COMPUTER NETWORKS

ASSIGNMENT – 1

Problem 1

A) Tell us which file you picked and describe briefly exactly what type of information is contained in this file.

I picked the file oix-full-snapshot-2013-08-25-1200.bz2. It contains all the IP Prefix announcements captured on August 25, 2013 for some time period and was last updated on 1210 hrs.
Each announcement tells the IP Prefix that the owner wants to announce along with AS Path, last router IP address and some other information. AS Path contains the numbers assigned to the autonomous systems (AS Number) which help to identify them uniquely. The last AS number in the list (at the most right position) refers to the origin of the announcement. AS path grows towards the left as it passes through different ASes.

B) Analysing the file, list all the IP prefixes that Georgia Tech announces. Does GT own any IP addresses that do not show up in this data?

The IP Prefixes owned and announced by Georgia Tech are:

- ✓ 128.61.0.0/19
- ✓ 128.61.32.0/19
- ✓ 128.61.64.0/18
- ✓ 128.61.128.0/17
- ✓ 130.207.0.0/16
- ✓ 143.215.0.0/16
- ✓ 204.152.10.0/23

In addition, there are some other IP Prefix announcements which go through Georgia Tech:

- ✓ 74.255.42.0/24
- ✓ 184.164.242.0/24
- ✓ 184.164.243.0/24
- ✓ 184.164.250.0/24

The IP Prefixes owned by Georgia Tech but not announced are:

- ✓ 2001:468:300::/48
- ✓ 2610:148::/32

These are IPv6 addresses.

C) List the ASes that GT is connected to. Identify AS# and organization/company.

The autonomous systems to which GT is connected are:

- ✓ **10490**
  ASName: SOUTHERN-CROSSROADS-SOX
  OrgName: Georgia Institute of Technology

- ✓ **209**
  ASName: ASN-QWEST
  OrgName: Qwest Communications Company, LLC

- ✓ **2914**
  ASName: NTT-COMMUNICATIONS-2914
  OrgName: NTT America, Inc.

- ✓ **3479**
  ASName: PEACHNET-AS1
  OrgName: Kennesaw State University

- ✓ **174**
  ASName: COGENT-174
  OrgName: Cogent Communications

- ✓ **47065**
  ASName: GENI-BGPMUX
  OrgName: BBN Technologies Corp. - Global Environment for Network Innovations (GENI)

D) For IP addresses advertised by Georgia Tech find and list all instances of AS prepending in the data. Does this information tell you anything about the preferences of the AS doing the pre-pending? Be as explicit as possible.

Below is the list of all the instances with AS path prepending in the data:

128.61.0.0/19 67.17.82.114 3204 0 0 3549 6939 6939 10490 2637 i
128.61.0.0/19 206.24.210.102 0 0 0 3561 209 2637 2637 2637 i
128.61.0.0/19 12.0.1.63 0 0 0 7018 209 2637 2637 2637 i
128.61.0.0/19 208.51.134.246 13264 0 0 3549 6939 6939 10490 2637 i
128.61.0.0/19 66.185.128.1 118 0 0 1668 1299 6939 6939 10490 2637 i
128.61.0.0/19 157.130.10.233 0 0 0 701 209 2637 2637 2637 i
128.61.0.0/19 89.149.178.10 10 0 0 3257 209 2637 2637 2637 i
128.61.0.0/19 129.250.0.11 6 0 0 2914 209 2637 2637 2637 i
128.61.0.0/19 144.228.241.130 0 0 0 1239 209 2637 2637 2637 i
128.61.0.0/19 80.91.255.62 0 0 0 1299 6939 6939 10490 2637 i
128.61.0.0/19 4.69.184.193 0 0 0 3356 3549 6939 6939 10490 2637 i
128.61.32.0/19 67.17.82.114 3204 0 0 3549 6939 6939 10490 2637 i
128.61.32.0/19 206.24.210.102 0 0 0 3561 209 2637 2637 2637 2637 i
128.61.32.0/19 208.51.134.246 13264 0 0 3549 6939 6939 10490 2637 i

128.61.32.0/19 80.91.255.62 0 0 0 1299 6939 6939 10490 2637 i
128.61.32.0/19 4.69.184.193 0 0 0 3356 3549 6939 6939 10490 2637 i
128.61.64.0/18 67.17.82.114 3204 0 0 3549 6939 6939 10490 2637 i
128.61.64.0/18 206.24.210.102 0 0 0 3561 209 2637 2637 2637 2637 i
128.61.64.0/18 208.51.134.246 13264 0 0 3549 6939 6939 10490 2637 i
128.61.64.0/18 80.91.255.62 0 0 0 1299 6939 6939 10490 2637 i
128.61.64.0/18 4.69.184.193 0 0 0 3356 3549 6939 6939 10490 2637 i
128.61.128.0/17 67.17.82.114 3204 0 0 3549 6939 6939 10490 2637 i
128.61.128.0/17 206.24.210.102 0 0 0 3561 209 2637 2637 2637 i
128.61.128.0/17 12.0.1.63 0 0 0 7018 209 2637 2637 2637 i
128.61.128.0/17 208.51.134.246 13264 0 0 3549 6939 6939 10490 2637 i
128.61.128.0/17 66.185.128.1 118 0 0 1668 1299 6939 6939 10490 2637 i
128.61.128.0/17 157.130.10.233 0 0 0 701 209 2637 2637 2637 i
128.61.128.0/17 89.149.178.10 10 0 0 3257 209 2637 2637 2637 i
128.61.128.0/17 129.250.0.11 6 0 0 2914 209 2637 2637 2637 i
128.61.128.0/17 144.228.241.130 0 0 0 1239 209 2637 2637 2637 i
128.61.128.0/17 80.91.255.62 0 0 0 1299 6939 6939 10490 2637 i
128.61.128.0/17 4.69.184.193 0 0 0 3356 3549 6939 6939 10490 2637 i
130.207.0.0/16 67.17.82.114 3204 0 0 3549 6939 6939 10490 2637 i
130.207.0.0/16 206.24.210.102 0 0 0 3561 209 2637 2637 2637 i
130.207.0.0/16 12.0.1.63 0 0 0 7018 209 2637 2637 2637 i
130.207.0.0/16 208.51.134.246 13264 0 0 3549 6939 6939 10490 2637 i
130.207.0.0/16 66.185.128.1 118 0 0 1668 1299 6939 6939 10490 2637 i
130.207.0.0/16 157.130.10.233 0 0 0 701 209 2637 2637 2637 i
130.207.0.0/16 129.250.0.11 73 0 0 2914 2637 2637 2637 2637 2637 i
130.207.0.0/16 89.149.178.10 10 0 0 3257 209 2637 2637 2637 i
130.207.0.0/16 144.228.241.130 0 0 0 1239 209 2637 2637 2637 i
130.207.0.0/16 80.91.255.62 0 0 0 1299 6939 6939 10490 2637 i
130.207.0.0/16 4.69.184.193 0 0 0 3356 3549 6939 6939 10490 2637 i
143.215.0.0/16 67.17.82.114 3204 0 0 3549 6939 6939 10490 2637 i
143.215.0.0/16 206.24.210.102 0 0 0 3561 209 2637 2637 2637 i
143.215.0.0/16 12.0.1.63 0 0 0 7018 209 2637 2637 2637 i
143.215.0.0/16 208.51.134.246 13264 0 0 3549 6939 6939 10490 2637 i
143.215.0.0/16 66.185.128.1 118 0 0 1668 1299 6939 6939 10490 2637 i
143.215.0.0/16 157.130.10.233 0 0 0 701 209 2637 2637 2637 i
143.215.0.0/16 129.250.0.11 73 0 0 2914 2637 2637 2637 2637 2637 i
143.215.0.0/16 89.149.178.10 10 0 0 3257 209 2637 2637 2637 i
143.215.0.0/16 144.228.241.130 0 0 0 1239 209 2637 2637 2637 i
143.215.0.0/16 80.91.255.62 0 0 0 1299 6939 6939 10490 2637 i
143.215.0.0/16 4.69.184.193 0 0 0 3356 3549 6939 6939 10490 2637 i
184.164.243.0/24 206.24.210.102 0 0 0 3561 209 2637 2637 2637 47065 i
184.164.243.0/24 202.232.0.3 0 0 0 2497 209 2637 2637 2637 47065 i
204.152.10.0/23 67.17.82.114 2523 0 0 3549 174 2637 2637 2637 2637 2637 i
204.152.10.0/23 206.24.210.102 0 0 0 3561 174 2637 2637 2637 2637 2637 i
204.152.10.0/23 85.114.0.217 0 0 0 8492 9002 174 2637 2637 2637 2637 2637 i

204.152.10.0/23 203.62.252.186 0 0 0 1221 4637 174 2637 2637 2637 2637 2637 i
204.152.10.0/23 198.129.33.85 0 0 0 293 6939 1299 174 2637 2637 2637 2637 2637 i
204.152.10.0/23 194.153.0.253 1015 0 0 5413 1299 174 2637 2637 2637 2637 2637 i
204.152.10.0/23 154.11.11.113 0 0 0 852 174 2637 2637 2637 2637 2637 i
204.152.10.0/23 12.0.1.63 0 0 0 7018 174 2637 2637 2637 2637 2637 i
204.152.10.0/23 213.144.128.203 1 0 0 13030 2828 174 2637 2637 2637 2637 2637 i
204.152.10.0/23 208.51.134.246 13227 0 0 3549 174 2637 2637 2637 2637 2637 i
204.152.10.0/23 66.185.128.1 64 0 0 1668 174 2637 2637 2637 2637 2637 i
204.152.10.0/23 129.250.0.11 7 0 0 2914 174 2637 2637 2637 2637 2637 i
204.152.10.0/23 96.4.0.55 0 0 0 11686 19782 174 2637 2637 2637 2637 2637 i
204.152.10.0/23 154.11.98.225 0 0 0 852 174 2637 2637 2637 2637 2637 i
204.152.10.0/23 216.18.31.102 0 0 0 6539 577 174 2637 2637 2637 2637 2637 i
204.152.10.0/23 144.228.241.130 0 0 0 1239 174 2637 2637 2637 2637 2637 i
204.152.10.0/23 157.130.10.233 0 0 0 701 174 2637 2637 2637 2637 2637 i
204.152.10.0/23 195.22.216.188 100 0 0 6762 174 2637 2637 2637 2637 2637 i
204.152.10.0/23 137.164.16.84 0 0 0 2152 3356 174 2637 2637 2637 2637 2637 i
204.152.10.0/23 216.218.252.164 0 0 0 6939 1299 174 2637 2637 2637 2637 2637 i
204.152.10.0/23 168.209.255.23 0 0 0 3741 174 2637 2637 2637 2637 2637 i
204.152.10.0/23 89.149.178.10 10 0 0 3257 174 2637 2637 2637 2637 2637 i
204.152.10.0/23 134.222.87.1 0 0 0 286 174 2637 2637 2637 2637 2637 i
204.152.10.0/23 80.91.255.62 0 0 0 1299 174 2637 2637 2637 2637 2637 i
204.152.10.0/23 4.69.184.193 0 0 0 3356 174 2637 2637 2637 2637 2637 i
204.152.10.0/23 147.28.7.1 0 0 0 3130 2914 174 2637 2637 2637 2637 2637 i
204.152.10.0/23 164.128.32.11 0 0 0 3303 174 2637 2637 2637 2637 2637 i
204.152.10.0/23 203.181.248.168 0 0 0 7660 2516 209 174 2637 2637 2637 2637 2637 i
204.152.10.0/23 147.28.7.2 0 0 0 3130 1239 174 2637 2637 2637 2637 2637 i
204.152.10.0/23 202.232.0.3 0 0 0 2497 2914 174 2637 2637 2637 2637 2637 i

Analysis of the prepending in the data:

In the above data, two of the autonomous systems are doing prepending.

One of them is AS 6939 which is prepending for the AS paths in which data is expected to come from AS 3549 or AS 1299 and is destined for 10490.

The other is AS 2637 (Georgia Tech's AS) which is prepending for the AS paths in which data is expected from 209, 2914 or 174.

A lot of path prepending has been observed specially for 174.

It indicates that the AS doing the prepending doesn't want the traffic to come to it through these ASes. For example, 2637 doesn't want the traffic to reach to it through the AS 174.

The possible reasons for this behavior are,

These ASes may have multiple service providers or are multi-homed customers and thus may have multiple paths/connections. So, they prefer one path over the other. Thus, to avoid the traffic on the path not preferred, they do prepending to increase the AS path length.

The preference of one path over the other may be because of the cost or speed/bandwidth factor. It is possible that one path costs less or they get more speed over that path and thus it is preferred.

Problem 2

Pick 10 traceroute.org servers. Perform a trace route from each of the servers to a location of your choosing on the Internet.

The servers picked are:

- ✓ REDHAT
- ✓ University of Southern California
- ✓ Cogent Co.
- ✓ CyberVerse Inc.
- ✓ T1 Shopper
- ✓ Willamette Valley Internet
- ✓ Interserver.net
- ✓ TowardEX Technology
- ✓ Hotlinks
- ✓ NetINS
- ✓ Opus One

The Destination is **173.194.115.16 (Google)**

The trace route output:

Server 1 - REDHAT

Result for **173.194.115.16**; modeset: {AS-Query , SOA-Owner-Query , ICMP-Query }:

traceroute.exe to 173.194.115.16 (173.194.115.16), 30 hops max, 38 byte packets
1 209.132.180.92 (209.132.180.92) [AS31976] hostmaster@redhat.com 0.495 ms 0.364 ms 0.271 ms
2 transit-2-180-132-209.redhat.com (209.132.180.2) [AS31976] hostmaster@redhat.com 0.710 ms 0.525 ms 0.645 ms
3 ip-161-181-132-209.redhat.com (209.132.181.161) [AS31976] hostmaster@redhat.com 0.578 ms 0.529 ms 0.571 ms
4 border1.ge3-14.redhatphx-1.phx004.pnap.net (69.25.120.241) [AS11855] hostmaster@pnap.net 0.726 ms 0.877 ms 0.716 ms
5 core3.po2-bbnet2.phx010.pnap.net (69.25.168.84) [AS11855] hostmaster@pnap.net 1.689 ms 1.996 ms 1.772 ms
6 ae2-103.phx10.ip4.tinet.net (77.67.94.73) [AS3257] netguard@tinet.net 1.221 ms 1.531 ms 1.363 ms
7 xe-1-3-0.lax21.ip4.tinet.net (141.136.108.9) [AS3257] netguard@tinet.net 10.856 ms 16.537 ms 10.840 ms
8 72.14.194.163 (72.14.194.163) [AS15169] dns-admin@google.com 11.651 ms 12.583 ms 11.799 ms
9 72.14.234.47 (72.14.234.47) [AS15169] dns-admin@google.com 11.609 ms 12.434 ms 11.603 ms
10 64.233.174.186 (64.233.174.186) [AS15169] dns-admin@google.com 12.007 ms 64.233.174.190 (64.233.174.190) [AS15169] dns-admin@google.com 11.866 ms 12.581 ms
11 64.233.174.141 (64.233.174.141) [AS15169] dns-admin@google.com 36.715 ms 73.225 ms 36.560 ms

12 72.14.237.216 (72.14.237.216) [AS15169] dns-admin@google.com 51.243 ms 43.833 ms 37.259 ms
13 209.85.254.127 (209.85.254.127) [AS15169] dns-admin@google.com 37.040 ms 36.906 ms 37.078 ms
14 173.194.115.16 (173.194.115.16) [AS15169] no SOA record 36.864 ms 99.580 ms 100.710 ms

Server 2 - University of Southern California

traceroute from 128.125.137.243 (www.usc.edu) to 173.194.115.16 (173.194.115.16) for 128.61.22.192
Executing 'traceroute -m 30 -q 3 -f 3 173.194.115.16'
traceroute to 173.194.115.16 (173.194.115.16), 30 hops max, 40 byte packets
3 v249-gw-6 (68.181.194.65) 0.849 ms 0.668 ms 0.631 ms [47]
4 lax-dc1--losnettos-dc.cenic.net (137.164.23.225) 0.602 ms 0.728 ms 0.630 ms [2152]
5 dc-lax-core1--lax-agg5-10ge.cenic.net (137.164.46.132) 4.774 ms 3.117 ms 3.683 ms[2152]
6 72.14.223.85 (72.14.223.85) 1.061 ms 3.323 ms 1.258 ms[15169]
7 216.239.46.40 (216.239.46.40) 0.837 ms 64.233.174.238 (64.233.174.238) 30.919 ms 216.239.46.40 (216.239.46.40) 1.373 ms [15169]
8 64.233.174.190 (64.233.174.190) 19.181 ms 64.233.174.188 (64.233.174.188) 2.173 ms 1.407 ms[15169]
9 64.233.174.141 (64.233.174.141) 35.733 ms 64.233.174.143 (64.233.174.143) 35.633 ms 64.233.174.141 (64.233.174.141) 54.388 ms[15169]
10 72.14.237.216 (72.14.237.216) 35.695 ms 72.14.237.220 (72.14.237.220) 43.207 ms 72.14.237.216 (72.14.237.216) 43.865 ms[15169]
11 209.85.254.127 (209.85.254.127) 35.899 ms 36.319 ms 36.441 ms[15169]
12 173.194.115.16 (173.194.115.16) 35.537 ms 35.678 ms 35.537 ms[15169]

Server 3 - Cogent Co.

traceroute to 173.194.115.16 (173.194.115.16), 30 hops max, 60 byte packets
1 vl5.mag01.par01.atlas.cogentco.com (130.117.254.73) 0.505 ms * [174]
2 te0-0-0-18.ccr21.par01.atlas.cogentco.com (154.54.58.117) 1.744 ms te0-7-0-18.ccr21.par01.atlas.cogentco.com (130.117.2.101) 0.511 ms[174]
3 te0-4-0-6.ccr21.lon13.atlas.cogentco.com (154.54.37.177) 8.062 ms te0-1-0-3.mpd22.lon13.atlas.cogentco.com (154.54.59.29) 8.904 ms [174]
4 te0-7-0-21.ccr22.lon01.atlas.cogentco.com (154.54.72.193) 9.059 ms te0-1-0-5.ccr22.lon01.atlas.cogentco.com (154.54.57.166) 9.357 ms [174]
5 te4-1.ccr01.lon18.atlas.cogentco.com (154.54.62.42) 8.164 ms te1-2.ccr01.lon18.atlas.cogentco.com (154.54.61.150) 8.623 ms[174]
6 149.14.8.50 (149.14.8.50) 62.137 ms 149.6.146.30 (149.6.146.30) 66.383 ms [174]
7 209.85.255.76 (209.85.255.76) 8.843 ms 209.85.255.78 (209.85.255.78) 9.023 ms [15169]
8 209.85.253.92 (209.85.253.92) 9.924 ms 8.640 ms[15169]
9 72.14.235.89 (72.14.235.89) 82.625 ms 82.588 ms[15169]
10 66.249.95.231 (66.249.95.231) 89.395 ms 89.705 ms[15169]
11 216.239.48.4 (216.239.48.4) 96.516 ms 97.012 ms[15169]
12 72.14.237.223 (72.14.237.223) 165.455 ms 209.85.240.82 (209.85.240.82) 121.327 ms[15169]
13 72.14.237.220 (72.14.237.220) 123.879 ms 121.313 ms[15169]
14 209.85.254.127 (209.85.254.127) 123.718 ms 123.547 ms[15169]
15 173.194.115.16 (173.194.115.16) 126.090 ms 121.223 ms[15169]

Server 4 - CyberVerse Inc.

Hop	Name	Packet Loss	RTT in ms		
			Best	Avg	Worst
1	sackett.la.cyberverse.net (209.151.232.33)[11051]	0.0%	0.3	18.9	103.7
2	a.sackett-taggart.la.cyberverse.net (209.151.232.28)[11051]	0.0%	0.3	35.2	193.2
3	google.com.any2ix.coresite.com (206.223.143.41)[7850]	0.0%	0.2	0.5	1.6
4	64.233.174.31 (64.233.174.31) [15169]	0.0%	0.2	10.8	114.5
5	64.233.174.188 (64.233.174.188) [15169]	0.0%	0.5	0.6	0.7
6	64.233.174.143 (64.233.174.143) [15169]	0.0%	35.1	35.3	36.0
7	72.14.237.216 (72.14.237.216) [15169]	0.0%	34.9	37.7	58.9
8	209.85.254.127 (209.85.254.127) [15169]	0.0%	35.2	35.3	35.4
9	173.194.115.16 (173.194.115.16) [15169]	0.0%	34.8	34.9	35.

Server 5 - T1 SHOPPER

traceroute to 173.194.115.16 (173.194.115.16), 20 hops max, 40 byte packets
1 208.64.252.229.uscolo.com (208.64.252.229) 0.485 ms 0.424 ms 0.482 ms [32743]
2 208.64.248.17.uscolo.com (208.64.248.17) 0.408 ms 0.463 ms 0.507 ms[32743]
3 tg1-7--100.br01.lsan.acedc.net (69.27.173.9) 0.237 ms 0.285 ms 0.283 ms [11798]
4 PR01.LAX03.google.com (206.223.123.21) 11.702 ms 11.698 ms 11.652 ms [6461]
5 209.85.248.187 (209.85.248.187) 0.958 ms 209.85.248.185 (209.85.248.185) 0.728 ms 209.85.248.187 (209.85.248.187) 0.909 ms[15169]
6 64.233.174.188 (64.233.174.188) 1.158 ms 64.233.174.192 (64.233.174.192) 0.828 ms 64.233.174.190 (64.233.174.190) 0.919 ms[15169]
7 64.233.174.141 (64.233.174.141) 33.891 ms 64.233.174.143 (64.233.174.143) 33.988 ms 64.233.174.141 (64.233.174.141) 33.822 ms[15169]
8 72.14.237.216 (72.14.237.216) 68.867 ms 72.14.237.220 (72.14.237.220) 33.645 ms 33.651 ms[15169]
9 209.85.254.127 (209.85.254.127) 34.232 ms 34.532 ms 34.356 ms[15169]
10 (173.194.115.16) 33.689 ms 33.798 ms 33.721 ms[15169]

Server 6 - Willamette Valley Internet

FROM www.wvi.com TO 173.194.115.16.
traceroute: Warning: Multiple interfaces found; using 204.119.27.10 @ ce0
traceroute to 173.194.115.16 (173.194.115.16), 30 hops max, 40 byte packets
1 wvi-gw.wvi.com (204.119.27.254) 0.331 ms 0.195 ms 0.175 ms[12044]
2 69.59.218.105 (69.59.218.105) 1.622 ms 1.642 ms 1.655 ms[13868]
3 google.nwax.net (198.32.195.34) 5.073 ms 5.068 ms 5.014 ms[101]
4 66.249.94.214 (66.249.94.214) 5.044 ms 5.200 ms 5.109 ms[15169]
5 66.249.94.195 (66.249.94.195) 5.449 ms 5.484 ms 66.249.94.197 (66.249.94.197) 5.330 ms[15169]
6 72.14.239.12 (72.14.239.12) 8.522 ms 8.591 ms 8.493 ms[15169]
7 72.14.232.62 (72.14.232.62) 24.218 ms 24.134 ms 24.129 ms[15169]

8 64.233.174.204 (64.233.174.204) 32.143 ms 50.412 ms 32.056 ms[15169]
9 64.233.174.141 (64.233.174.141) 66.415 ms 66.525 ms 66.538 ms[15169]
10 72.14.237.216 (72.14.237.216) 66.325 ms 66.704 ms 79.663 ms[15169]
11 209.85.254.127 (209.85.254.127) 66.813 ms 66.583 ms 66.607 ms[15169]
12 173.194.115.16 (173.194.115.16) 66.237 ms 66.280 ms 66.248 ms[15169]

Server 7 - INTERSERVER.NET

traceroute to 173.194.115.16 (173.194.115.16), 30 hops max, 60 byte packets
1 teb1.111.05.interserver.net (66.45.228.190) 0.066 ms 0.019 ms 0.017 ms [19318]
2 64.20.32.213 (64.20.32.213) 0.423 ms 0.427 ms 0.499 ms[19318]
3 vl568.cr1.lga2.us.as19318.net (64.20.32.66) 0.472 ms 0.469 ms 0.606 ms[19318]
4 core1-0-0-8.lga.net.google.com (198.32.118.39) 0.580 ms 0.551 ms 0.519 ms [15169]
5 209.85.248.178 (209.85.248.178) 0.645 ms 209.85.248.180 (209.85.248.180) 4.860 ms 0.823 ms[15169]
6 72.14.236.206 (72.14.236.206) 0.822 ms 209.85.252.250 (209.85.252.250) 0.762 ms 0.806 ms[15169]
7 72.14.239.93 (72.14.239.93) 6.549 ms 6.564 ms 6.513 ms[15169]
8 66.249.95.231 (66.249.95.231) 14.868 ms 13.565 ms 72.14.235.12 (72.14.235.12) 13.583 ms[15169]
9 72.14.239.66 (72.14.239.66) 20.785 ms 20.835 ms 20.784 ms[15169]
10 72.14.237.223 (72.14.237.223) 42.760 ms 209.85.240.82 (209.85.240.82) 39.052 ms 39.033 ms[15169]
11 72.14.237.220 (72.14.237.220) 39.001 ms 38.971 ms 39.497 ms[15169]
12 209.85.254.127 (209.85.254.127) 39.968 ms 39.791 ms 39.118 ms[15169]
13 173.194.115.16 (173.194.115.16) 39.006 ms 38.951 ms 38.933 ms[15169]

Server 8 - TOWARDEX TECHNOLOGY

traceroute to 173.194.115.16 (173.194.115.16), 30 hops max, 40 byte packets
1 dcr01-lt-1-1-10-503.bos03.twdx.net (216.93.240.253) 0.298 ms 0.208 ms 0.210 ms [27552]
2 bbr02-ae-3-20G.bos01.twdx.net (216.93.255.197) 0.400 ms 0.336 ms 0.353 ms
MPLS Label=305504 CoS=0 TTL=1 S=1[27552]
3 bbr01-xe-1-2-0.jfk01.twdx.net (198.160.63.138) 5.081 ms 5.121 ms 5.024 ms[27552]
4 core1-0-2-0.lga.net.google.com (198.32.160.130) 5.339 ms 5.233 ms 5.129 ms[39326]
5 209.85.248.178 (209.85.248.178) 5.423 ms 5.417 ms 209.85.248.180 (209.85.248.180) 5.328 ms[15169]
6 72.14.236.206 (72.14.236.206) 11.782 ms 72.14.236.208 (72.14.236.208) 5.337 ms 5.321 ms
MPLS Label=750238 CoS=4 TTL=1 S=1 [15169]
7 72.14.239.93 (72.14.239.93) 12.114 ms 11.811 ms 11.844 ms
MPLS Label=6232 CoS=4 TTL=1 S=1 [15169]
8 66.249.95.231 (66.249.95.231) 18.294 ms 18.243 ms 72.14.235.12 (72.14.235.12) 18.161 ms
MPLS Label=10257 CoS=4 TTL=1 S=1 [15169]
9 72.14.239.66 (72.14.239.66) 25.337 ms 25.841 ms 25.403 ms
MPLS Label=647125 CoS=4 TTL=1 S=1 [15169]
10 72.14.237.223 (72.14.237.223) 47.400 ms 209.85.240.82 (209.85.240.82) 47.452 ms 47.421 ms
MPLS Label=593197 CoS=4 TTL=1 S=1[15169]
11 72.14.237.220 (72.14.237.220) 51.435 ms 70.414 ms 47.410 ms[15169]
12 209.85.254.127 (209.85.254.127) 47.581 ms 43.891 ms 51.916 ms[15169]

13 173.194.115.16 (173.194.115.16) 47.375 ms 47.731 ms 47.331 ms[15169]

Server 9 - HOTLINKS

1 www-gw (217.14.129.1) 0.341 ms 0.312 ms 0.366 ms [20976]
2 ge-0-1-0.me-julie-thn.hotlinks.co.uk (217.14.130.65) 0.366 ms 0.352 ms 0.369 ms [20976]
3 no-dns-yet.inetc.co.uk (85.91.224.45) 0.868 ms 0.480 ms 0.243 ms[34270]
4 195.66.224.125 (195.66.224.125) 0.370 ms 0.357 ms 0.493 ms [50300]
5 209.85.240.63 (209.85.240.63) 0.619 ms 209.85.240.61 (209.85.240.61) 30.345 ms 0.603 ms [15169]
6 209.85.253.90 (209.85.253.90) 0.994 ms 0.983 ms 0.867 ms[15169]
7 72.14.235.89 (72.14.235.89) 77.207 ms 72.14.235.91 (72.14.235.91) 76.809 ms 76.813 ms[15169]
8 66.249.95.229 (66.249.95.229) 84.074 ms 83.931 ms 66.249.95.231 (66.249.95.231) 83.570 ms[15169]
9 216.239.48.4 (216.239.48.4) 91.055 ms 72.14.239.64 (72.14.239.64) 91.807 ms 216.239.48.4 (216.239.48.4) 91.056 ms[15169]
10 72.14.237.223 (72.14.237.223) 116.917 ms 116.977 ms 117.982 ms[15169]
11 72.14.237.220 (72.14.237.220) 109.487 ms 113.475 ms 118.985 ms[15169]
12 209.85.254.127 (209.85.254.127) 116.986 ms 112.976 ms 116.984 ms[15169]
13 173.194.115.16 (173.194.115.16) 113.988 ms 109.473 ms 113.984 ms[15169]

Server 10 – netINS

TTL LFT trace to 173.194.115.16/icmp
1 [5056] [IOWANET] ins-db1-et-10-44.desm.netins.net (167.142.67.89) 0.2ms
2 [5056] [IOWANET] ins-dc2-et-8-3.desm.netins.net (167.142.67.25) 0.2ms
3 [5056] [IOWANET] ins-db3-te-0-7-0-0.desm.netins.net (167.142.67.182) 0.8ms
4 [36280] [GLC-216-176-4-0-24] ord1.ins.indatelservices.com (216.176.4.29) 15.8ms
5 [36280] [GLC-216-176-4-0-24] google.indatelservices.com (216.176.4.58) 15.2ms
6 [15169] [GOOGLE] 209.85.254.120 13.6ms
7 [15169] [GOOGLE] 72.14.237.108 18.7ms
8 [15169] [GOOGLE] 72.14.239.15 34.5ms
9 [15169] [GOOGLE] 216.239.47.120 34.9ms
10 [15169] [GOOGLE] 72.14.237.216 58.0ms
11 [15169] [GOOGLE] 209.85.254.127 35.0ms
12 [15169] [GOOGLE] [target] 173.194.115.16 34.1ms

Server 11 - OPUS ONE

traceroute to 173.194.115.16 (173.194.115.16), 30 hops max, 40 byte packets
2 Opus-GW.Opus1.COM (207.182.35.49) 0.775 ms 0.742 ms 0.799 ms [6373]
3 209.104.3.89 (209.104.3.89) 28.637 ms 28.720 ms 28.710 ms[22772]
4 dsl-206.169.93.41.wenet.com (206.169.93.41) 1.650 ms 1.644 ms 1.632 ms[4323]
5 64-129-238-190.static.twtelecom.net (64.129.238.190) 14.587 ms 14.582 ms 14.481 ms[4323]
6 72.14.213.97 (72.14.213.97) 14.846 ms 14.781 ms 14.776 ms [15169]
7 64.233.174.238 (64.233.174.238) 48.942 ms 216.239.46.40 (216.239.46.40) 14.737 ms 64.233.174.238 (64.233.174.238) 14.681 ms[15169]
8 64.233.174.192 (64.233.174.192) 14.938 ms 64.233.174.188 (64.233.174.188) 15.017 ms 64.233.174.190 (64.233.174.190) 14.920 ms[15169]
9 64.233.174.141 (64.233.174.141) 42.309 ms 42.329 ms 42.325 ms[15169]

10 72.14.237.220 (72.14.237.220) 42.281 ms 42.245 ms 72.14.237.216 (72.14.237.216) 42.223 ms[15169]
11 209.85.254.127 (209.85.254.127) 42.445 ms 42.461 ms 42.590 ms[15169]
12 (173.194.115.16) 42.038 ms 42.024 ms 41.964 ms[15169]

For each Trace route path try to determine the number of ASes that the path is going over.

- ✓ REDHAT
  - Total Routers: 14
  - Total AS: 4

- ✓ University of Southern California
  - Total Routers: 10
  - Total AS: 3

- ✓ Cogent Co.
  - Total Routers: 15
  - Total AS : 2

- ✓ CyberVerse Inc.
  - Total Routers: 9
  - Total AS: 3

- ✓ T1 Shopper
  - Total Routers: 10
  - Total AS: 4

- ✓ Willamette Valley Internet
  - Total Routers: 12
  - Total AS: 4

- ✓ Interserver.net
  - Total Routers: 13
  - Total AS: 2

- ✓ TowardEX Technology
  - Total Routers: 13
  - Total AS: 3

- ✓ Hotlinks
  - Total Routers: 13
  - Total AS: 4

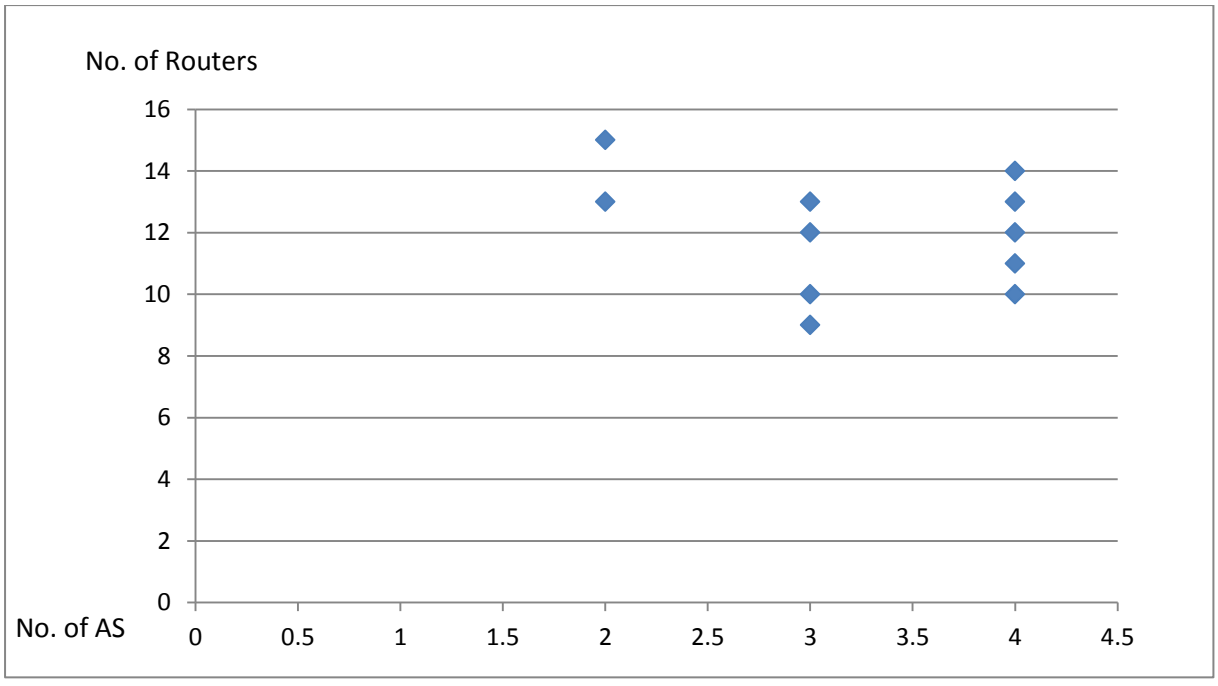
- ✓ NetINS
  - Total Routers: 12
  - Total AS: 3

- ✓ Opus One
  - Total Routers: 11
  - Total AS: 4

Plot a graph with the number of ASes on the path on the x-axis and the number of routers on the same path on the y-axis.

The data to plot the graph:

X Axis (No. of ASes)	Y Axis (No. of Routers)
4	14
3	10
2	15
3	9
4	10
4	12
2	13
3	13
4	13
3	12
4	11



X-Axis: No. of ASes on a path.

Y-Axis: No. of Routers on the same path

Problem 3 – Repeating Detour Results

"Detour" paper basically addresses the problems that internet suffers, defines detour prototype and discusses some experiments performed to analyse these problems. According to the paper, the Internet design has focused on robustness and adaptability. But, for all practical purposes the Internet is the largest performance and availability bottleneck today for end-to-end applications. One of the most important reasons for these problems is routing inefficiency. The routing efficiency can be because of poor routing metrics, restrictive routing policies, manual load balancing or single path routing.

The experiment conducted tries to estimate the degree of routing inefficiency in the internet. Path between two hosts can be called inefficient if there exists some alternate path with superior latency. For example, if there is a path from source A to destination B and if we can come up with some alternate path, say A to C to B, such that the latency (AC + CB) < Latency (AB), then the path AB would be considered as inefficient. The goal was to measure the fraction of routes for which this occurs and the magnitude of this inefficiency.

Replicating the Experiment

To replicate the experiment, let's consider 5 servers which are following:

SERVER	IP	Representation
University of Southern California	128.125.137.243	USC
Redhat	209.132.180.92	RH
netINS	167.142.67.89	NI
NetPlex	204.213.176.102	NP
T1 Shopper	208.64.252.229	T1

Now onwards, the servers will be referred by their representation.

For this group of servers, we collect the pair-wise latency by performing trace route. These servers are available on traceroute.org from where we can perform trace route from each server to each other server. For the trace route between each pair of servers, we record the round-trip time as the average of the three round-trip times returned by the last record of trace route.

Thus, the raw data in our experiment is basically the trace route performed for each pair of servers and the round-trip time that we got. From this trace route, we pick the last record and take the three round-trip times. Thus, for each pair, we have three round-trip times. Now, we take the average of these three to get the round trip time. After calculating the average round trip time we get the following matrix.

	USC	RH	NI	NP	T1
USC	NA	92.39 ms	61.19 ms	85.2 ms	1.45 ms
RH	96.98 ms	NA	51.29 ms	73.3 ms	10.8 ms
NI	58.4 ms	49.6 ms	NA	42.9 ms	47.8 ms
NP	78.85 ms	73.82 ms	43.68 ms	NA	83.06 ms
T1	1.69 ms	11.42 ms	47.73 ms	83.89 ms	NA

Now, for each pair of servers, we set one as source (S) and the other as destination (D). Thus, the average round-trip time as shown in the table becomes the default latency between these two servers. Then, we consider each of the other 3 servers as the intermediate (I) server. This provides us 3 alternate routes (S to I to D) to reach from source to destination through the intermediate server.

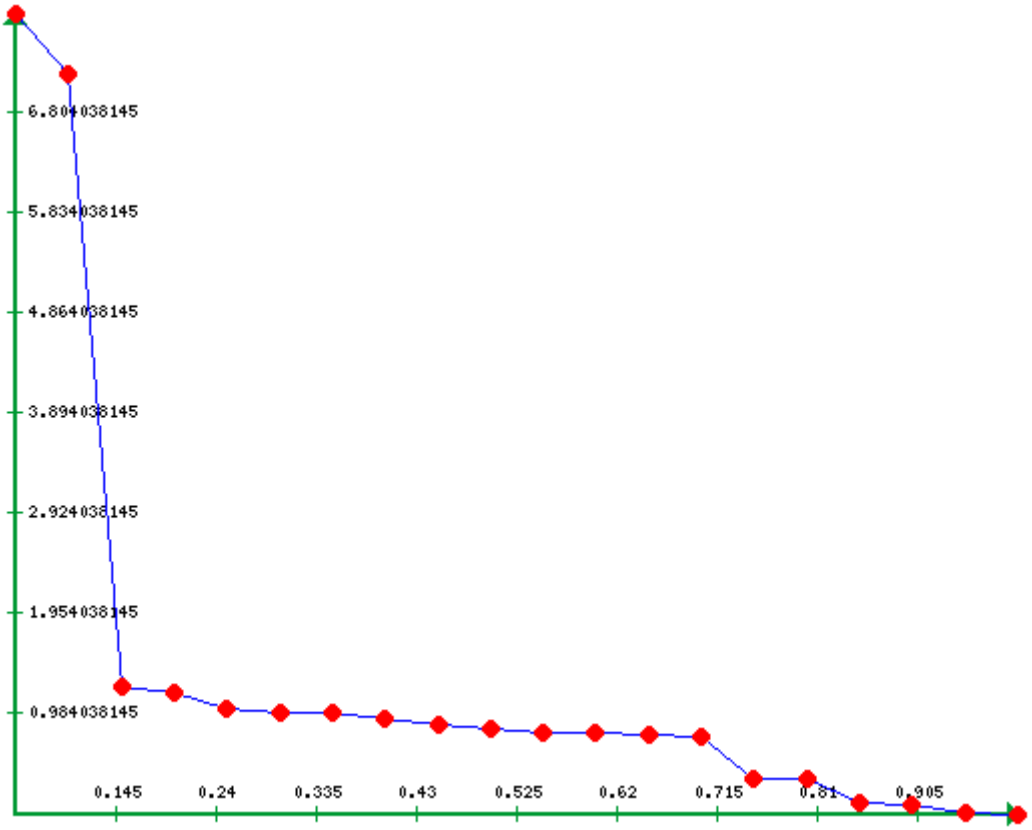
We calculate the total round-trip time (SI+ID) for all the three alternate routes for each of the (S, D) pair. Then, we choose the best of these 3 alternate routes (with minimum latency) and calculate the ratio of default-path latency to best alternate path latency.

Thus, for each pair (S, D) of servers, we have default path latency, best alternate path latency and the ratio of these two. We have total 20(5x4) such pair entries. Finally, we get following data.

S.No.	Source	Destination	Default Route Latency	Best Alternate Route	Best Alternate route Latency (ms)	Ratio of Default to Best Alternate Route Latency (ms)	Is the default route inefficient
1	USC	RH	92.39	USC-T1-RH	12.87	7.17871	Yes
2	USC	NI	61.19	USC-T1-NI	49.18	1.244205	Yes
3	USC	NP	85.2	USC-T1-NP	85.1	1.001175	Yes
4	USC	T1	1.45	USC-RH-T1	103.19	0.014052	No
5	RH	USC	96.98	RH-T1-USC	12.49	7.764612	Yes
6	RH	NI	51.29	RH-T1-NI	58.53	0.876303	No
7	RH	T1	10.8	RH-USC-T1	98.43	0.109723	No
8	RH	NP	73.3	RH-NI-NP	94.19	0.778214	No
9	NI	USC	58.4	NI-T1-USC	49.49	1.180036	Yes
10	NI	RH	49.6	NI-T1-RH	59.22	0.837555	No
11	NI	NP	42.9	NI-RH-NP	122.9	0.349064	No
12	NI	T1	47.8	NI-USC-T1	59.95	0.797331	No
13	NP	USC	78.85	NP-T1-USC	84.75	0.930383	No
14	NP	RH	73.82	NP-NI-RH	93.28	0.791381	No
15	NP	NI	43.68	NP-RH-NI	125.11	0.349133	No
16	NP	T1	83.06	NP-USC-T1	80.30	1.034371	Yes
17	T1	USC	1.69	T1-NI-USC	106.13	0.015924	No
18	T1	RH	11.42	T1-USC-RH	94.08	0.121386	No
19	T1	NI	47.73	T1-RH-NI	62.71	0.761123	No
20	T1	NP	83.89	T1-RH-NP	84.72	0.990203	No

OBSERVATION:

From the above specified data, we can observe that for 6 pairs (S, D) the default route was not the best route as we got an alternate route for which the latency was less than the latency of the default path. We can also verify the same by looking at the values of the ratio of the default-route latency to best alternate path latency. There are total 6 entries in this column for which the value is greater than 1. Thus, we can conclude that the 6 routes out of the 20 routes are inefficient. Therefore, 0.3 fractions of total routes have been found inefficient. We can also represent this observation in the graphical form as shown below:



In the graph,

X-Axis represents the fraction of paths measured.

Y-Axis represents the ratio of default-path latency to best alternate-path latency.

Here, we can see that for 0.3 fraction of paths measured the ratio is greater than 1.

Comparison with the Actual Experiment:

The final graph obtained is almost similar to the graph presented in the paper. But, there is a difference with respect to the fraction of inefficient routes. In the actual experiment, they concluded that for around half of the paths, there was an alternate faster route. In the above performed experiment, around 30% of the measured paths have been found inefficient.

The reason for the difference is that the above conducted experiment is not that much comprehensive. We took only 5 servers while 43 servers were considered in the actual experiment. We observed the trace route values only for a small period. In the actual experiment, it was measured for 35 days. Thus, the number of servers and the time period are the reasons for this difference. If we conduct the experiment on more number of servers for a longer time period, it is highly possible that we would map to the actual conclusion of the paper. It is also possible that if we conduct the same experiment again, we may get different fraction values. The reason is the dynamic nature of the routers, route selection and network traffic. Every time we do a trace route, we may get a different latency value which can affect the results. But, still this experiment shows the similar results as found in the actual experiment and directs towards the inefficiencies in internet routing.