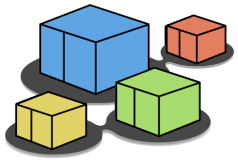
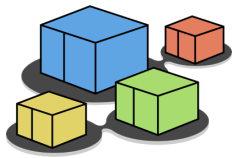


Kathará

kathara lab

basic IPv4 configuration, ping, traceroute and arp

Version	1.0
Author(s)	L. Ariemma, T. Caiazzi, G. Di Battista, M. Patrignani, M. Pizzonia, F. Ricci, M. Rimondini
E-mail	contact@kathara.org
Web	http://www.kathara.org/
Description	basic IPv4 configuration commands, usage of ping and traceroute, arp behaviour



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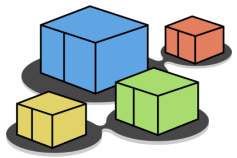
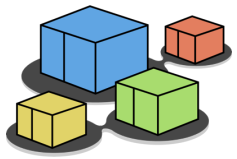
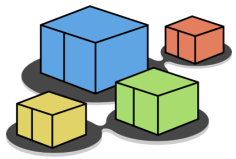


content of the lab

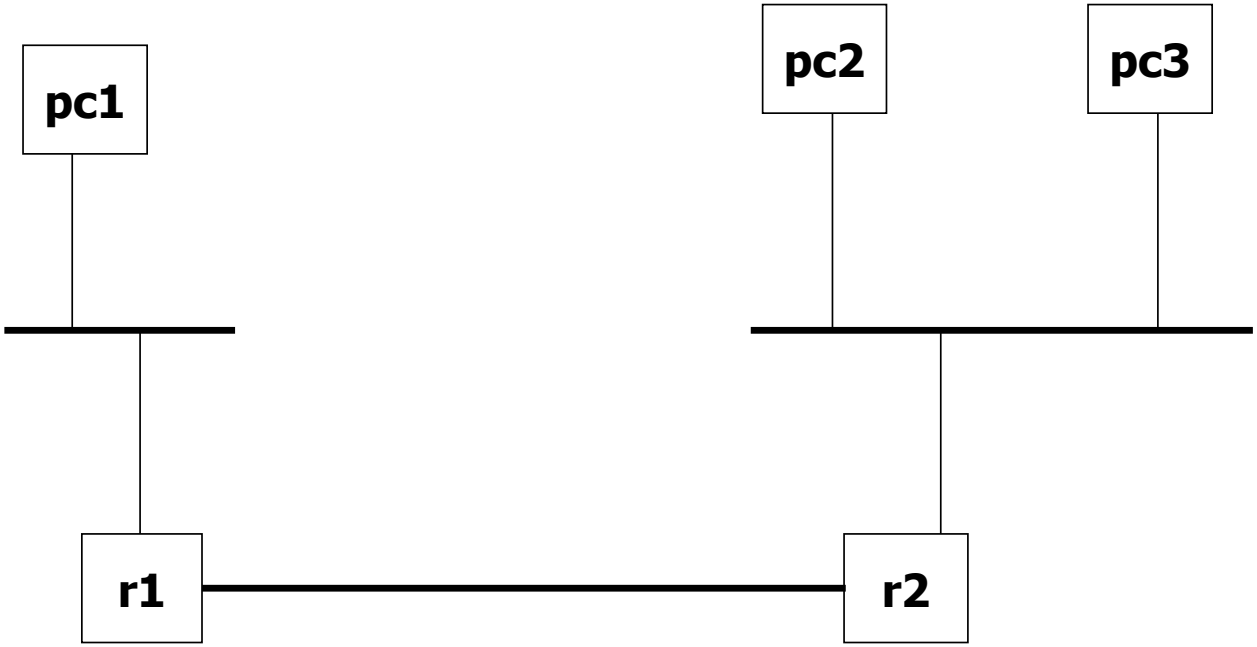
- there are two routers, called r1 and r2, and three hosts, called pc1, pc2, and pc3
  - they are connected via three LANs
  - we force their MAC addresses to be easily readable
- we will learn how to:
  - assign an IPv4 address and a netmask to the interface of a host
  - assign a default gateway to the interface of a host
  - set the routing table of a router
- we will use the ping and traceroute commands
- we will observe the behavior of ARP

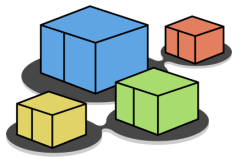


lab configuration

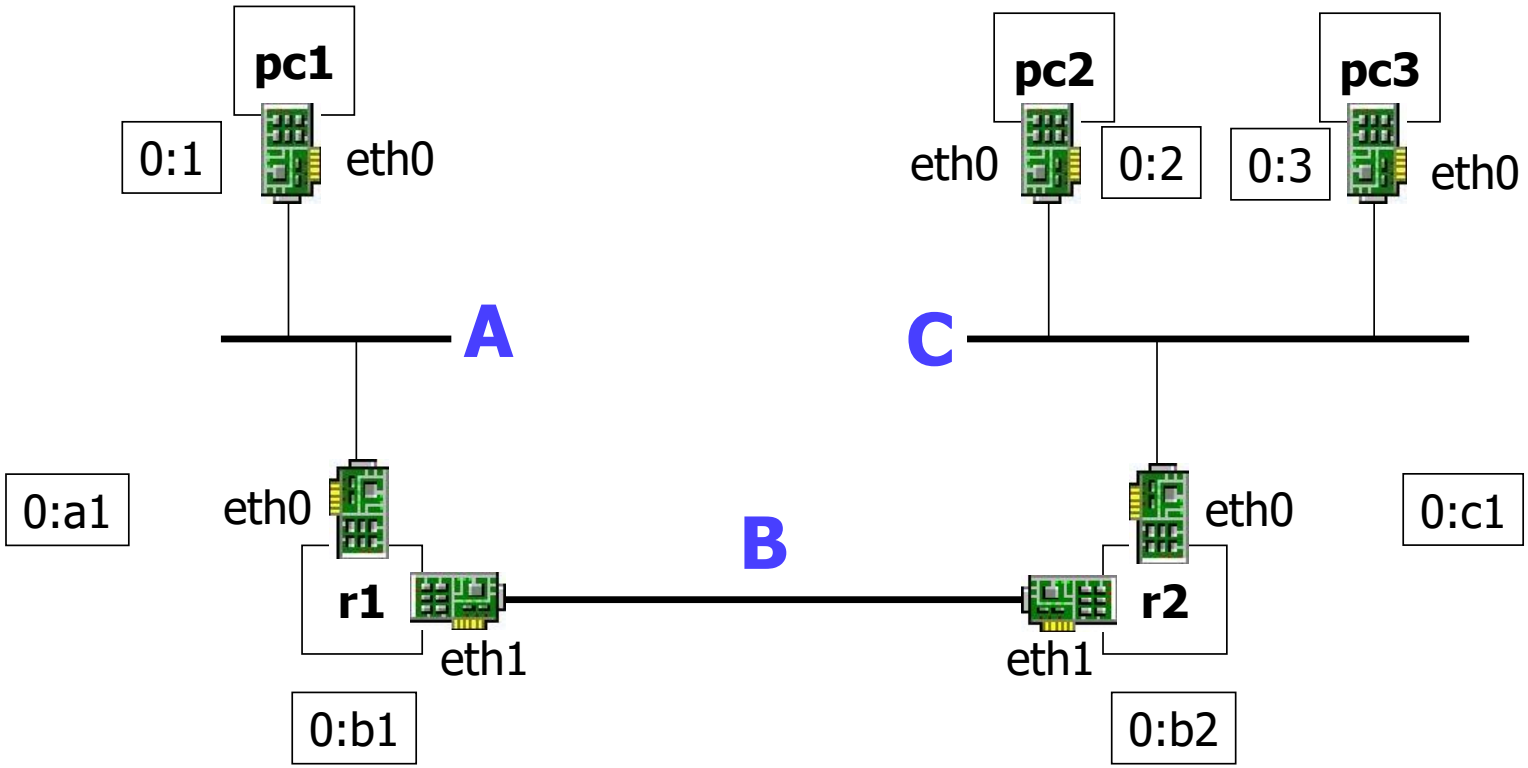


network topology – high level view

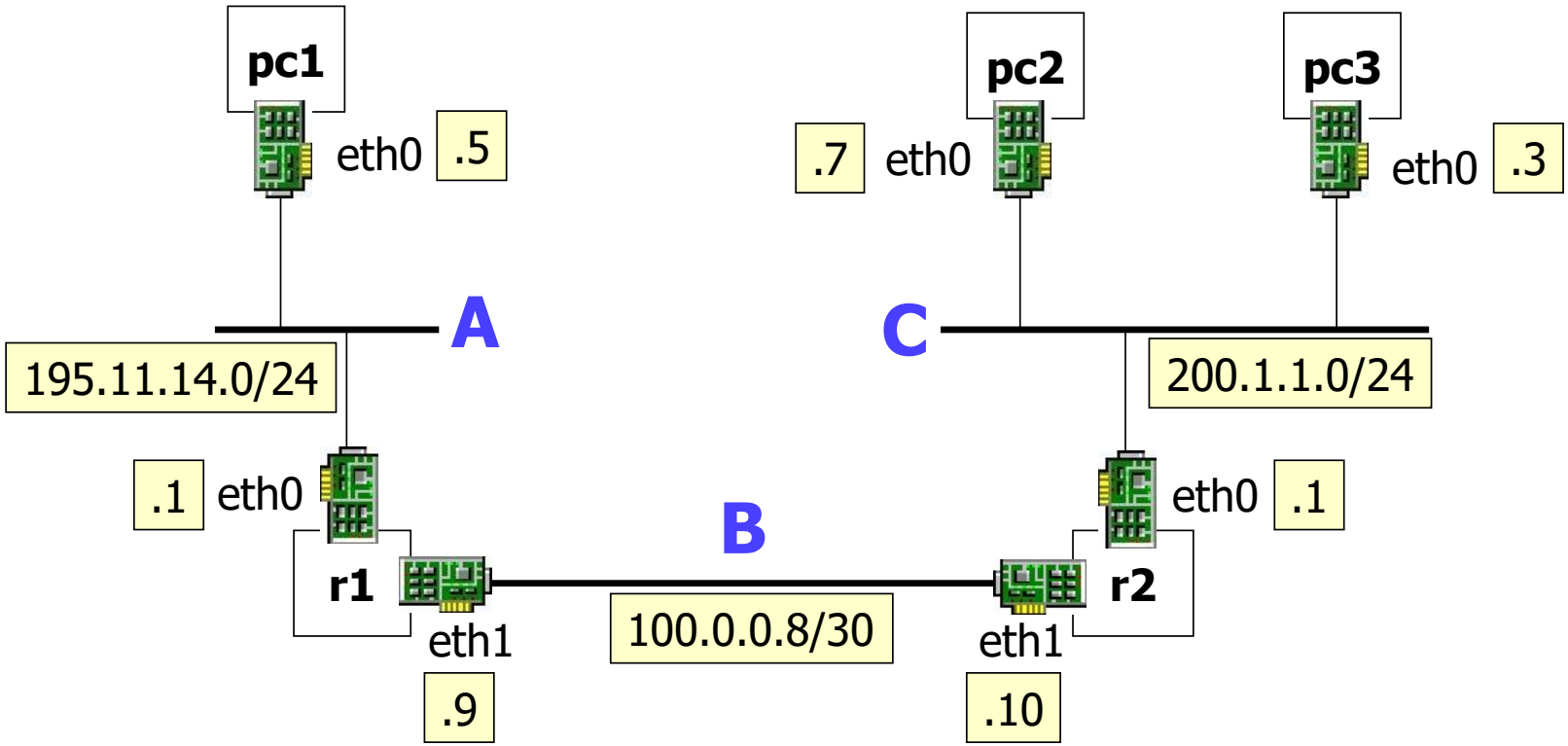




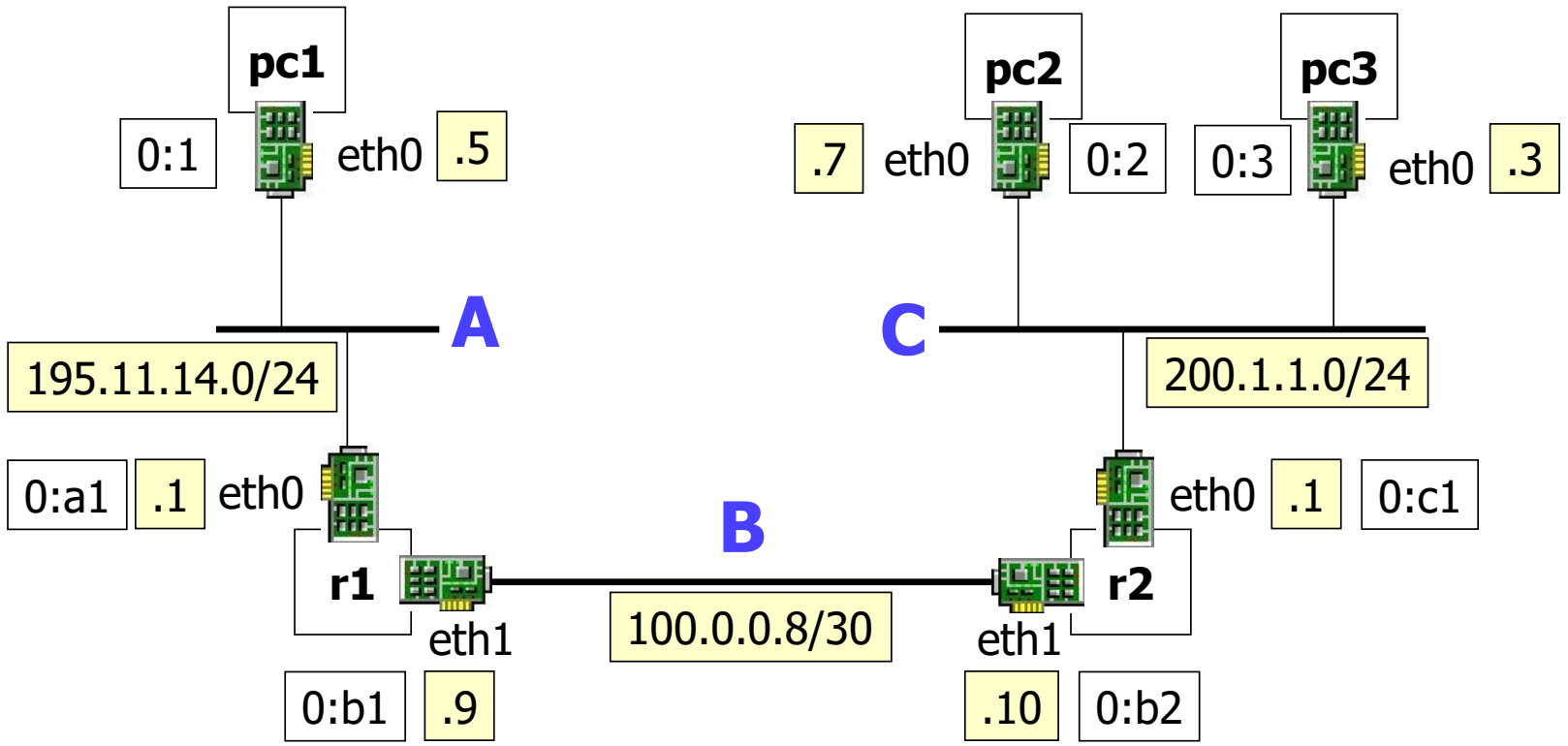
network topology – MAC addresses

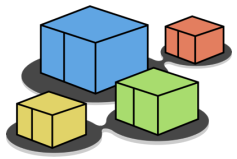


network topology – IPv4 address plan



network topology – complete overview





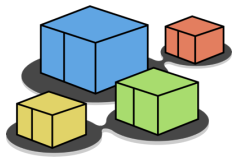
a quick look at the lab

lab.conf

```
r1[0]="A"
r1[1]="B"
r1[image]="kathara/base"
r1[ipv6]="false"

r2[0]="C"
r2[1]="B"
r2[image]="kathara/base"
r2[ipv6]="false"

pc1[0]="A"
pc1[image]="kathara/base"
pc1[ipv6]="false"
```

lab.conf

```
pc2[0]="C"
pc2[image]="kathara/base"
pc2[ipv6]="false"

pc3[0]="C"
pc3[image]="kathara/base"
pc3[ipv6]="false"

wireshark[bridged]=true
wireshark[port]="3000:3000"
wireshark[image]="lscr.io/linuxserver/wireshark"
wireshark[num_terms]=0
```



a quick look at the lab

pc1.startup

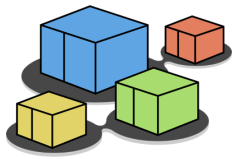
```
ip link set dev eth0 address 00:00:00:00:00:01
ip address add 195.11.14.5/24 dev eth0
ip route add default via 195.11.14.1
```

pc2.startup

```
ip link set dev eth0 address 00:00:00:00:00:02
ip address add 200.1.1.7/24 dev eth0
ip route add default via 200.1.1.1 dev eth0
```

pc3.startup

```
ip link set dev eth0 address 00:00:00:00:00:03
ip address add 200.1.1.3/24 dev eth0
ip route add default via 200.1.1.1 dev eth0
```



a quick look at the lab

an IPv4 address is assigned to the eth0 interfaces of hosts

pc1.startup

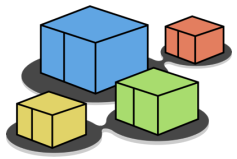
```
ip link set dev eth0 address 00:00:00:00:00:01
ip address add 195.11.14.5/24 dev eth0
ip route add default via 195.11.14.1
```

pc2.startup

```
ip link set dev eth0 address 00:00:00:00:00:02
ip address add 200.1.1.7/24 dev eth0
ip route add default via 200.1.1.1 dev eth0
```

pc3.startup

```
ip link set dev eth0 address 00:00:00:00:00:03
ip address add 200.1.1.3/24 dev eth0
ip route add default via 200.1.1.1 dev eth0
```



a quick look at the lab

an IPv4 address is assigned to the eth0 interfaces of hosts

a default gateway is set for all hosts

pc1.startup

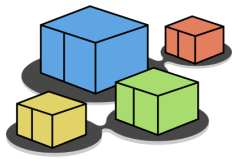
```
ip link set dev eth0 address 00:00:00:00:00:01
ip address add 195.11.14.5/24 dev eth0
ip route add default via 195.11.14.1
```

pc2.startup

```
ip link set dev eth0 address 00:00:00:00:00:02
ip address add 200.1.1.7/24 dev eth0
ip route add default via 200.1.1.1 dev eth0
```

pc3.startup

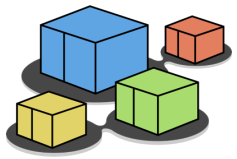
```
ip link set dev eth0 address 00:00:00:00:00:03
ip address add 200.1.1.3/24 dev eth0
ip route add default via 200.1.1.1 dev eth0
```



a quick look at the lab

r1.startup

```
ip link set dev eth0 address 00:00:00:00:00:a1
ip link set dev eth1 address 00:00:00:00:00:b1
ip address add 195.11.14.1/24 dev eth0
ip address add 100.0.0.9/30 dev eth1
ip route add 200.1.1.0/24 via 100.0.0.10 dev eth1
```



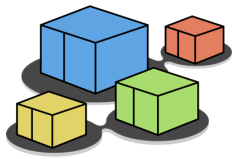
a quick look at the lab

r1.startup

```
ip link set dev eth0 address 00:00:00:00:00:a1
ip link set dev eth1 address 00:00:00:00:00:b1
ip address add 195.11.14.1/24 dev eth0
ip address add 100.0.0.9/30 dev eth1
ip route add 200.1.1.0/24 via 100.0.0.10 dev eth1
```

an IPv4 address is assigned to interfaces eth0 and eth1 of router r1

consequently, the corresponding LANs are considered *directly connected*



a quick look at the lab

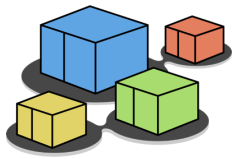
r1.startup

```
ip link set dev eth0 address 00:00:00:00:00:a1
ip link set dev eth1 address 00:00:00:00:00:b1
ip address add 195.11.14.1/24 dev eth0
ip address add 100.0.0.9/30 dev eth1
ip route add 200.1.1.0/24 via 100.0.0.10 dev eth1
```

an IPv4 address is assigned to interfaces eth0 and eth1 of router r1

consequently, the corresponding LANs are considered *directly connected*

a row is added to the routing table on how to reach a LAN that is not directly connected



a quick look at the lab

r1.startup

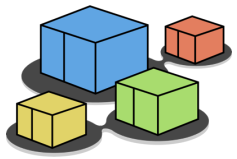
```
ip link set dev eth0 address 00:00:00:00:00:a1
ip link set dev eth1 address 00:00:00:00:00:b1
ip address add 195.11.14.1/24 dev eth0
ip address add 100.0.0.9/30 dev eth1
ip route add 200.1.1.0/24 via 100.0.0.10 dev eth1
```

an IPv4 address is assigned to interfaces eth0 and eth1 of router r1

consequently, the corresponding LANs are considered *directly connected*

a row is added to the routing table on how to reach a LAN that is not directly connected

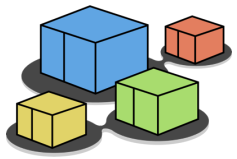
similar configuration for router r2



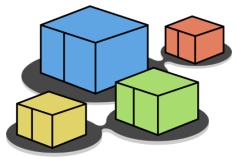
start the lab

- start the lab

```
user@localhost:~$ cd kathara-lab_basic-ipv4
user@localhost:~/kathara-lab_basic-ipv4$ kathara lstart
```



useful commands



check the IPv4 addresses

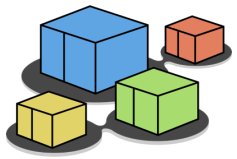
- on pc1, pc2, pc3, r1, and r2
  - perform the `ip address` command, to check the IPv4 addresses assigned to the interfaces
    - look at eth and loopback interfaces

loopback interface
127.0.0.1/8

eth0
195.11.14.5/24

pc1

```
root@pc1:/# ip address
1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN
group default qlen 1000
    link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
    inet 127.0.0.1/8 scope host lo
       valid_lft forever preferred_lft forever
7: eth0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc fq_codel
state UP group default qlen 1000
    link/ether 00:00:00:00:00:01 brd ff:ff:ff:ff:ff:ff
    inet 195.11.14.5/24 scope global eth0
       valid_lft forever preferred_lft forever
```



check the default route

- on pc1, pc2, and pc3
  - perform the `routel` command, to check the presence of a default route

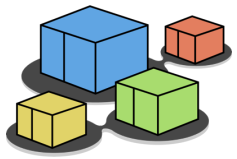
default route by r1

loopback prefix

useful information: for each d.c. network, my address and broadcast

pc1

```
root@pc1:/# routel
Dst              Gateway          Prefsrc          Protocol  Scope   Dev     Table
default          195.11.14.1                                         eth0
195.11.14.0/24                    195.11.14.5      kernel    link    eth0
127.0.0.0/8                       127.0.0.1        kernel    host    lo      local
127.0.0.1                         127.0.0.1        kernel    host    lo      local
127.255.255.255                   127.0.0.1        kernel    link    lo      local
195.11.14.5                       195.11.14.5      kernel    host    eth0    local
195.11.14.255                     195.11.14.5      kernel    link    eth0    local
```



check the router routing tables

- on r1, and r2
  - perform the `routel` command, to check the routing table

Lan B

Lan A

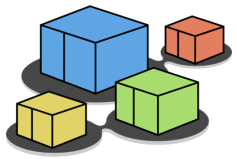
Lan C

useful information: for each d.c. network, my address and broadcast

r1

```
root@r1:/# routel
Dst              Gateway          Prefsrc         Protocol  Scope   Dev    Table
100.0.0.8/30                      100.0.0.9       kernel    link    eth1
195.11.14.0/24                    195.11.14.1     kernel    link    eth0
200.1.1.0/24     100.0.0.10                                         eth1
100.0.0.9                         100.0.0.9       kernel    host    eth1   local
100.0.0.11                        100.0.0.9       kernel    link    eth1   local
127.0.0.0/8                       127.0.0.1       kernel    host    lo     local
127.0.0.1                         127.0.0.1       kernel    host    lo     local
127.255.255.255                  127.0.0.1       kernel    link    lo     local
195.11.14.1                       195.11.14.1     kernel    host    eth0   local
195.11.14.255                     195.11.14.1     kernel    link    eth0   local
```

r2

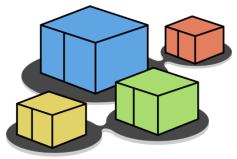


sniff the traffic

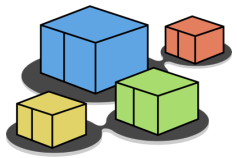
- connect the wireshark device to collision domain C

```
user@localhost:~/kathara-lab_basic-ipv4$ kathara lconfig -n wireshark --add C
```

- open any browser on the host machine
  - on **localhost:3000**
  - sniff eth1

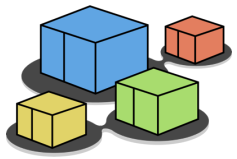


ping from pc3 to pc2 and related arp behavior



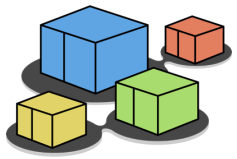
on pc3

1. inspect the ARP cache
2. execute a ping command towards pc2
3. inspect again the ARP cache
4. give a look at the packets captured by Wireshark



inspecting the arp cache of pc3

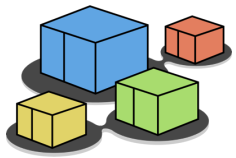
```
ARP(8)              Linux System Administrator's Manual
NAME
       arp - manipulate the system ARP cache

SYNOPSIS
    arp [-vn] [-H type] [-i if] [-ae] [hostname]
    arp [-v] [-i if] -d hostname [pub]
    arp [-v] [-H type] [-i if] -s hostname hw_addr [temp]
    arp [-v] [-H type] [-i if] -s hostname hw_addr [netmask nm] pub
    arp [-v] [-H type] [-i if] -Ds hostname ifname [netmask nm] pub
    arp [-vnD] [-H type] [-i if] -f [filename]

DESCRIPTION
Arp manipulates or displays the kernel's IPv4 network neighbour cache.
It can add entries to the table, delete one or display the currennt content.

ARP stands for Address Resolution Protocol, which is used to find the media
access control address of  a  network neighbour for a given IPv4 Address

.......
```



inspecting the arp cache

- `arp` is the command to inspect the arp cache
- the `–n` parameter tells arp to not resolve the IP addresses with DNS names

```
root@pc3:/# arp -n
Address                  HWtype  HWaddress           Flags Mask    Iface
200.1.1.7                ether   00:00:00:00:00:02   C             eth0
```



inspecting the arp cache

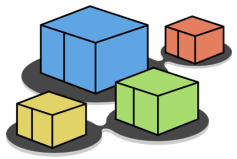
the arp cache is initially empty

sending packets to 200.1.1.7 requires address resolution

pc3

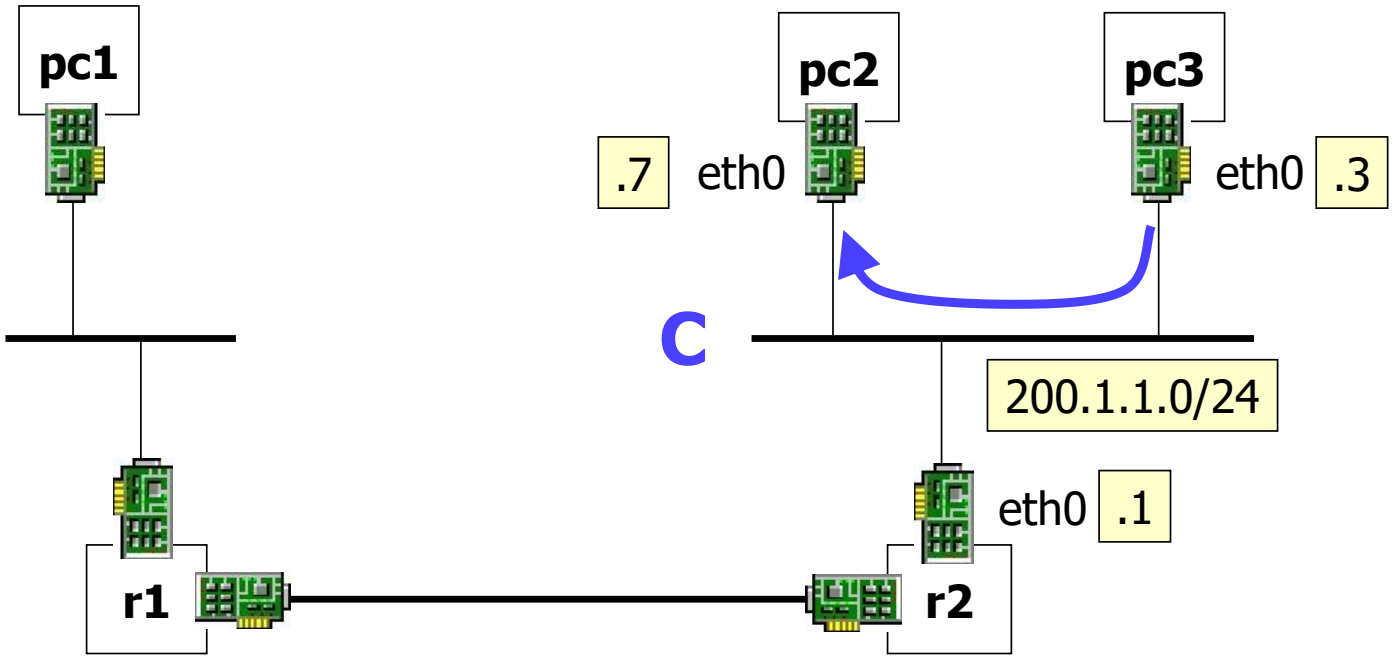
```
root@pc3:/# arp -n
root@pc3:/# ping 200.1.1.7
PING 200.1.1.7 (200.1.1.7) 56(84) bytes of data.
64 bytes from 200.1.1.7: icmp_seq=1 ttl=64 time=1.93 ms
64 bytes from 200.1.1.7: icmp_seq=2 ttl=64 time=0.638 ms
--- 200.1.1.7 ping statistics ---
2 packets transmitted, 2 received, 0% packet loss, time 1001ms
rtt min/avg/max/mdev = 0.638/1.283/1.929/0.645 ms
root@pc3:/# arp -n
Address                  HWtype  HWaddress           Flags Mask    Iface
200.1.1.7                ether   00:00:00:00:00:02   C             eth0
```

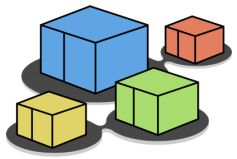
address resolution results are stored in the arp cache



inspecting the arp cache

- traffic within the same network does not traverse routers



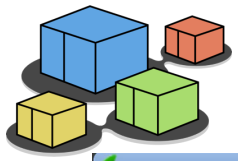


inspecting the arp cache

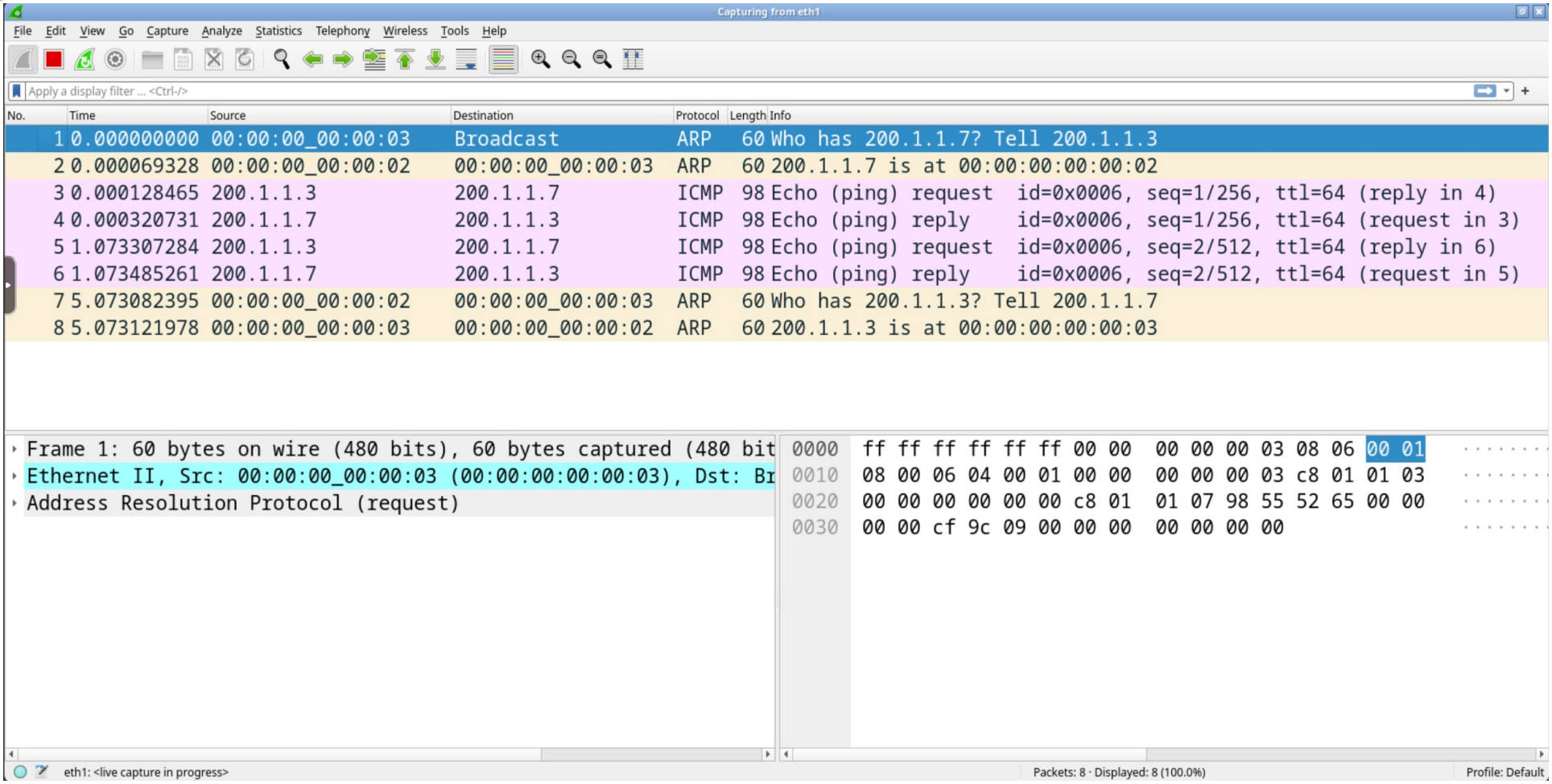
- communications are usually bi-directional
- the receiver of the arp request learns the mac address of the other party, to avoid a new arp in opposite direction (standard behavior, see rfc 826)

pc2

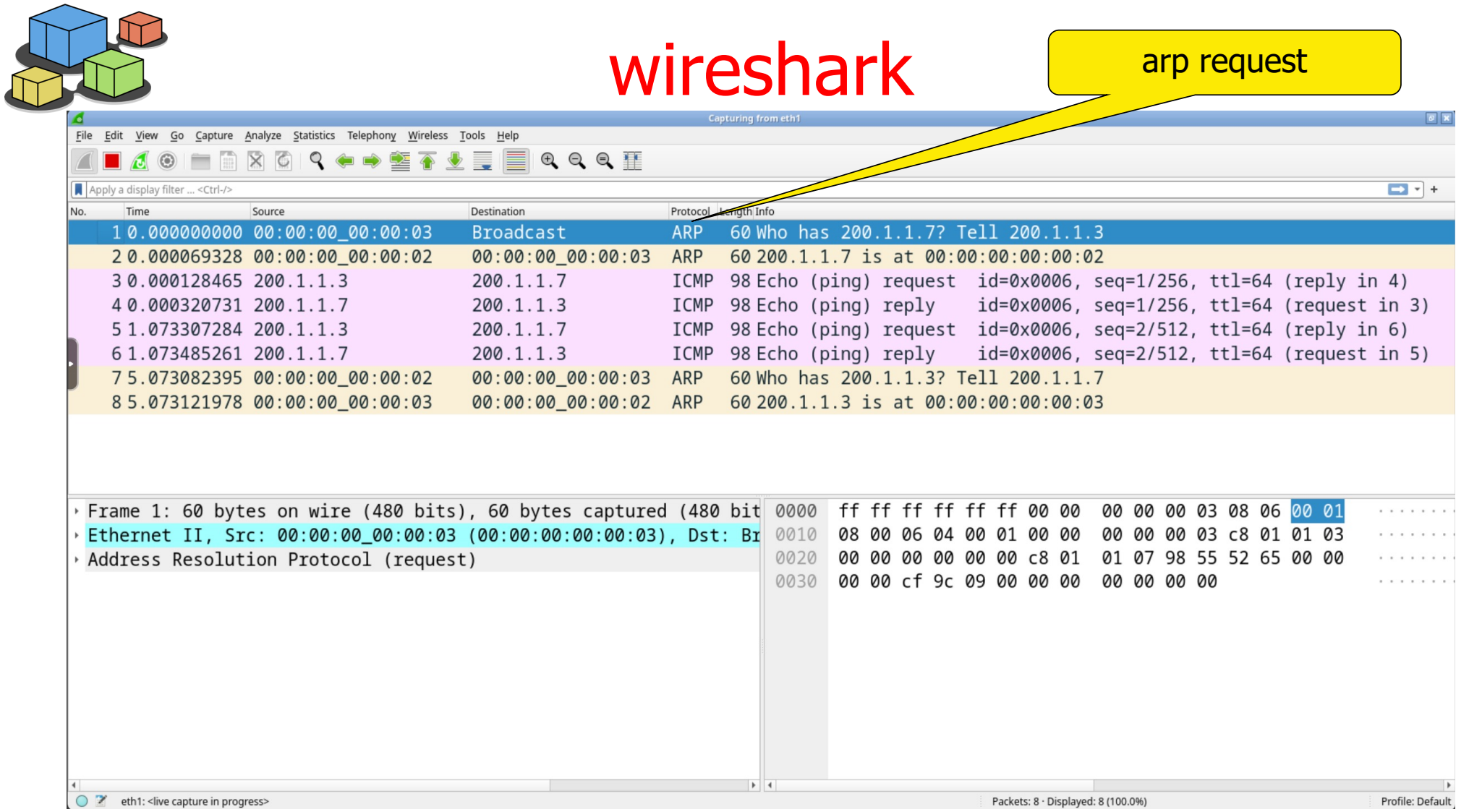
```
root@pc2:/# arp -n
Address                  HWtype  HWaddress           Flags Mask  Iface
200.1.1.3                ether   00:00:00:00:00:03   C           eth0
```



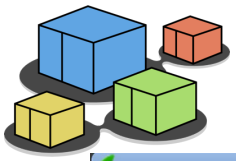
wireshark

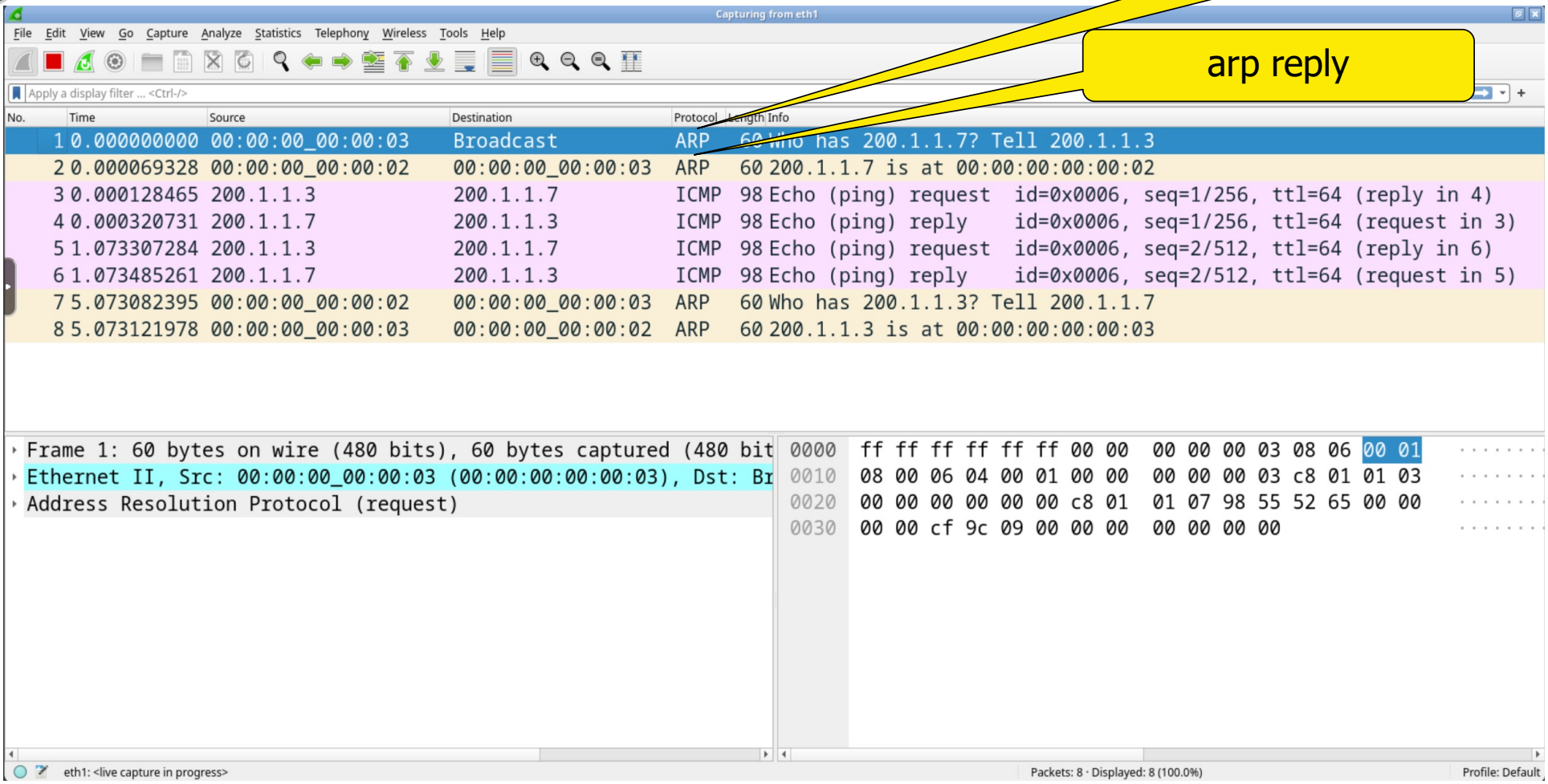


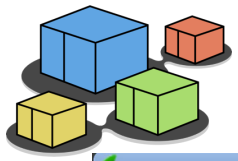
wireshark



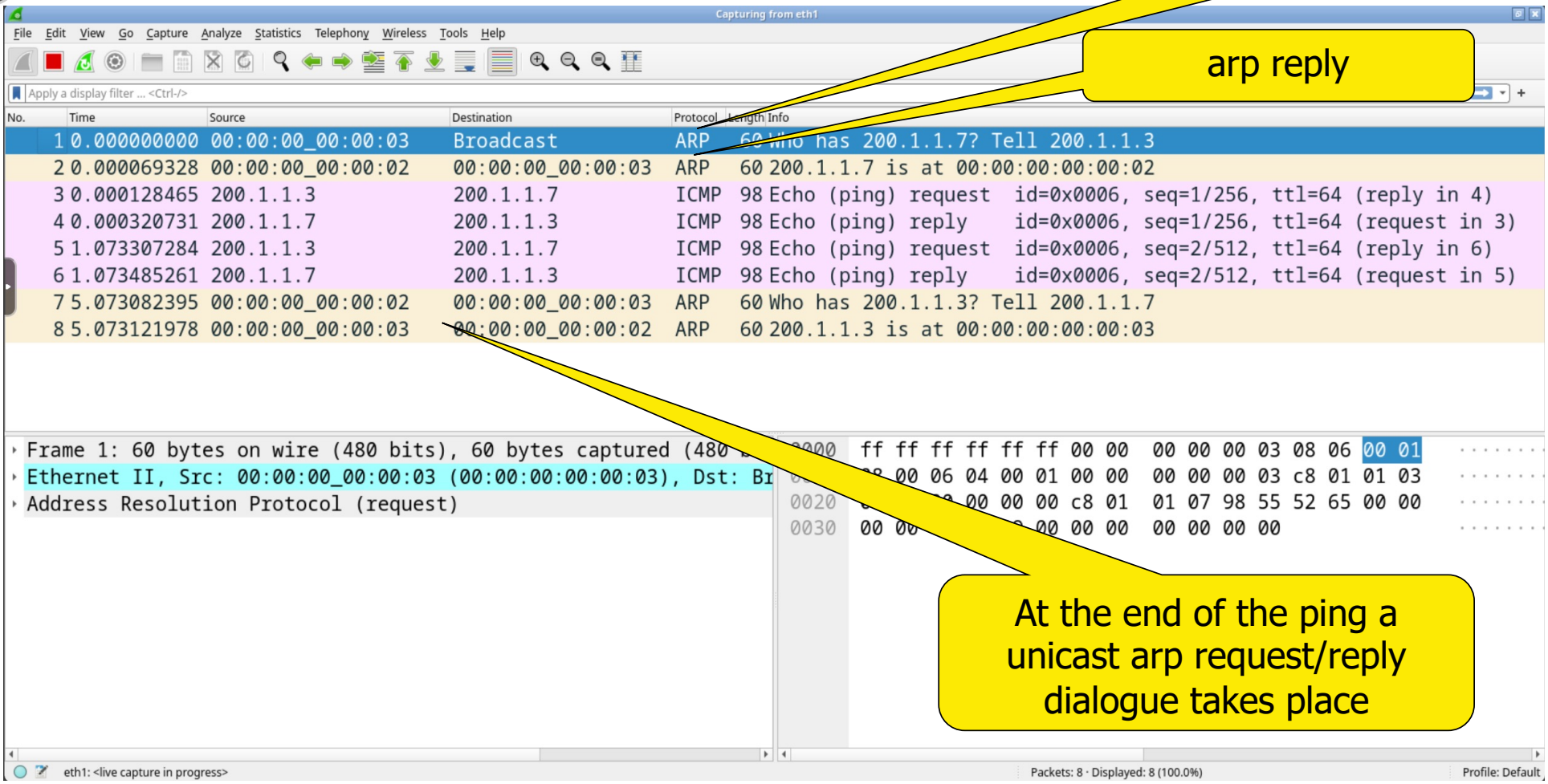
wireshark

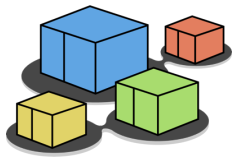




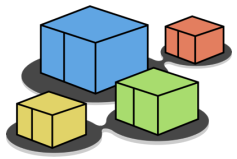


wireshark





ping from pc2 to pc1 and related arp behavior

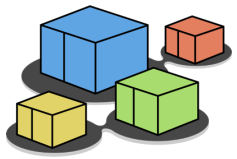


sniff the traffic

- connect the wireshark device to collision domain B

```
user@localhost:~/kathara-lab_basic-ipv4$ kathara lconfig -n wireshark --add B
```

- open any browser on the host machine
  - on **localhost:3000**
  - sniff eth2

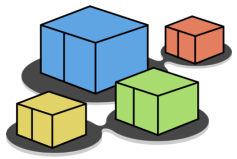


on pc2

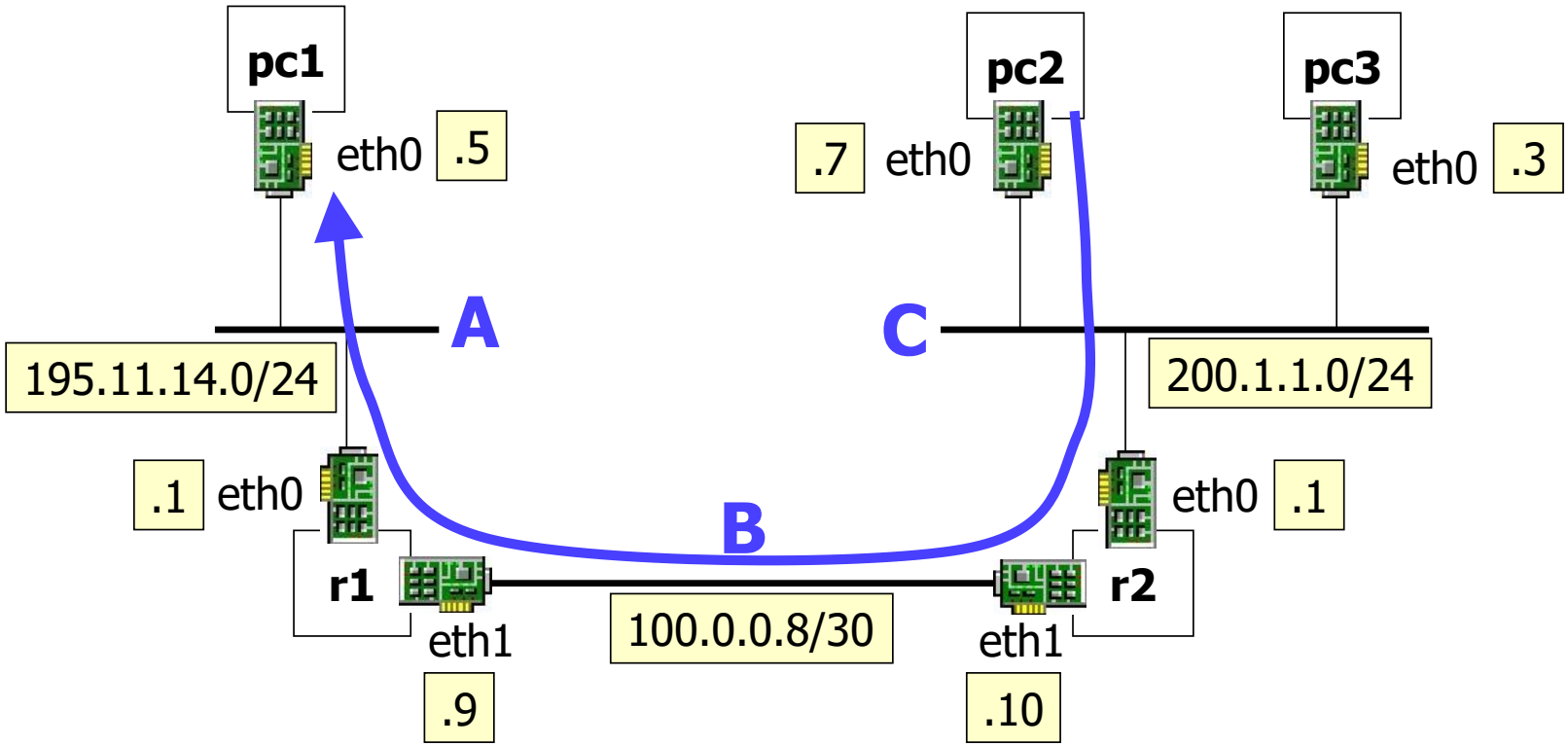
- execute a ping command towards pc1

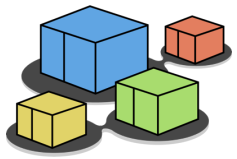
pc2

```
root@pc2:/# ping 195.11.14.5
PING 195.11.14.5 (195.11.14.5) 56(84) bytes of data.
64 bytes from 195.11.14.5: icmp_seq=1 ttl=62 time=5.86 ms
64 bytes from 195.11.14.5: icmp_seq=2 ttl=62 time=1.69 ms
--- 195.11.14.5 ping statistics ---
2 packets transmitted, 2 received, 0% packet loss, time 1002ms
rtt min/avg/max/mdev = 1.688/3.771/5.855/2.083 ms
```



inspecting the arp cache (non local traffic)





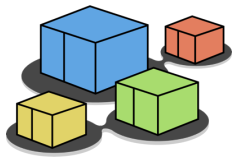
inspecting the arp cache (non local traffic)

- when ip traffic is addressed outside the local network, the sender needs the mac address of the router
- arp requests can get replies only within the local network

pc2

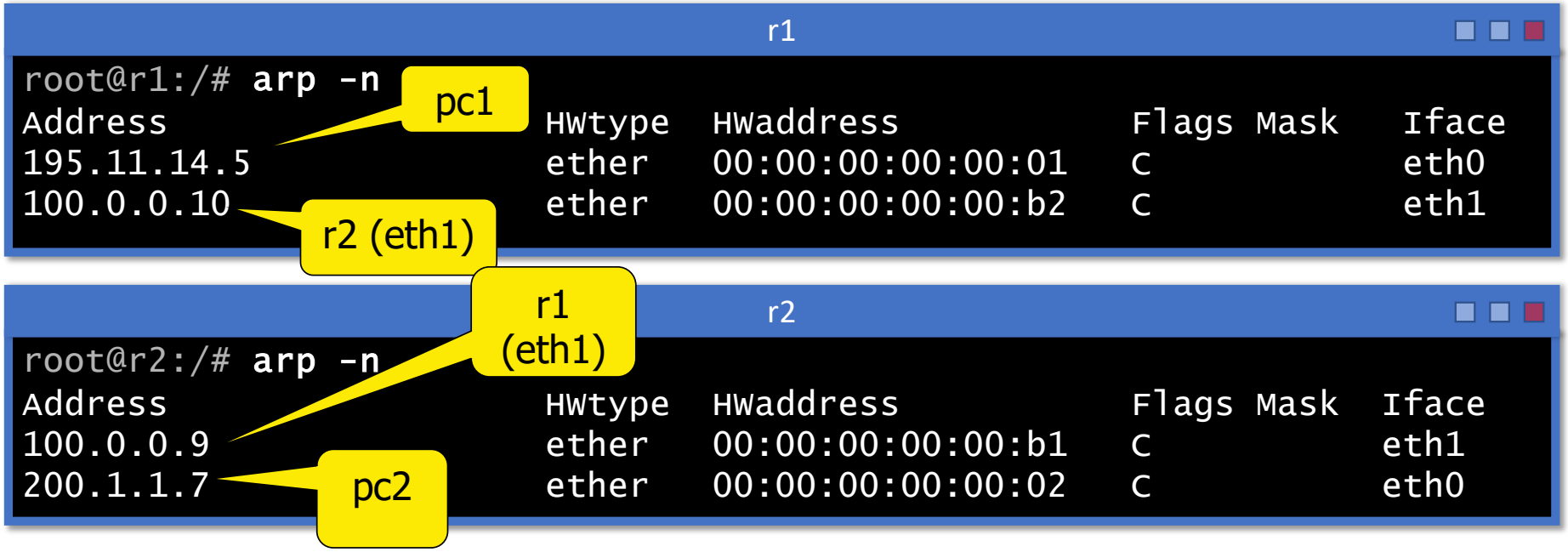
```
root@pc2:/# arp -n
Address                  HWtype  HWaddress           Flags Mask   Iface
200.1.1.1                ether   00:00:00:00:00:c1   C            eth0
200.1.1.3                ether   00:00:00:00:00:03   C            eth0
root@pc2:/#
```

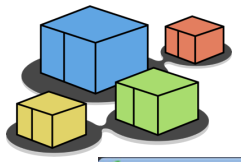
mac address of eth0 on r2



inspecting the arp cache
(non local traffic)

- what about routers?
- routers perform arp too (hence have arp caches) anytime they have to send ip packets on an ethernet lan





wireshark

which is the mac address of r1

Capturing from eth2

File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help

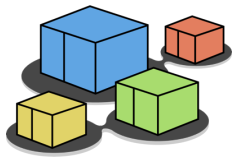
Apply a display filter ... <Ctrl-/>

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	00:00:00_00:00:b2	Broadcast	ARP	60	Who has 100.0.0.9? Tell 100.0.0.10
2	0.000113040	00:00:00_00:00:b1	00:00:00_00:00:b2	ARP	60	100.0.0.9 is at 00:00:00:00:00:b1
3	0.000165061	200.1.1.7	195.11.14.5	ICMP	98	Echo (ping) request id=0x0007, seq=1/256, ttl=63 (reply in 4)
4	0.000775595	195.11.14.5	200.1.1.7	ICMP	98	Echo (ping) reply id=0x0007, seq=1/256, ttl=63 (request in 3)
5	0.999746816	200.1.1.7	195.11.14.5	ICMP	98	Echo (ping) request id=0x0007, seq=2/512, ttl=63 (reply in 6)
6	0.999887390	195.11.14.5	200.1.1.7	ICMP	98	Echo (ping) reply id=0x0007, seq=2/512, ttl=63 (request in 5)
7	5.044520000	00:00:00_00:00:b1	00:00:00_00:00:b2	ARP	60	Who has 100.0.0.10? Tell 100.0.0.9
8	5.044526554	00:00:00_00:00:b2	00:00:00_00:00:b1	ARP	60	100.0.0.10 is at 00:00:00:00:00:b2

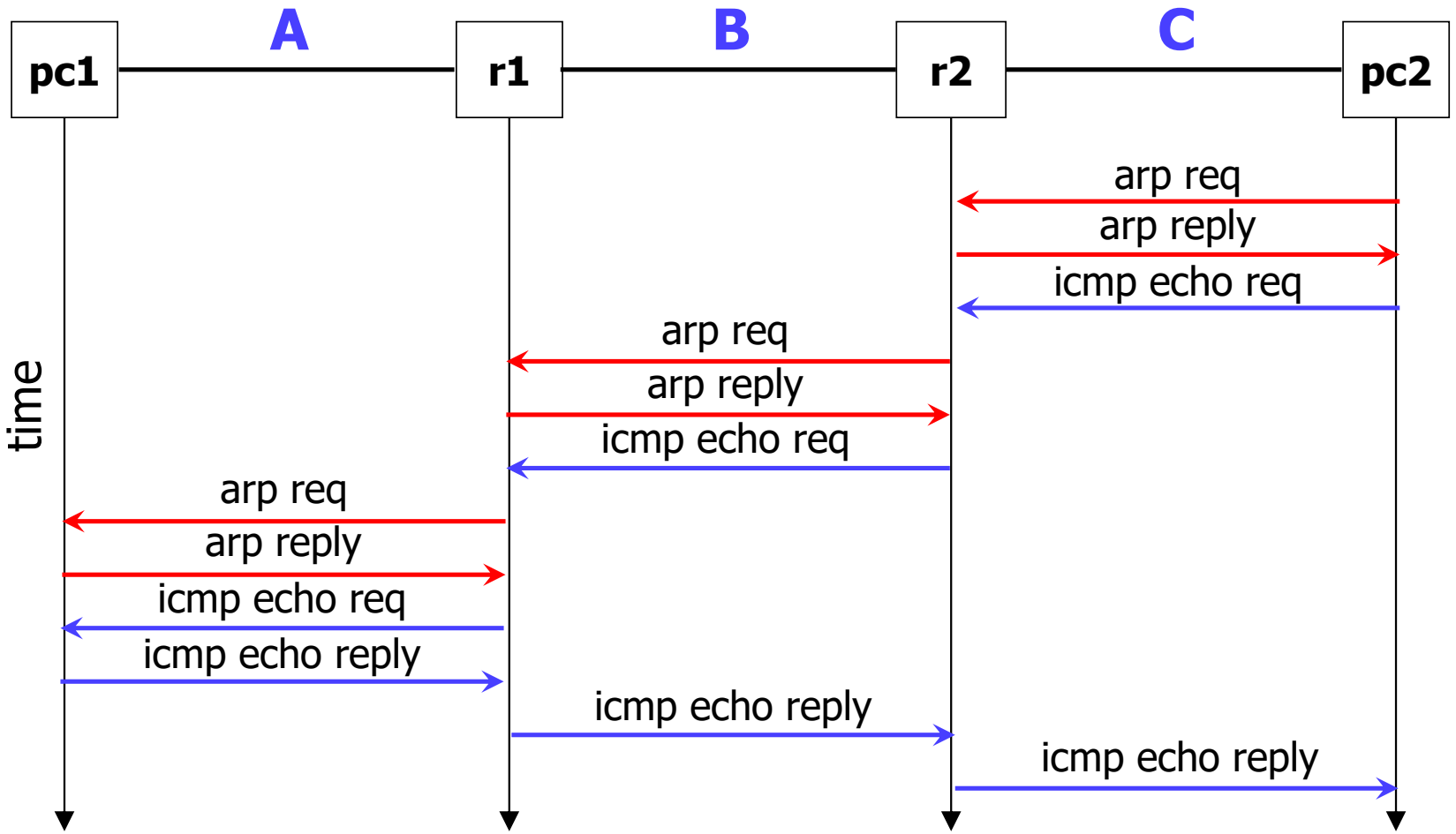
```
▸ Frame 1: 60 bytes on wire (480 bits), 60 bytes captured (480 b…
▸ Ethernet II, Src: 00:00:00_00:00:b2 (00:00:00:00:00:b2), Dst: …
▸ Address Resolution Protocol (request)
```

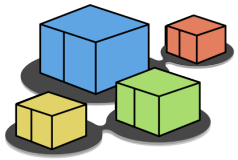
```
0000  ff ff ff ff ff ff 00 00  00 00 00 b2 08 06 00 01   ........
0010  08 00 06 04 00 01 00 00  00 00 00 b2 64 00 00 0a   ........
0020  00 00 00 00 00 00 64 00  00 09 37 2d 30 30 30 30   ......d·
0030  30 00 00 00 00 00 00 00  00 00 00 00               0·......
```

eth2: <live capture in progress> Packets: 8 · Displayed: 8 (100.0%) Profile: Default

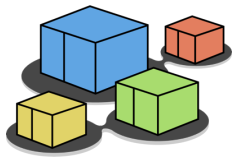


understanding the whole picture



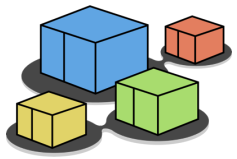


traceroute from pc2 to pc1 and related arp behavior



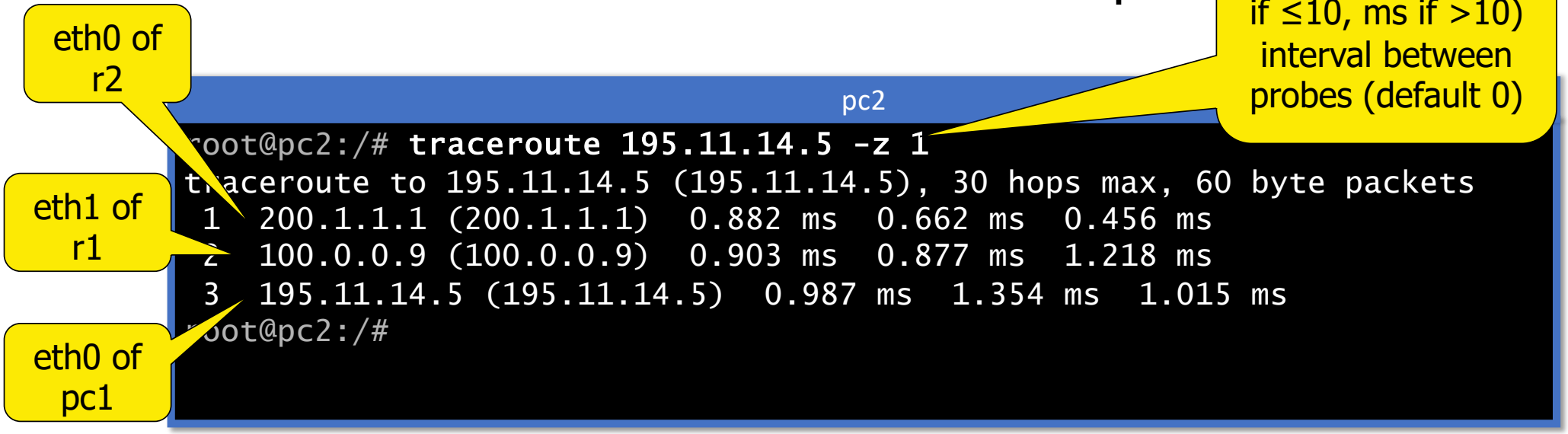
sniff the traffic

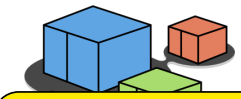
- the wireshark host is already connected to collision domain C
- open any browser on the host machine
  - on **localhost:3000**
  - sniff eth1



on pc2

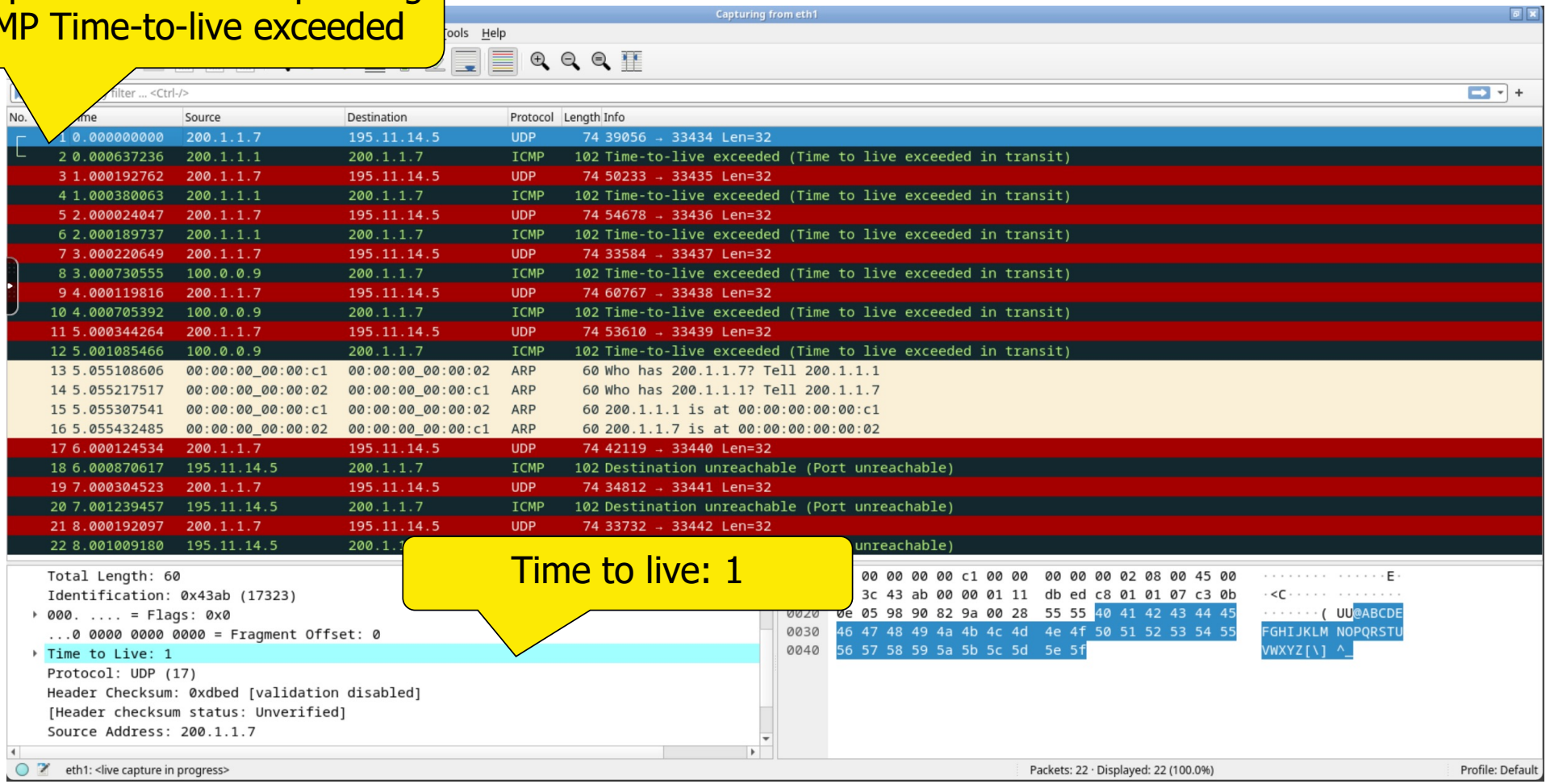
- execute a traceroute command towards pc1

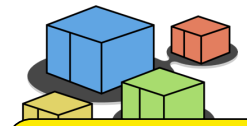




udp packet and corresponding ICMP Time-to-live exceeded

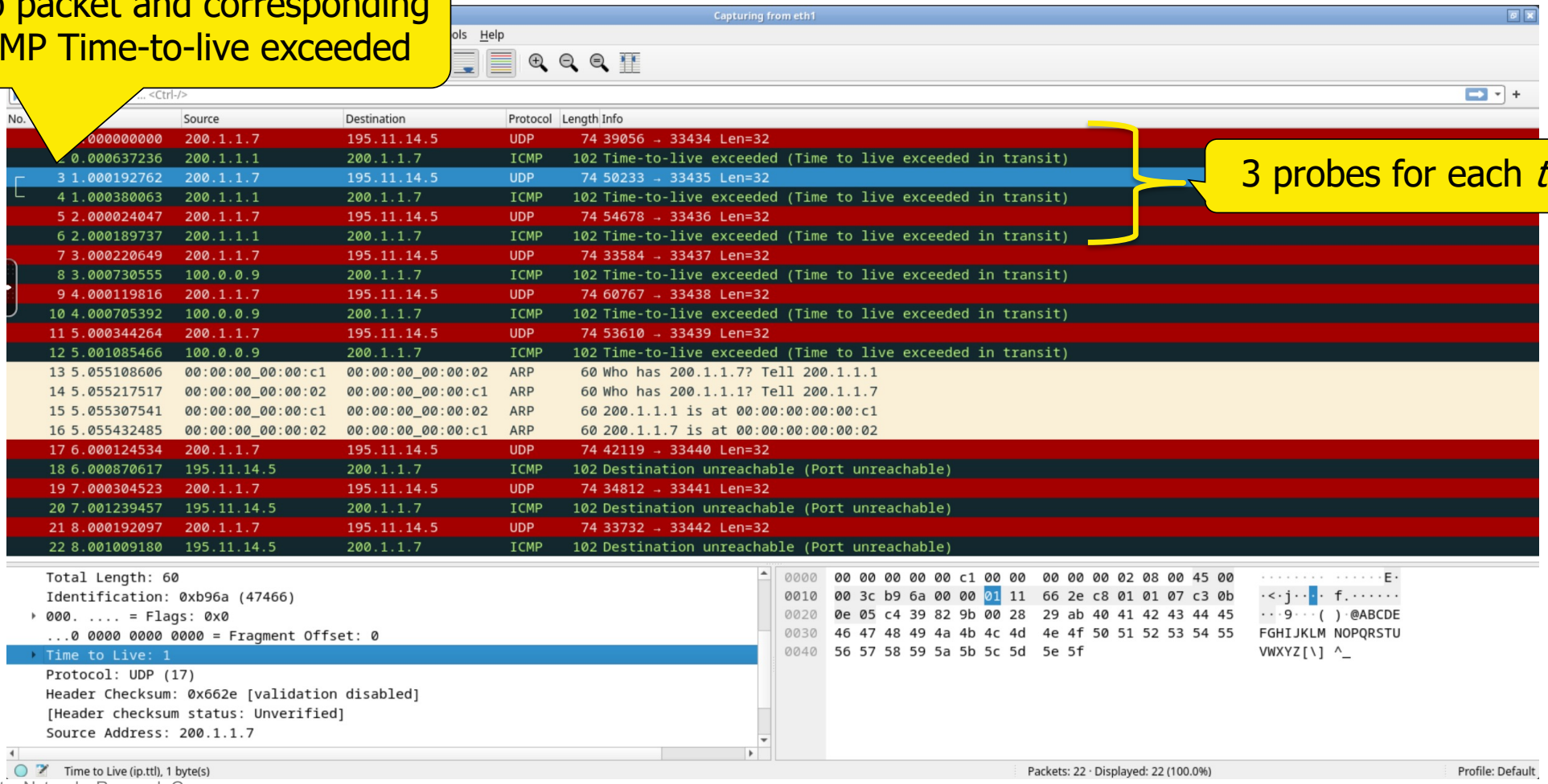
wireshark



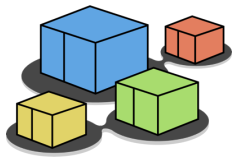


udp packet and corresponding ICMP Time-to-live exceeded

wireshark

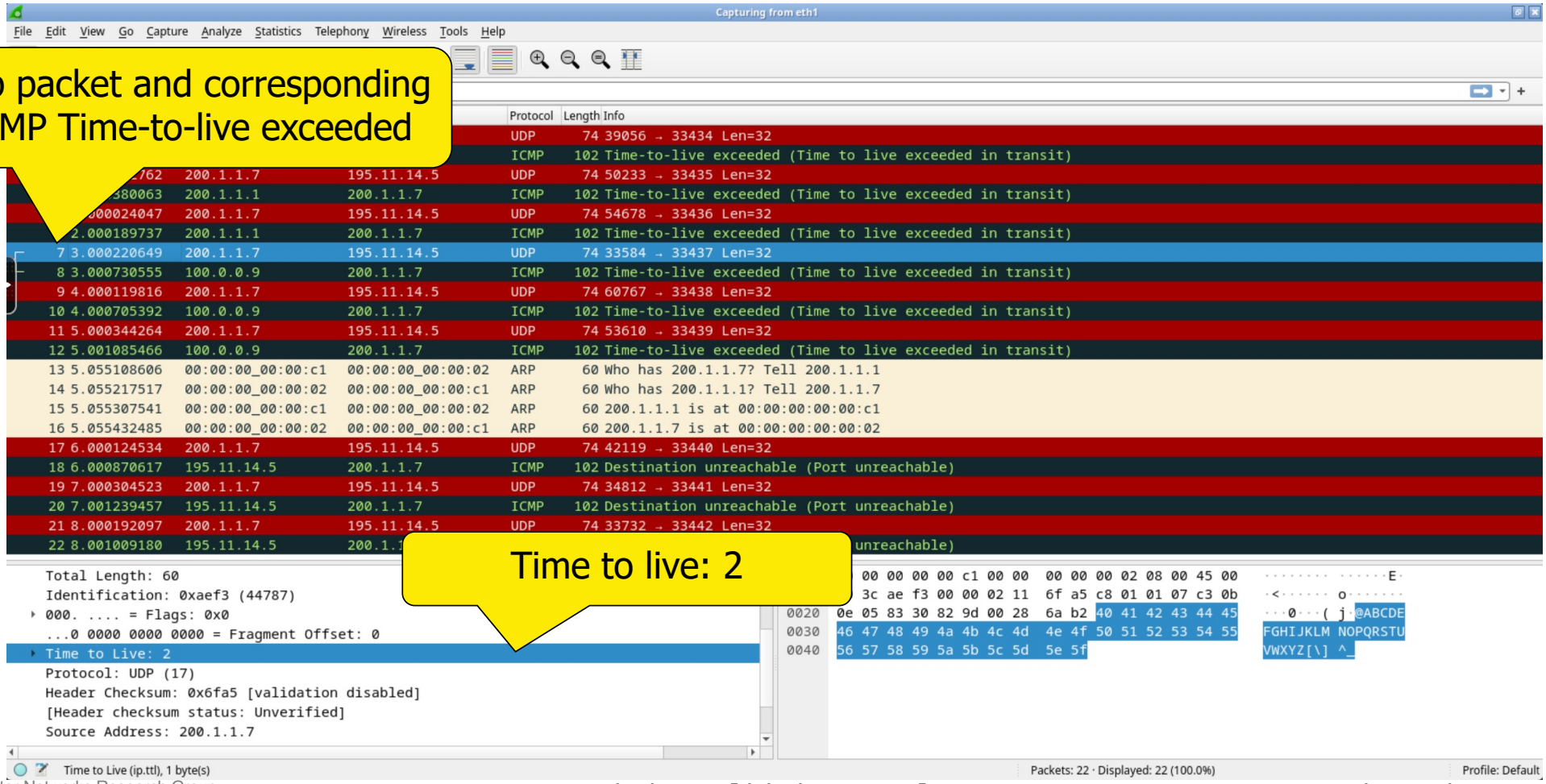


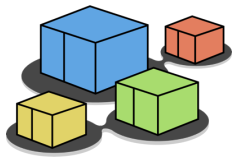
3 probes for each *ttl*



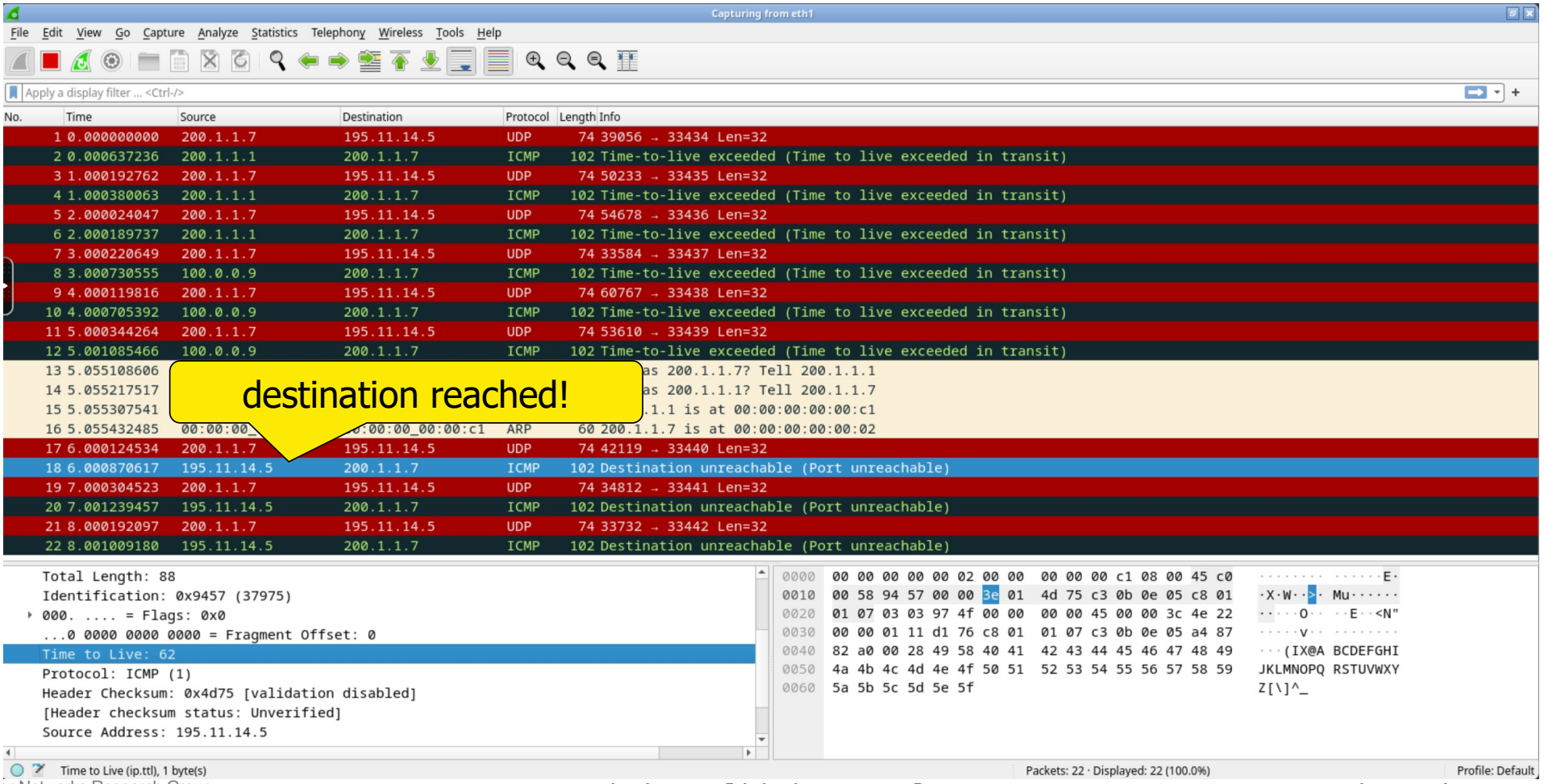
wireshark

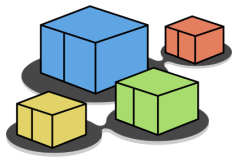
udp packet and corresponding ICMP Time-to-live exceeded



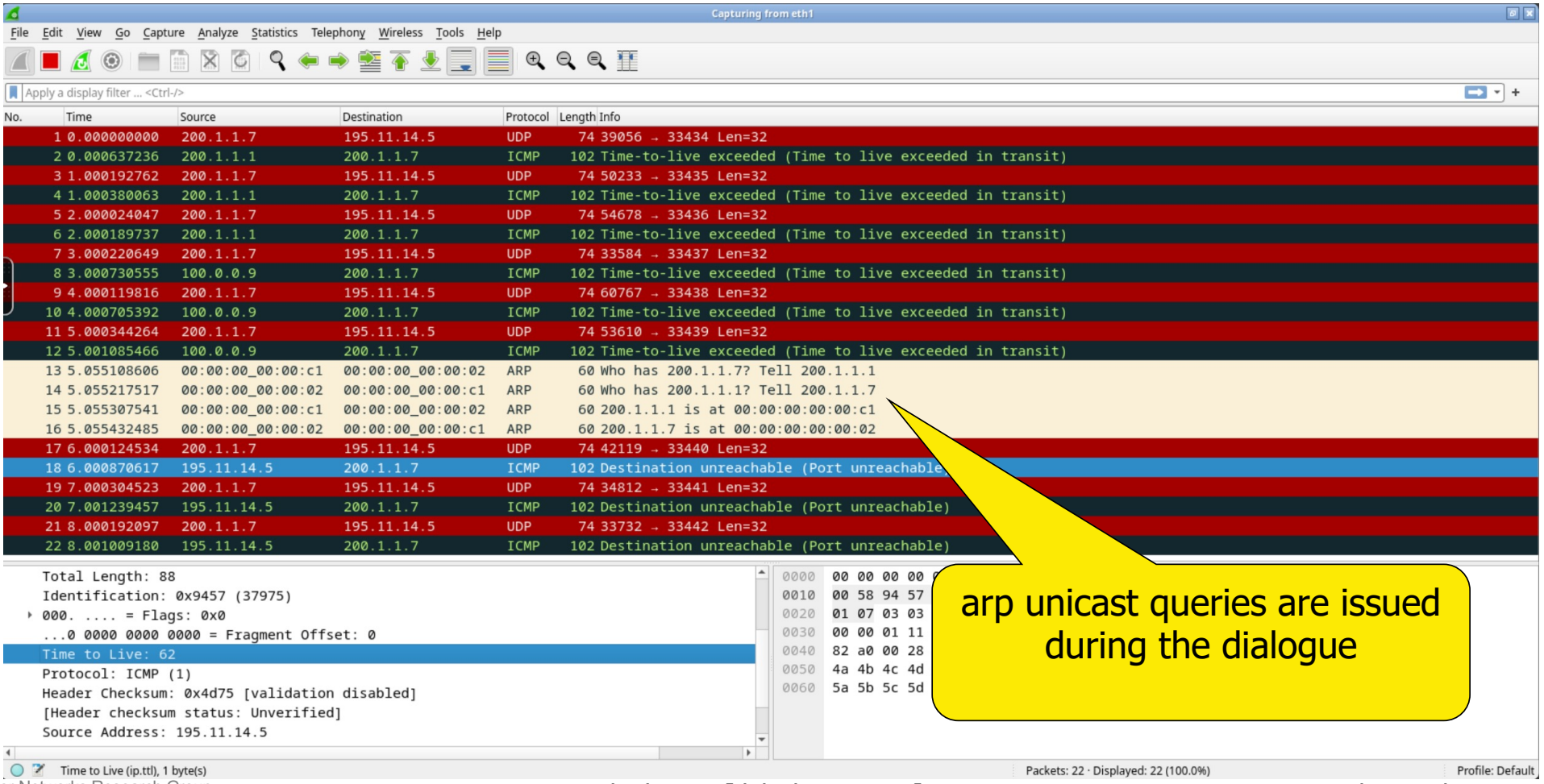


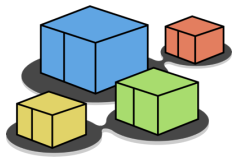
wireshark





wireshark





proposed exercises

- check the different error messages obtained by trying to ping an unreachable destination in the case of
  - local destination
  - non-local destination
- which packets are exchanged in the local collision domain in the two cases?