COMP 416: Computer Networks - Project 3

Network Layer Analysis and DV Routing Simulator

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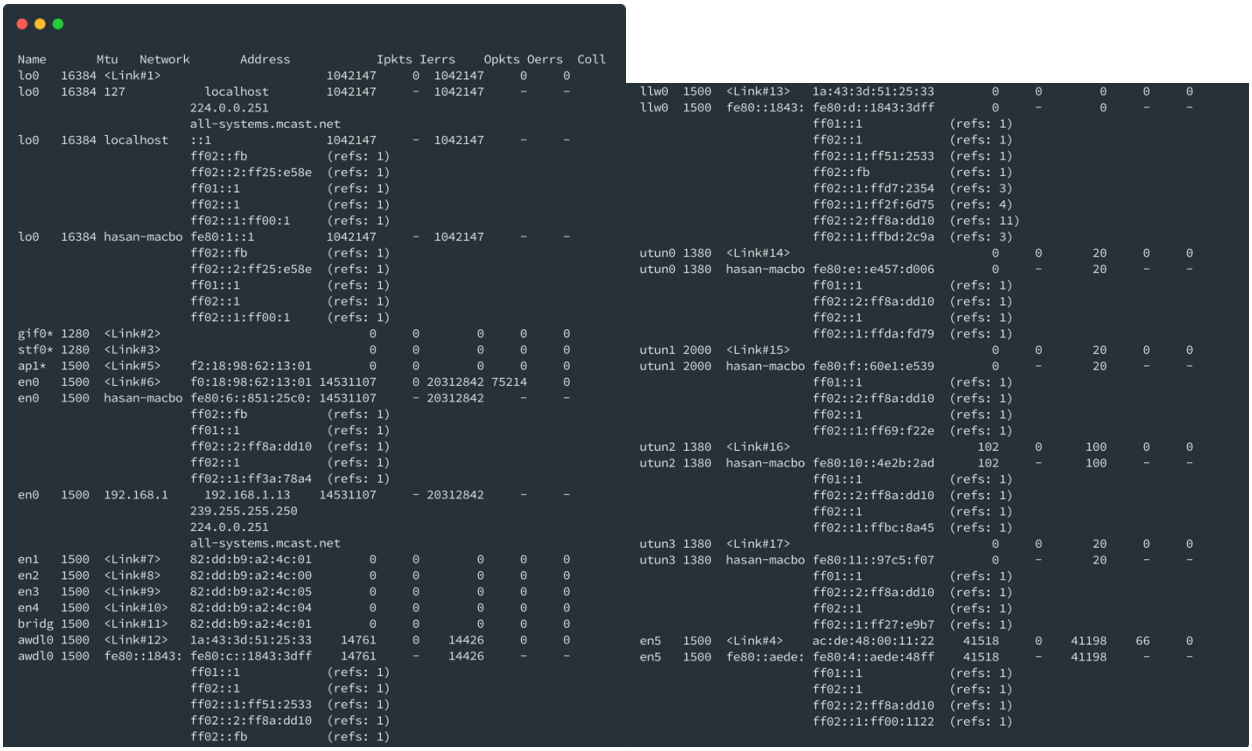
Part 1. Network Layer Analysis

Part 1A. Network Interface Analysis

1. We provide 2 parameters to netstat command. First `-a` parameter displays all active TCP connections and the TCP and UDP ports on which the computer is listening, `-i` parameter displays network interface status. So `netstat -ai` command shows the state of the network interfaces and their TCP connections.



```
Name       Mtu   Network       Address           Ipkts Ierrs    Opkts Oerrs  Coll
lo0   16384 <Link#1>                      1042147     0  1042147     0     0
lo0   16384 127           localhost       1042147     -  1042147     -     -
                      224.0.0.251
                      all-systems.mcast.net
lo0   16384 localhost   ::1               1042147     -  1042147     -     -
                      ff02::fb          (refs: 1)
                      ff02::2:ff25:e58e  (refs: 1)
                      ff01::1           (refs: 1)
                      ff02::1           (refs: 1)
                      ff02::1:ff00:1    (refs: 1)
lo0   16384 hasan-macbo fe80:1::1         1042147     -  1042147     -     -
                      ff02::fb          (refs: 1)
                      ff02::2:ff25:e58e  (refs: 1)
                      ff01::1           (refs: 1)
                      ff02::1           (refs: 1)
                      ff02::1:ff00:1    (refs: 1)
gif0* 1280  <Link#2>                           0     0       0     0     0
stf0* 1280  <Link#3>                           0     0       0     0     0
ap1*  1500  <Link#5>    f2:18:98:62:13:01      0     0       0     0     0
en0   1500  <Link#6>    f0:18:98:62:13:01 14531107     0 20312842 75214     0
en0   1500  hasan-macbo fe80:6::851:25c0: 14531107     - 20312842     -     -
                      ff02::fb          (refs: 1)
                      ff01::1           (refs: 1)
                      ff02::2:ff8a:dd10  (refs: 1)
                      ff02::1           (refs: 1)
                      ff02::1:ff3a:78a4  (refs: 1)
en0   1500  192.168.1    192.168.1.13    14531107     - 20312842     -     -
                      239.255.255.250
                      224.0.0.251
                      all-systems.mcast.net
en1   1500  <Link#7>    82:dd:b9:a2:4c:01      0     0       0     0     0
en2   1500  <Link#8>    82:dd:b9:a2:4c:00      0     0       0     0     0
en3   1500  <Link#9>    82:dd:b9:a2:4c:05      0     0       0     0     0
en4   1500  <Link#10>   82:dd:b9:a2:4c:04      0     0       0     0     0
bridg 1500  <Link#11>   82:dd:b9:a2:4c:01      0     0       0     0     0
awdl0 1500  <Link#12>   1a:43:3d:51:25:33    14761     0   14426     0     0
awdl0 1500  fe80::1843: fe80:c::1843:3dff    14761     -   14426     -     -
                      ff01::1           (refs: 1)
                      ff02::1           (refs: 1)
                      ff02::1:ff51:2533  (refs: 1)
                      ff02::2:ff8a:dd10  (refs: 1)
                      ff02::fb          (refs: 1)
llw0  1500  <Link#13>   1a:43:3d:51:25:33      0     0       0     0     0
llw0  1500  fe80::1843: fe80:d::1843:3dff      0     -       0     -     -
                      ff01::1           (refs: 1)
                      ff02::1           (refs: 1)
                      ff02::1:ff51:2533  (refs: 1)
                      ff02::fb          (refs: 1)
                      ff02::1:ffd7:2354  (refs: 3)
                      ff02::1:ff2f:6d75  (refs: 4)
                      ff02::2:ff8a:dd10  (refs: 11)
                      ff02::1:ffbd:2c9a  (refs: 3)
utun0 1380  <Link#14>                          0     0      20     0     0
utun0 1380  hasan-macbo fe80:e::e457:d006      0     -      20     -     -
                      ff01::1           (refs: 1)
                      ff02::2:ff8a:dd10  (refs: 1)
                      ff02::1           (refs: 1)
                      ff02::1:ffda:fd79  (refs: 1)
utun1 2000  <Link#15>                          0     0      20     0     0
utun1 2000  hasan-macbo fe80:f::60e1:e539      0     -      20     -     -
                      ff01::1           (refs: 1)
                      ff02::2:ff8a:dd10  (refs: 1)
                      ff02::1           (refs: 1)
                      ff02::1:ff69:f22e  (refs: 1)
utun2 1380  <Link#16>                        102     0     100     0     0
utun2 1380  hasan-macbo fe80:10::4e2b:2ad     102     -     100     -     -
                      ff01::1           (refs: 1)
                      ff02::2:ff8a:dd10  (refs: 1)
                      ff02::1           (refs: 1)
                      ff02::1:ffbc:8a45  (refs: 1)
utun3 1380  <Link#17>                          0     0      20     0     0
utun3 1380  hasan-macbo fe80:11::97c5:f07      0     -      20     -     -
                      ff01::1           (refs: 1)
                      ff02::2:ff8a:dd10  (refs: 1)
                      ff02::1           (refs: 1)
                      ff02::1:ff27:e9b7  (refs: 1)
en5   1500  <Link#4>    ac:de:48:00:11:22   41518     0   41198    66     0
en5   1500  fe80::aede: fe80:4::aede:48ff   41518     -   41198     -     -
                      ff01::1           (refs: 1)
                      ff02::1           (refs: 1)
                      ff02::2:ff8a:dd10  (refs: 1)
                      ff02::1:ff00:1122  (refs: 1)
```

2. Destination column: Shows the destination network.
Gateway column: Indicates the router through which packets are forwarded.
Flags column: The U flag indicates that the route is up route is valid.
The G flag indicates that the route is to a gateway.
The S flag indicates route added with the route command.
The H flag indicates route is to a host rather than to a network, where the destination address is a complete address.
Netif column: Indicates the interface on the local host that is the source endpoint of the transmission.

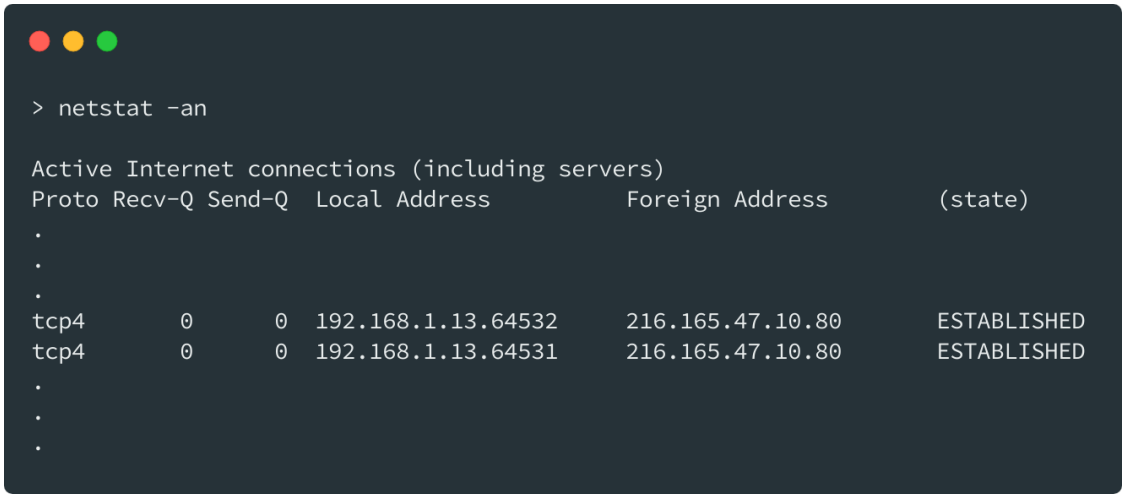
```
Internet:
Destination        Gateway            Flags        Netif Expire
default            192.168.1.1        UGScg          en0
127                localhost          UCS            lo0
localhost          localhost          UH             lo0
169.254            link#6             UCS            en0      !
169.254.91.108     link#6             UHLSW          en0      !
169.254.103.19     link#6             UHLSW          en0      !
169.254.196.189    link#6             UHLSW          en0      !
192.168.1          link#6             UCS            en0      !
192.168.1.1/32     link#6             UCS            en0      !
192.168.1.1        c8:3a:35:dc:2d:58  UHLWIir        en0   1166
192.168.1.2        7c:1:91:65:88:b6   UHLWIi         en0    293
192.168.1.3        40:b8:9a:63:fa:d   UHLWI          en0    616
192.168.1.5        6c:96:cf:89:b1:95  UHLWI          en0    733
192.168.1.12       f2:4b:73:fe:12:19  UHLWIi         en0    967
192.168.1.13/32    link#6             UCS            en0      !
192.168.1.255      ff:ff:ff:ff:ff:ff  UHLWbI         en0      !
224.0.0/4          link#6             UmCS           en0      !
224.0.0.251        1:0:5e:0:0:fb      UHmLWI         en0
239.255.255.250    1:0:5e:7f:ff:fa    UHmLWI         en0
255.255.255.255/32 link#6             UCS            en0      !
```

3. My client using ports 64532 and 64531 to connect nyu.edu. First, I get the IP address of the host, using `nslookup`.

```
> nslookup -type=A nyu.edu

Name:    nyu.edu
Address: 216.165.47.10
```

Then using `netstat -P tcp` command, we can find nyu.edu's IP address in the list.

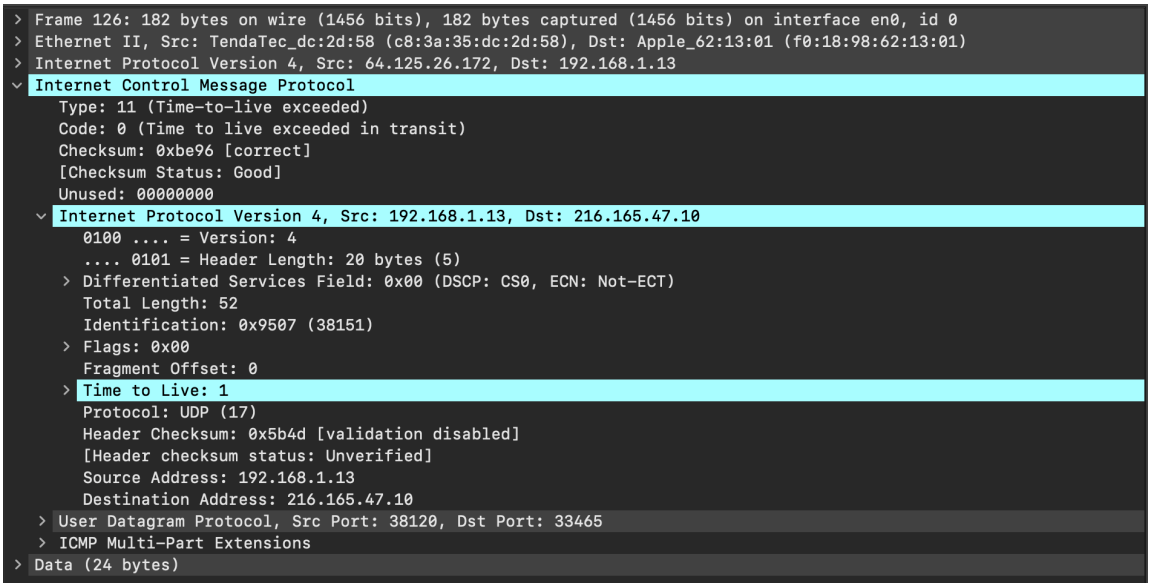


Part 1B. ICMP Analysis

4. TTL, time to live is the number of hops or amount of time that a packet exists inside a network. When TTL exceeded, packet is discarded. Time to live is important for caching information. It determines how long the data can be cached and when the information should be updated. We can find TTL under the network layer, for example under the Internet Protocol.

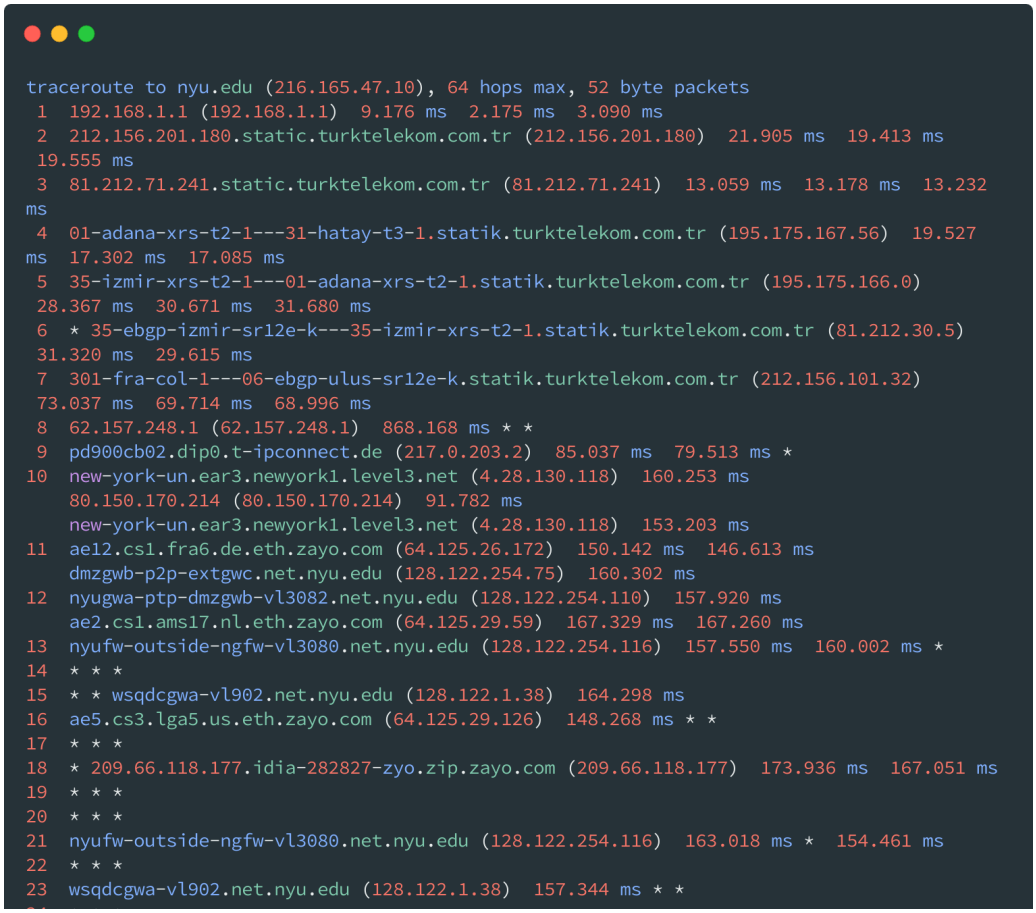
5. ICMP protocol is designed to communicate between network layers. However, port numbers are used to communicate between application layers, so ICMP has neither destination nor source port number.

6. Minimum TTL is 1.



7. My computer sends first a packet with TTL = 1, the second packet has TTL = 2 so and so on. A router will decrement the packet's TTL when the packet passes through. If the packet arrives the router with TTL value equals to 1, then router sends an ICMP packet to the source. In this way we can count the router along the path to the destination.

8. For each router along the path, `traceroute` sends 3 probes.



```
traceroute to nyu.edu (216.165.47.10), 64 hops max, 52 byte packets
 1  192.168.1.1 (192.168.1.1)  9.176 ms  2.175 ms  3.090 ms
 2  212.156.201.180.static.turktelekom.com.tr (212.156.201.180)  21.905 ms  19.413 ms
 19.555 ms
 3  81.212.71.241.static.turktelekom.com.tr (81.212.71.241)  13.059 ms  13.178 ms  13.232
ms
 4  01-adana-xrs-t2-1---31-hatay-t3-1.statik.turktelekom.com.tr (195.175.167.56)  19.527
ms  17.302 ms  17.085 ms
 5  35-izmir-xrs-t2-1---01-adana-xrs-t2-1.statik.turktelekom.com.tr (195.175.166.0)
 28.367 ms  30.671 ms  31.680 ms
 6  * 35-ebgp-izmir-sr12e-k---35-izmir-xrs-t2-1.statik.turktelekom.com.tr (81.212.30.5)
 31.320 ms  29.615 ms
 7  301-fra-col-1---06-ebgp-ulus-sr12e-k.statik.turktelekom.com.tr (212.156.101.32)
 73.037 ms  69.714 ms  68.996 ms
 8  62.157.248.1 (62.157.248.1)  868.168 ms * *
 9  pd900cb02.dip0.t-ipconnect.de (217.0.203.2)  85.037 ms  79.513 ms *
10  new-york-un.ear3.newyork1.level3.net (4.28.130.118)  160.253 ms
    80.150.170.214 (80.150.170.214)  91.782 ms
    new-york-un.ear3.newyork1.level3.net (4.28.130.118)  153.203 ms
11  ae12.cs1.fra6.de.eth.zayo.com (64.125.26.172)  150.142 ms  146.613 ms
    dmzgwb-p2p-extgwc.net.nyu.edu (128.122.254.75)  160.302 ms
12  nyugwa-ptp-dmzgwb-vl3082.net.nyu.edu (128.122.254.110)  157.920 ms
    ae2.cs1.ams17.nl.eth.zayo.com (64.125.29.59)  167.329 ms  167.260 ms
13  nyufw-outside-ngfw-vl3080.net.nyu.edu (128.122.254.116)  157.550 ms  160.002 ms *
14  * * *
15  * * wsqdcgwa-vl902.net.nyu.edu (128.122.1.38)  164.298 ms
16  ae5.cs3.lga5.us.eth.zayo.com (64.125.29.126)  148.268 ms * *
17  * * *
18  * 209.66.118.177.idia-282827-zyo.zip.zayo.com (209.66.118.177)  173.936 ms  167.051 ms
19  * * *
20  * * *
21  nyufw-outside-ngfw-vl3080.net.nyu.edu (128.122.254.116)  163.018 ms *  154.461 ms
22  * * *
23  wsqdcgwa-vl902.net.nyu.edu (128.122.1.38)  157.344 ms * *
```

9. I reach to the destination much faster, at 11 hops, when tracing 18.31.0.200.

10. Routing Blackhole is the routing the all network traffic into blackhole and lost it. We can use such a system to prevent attacks to our networks like DDoS attack. However, normal traffic is also affected such prevention system

11. We can arrange the output fields by using the -o flag. I use following command:

```
sudo mtr -o "LSDR NBAW JMXI" nyu.edu
```

```
                                                  Packets                Pings
Host                                           Loss%   Snt Drop  Rcv  Last  Best  Avg  Wrst Jttr Javg Jmax Jint
 1. 192.168.1.1                                 3.4%    89    3   86  12.5   2.0  23.7 317.8  7.4 17.6 295. 156.
 2. 212.156.201.180.static.turktelekom.com.tr   1.1%    89    1   87  19.6  15.2  50.2 355.5 21.2 23.7 183. 307.
 3. 81.212.71.241.static.turktelekom.com.tr     0.0%    88    0   88  13.3  13.1  37.5 301.5  4.6 17.7 144. 188.
 4. 01-adana-xrs-t2-1---31-hatay-t3-1.statik.turktelekom.com.tr  0.0%  88  0  88  18.4  15.3  37.5 276.3  7.6 18.7 164. 162.
 5. 35-izmir-xrs-t2-1---01-adana-xrs-t2-1.statik.turktelekom.com.tr  0.0%  88  0  88  33.0  29.7  49.1 253.2  6.4 18.2 183. 129.
 6. 35-ebgp-izmir-sr12e-k---35-izmir-xrs-t2-1.statik.turktelekom.com.tr  2.3%  88  2  86  35.9  28.9  46.9 210.7 16.6 16.4 167. 218.
 7. 301-fra-col-1---06-ebgp-ulus-sr12e-k.statik.turktelekom.com.tr  1.1%  88  1  87  73.4  68.9  85.8 403.2  2.9 20.0 330. 179.
 8. 62.67.19.245                                96.6%   88   84    3  80.8  77.3  79.2  80.8  3.5  1.8  3.5  5.4
 9. ae-1-3501.ear3.newyork1.level3.net          84.1%   88   74   14 164.3 156.6 176.4 354.0  6.5 33.1 197. 252.
10. new-york-un.ear3.newyork1.level3.net         1.1%   88    1   87 160.1 153.3 191.9 549.2 22.5 25.2 302. 245.
11. dmzgwb-p2p-extgwc.net.nyu.edu               81.6%   88   71   16 157.9 157.0 215.1 479.1 22.9 52.3 322. 443.
12. nyugwa-ptp-dmzgwb-vl3082.net.nyu.edu         1.1%   88    1   87 159.5 155.5 194.7 487.4  1.1 34.8 250. 460.
13. nyufw-outside-ngfw-vl3080.net.nyu.edu       79.3%   88   69   18 158.3 155.7 169.2 208.5 50.2 17.3 50.2 208.
14. (waiting for reply)
15. wsqdcgwa-vl902.net.nyu.edu                  95.4%   88   83    4 185.2 159.3 271.1 468.2 86.6 148. 308. 542.
16. (waiting for reply)
```

These fields are described in man page of `mtr` as follows:

```
+--+--------------------+
|L | Loss ratio         |
+--+--------------------+
|D | Dropped packets    |
+--+--------------------+
|R | Received packets   |
+--+--------------------+
|S | Sent Packets       |
+--+--------------------+
|N | Newest RTT(ms)     |
+--+--------------------+
|B | Min/Best RTT(ms)   |
+--+--------------------+
|A | Average RTT(ms)    |
+--+--------------------+
|W | Max/Worst RTT(ms)  |
+--+--------------------+
|V | Standard Deviation |
+--+--------------------+
|G | Geometric Mean     |
+--+--------------------+
|J | Current Jitter     |
+--+--------------------+
|M | Jitter Mean/Avg.   |
+--+--------------------+
|X | Worst Jitter       |
+--+--------------------+
|I | Interarrival Jitter|
+--+--------------------+
```

12. `mtr` continuously updates times by polling a remote server and allows us to see how the latency and performance changes over time. On the other hand, `traceroute` allows us to discover the pathway to a host. When we compare two Wireshark record, we can see that `mtr` continuously sends probes whilst `traceroute` sends predetermined number of probes.

Part 2. DV Routing Simulator

Part 2A. Implementation

When constructing Node class, I initialize id from static counter, get cost and neighbors from static arrays of `DVSimulator` class. `myDV` is initially equals to cost of that node. I initialize `bestPath` array based on following conditions: If nodes id or neighbor's id is equal to destination id, then use that id, otherwise get a random node from `randomNeighbor` method.

```
public Node() {
    this.id = count++;
    this.cost = DVSimulator.cost[this.id];
    this.neighbors = DVSimulator.neighbors[this.id];
    this.myDV = this.cost;

    for (int i = 0; i < DVSimulator.NUMNODES; i++) {
        if (i == this.id) {
            this.bestPath[i] = this.id;
        } else if (Node.contains(neighbors, i)) {
            this.bestPath[i] = i;
        } else {
            this.bestPath[i] = randomNeighbor();
        }
    }

    notifyNeighbors();
}
```

For the `notifyNeighbors` method, I create a new packet for each neighbor that created with current node `id` as source, neighbor id as destination and current node's `myDV` array as the dv. Then, I send the packet.

```java
public void notifyNeighbors() {
    for (int neighbor : neighbors) {
        Packet packet = new Packet(this.id, neighbor, this.myDV);
        DVSimulator.sendPacket(packet);
    }
}
```

Note: I get the following method from https://stackoverflow.com/a/34541755. It is simple method for ease of use when searching a value in array.

```java
public static boolean contains(final int[] arr, final int key) {
    return Arrays.stream(arr).anyMatch(i -> i == key);
}
```

Part 2B. Optional (Bonus)

I compare for each value in the DV received from neighbor as `new_cost` and current DV as `current_cost`. If there is a cheaper path, I update `myDV` with corresponding cost and update `bestPath` with corresponding neighbor's id. If there is such a change in current Node's DV I update `hasDVChanged` value as true. If `hasDVChanged` value is true, then I `notifyNeighbors` and increment `numUpdates`. By doing that, I increment and notify neighbors just once for each packet.

```
public void updateDV(Packet p) {
      int neighbor_id = p.getSource();
      neighborDV[neighbor_id] = p.getDV();
      boolean hasDVChanged = false;

      for (int i = 0; i < myDV.length; i++) {
          int new_cost = cost[neighbor_id] + neighborDV[neighbor_id][i];
          int current_cost = myDV[i];

          if (new_cost < current_cost) {
              myDV[i] = new_cost;
              bestPath[i] = neighbor_id;
              hasDVChanged = true;
          }
      }

      if (hasDVChanged) {
          notifyNeighbors();
          numUpdates++;
      }
  }
```