

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-lubuntu1.14-Ubuntu <<>> website.AntoineEzedine-Lab3.ch-geni-net.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-ubuntu1.14-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+4etW9M7KKvpaCmY4J8CPb2Xq5r0EadJlEX3xnRH6qNwYlsIf4uT ycDTS2Pnp7VhRM+SABeXq6eDWLbWZzDk4+TI2laUMjp
XE5/N2PLETU0E rGSWAAgjbqDfdyNw8/QZr0Y5hiJ+xchtR4whgmkteK5GeIU28t+BRmEI fsPKAv1+ABRS36ct+9AYxsjQYD6oY
I7HoA82PoieGkHT/W7jstyBEL// tgyDpIM3FiNdFU3ntXtg42jLNSZwG7VXMOIDxBrfj0UxYQhpMRA0uFOV iPAus2+uK6pIH7l
wKRUChAhZmyUebwcc891/pum9hB887HENQlmbTHdl ON88Ew==
;; 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
L3BHj2NelueGZFRGI0I4e+EmeAy2lMnPtCezmktFYts168d2oWnPQzm 963Jhxl12Ly3yPVBfBHVelPhAAaOqLK5FVapRqXQL29lG
TZVlX8Z4OVj4 g62CHSH628PAVAMXZkplgn/kH6+Ra6qys02qpnUXQI26PgIOhuDJKMme 8YWHHe2qzdQzNWD5z4zKpkmElBwdoe
M/uzrvnsXIiskCno22sWAT+LHR WR077jjjVzVuj00AYAP/800xsZmpiUZXQfKFRVYUoCh3AjzAoXLYCn11 HLKTTJl1rRD5E4wq
y1zHrQvmdQcnGj1/wfG+PX2h4g45k9wDhlm98K7q H0BkJg==
```

```
cenic.net.    172800 IN      NS      ns4.cenic.org.
cenic.net.    172800 IN      NS      ns3.cenic.org.
cenic.net.    172800 IN      NS      ns6.cenic.org.
AIR798BS5Qc9NF15189HC147ULJG6JH.net. 86400 IN NSEC3 1 1 0 - AIrUUFFJkCT2Q54P76F8EJGJ8JBK7I8B NS SOA RRSIG DNSKEY NSEC3PARAM
AIR798BS5Qc9NF15189HC147ULJG6JH.net. 86400 IN RRSIG NSEC3 8 2 86400 20210410052911 20210403041911 30944 net. ILmw6evOMgxt0FTpPwOV+1h/WyOGP1Cx2F3WyV0Yp09R9tmsmu0tV/A W8NdFym870EPgAgg2ne6IN
Wp33AFM+CMEM6tsEO9/0uFhW+hw804iiq6 qvE0Zf10qBMSMF19tEfHYchdvRHXs8f893EKYpwllySkiehjd8l882nT U12UXHX+TpdEgoruRl6LpRl7IAM190chB3pcjnuUQzroEWpw==
USMDVjVFPFP64UN7QCNJUE0253QSR.net. 86400 IN NSEC3 1 1 0 - USMIIEBBJd8NVAGSLD7FLOCF8UM8GDJ NS DS RRSIG
USMDVjVFPFP64UN7QCNJUE0253QSR.net. 86400 IN RRSIG NSEC3 8 2 86400 20210409052753 20210402041759 30944 net. NBLgYJR8UCayibSg8dNhpPcGi0jo+EnwESYUwQpLUGuXUkId+Vwznl ai7cm1TyTlpyiNwn0J/kpJ
LH/Rwqrcpi17Vca2EtGsj188MTsk87ep/K 4kodDgdDqes+2pbylhPKYJR2zU8FRl2KaTLmJN2aVJD3Pv04bqf78H 61u2artUwlc2hvc1Mpt4XDVlB1bezzuR0aaKtampXSHjYQ==
;; 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)

```
Ubuntu Logo Apache2 Ubuntu Default Page                               Apache2 Ubuntu Default Page: It works [01 of 01]
It works!

This is the default welcome page used to test the correct operation of the Apache2 server after installation on Ubuntu systems. It is based on the equivalent page on Debian, from which the Ubuntu Apache packaging is derived. If you can read this page, it means that the Apache HTTP server installed at this site is working properly. You should replace this file (located at /var/www/html/index.html) before continuing to operate your HTTP server.

If you are a normal user of this web site and don't know what this page is about, this probably means that the site is currently unavailable due to maintenance. If the problem persists, please contact the site's administrator.
Configuration Overview

Ubuntu's Apache2 default configuration is different from the upstream default configuration, and split into several files optimized for interaction with Ubuntu tools. The configuration system is fully documented in /usr/share/doc/apache2/README.Debian.gz. Refer to this for the full documentation. Documentation for the web server itself can be found by accessing the manual if the apache2-doc package was installed on this server.

The configuration layout for an Apache2 web server installation on Ubuntu systems is as follows:
/etc/apache2/
|-- apache2.conf
|   |-- ports.conf
|-- mods-enabled
|   |-- *.load
|   |-- *.conf
|-- conf-enabled
|   |-- *.conf
|-- sites-enabled
|   |-- *.conf

* apache2.conf is the main configuration file. It puts the pieces together by including all remaining configuration files when starting up the web server.
* ports.conf is always included from the main configuration file. It is used to determine the listening ports for incoming connections, and this file can be customized anytime.
* Configuration files in the mods-enabled/, conf-enabled/ and sites-enabled/ directories contain particular configuration snippets which manage modules, global configuration fragments, or virtual host configurations, respectively.
* They are activated by symlinking available configuration files from their respective *-available/ counterparts. These should be managed by using our helpers a2enmod, a2dismod, a2ensite, a2disite, and a2enconf, a2disconf . See their respective man pages for detailed information.
* The binary is called apache2. Due to the use of environment variables, in the default configuration, apache2 needs to be started/stopped with /etc/init.d/apache2 or apache2ctl. Calling /usr/bin/apache2 directly will not work with the default configuration.

Document Roots

By default, Ubuntu does not allow access through the web browser to any file apart of those located in /var/www, public_html directories (when enabled) and /usr/share (for web applications). If your site is using a web document root located elsewhere (such as in /srv) you may need to whitelist your document root directory in /etc/apache2/apache2.conf.

The default Ubuntu document root is /var/www/html. You can make your own virtual hosts under /var/www. This is different to previous releases which provides better security out of the box.

Reporting Problems

Please use the ubuntu-bug tool to report bugs in the Apache2 package with Ubuntu. However, check existing bug reports before reporting a new bug.
-- press space for next page --
Arrow keys: Up and down to move. Right to follow a link; Left to go back.
H)elp O)ptions P)rint Q)u)it /-search [delete]-history list
```

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 4078480161, 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 [nop,nop,TS val 1811899544 ecr 3889861108], length 0
```

Web site:

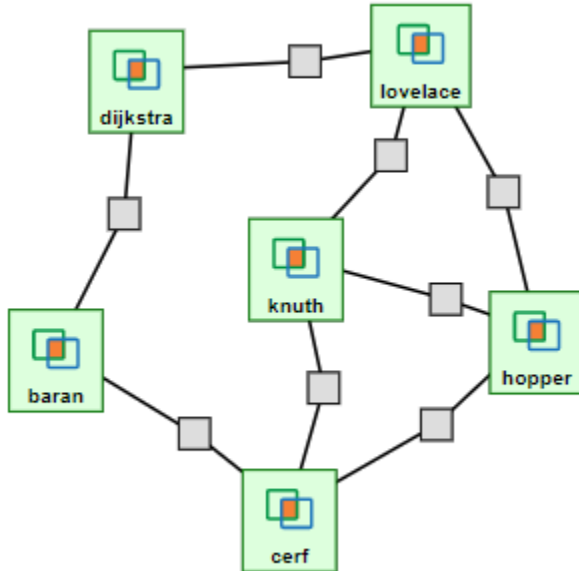
```
20:42:23.063023 IP 172.17.3.3.38496 > 204.102.244.53.80: Flags [S], seq 4078480160, win 64240, options [mss 1460,sackOK,TS val 1811899039 ecr 0,nop,wscale 7], length 0
20:42:23.063098 IP 204.102.244.53.80 > 172.17.3.3.38496: Flags [S.], seq 2288506399, ack 4078480161, win 65160, options [mss 1460,sackOK,TS val 3889861108 ecr 1811899039,nop,wscale 7], length 0
20:42:23.568653 IP 172.17.3.3.38496 > 204.102.244.53.80: Flags [.] , ack 1, win 502, 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	∞	45.781	∞
2	cerf, hopper, knuth, baran	dijkstra, lovelace	lovelace	0	∞	126.778	233.553	45.781	283.551
3	cerf, knuth, baran	dijkstra, lovelace, hopper	hopper	0	298.322	126.778	233.553	45.781	283.551
4	cerf, knuth	dijkstra, lovelace, hopper, baran	baran	0	298.322	126.778	233.553	45.781	283.551
5	cerf	dijkstra, lovelace, hopper, knuth	knuth	0	76.764	126.778	233.553	45.781	283.551
6		dijkstra, lovelace, hopper, cerf	cerf	0	76.764	126.778	233.553	45.781	283.551

3)

