Exercise 1.1

1)

```
ekargoug@gateway:~$ sudo tcpdump -i eth1 -n -e -v "udp port 67 or udp port 68"
tcpdump: listening on eth1, link-type EN10MB (Ethernet), capture size 262144 byt
es
18:44:41.021919 02:9b:f5:d0:81:ad > ff:ff:ff:ff:ff:ff, ethertype IPv4 (0x0800), length 342: (tos 0x1
0, ttl 128, id 0, offset 0, flags [none], proto UDP (17), length 328)
    0.0.0.0.68 > 255.255.255.255.67: BOOTP/DHCP, Request from 02:9b:f5:d0:81:ad, length 300, xid 0x3
fc456, Flags [none]
          Client-Ethernet-Address 02:9b:f5:d0:81:ad
          Vendor-rfc1048 Extensions
            Magic Cookie 0x63825363
            DHCP-Message Option 53, length 1: Discover
            Hostname Option 12, length 8: "client-1"
            Parameter-Request Option 55, length 13:
              Subnet-Mask, BR, Time-Zone, Default-Gateway
              Domain-Name, Domain-Name-Server, Option 119, Hostname
              Netbios-Name-Server, Netbios-Scope, MTU, Classless-Static-Route
              NTP
18:44:43.040726 02:9b:f5:d0:81:ad > ff:ff:ff:ff:ff:ff, ethertype IPv4 (0x0800), length 342: (tos 0x1
0, ttl 128, id 0, offset 0, flags [none], proto UDP (17), length 328)
    0.0.0.0.68 > 255.255.255.255.67: BOOTP/DHCP, Request from 02:9b:f5:d0:81:ad, length 300, xid 0x3
fc456, secs 3, Flags [none]
          Client-Ethernet-Address 02:9b:f5:d0:81:ad
          Vendor-rfc1048 Extensions
            Magic Cookie 0x63825363
            DHCP-Message Option 53, length 1: Discover
            Hostname Option 12, length 8: "client-1"
            Parameter-Request Option 55, length 13:
              Subnet-Mask, BR, Time-Zone, Default-Gateway
              Domain-Name, Domain-Name-Server, Option 119, Hostname
              Netbios-Name-Server, Netbios-Scope, MTU, Classless-Static-Route
              NTP
18:44:44.027234 02:97:cf:69:e2:2c > 02:9b:f5:d0:81:ad, ethertype IPv4 (0x0800), length 342: (tos 0xc
0, ttl 64, id 38162, offset 0, flags [none], proto UDP (17), length 328)
    192.168.100.1.67 > 192.168.100.140.68: BOOTP/DHCP, Reply, length 300, xid 0x3fc456, Flags [none]
          Your-IP 192.168.100.140
          Server-IP 192.168.100.1
          Client-Ethernet-Address 02:9b:f5:d0:81:ad
          Vendor-rfc1048 Extensions
            Magic Cookie 0x63825363
            DHCP-Message Option 53, length 1: Offer
            Server-ID Option 54, length 4: 192.168.100.1
            Lease-Time Option 51, length 4: 14400
            RN Option 58, length 4: 7200
            RB Option 59, length 4: 12600
            Subnet-Mask Option 1, length 4: 255.255.255.0
```

```
18:44:44.030146 02:9b:f5:d0:81:ad > ff:ff:ff:ff:ff:ff, ethertype IPv4 (0x0800), length 342: (tos 0x1
0, ttl 128, id 0, offset 0, flags [none], proto UDP (17), length 328)
    0.0.0.0.68 > 255.255.255.255.67: BOOTP/DHCP, Request from 02:9b:f5:d0:81:ad, length 300, xid 0x3
fc456, secs 3, Flags [none]
          Client-Ethernet-Address 02:9b:f5:d0:81:ad
          Vendor-rfc1048 Extensions
            Magic Cookie 0x63825363
            DHCP-Message Option 53, length 1: Request
            Server-ID Option 54, length 4: 192.168.100.1
            Requested-IP Option 50, length 4: 192.168.100.140
            Hostname Option 12, length 8: "client-1"
            Parameter-Request Option 55, length 13:
              Subnet-Mask, BR, Time-Zone, Default-Gateway
              Domain-Name, Domain-Name-Server, Option 119, Hostname
              Netbios-Name-Server, Netbios-Scope, MTU, Classless-Static-Route
              NTP
18:44:44.060856 02:97:cf:69:e2:2c > 02:9b:f5:d0:81:ad, ethertype IPv4 (0x0800), length 344: (tos 0xc
0, ttl 64, id 38171, offset 0, flags [none], proto UDP (17), length 330)
    192.168.100.1.67 > 192.168.100.140.68: BOOTP/DHCP, Reply, length 302, xid 0x3fc456, secs 3, Flag
s [none]
          Your-IP 192.168.100.140
          Server-IP 192.168.100.1
          Client-Ethernet-Address 02:9b:f5:d0:81:ad
          Vendor-rfc1048 Extensions
            Magic Cookie 0x63825363
            DHCP-Message Option 53, length 1: ACK
            Server-ID Option 54, length 4: 192.168.100.1
            Lease-Time Option 51, length 4: 14400
            RN Option 58, length 4: 7200
            RB Option 59, length 4: 12600
            Subnet-Mask Option 1, length 4: 255.255.255.0
            BR Option 28, length 4: 192.168.100.255
            Hostname Option 12, length 8: "client-1"
            Domain-Name-Server Option 6, length 4: 192.168.100.1
            Default-Gateway Option 3, length 4: 192.168.100.1
```

Source: 0.0.0.0.68

Destination: 255.255.255.67

MAC address: 02:9b:f5:d0:81:ad

2)

```
Your-IP 192.168.100.140
Server-IP 192.168.100.1
Client-Ethernet-Address 02:9b:f5:d0:81:ad
Vendor-rfc1048 Extensions
  Magic Cookie 0x63825363
  DHCP-Message Option 53, length 1: Offer
  Server-ID Option 54, length 4: 192.168.100.1
  Lease-Time Option 51, length 4: 14400
  RN Option 58, length 4: 7200
  RB Option 59, length 4: 12600
  Subnet-Mask Option 1, length 4: 255.255.255.0
  BR Option 28, length 4: 192.168.100.255
  Domain-Name-Server Option 6, length 4: 192.168.100.1
  Default-Gateway Option 3, length 4: 192.168.100.1
```

Default gateway

name server

3)

```
Client-Ethernet-Address 02:9b:f5:d0:81:ad
Vendor-rfc1048 Extensions
  Magic Cookie 0x63825363
  DHCP-Message Option 53, length 1: Request
  Server-ID Option 54, length 4: 192.168.100.1
  Requested-IP Option 50, length 4: 192.168.100.140
  Hostname Option 12, length 8: "client-1"
  Parameter-Request Option 55, length 13:
    Subnet-Mask, BR, Time-Zone, Default-Gateway
    Domain-Name, Domain-Name-Server, Option 119, Hostname
    Netbios-Name-Server, Netbios-Scope, MTU, Classless-Static-Route
    NTP
```

Server Id

Requested- Id

192.168.100.140

4)

```
  Your-IP 192.168.100.140
  Server-IP 192.168.100.1
  Client-Ethernet-Address 02:9b:f5:d0:81:ad
  Vendor-rfc1048 Extensions
    Magic Cookie 0x63825363
    DHCP-Message Option 53, length 1: ACK
    Server-ID Option 54, length 4: 192.168.100.1
    Lease-Time Option 51, length 4: 14400
    RN Option 58, length 4: 7200
    RB Option 59, length 4: 12600
    Subnet-Mask Option 1, length 4: 255.255.255.0
    BR Option 28, length 4: 192.168.100.255
    Hostname Option 12, length 8: "client-1"
    Domain-Name-Server Option 6, length 4: 192.168.100.1
    Default-Gateway Option 3, length 4: 192.168.100.1
```

5)

```
ekargoug@client-1:~$ ifconfig eth1
eth1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet 192.168.100.140  netmask 255.255.255.0  broadcast 192.168.100.255
        ether 02:9b:f5:d0:81:ad  txqueuelen 1000  (Ethernet)
        RX packets 583  bytes 55393 (55.3 KB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 586  bytes 48563 (48.5 KB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0
```

By looking at the inet: 192.168.100.140, I know that is the adress it's now using and it corresponds with the IP adress in the request and acknowledgement.

Exercise 1.2

1)

```
ekargoug@client-2:~$ dig website.AntoineEzedine-Lab3.ch-geni-net.instageni.cenic
.net

; <<>> DiG 9.11.3-1ubuntu1.14-Ubuntu <<>> website.AntoineEzedine-Lab3.ch-geni-ne
t.instageni.cenic.net
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 5280
;; flags: qr aa rd ra; QUERY: 1, ANSWER: 2, AUTHORITY: 2, ADDITIONAL: 2

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags:; udp: 4096
; COOKIE: 7823385972196b5d348739e5606a7e4b03f83df5f7f0776d (good)
;; QUESTION SECTION:
;website.AntoineEzedine-Lab3.ch-geni-net.instageni.cenic.net. IN        A

;; ANSWER SECTION:
website.AntoineEzedine-Lab3.ch-geni-net.instageni.cenic.net. 1 IN CNAME pcvm2-8.
instageni.cenic.net.
pcvm2-8.instageni.cenic.net. 30 IN      A       204.102.244.53

;; AUTHORITY SECTION:
instageni.cenic.net.    30      IN      NS      ns.instageni.cenic.net.
instageni.cenic.net.    30      IN      NS      ns.emulab.net.

;; ADDITIONAL SECTION:
ns.instageni.cenic.net. 30      IN      A       204.102.244.4

;; Query time: 2 msec
;; SERVER: 192.168.100.1#53(192.168.100.1)
;; WHEN: Sun Apr 04 20:04:43 PDT 2021
;; MSG SIZE  rcvd: 211
```

instageni.cenic.net. 30 IN NS ns.instageni.cenic.net.

instageni.cenic.net. 30 IN NS ns.emulab.net.

2)

pcvm2-8.instageni.cenic.net. 30 IN A 204.102.244.53

instageni.cenic.net. 30 IN NS ns.instageni.cenic.net.

instageni.cenic.net. 30 IN NS ns.emulab.net.

```
; <<>> DiG 9.11.3-1ubuntu1.14-Ubuntu <<>> +trace website.AntoineEzedine-Lab3.ch-geni-net.instageni.c
enic.net
;; global options: +cmd
.                       42006   IN      NS      b.root-servers.net.
.                       42006   IN      NS      e.root-servers.net.
.                       42006   IN      NS      c.root-servers.net.
.                       42006   IN      NS      j.root-servers.net.
.                       42006   IN      NS      a.root-servers.net.
.                       42006   IN      NS      l.root-servers.net.
.                       42006   IN      NS      d.root-servers.net.
.                       42006   IN      NS      f.root-servers.net.
.                       42006   IN      NS      k.root-servers.net.
.                       42006   IN      NS      m.root-servers.net.
.                       42006   IN      NS      i.root-servers.net.
.                       42006   IN      NS      g.root-servers.net.
.                       42006   IN      NS      h.root-servers.net.
.                       48406   IN      RRSIG   NS 8 0 518400 20210412050000 20210330040000 42351 .
AtIn+4etW9M7KKvpaCmY4J8CPb2Xq5rOEadJ1EX3xnRH6qNWYLsIf4uT ycDTS2Pnp7VhRM+SAveXq6eDWlbWZzDk4+TI2laJMjp
XF5/N2PlETU0E rGSWAAGjbjqDfdyNw8/QZr0Y5hiJ+xchtR4whqmtek5GeiU28t+BKmEI fsPKAv1+AbRS36ct+9AYxsjQYD6oY
I7HoA82PoieGkHT/W7jstyBPL// tGyDpiM3FiNdFU3NtXtg42jLNSzwG7VXMOIDxBrFjoUxYQhpMRA0uFOV iPAus2+uK6pIH7l
wKrUHCAhZmyUebwcC89I/pum9hB887HENQLmbTHdl 0N88Ew==
;; Received 1125 bytes from 204.102.244.4#53(204.102.244.4) in 1 ms

net.                    172800  IN      NS      a.gtld-servers.net.
net.                    172800  IN      NS      j.gtld-servers.net.
net.                    172800  IN      NS      d.gtld-servers.net.
net.                    172800  IN      NS      b.gtld-servers.net.
net.                    172800  IN      NS      c.gtld-servers.net.
net.                    172800  IN      NS      f.gtld-servers.net.
net.                    172800  IN      NS      k.gtld-servers.net.
net.                    172800  IN      NS      e.gtld-servers.net.
net.                    172800  IN      NS      h.gtld-servers.net.
net.                    172800  IN      NS      i.gtld-servers.net.
net.                    172800  IN      NS      m.gtld-servers.net.
net.                    172800  IN      NS      l.gtld-servers.net.
net.                    172800  IN      NS      g.gtld-servers.net.
net.                    86400   IN      DS      35886 8 2 7862B27F5F516EBE19680444D4CE5E762981931842
C465F00236401D 8BD973EE
net.                    86400   IN      RRSIG   DS 8 1 86400 20210417170000 20210404160000 14631 . r
L3BHjZNeluEGZPRGIOl4e+EmeAyZlMnPtCezmktFYts168d2oWnPQzm 963Jhxl12Ly3yPVBfBHVelPhAAaOqLK5FVapRxQL29lG
TZV1X8Z4OVj4 g62CHSH6Z8PAVAMXZkplgn/kH6+Ra6qys02qpnUXQI26PgIOhuDJKMme 8YWHeH2qzdQzNWD5z4zKpkmElBwdoe
M/uzrvnsXIiskCnoZ2sWAT+LHR WR077jjVZiVuj00AYAP/80OxszmpiUZXQfKFRVyUoCh3AjzAoXLYCnll HLKTTJI1rRD5E4wq
yizHrQvmdQcnGjl/wfG+PX2h4g45k9wDhhm98K7q H0BkJg==
```

```
cenic.net.              172800  IN      NS      ns4.cenic.org.
cenic.net.              172800  IN      NS      ns5.cenic.org.
cenic.net.              172800  IN      NS      ns6.cenic.org.
A1RT98BS5QGC9NFI5189HCI47ULJG6JH.net. 86400 IN NSEC3 1 1 0 - A1RUUFFJKCT2Q54P78F8EJGJ8JBK7I8B  NS SOA RRSIG DNSKEY NSEC3PARAM
A1RT98BS5QGC9NFI5189HCI47ULJG6JH.net. 86400 IN RRSIG NSEC3 8 2 86400 20210410052911 20210403041911 30944 net. ILmw6evOMgxT0FtpPwOV+1h/WyOGPiCx2P3WyVUy6pO9RTnpsmu0tV/A W8NdFpm870EPgAgg2ne6IN
Wp33AFM+cMPM6tsEO9/0uFhW+hw8D4iiQ6 qvE0Zfl0qBMSMFi9tEFhYcHdVrHXsBf893EKYpwlIySxlehjdRl882nT UiZUXHX+TpDEoruRl6LpRI7IAMi90chB3pcjmUQrzoEWpw==
USMDDVPVPPP6S4UN7QJCNUJUEO253Q5R.net. 86400 IN NSEC3 1 1 0 - USMIIEBBJD8NVAHG5LD7FLOCF8UM8GDJ  NS DS RRSIG
USMDDVPVPPP6S4UN7QJCNUJUEO253Q5R.net. 86400 IN RRSIG NSEC3 8 2 86400 20210409052753 20210402041753 30944 net. NBLqYJJR8UCayHbSqB9dNHppCgI0jo+EnwESYWuGApLUgXuXlD+Vwzn1 aI7omlTyTlpyiNwnOJ/kpJ
LH/RwQrypi7VcoZPtGajIS8MTSkk8Tep/K 4kodUgdZUqes+2pbyLhPKYJR2zUhFRlZKaTLmJN2aVJDdPv04bQff7SH Glu2artUwiC2hvClMpt4XDVIBlBezzuK0aaKtampXEHjYQ==
;; Received 700 bytes from 192.12.94.30#53(e.gtld-servers.net) in 26 ms

instageni.cenic.net.    300     IN      NS      ns.emulab.net.
instageni.cenic.net.    300     IN      NS      ns.instageni.cenic.net.
;; Received 173 bytes from 137.164.29.69#53(ns5.cenic.org) in 11 ms

website.AntoineEzedine-Lab3.ch-geni-net.instageni.cenic.net. 1 IN CNAME pcvm2-8.instageni.cenic.net.
pcvm2-8.instageni.cenic.net. 30 IN      A       204.102.244.53
instageni.cenic.net.    30      IN      NS      ns.instageni.cenic.net.
instageni.cenic.net.    30      IN      NS      ns.emulab.net.
;; Received 227 bytes from 155.98.32.70#53(ns.emulab.net) in 21 ms

ekargoug@gateway:~$
ekargoug@gateway:~$ pcvm2-8.instageni.cenic.net. 30 IN      A       204.102.244.53
pcvm2-8.instageni.cenic.net.: command not found
ekargoug@gateway:~$ instageni.cenic.net.    30      IN      NS      ns.instageni.cenic.net.
instageni.cenic.net.: command not found
ekargoug@gateway:~$ instageni.cenic.net.    30      IN      NS      ns.emulab.net.
```

Exercise 1.3

1)

Public IP address: 204.102.244.18

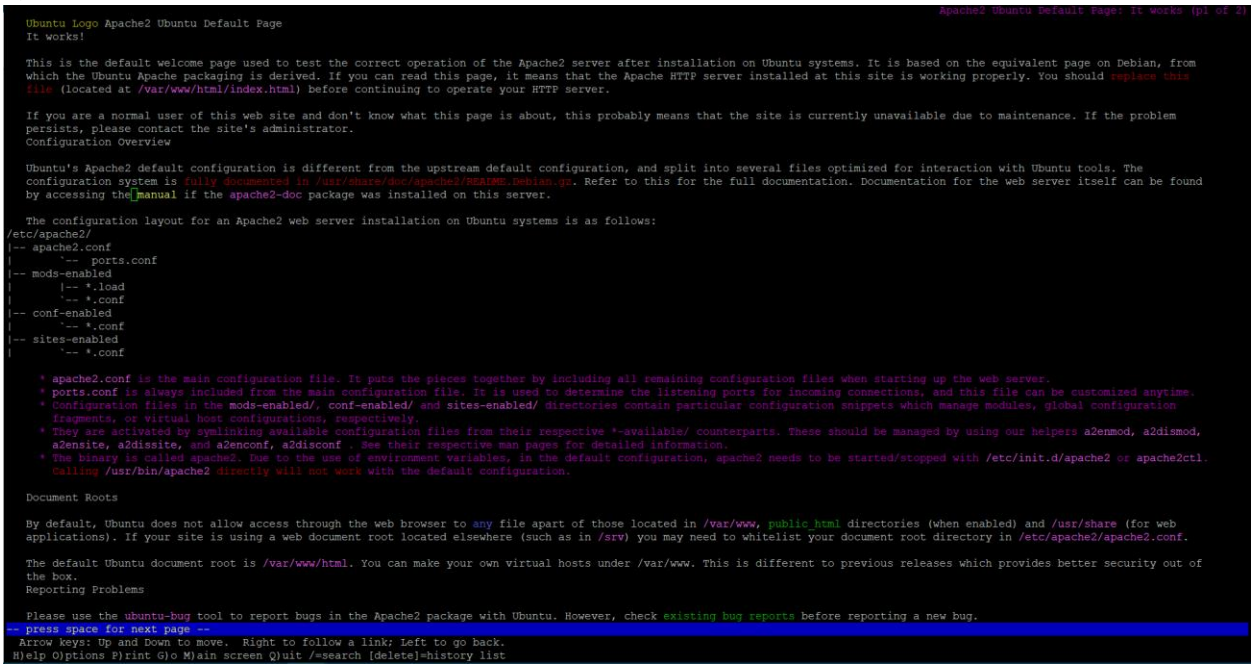
```
ekargoug@gateway:~$ wget -qO- http://ipinfo.io/
{
  "ip": "204.102.244.18",
  "hostname": "pc3.instageni.cenic.net",
  "city": "Clearlake",
  "region": "California",
  "country": "US",
  "loc": "38.9582,-122.6264",
  "org": "AS2152 California State University, Office of the Chancellor",
  "postal": "95422",
  "timezone": "America/Los_Angeles",
  "readme": "https://ipinfo.io/missingauth"
}ekargoug@gateway:~$ 204.102.244.18
```

2) Home network IP address: 204.102.244.18

```
ekargoug@client-1:~$ wget -qO- http://ipinfo.io/
{
  "ip": "204.102.244.18",
  "hostname": "pc3.instageni.cenic.net",
  "city": "Clearlake",
  "region": "California",
  "country": "US",
  "loc": "38.9582,-122.6264",
  "org": "AS2152 California State University, Office of the Chancellor",
  "postal": "95422",
  "timezone": "America/Los_Angeles",
  "readme": "https://ipinfo.io/missingauth"
}ekargoug@client-1:~$
```

```
ekargoug@client-2:~$ wget -qO- http://ipinfo.io/
{
  "ip": "204.102.244.18",
  "hostname": "pc3.instageni.cenic.net",
  "city": "Clearlake",
  "region": "California",
  "country": "US",
  "loc": "38.9582,-122.6264",
  "org": "AS2152 California State University, Office of the Chancellor",
  "postal": "95422",
  "timezone": "America/Los_Angeles",
  "readme": "https://ipinfo.io/missingauth"
}ekargoug@client-2:~$
```

3)



4)

Gateway:

```
20:42:23.060231 IP 192.168.100.183.38496 > 204.102.244.53.80: Flags [S], seq 4078480160, win 64240,
options [mss 1460,sackOK,TS val 1811899039 ecr 0,nop,wscale 7], length 0
20:42:23.565340 IP 204.102.244.53.80 > 192.168.100.183.38496: Flags [S.], seq 2288506399, ack 407848
0161, win 65160, options [mss 1460,sackOK,TS val 3889861108 ecr 1811899039,nop,wscale 7], length 0
20:42:23.565950 IP 192.168.100.183.38496 > 204.102.244.53.80: Flags [.], ack 1, win 502, options [no
p,nop,TS val 1811899544 ecr 3889861108], length 0
```

Web site:

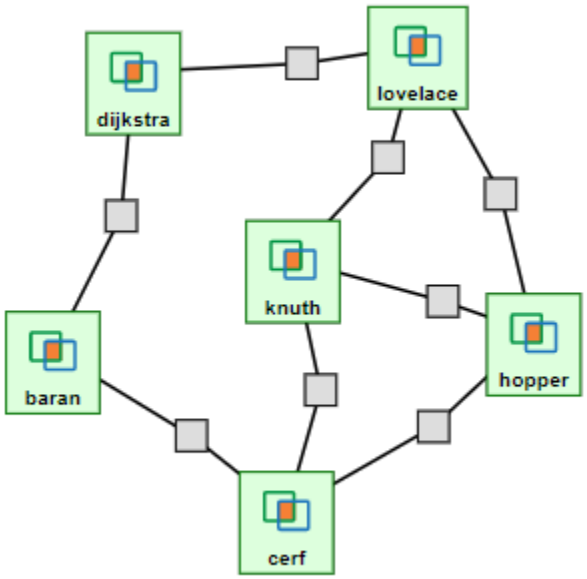
```
20:42:23.063023 IP 172.17.3.3.38496 > 204.102.244.53.80: Flags [S], seq 40784801
60, win 64240, options [mss 1460,sackOK,TS val 1811899039 ecr 0,nop,wscale 7], l
ength 0
20:42:23.063098 IP 204.102.244.53.80 > 172.17.3.3.38496: Flags [S.], seq 2288506
399, ack 4078480161, win 65160, options [mss 1460,sackOK,TS val 3889861108 ecr 1
811899039,nop,wscale 7], length 0
20:42:23.568653 IP 172.17.3.3.38496 > 204.102.244.53.80: Flags [.], ack 1, win 5
02, options [nop,nop,TS val 1811899544 ecr 3889861108], length 0
```

You can see how the IP addresses are rewritten in the packet headers. On the LAN (the tcpdump running on the **gateway** interface facing the LAN), the Layer 3 packet header shows the connection between 192.168.100.183 (port 38496) and 204.102.244.53 (port 80). However, for the same packets, the tcpdump running on the **website** node (on the WAN) shows the connection as being between 172.17.3.3 (port 38496) and 100.102.53.80 (port 80).

So the packet headers must be being rewritten in the NAT gateway.

Exercise 2.1

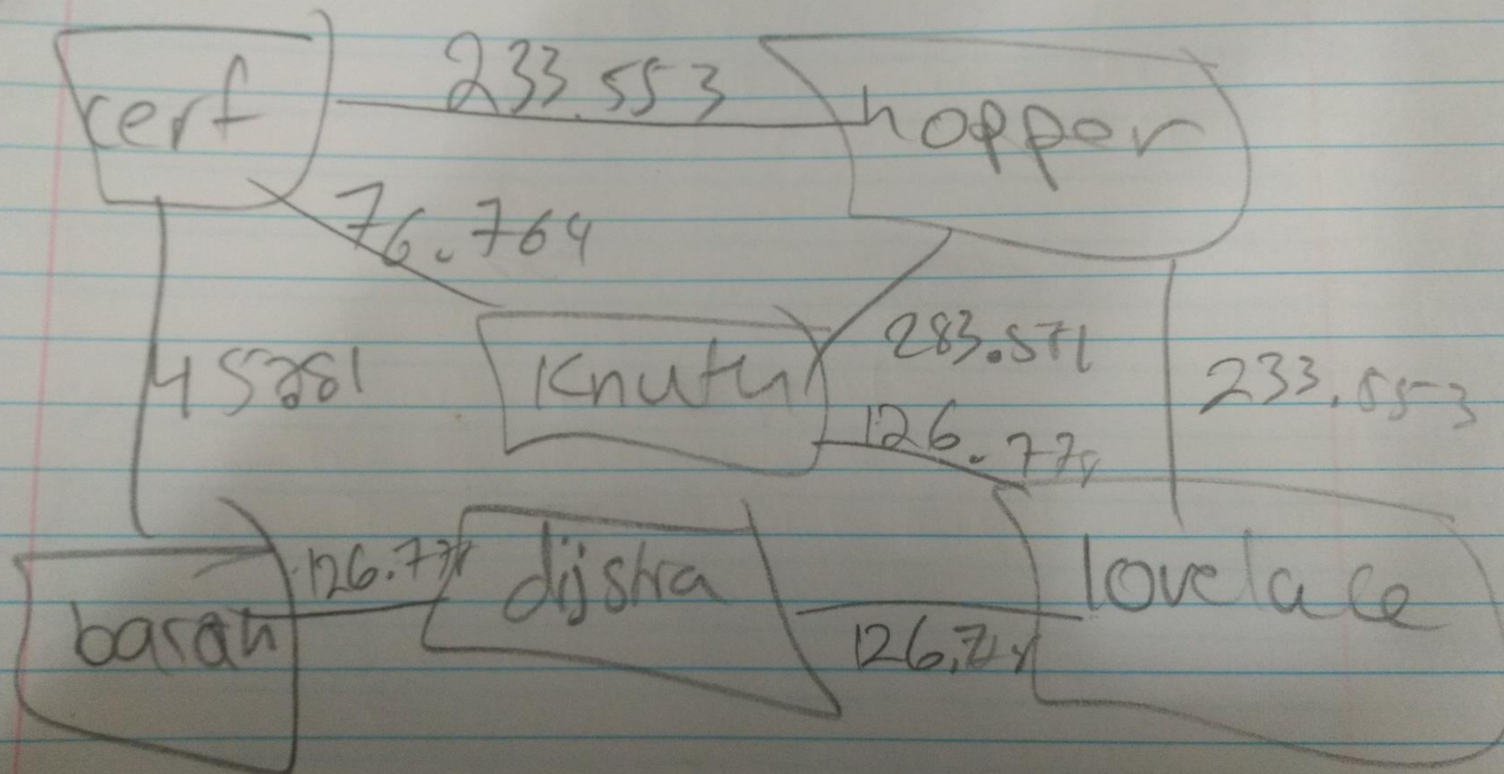
1)



2)

Iteration	Unvisited	Visited	Current	dijkstra	cerf	lovelace	hopper	baran	knuth
0	dijkstra, cerf, lovelace, hopper, baran knuth	-	-	0 -	∞ -	∞ -	∞ -	∞ -	∞ -
1	cerf, lovelace, hopper, baran, knuth	dijkstra	dijkstra	0 -	∞ -	126.778 dijkstra	∞ -	45.781 dijkstra	∞ -
2	cerf, hopper, knuth, baran	dijkstra, lovelace	lovelace	0 -	∞ -	126.778 dijkstra	233.553 lovelace	45.781 dijkstra	283.551 lovelace
3	cerf, knuth, baran	dijkstra, lovelace, hop	hopper	0 -	298.322 hopper	126.778 dijkstra	233.553 lovelace	45.781 dijkstra	283.551 lovelace
4	cerf, knuth	dijkstra, lovelace, hop	baran	0 -	298.322 hopper	126.778 dijkstra	233.553 lovelace	45.781 dijkstra	283.551 lovelace
5	cerf	dijkstra, lovelace, hop	knuth	0 -	76.764 knuth	126.778 dijkstra	233.553 lovelace	45.781 dijkstra	283.551 lovelace
6		dijkstra, lovelace, hop	cerf	0 -	76.764 knuth	126.778 dijkstra	233.553 lovelace	45.781 dijkstra	283.551 lovelace

3)


cerf
233.553
hopper
76.764
45381
knuth
283.571
233.553
126.778
barah
126.77
dijshra
126.7
lovelace