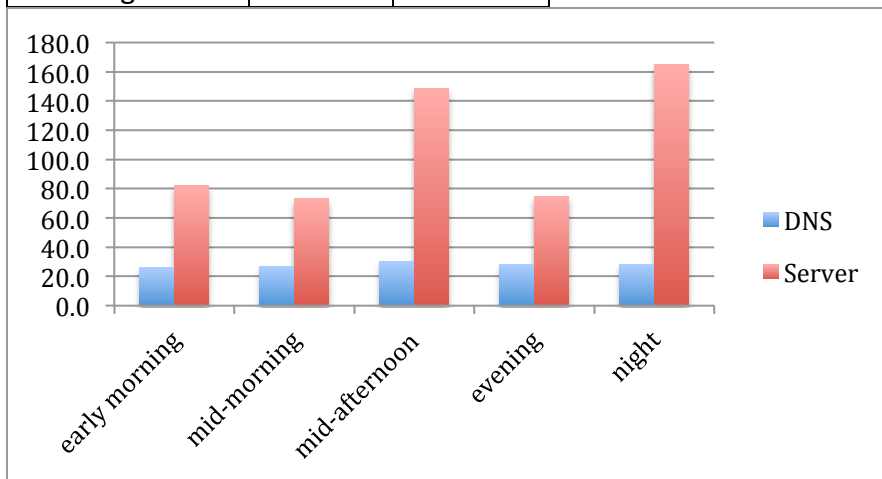


For the Google website, the DNS response time varies. If we explore from its raw data, the local DNS will response with different IP address for Google. If the response IP address is "74.125.65.*", the DNS feedback time is almost always 1 ms, otherwise if the IP address is "173.194.73.*", it will take 20 or so milliseconds. The local DNS may contact an upper level DNS, and if the upper level DNS server does not have a record for the Google.com, it may forward the request to upper level, or even the root sever to resolve a Google address. In such a case, the DNS response time may

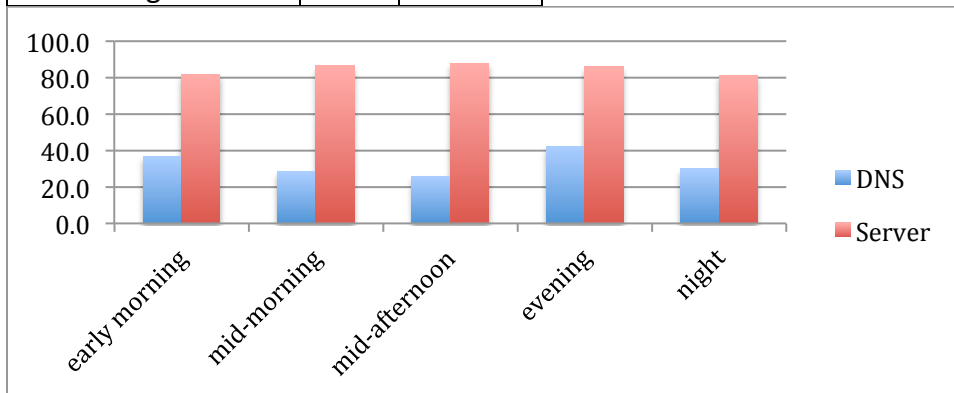
take longer. However, the Google server service time is almost constant, regardless of day and night. It may be inferred that Google may implement some techniques to balance its network flow all over the world.

3.3 Harvard (www.harvard.edu)

3.25~3.26		
Time	DNS	Server
Early morning	26.0	82.3
Mid-morning	27.0	73.0
Mid-afternoon	30.5	148.5
Evening	28.5	75.0
Night	28.2	164.8



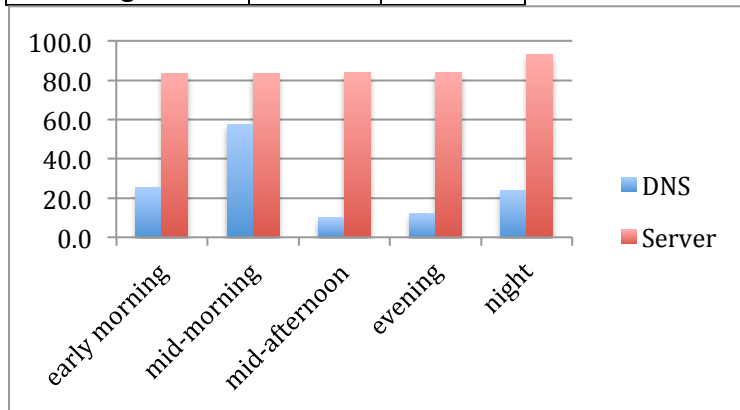
3.28~3.29		
Time	DNS	Server
Early morning	36.8	82.0
Mid-morning	28.3	86.5
Mid-afternoon	26.0	87.8
Evening	42.3	86.0
Night	29.9	81.2



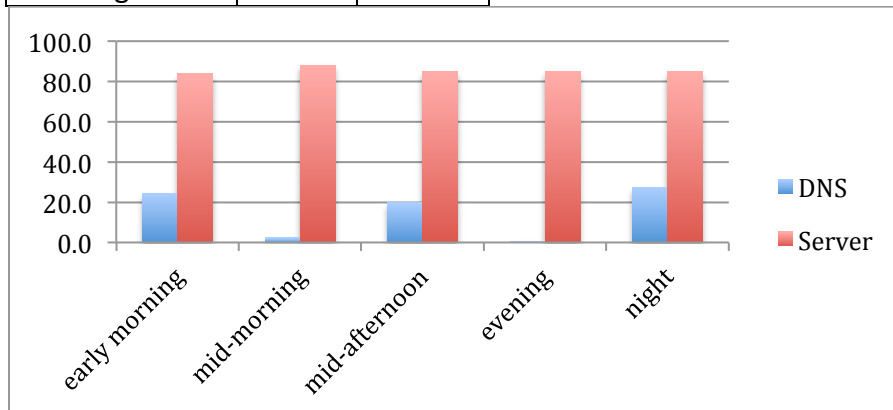
The access to the Harvard University, the DNS response time is generally stable, during the first experiment, the web server response time has some fluctuations, but this may be due the small sample size, or before the experiment. If manually type the URL in the browser may have some impact on the local DNS record.

3. 4 Washington University in St. Louis (wustl.edu)

3.25~3.26		
Time	DNS	Server
Early morning	25.3	83.5
Mid-morning	57.5	83.5
Mid-afternoon	9.8	83.8
Evening	12.3	84.0
Night	23.9	93.0



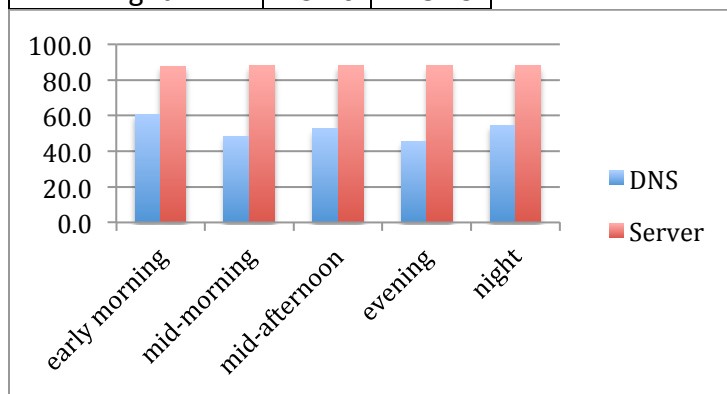
3.28~3.29		
Time	DNS	Server
Early morning	24.5	83.8
Mid-morning	2.3	88.0
Mid-afternoon	19.7	84.8
Evening	0.5	85.0
Night	27.3	84.8



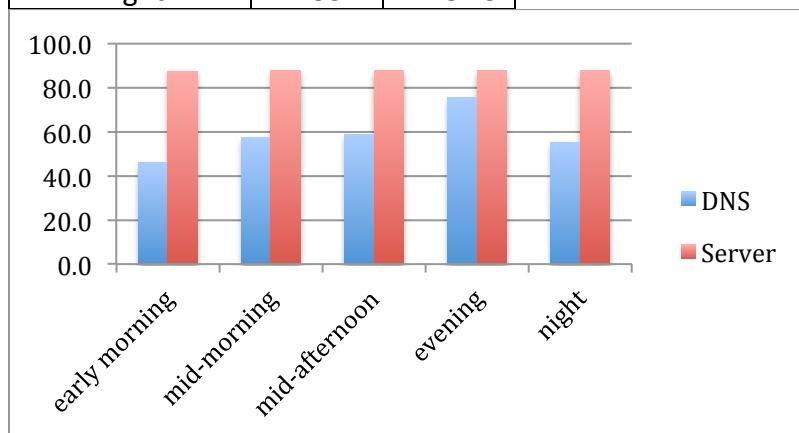
The DNS response time is small and sometimes a single digit. In this case, it's unstable across the day. The web server for wustl.edu is significantly stable at 80~90 ms range.

3.5 UMN(www.umn.edu)

3.25~3.26		
Time	DNS	Server
Early morning	60.8	87.8
Mid-morning	48.5	88.0
Mid-afternoon	52.5	88.2
Evening	45.5	88.0
Night	54.6	87.9



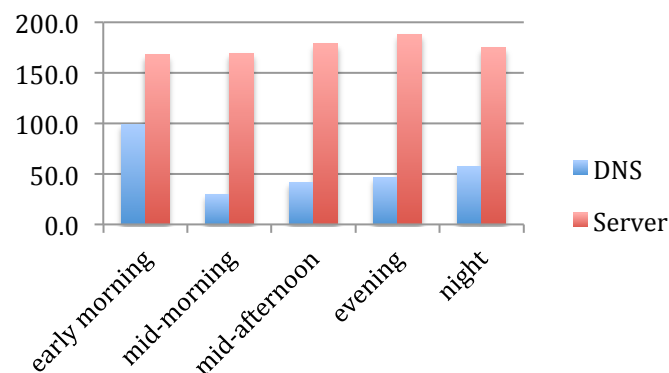
3.28~3.29		
Time	DNS	Server
Early morning	46.0	87.5
Mid-morning	57.3	88.0
Mid-afternoon	58.8	88.0
Evening	75.8	87.8
Night	55.2	87.9



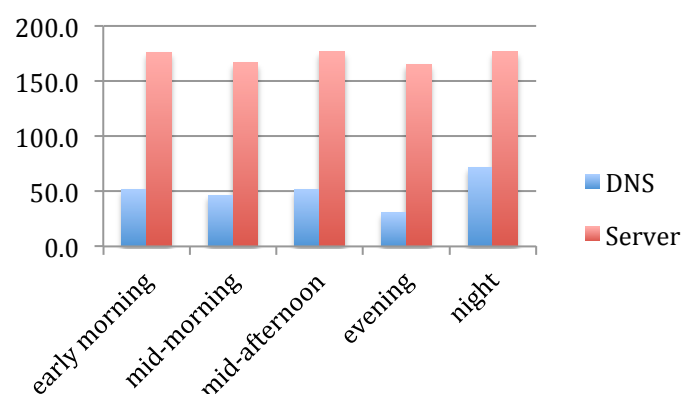
For the university of Minnesota, both the DNS response time and the web server response time are stable across the day.

3.6 University of Colorado (www.colorado.edu)

3.25~3.26		
Time	DNS	Server
Early morning	99.0	168.0
Mid-morning	29.5	169.0
Mid-afternoon	41.7	178.7
Evening	46.0	188.0
Night	56.9	175.0



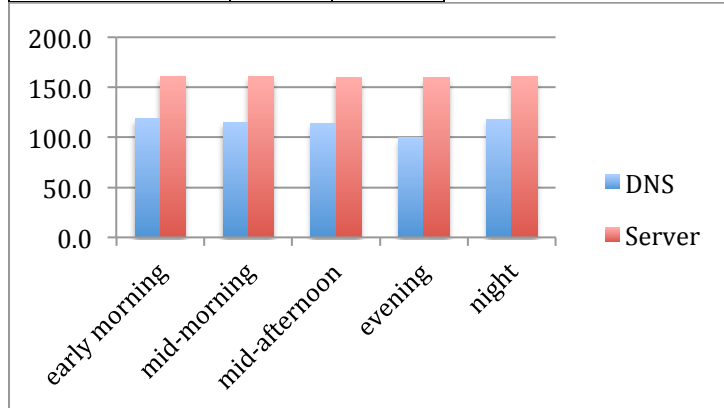
3.28~3.29		
Time	DNS	Server
Early morning	52.0	175.8
Mid-morning	46.5	166.5
Mid-afternoon	52.0	176.7
Evening	30.5	165.3
Night	71.7	176.5



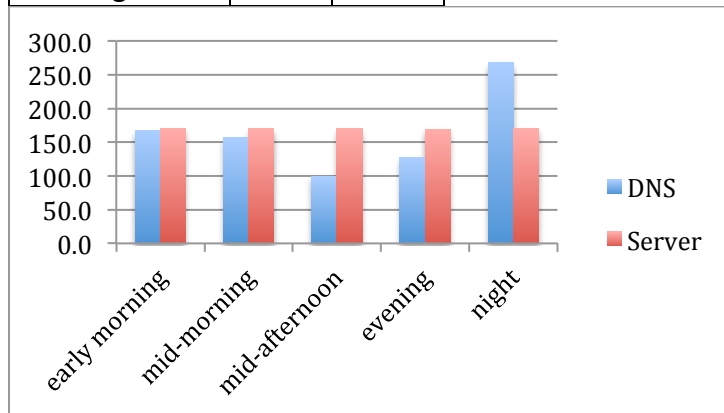
The DNS response time is almost the same as the university in a central region, however it takes longer to access to its web server. The response time almost doubles.

3.7 Stanford University (www.stanford.edu)

3.25~3.26		
Time	DNS	Server
Early morning	118.5	161.3
Mid-morning	115.0	161.0
Mid-afternoon	113.7	160.2
Evening	99.8	160.3
Night	118.1	160.6



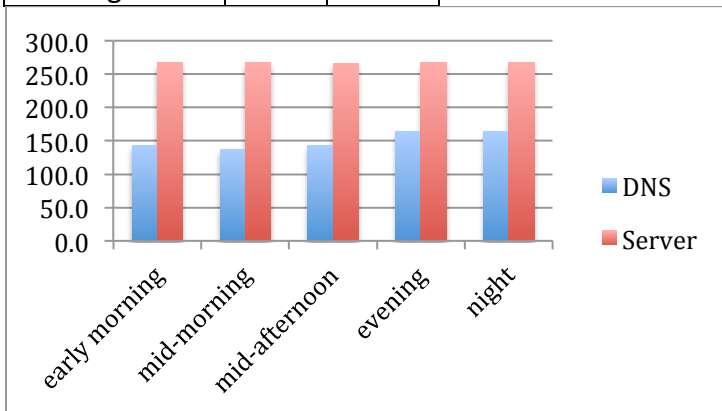
3.28~3.29		
Time	DNS	Server
Early morning	166.8	170.3
Mid-morning	156.5	169.8
Mid-afternoon	99.5	169.7
Evening	126.8	169.5
Night	267.5	170.1



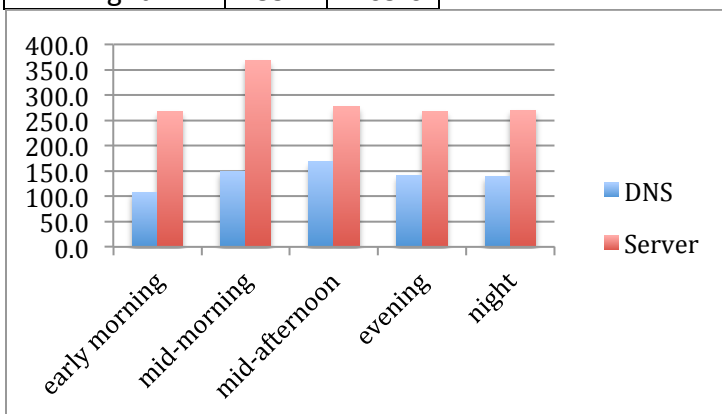
Both the DNS and web server response time increases greatly compared with the access to a website at an eastern zone. It may suggest that the DNS also takes more redirects to resolve the address of Stanford University.

3.8 University of Alaska (www.alaska.edu)

3.25~3.26		
Time	DNS	Server
Early morning	143.0	267.0
Mid-morning	137.5	267.5
Mid-afternoon	143.5	266.7
Evening	164.5	267.3
Night	164.4	267.4



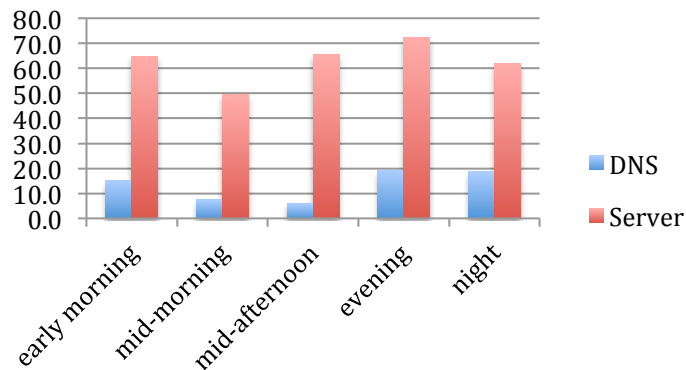
3.28~3.29		
Time	DNS	Server
Early morning	108.3	267.8
Mid-morning	149.3	368.8
Mid-afternoon	168.5	277.7
Evening	141.3	268.3
Night	139.7	269.6



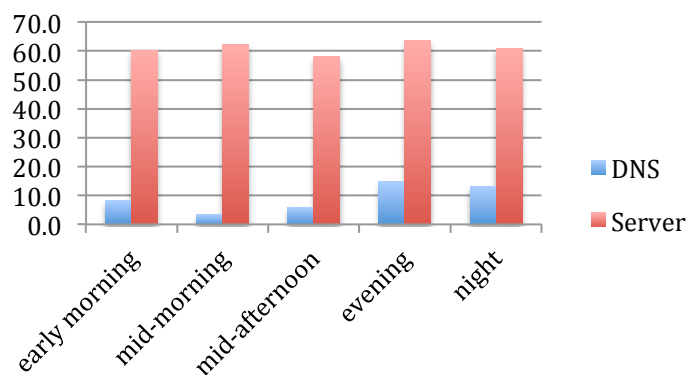
The DNS server response time is almost the same as a western state university. It may suggest that the address is resolved within a DNS server located on the major continent of the US, and it takes more hops to access its webserver. In the first experiment, no obvious access speed variation across the day. In the 2nd experiment, a bit more access time occurs in the mid-morning.

3.9 YouTube (www.youtube.com)

3.25~3.26		
Time	DNS	Server
Early morning	15.0	64.8
Mid-morning	7.5	49.5
Mid-afternoon	6.0	65.7
Evening	19.3	72.3
Night	18.6	62.0



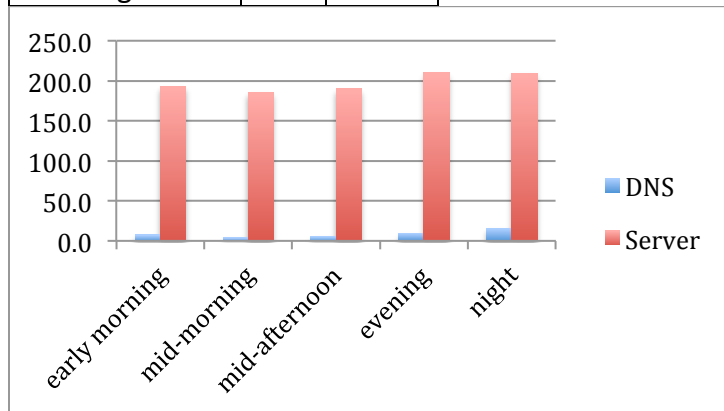
3.28~3.29		
Time	DNS	Server
Early morning	8.3	60.0
Mid-morning	3.5	62.3
Mid-afternoon	6.0	58.0
Evening	14.8	63.5
Night	13.1	60.7



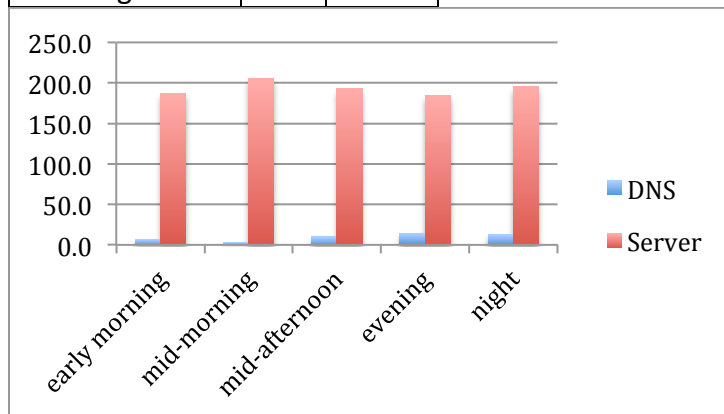
YouTube.com is a well-known address. The DNS response time is low around 10, and the web server response time is also almost constant across the day around 60. YouTube may implement some traffic balancing and buffer mechanism.

3. 10 Facebook (www.facebook.com)

3.25~3.26		
Time	DNS	Server
Early morning	7.5	192.8
Mid-morning	4.0	185.5
Mid-afternoon	5.5	189.8
Evening	9.8	210.0
Night	15.3	209.6



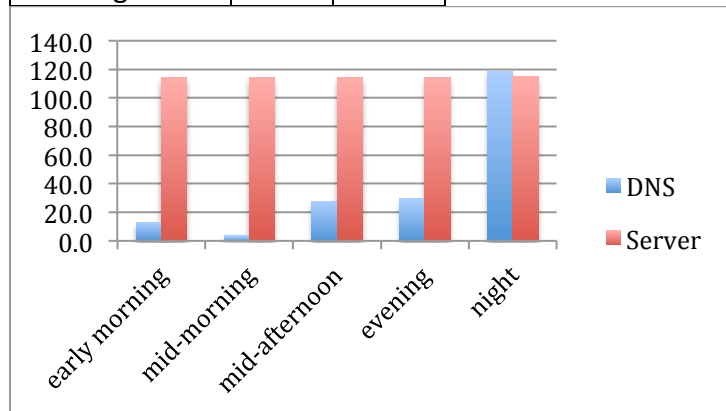
3.28~3.29		
Time	DNS	Server
Early morning	7.0	187.3
Mid-morning	3.3	206.0
Mid-afternoon	9.8	192.8
Evening	14.3	184.5
Night	12.9	195.5



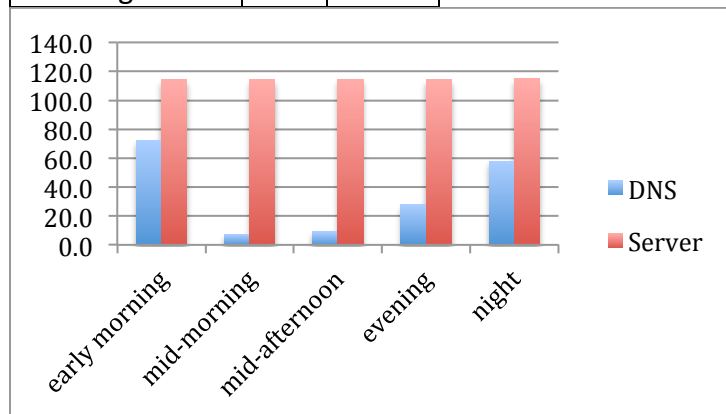
As a famous SNS site, the DNS response time is almost the same access to the UNC, however, it takes longer to access its web server. Since the server of Facebook is located at the western coast, it takes almost the same time as access to Stanford University. Also, no obvious difference of speed is observed across the day.

3.11 Wikipedia(www.wikipedia.org)

3.25~3.26		
Time	DNS	Server
Early morning	13.0	114.0
Mid-morning	3.5	114.0
Mid-afternoon	27.8	114.2
Evening	29.5	114.3
Night	118.7	115.3



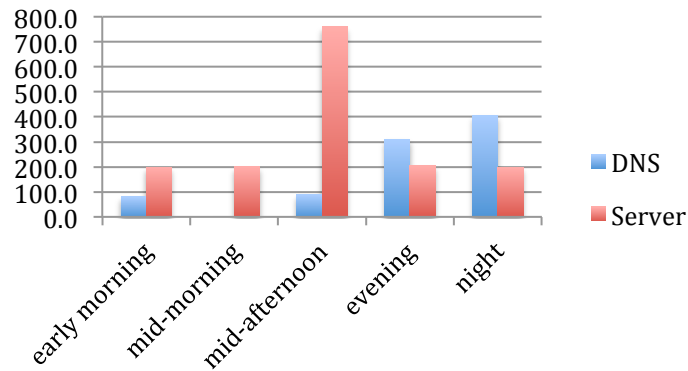
3.28~3.29		
Time	DNS	Server
Early morning	72.0	114.3
Mid-morning	7.5	114.3
Mid-afternoon	9.2	114.7
Evening	28.3	114.3
Night	57.5	115.3



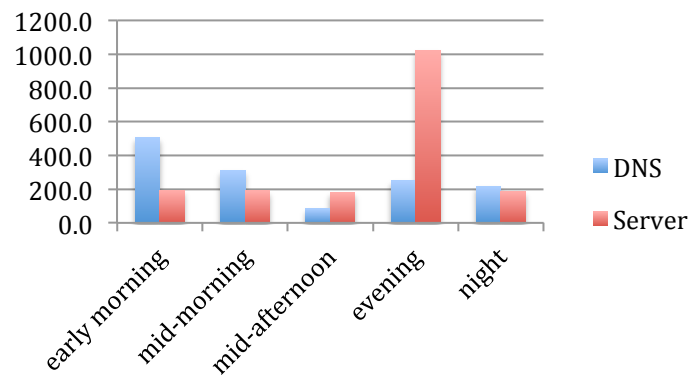
The DNS resolving time is larger during the early evening and night. The web response time is around 114 ms, stable across the day.

3.12) University of Mexico (www.unam.mx)

3.25~3.26		
Time	DNS	Server
Early morning	81.0	197.0
Mid-morning	0.0	201.0
Mid-afternoon	90.2	761.3
Evening	310.5	203.5
Night	406.3	199.4



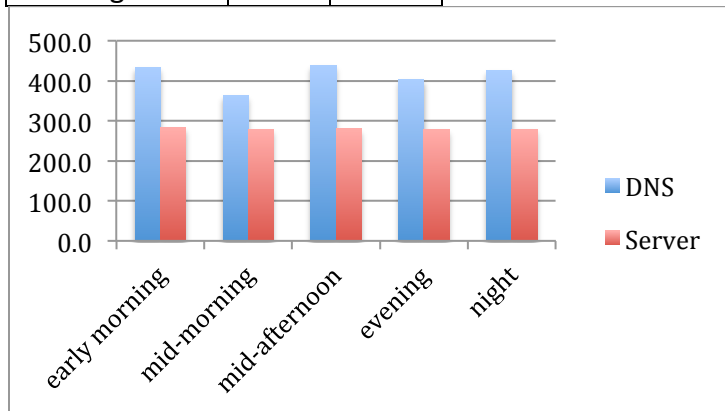
3.28~3.29		
Time	DNS	Server
Early morning	507.5	194.8
Mid-morning	310.5	190.5
Mid-afternoon	85.5	182.0
Evening	249.0	1024.3
Night	217.3	188.3



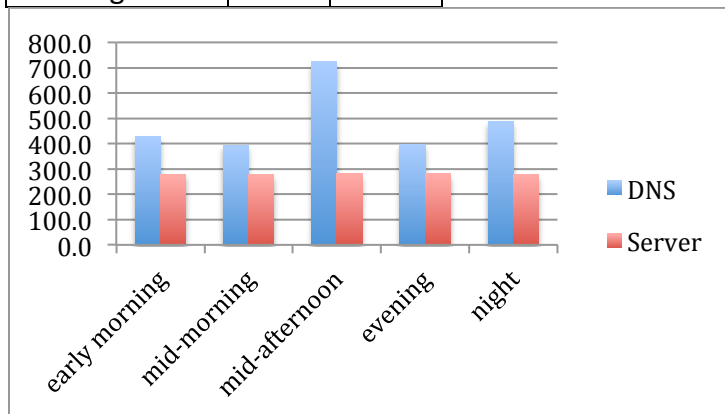
For the access of a website in Mexico, it takes longer time to get a DNS response and webserver response. The extreme abnormal web server response time may due to some data outlier. After investigate the raw data, the 1000+ value results from exceptional 3000+ isolated data.

3.13 State University of Campinas, Brazil (www.unicampe.br)

3.25~3.26		
Time	DNS	Server
Early morning	433.5	282.5
Mid-morning	364.5	278.5
Mid-afternoon	438.2	279.8
Evening	403.0	279.5
Night	425.6	279.1



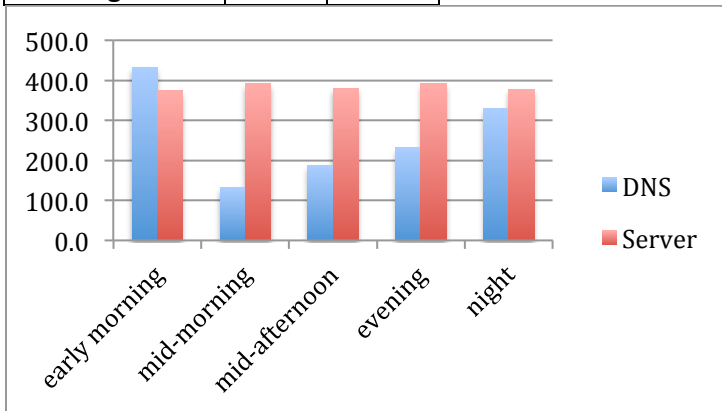
3.28~3.29		
Time	DNS	Server
Early morning	429.3	278.5
Mid-morning	394.0	279.8
Mid-afternoon	723.5	280.7
Evening	396.3	280.3
Night	487.5	279.9



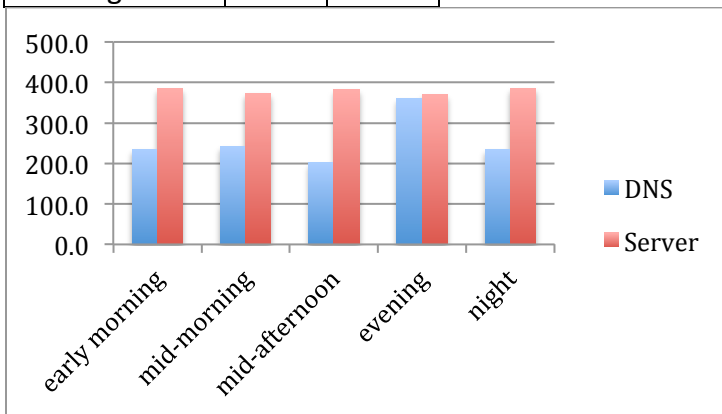
For the access a Brazil university, it takes longer time to resolve the IP address from a DNS server than the actual access to the corresponding web server.

3.14 (www2.planalto.gov.br)

3.25~3.26		
Time	DNS	Server
Early morning	433.0	373.8
Mid-morning	133.0	391.5
Mid-afternoon	187.7	381.0
Evening	231.3	392.0
Night	330.8	378.4



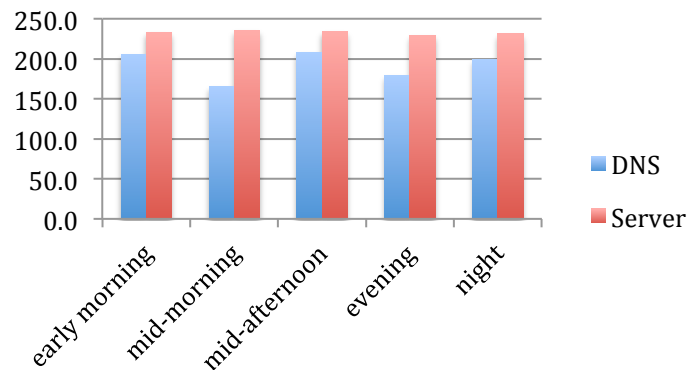
3.28~3.29		
Time	DNS	Server
Early morning	234.3	384.8
Mid-morning	242.3	373.8
Mid-afternoon	201.8	383.2
Evening	360.3	370.3
Night	233.7	385.0



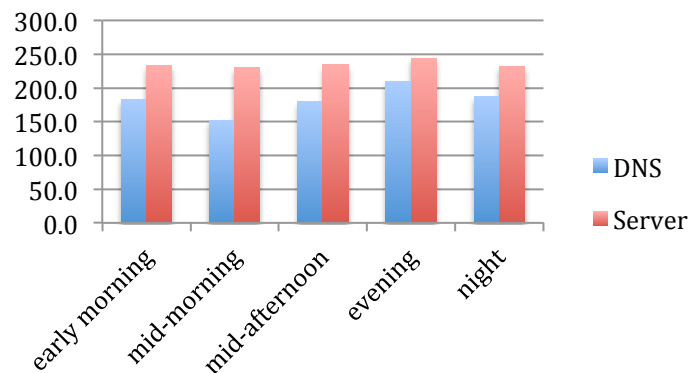
For the access to a Brazil government website, when access with the obtained IP address, the response time is almost the same across the day. The DNS response time varies, which may due to the DNS traffic and the cache mechanism.

3.15 BBC (www.bbc.co.uk)

3.25~3.26		
Time	DNS	Server
Early morning	205.8	233.0
Mid-morning	165.5	235.5
Mid-afternoon	208.3	234.3
Evening	179.8	229.8
Night	199.5	231.5



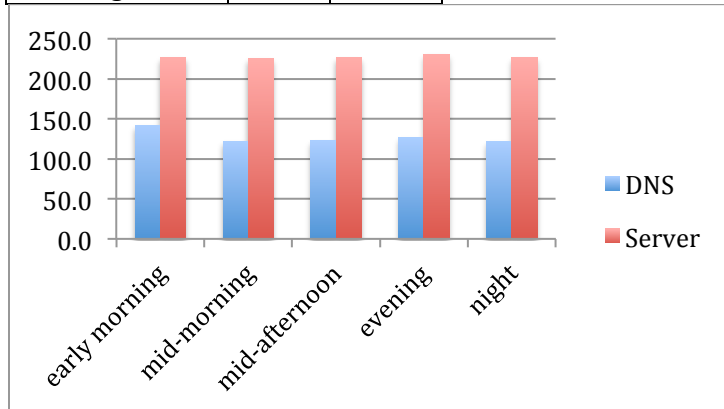
3.28~3.29		
Time	DNS	Server
Early morning	182.5	233.0
Mid-morning	151.8	229.8
Mid-afternoon	179.7	234.3
Evening	209.8	244.0
Night	187.1	232.4



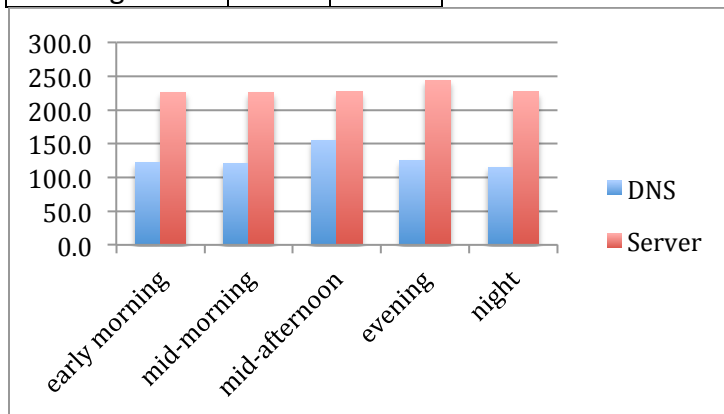
For the access a world famous news website, in UK, the BBC, both the DNS response time and first-byte web response time are stable across the day and night. The DNS response time is almost the same the time to resolve a western coast website, like the Stanford University.

3.16 University of Oxford, United Kingdom (www.ox.ac.uk)

3.25~3.26		
Time	DNS	Server
Early morning	142.3	227.0
Mid-morning	122.0	225.5
Mid-afternoon	122.8	226.8
Evening	126.5	230.8
Night	122.3	226.8



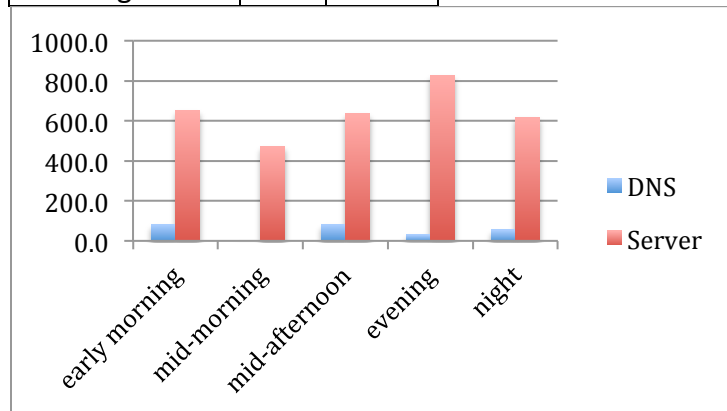
3.28~3.29		
Time	DNS	Server
Early morning	122.0	225.5
Mid-morning	120.3	226.3
Mid-afternoon	154.8	227.0
Evening	124.8	244.0
Night	115.1	226.7



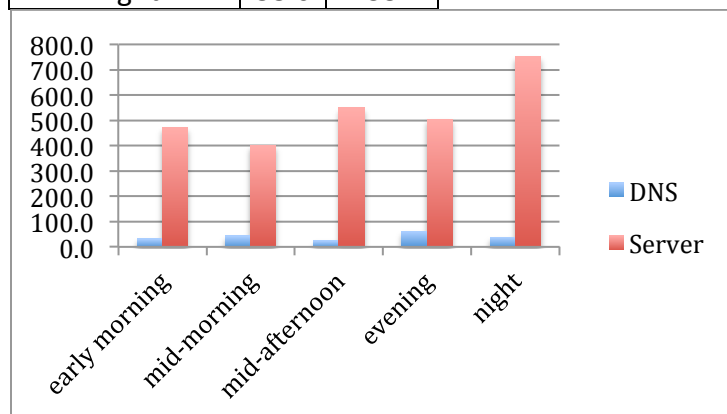
For the access the University of Oxford at UK, the DNS response time is also the same as resolving a western coast server. The first-byte webserver response time almost the same as accessing the famous Britain BBC website. There is also no obvious speed variation between day and night.

3.17 University of Cambridge, United Kingdom (www.cam.ac.uk)

3.25~3.26		
Time	DNS	Server
Early morning	82.3	652.5
Mid-morning	1.0	474.0
Mid-afternoon	82.3	636.2
Evening	31.8	825.8
Night	55.9	618.8



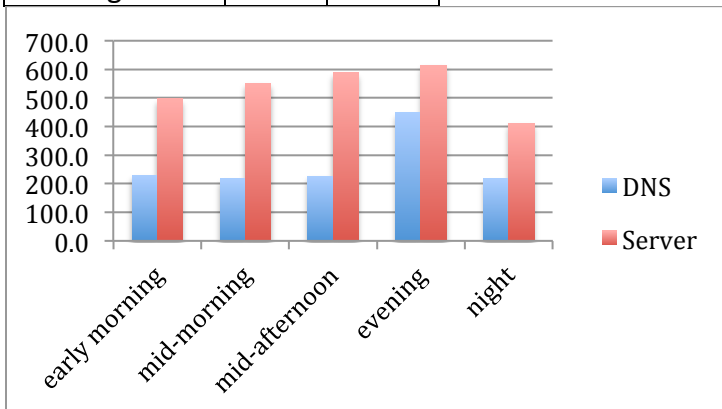
3.28~3.29		
Time	DNS	Server
Early morning	32.3	472.5
Mid-morning	43.3	401.8
Mid-afternoon	25.2	549.3
Evening	61.5	504.3
Night	38.6	753.2



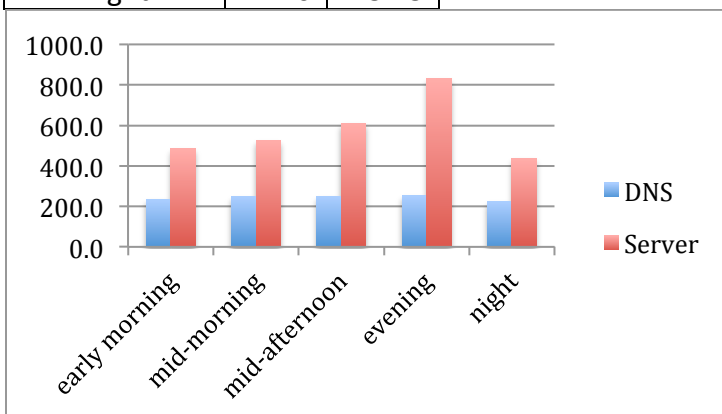
The University of Cambridge is also a famous University in UK. However, both the DNS response time and the first-byte webserver response time vary greatly from that of Oxford. The DNS resolving time is significantly lower, almost at the level of resolving a website at the central time zone. However, the first-byte website response time is significantly larger. It is suspected that the underlying routing is different from Oxford and BBC.

3.18 King Saud University, Riyadh, Saudi Arabia (www.ksu.edu.sa)

3.25~3.26		
Time	DNS	Server
Early morning	230.3	497.3
Mid-morning	217.0	551.5
Mid-afternoon	227.0	587.5
Evening	448.0	614.8
Night	216.6	412.0



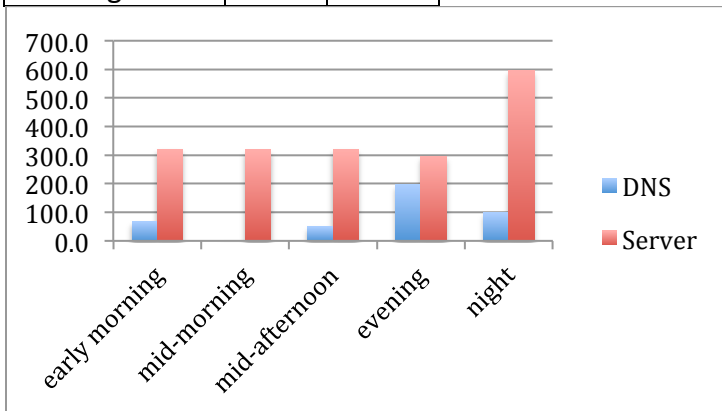
3.28~3.29		
Time	DNS	Server
Early morning	234.5	485.8
Mid-morning	249.5	527.8
Mid-afternoon	250.2	610.7
Evening	253.0	834.0
Night	224.6	437.3



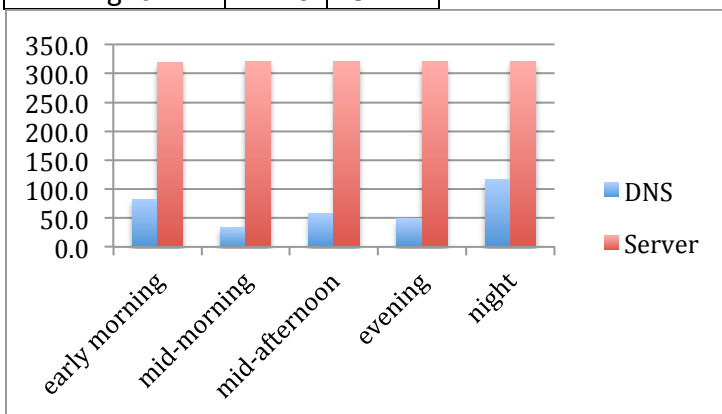
For the accessing a mid-east university, the DNS response time is around 240 level. The first-byte webserver response time is around 400~700 level. There is also speed fluctuation across the day. From morning to evening, the speed goes increasingly lower. But since the time zone is different, the measure interval is subject to change accordingly for further analysis.

3.19 Moscow State University, (www.msu.ru)

3.25~3.26		
Time	DNS	Server
Early morning	68.5	321.0
Mid-morning	1.0	319.0
Mid-afternoon	51.0	320.2
Evening	196.8	296.3
Night	98.6	594.9



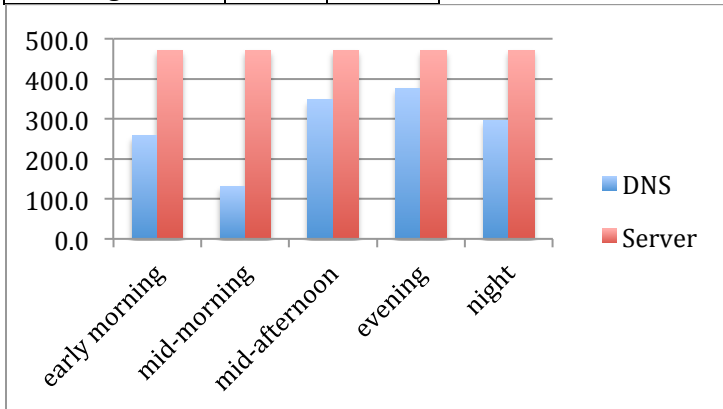
3.28~3.29		
Time	DNS	Server
Early morning	82.8	319.5
Mid-morning	33.3	320.5
Mid-afternoon	57.0	320.8
Evening	48.5	320.5
Night	117.0	321.1



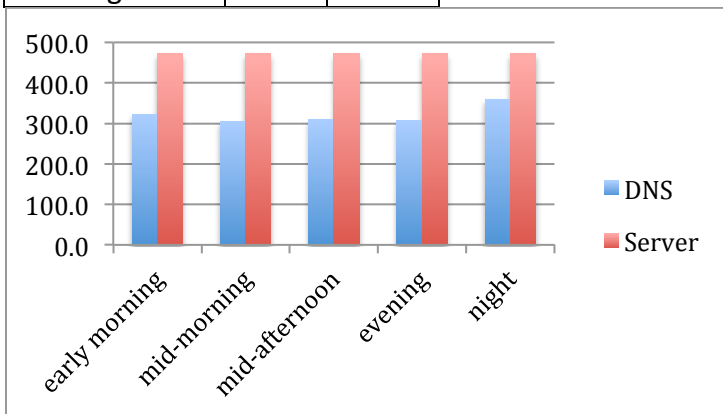
For the access of a Russia University the DNS response time fluctuates relatively greatly. It may be due to the DNS traffic and caching variation. The first-byte webserver response time is stable across the day a 320 ms level.

3.20 The University of Sydney (Sydney. Edu.au)

3.25~3.26		
Time	DNS	Server
Early morning	258.0	471.0
Mid-morning	131.0	471.0
Mid-afternoon	347.3	471.2
Evening	376.0	470.5
Night	295.9	471.0



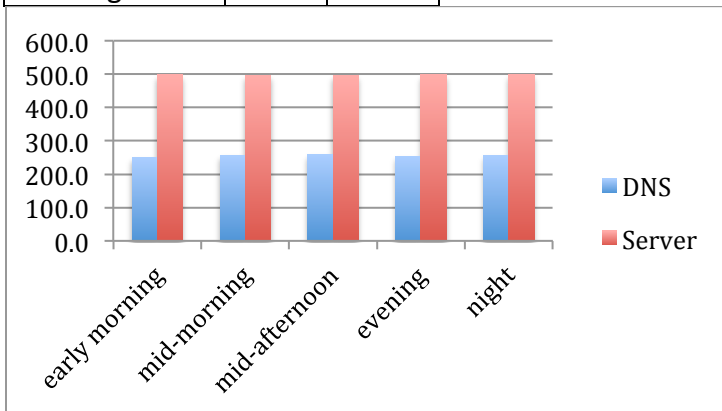
3.28~3.29		
Time	DNS	Server
Early morning	323.0	472.5
Mid-morning	305.5	472.5
Mid-afternoon	311.0	472.7
Evening	306.5	472.3
Night	359.1	472.2



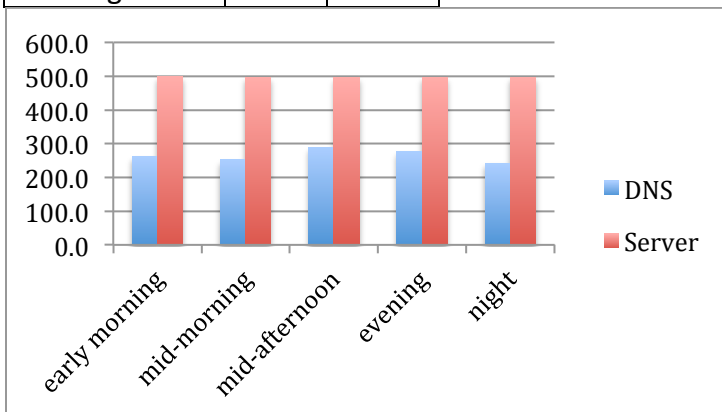
For the access an Australian University, the DNS response time is around 320 level and the web server response time is amazingly about 472 ms.

3.21 The University of Melbourne, Australia (www.unimelb.edu.au)

3.25~3.26		
Time	DNS	Server
Early morning	251.0	497.8
Mid-morning	256.0	497.5
Mid-afternoon	259.0	497.5
Evening	253.8	497.8
Night	257.4	498.3



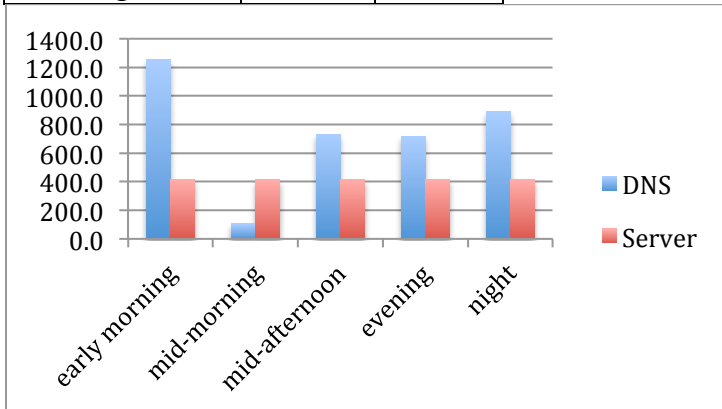
3.28~3.29		
Time	DNS	Server
Early morning	260.8	498.5
Mid-morning	252.0	497.5
Mid-afternoon	289.8	497.2
Evening	277.8	497.5
Night	241.3	497.5



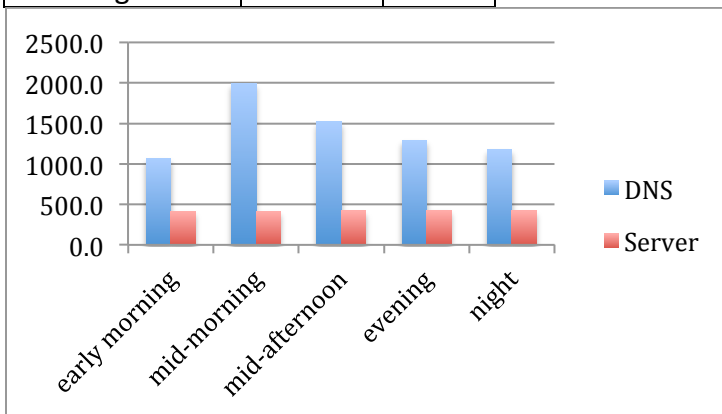
Similarly to access the University of Sydney, access to the University of Melbourne is also amazingly stable both the DNS response time and the first-byte webserver response time. It may be inferred that both the traffic condition and routing path are fixed during each experiment for access an Australia University.

3.22 The University of Auckland, New Zealand, Oceania (www.auckland.ac.nz)

3.25~3.26		
Time	DNS	Server
Early morning	1252.3	415.5
Mid-morning	107.0	414.5
Mid-afternoon	733.8	417.7
Evening	717.0	418.5
Night	891.4	418.4



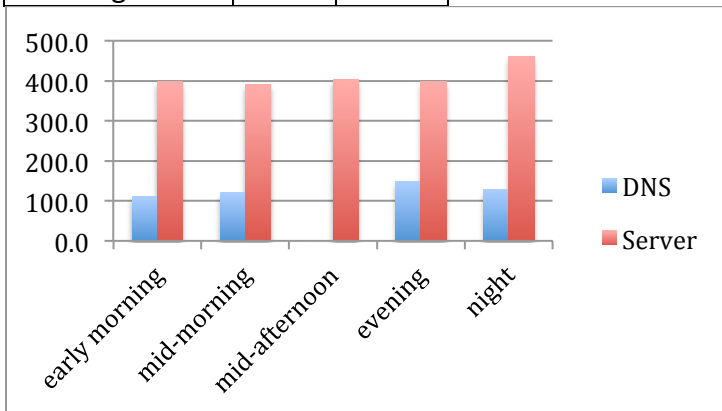
3.28~3.29		
Time	DNS	Server
Early morning	1071.5	418.0
Mid-morning	1991.0	417.3
Mid-afternoon	1519.3	418.5
Evening	1289.3	429.5
Night	1173.9	419.7



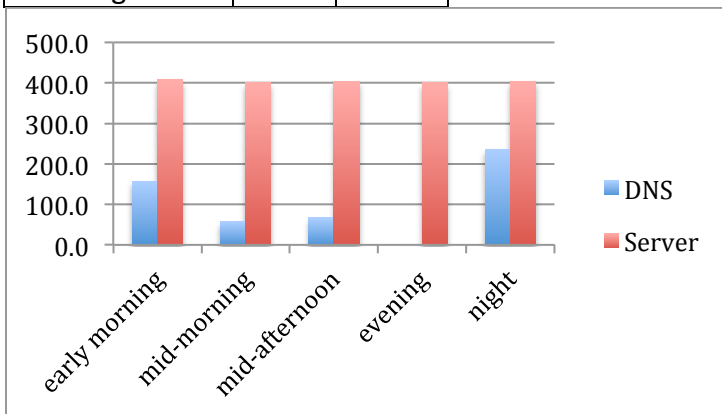
For the access a New Zealand University, The DNS response time is unstable, it varies greatly for both sets of experiment. But the webserver response time is almost constant. It can also be observed that the DNS resolving time takes the majority of the total access time.

3.23 The University of Tokyo, Japan, Asia (www.u-tokyo.ac.jp)

3.25~3.26		
Time	DNS	Server
Early morning	111.5	398.5
Mid-morning	120.0	390.0
Mid-afternoon	1.8	402.3
Evening	149.0	397.5
Night	128.9	460.8



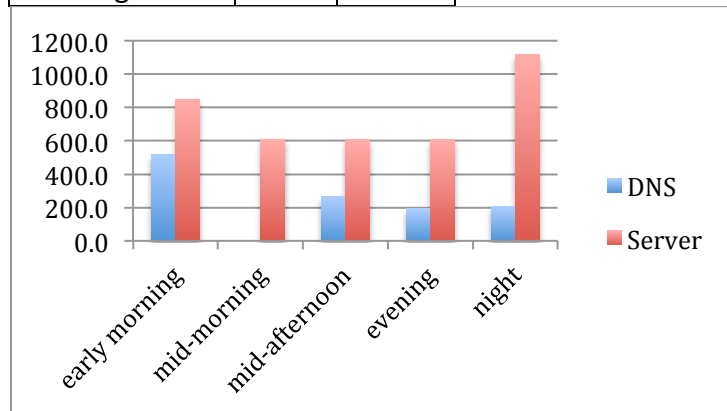
3.28~3.29		
Time	DNS	Server
Early morning	156.3	407.5
Mid-morning	57.3	400.0
Mid-afternoon	66.5	404.7
Evening	1.5	400.0
Night	235.3	402.7



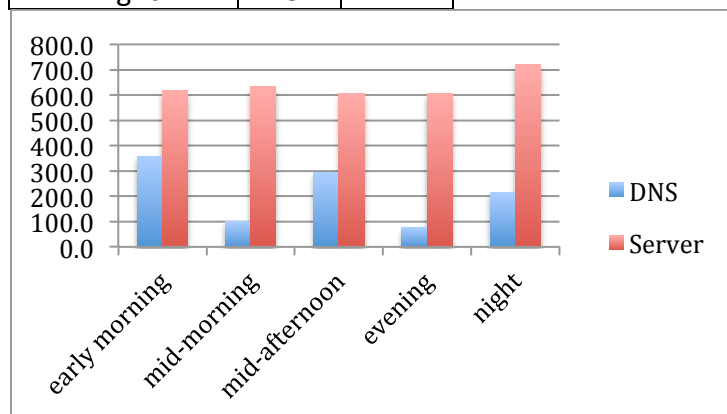
The DNS response time varies sometimes and the first-byte webserver response time is almost constant. The DNS response time takes almost ½ of the actual webserver response time.

3.24 The University of South Africa (www.unisa.ac.za)

3.25~3.26		
Time	DNS	Server
Early morning	517.0	848.8
Mid-morning	0.0	608.5
Mid-afternoon	264.7	606.0
Evening	191.5	606.3
Night	208.4	1116.2



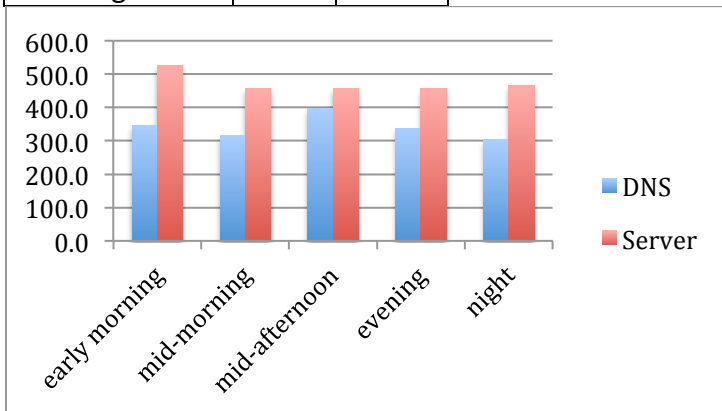
3.28~3.29		
Time	DNS	Server
Early morning	356.8	616.8
Mid-morning	101.0	632.5
Mid-afternoon	292.7	606.0
Evening	77.0	606.5
Night	215.1	721.1



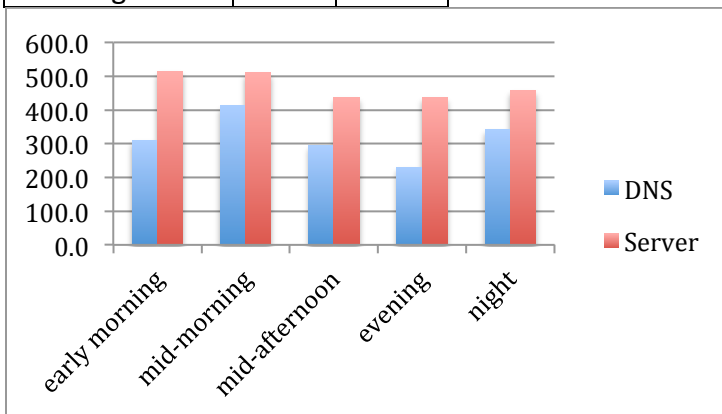
The DNS response time is unstable across the day without obvious patterns. The webserver response time is almost constant at 600 level.

3.25 Nankai University, Tianjin, China (www.nankai.edu.cn)

3.25~3.26		
Time	DNS	Server
Early morning	346.3	525.3
Mid-morning	316.0	457.5
Mid-afternoon	397.5	457.2
Evening	338.5	457.3
Night	302.7	467.2



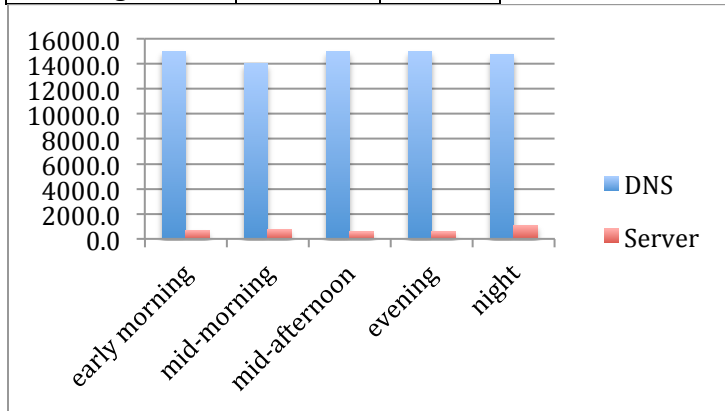
3.28~3.29		
Time	DNS	Server
Early morning	309.0	514.5
Mid-morning	412.3	510.5
Mid-afternoon	294.3	438.0
Evening	229.8	437.8
Night	342.3	456.5



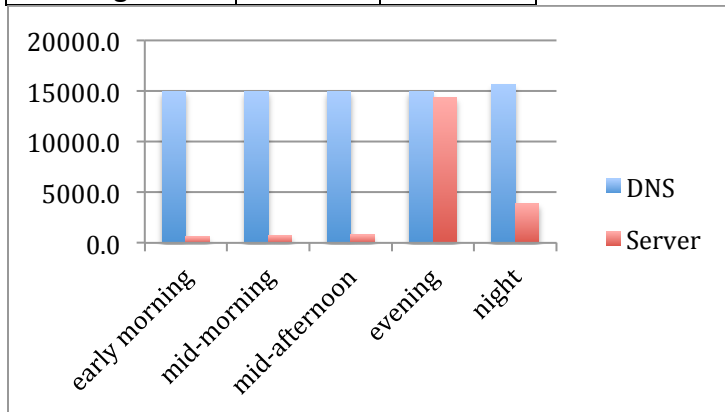
For the access a famous University in China, both the DNS response time and first-byte webserver response time are stable across the day. The DNS response time is about 3/5 of the actual server response time.

3.26 The government of Dalian, Liaoning Province, China (english.dl.gov.cn)

3.25~3.26		
Time	DNS	Server
Early morning	15009.8	700.8
Mid-morning	14011.0	778.5
Mid-afternoon	15010.5	585.7
Evening	15010.5	587.0
Night	14759.3	1094.0



3.28~3.29		
Time	DNS	Server
Early morning	15008.3	631.0
Mid-morning	15008.5	736.8
Mid-afternoon	15008.3	811.3
Evening	15007.8	14365.8
Night	15652.1	3914.2



Here is a very obscure website located in a northeastern city in China. The DNS response time takes the majority of the role. For its address (english.dl.gov.cn) the DNS will contact the root server, authorities servers and multiple jumps to access the website. There may be bottleneck part network during resolving.

4. Conclusion.

Overall, the DNS network plays an important role in the performance of networking. Except for a local, famous website, the DNS name resolving time takes at least half of the total access time. The more obscure a website, the more time is needed for the DNS network to return an IP address.

The DNS response time fluctuates obviously for those hostname with different IP addresses. And subject to network condition traffic condition if it is with a nearby network.

The first-byte webserver response varies obviously across a day when accessing a website in the United States, which may result from the network traffic condition. On the contrary, the fluctuation is not obvious for the access a website outside the United States. It may be considered that the traffic-induced speed difference is relatively small to the overall international cable nodal processing and queuing time, and not reflected in the overall access time. Like accessing the universities in Australia, the DNS response time and first-byte webserver response time are almost always constant.

DNS Caching also takes a role in access a website. For instance, all the numbers less than 5 in the above tables may be due to I test the website in my browser. If an address is cached, it will spend significantly small time to get the resolved IP address from DNS.