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DUT · SEMESTER 3 · COMPUTER SCIENCE

Network Administration

Session 02 · DHCP: automatic addressing

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Today's session

01 Why DHCP

02 The DORA exchange

03 Leases, pools and reservations

04 A DHCP server on Fedora with Kea

05 Beyond one LAN

TODAY'S FOCUS

Last session, you typed srv1's address by hand. Today srv1 becomes the machine that gives addresses to everyone else.

You will see each DHCP message in a real capture, then write the server's configuration.

Learning objectives

1. Explain why networks use DHCP and list the settings it delivers
2. Describe the four DORA messages, with their source and destination addresses
3. Explain what a lease is and when a client renews it
4. Configure, start and check a Kea DHCP server on Fedora

PREREQUISITES

- Session 01: nmcli, systemctl, editing files with nano
- CCNA 1: broadcast, MAC address, UDP ports
- srv1 and client1 VMs on the labnet internal network

MODULE OVERVIEW

Where we are in the module

01

Linux server

Done: srv1 with a fixed address

02

DHCP

Today: hosts receive their settings automatically

03

DNS

Names resolve to addresses

04

Web server

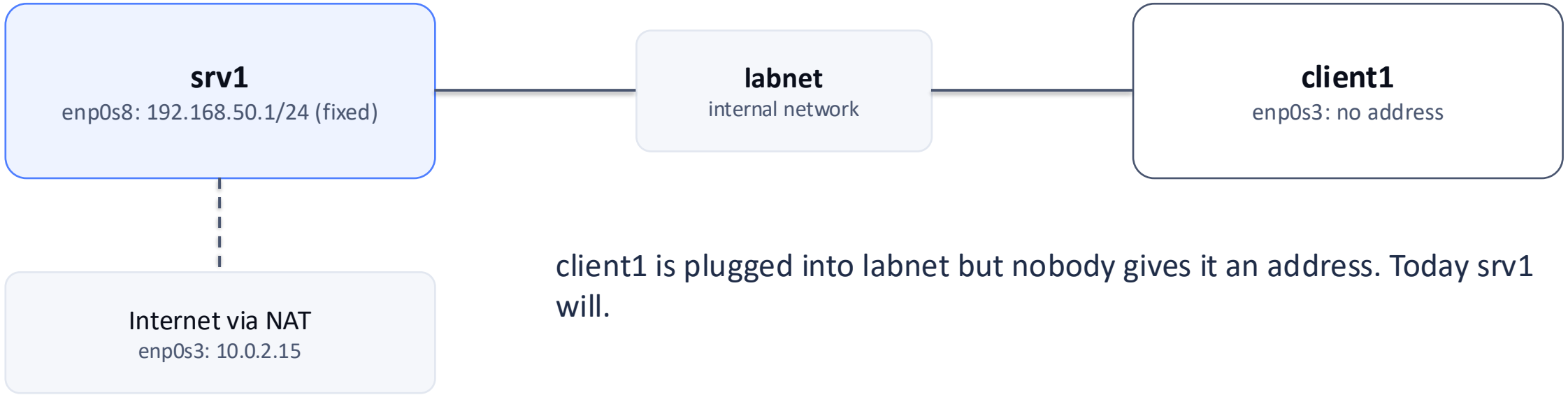
A site published on the lab network

05

Full network

DHCP, DNS and web working together

Where we stopped in Session 01



client1 is plugged into labnet but nobody gives it an address. Today srv1 will.

Figure 1. srv1 and client1 on the labnet internal network. Legend: blue = configured, grey = not configured yet, dashed = VirtualBox NAT to the Internet.

01

CHAPTER

Why DHCP

What goes wrong when every host is configured by hand, and what DHCP gives instead

Configuring 200 PCs by hand

- Each PC needs four settings: address, mask, gateway, DNS server
  - 200 PCs means 800 values typed by someone, one machine at a time
- Two PCs with the same address stop working
  - An address conflict is hard to find: it appears only when both machines are on
- When the DNS server changes, every PC must be edited again
- Laptops and phones move between networks several times a day

KEY TAKEAWAY

Manual configuration is fine for a few servers. For clients, it is slow, error-prone and impossible to keep up to date.

What DHCP is

DEFINITION

DHCP (Dynamic Host Configuration Protocol) lets a host ask the network for its settings when it connects, and receive them from a DHCP server.

EXAMPLE

Your phone joins the campus Wi-Fi and receives an address, a mask, a gateway and a DNS server in less than a second.

IN THE PROTOCOL STACK

DHCP runs over UDP: the server listens on port 67, the client on port 68. It is defined in RFC 2131 (1997).

What a DHCP server sends: options

Option	Name	Value in our lab	Why the client needs it
(header)	Your IP address	192.168.50.100	Its own address
1	Subnet mask	255.255.255.0	To tell local from remote destinations
3	Router	192.168.50.254	Default gateway
6	Domain name server	192.168.50.2	To resolve names
15	Domain name	lab.internal	Suffix for short names
51	Lease time	3600 s	How long it may keep the address

Table 1. Values taken from a real DHCP exchange with the configuration used later in this session. Option numbers: RFC 2132.

Three ways a host gets its address

Static (manual)

Typed on the host itself

Never changes

Used for: servers, routers, the DHCP server itself

DHCP pool (dynamic)

Chosen by the server from a range

May change after the lease ends

Used for: PCs, laptops, phones

DHCP reservation

Given by the server, always the same for one MAC address

Managed centrally

Used for: printers, cameras

Knowledge check

QUESTION

Which machine in our lab should NOT receive its address from DHCP?

A

client1

B

A student's laptop on labnet

C

srv1, the DHCP server

D

A phone on the campus Wi-Fi

02

CHAPTER

The DORA exchange

Four messages, a real packet capture, and how a client with no address can talk at all

The problem of the first packet

DEFINITION

When client1 starts, it has no IP address and does not know the server's address. It must still send a packet and receive an answer.

THE SOLUTION FOR THE SOURCE

The client uses 0.0.0.0, which means "I have no address yet".

THE SOLUTION FOR THE DESTINATION

The client sends to 255.255.255.255, the broadcast address: every host on the local network receives it.

Reminder from CCNA 1: unicast and broadcast

Unicast

- One sender, one receiver
- Destination MAC: the receiver's MAC address
- Destination IP: the receiver's address, e.g. 192.168.50.1

Broadcast

- One sender, every host on the LAN
- Destination MAC: ff:ff:ff:ff:ff:ff
- Destination IP: 255.255.255.255
- Stopped by routers: it never leaves the subnet

DORA: Discover, Offer, Request, Acknowledge

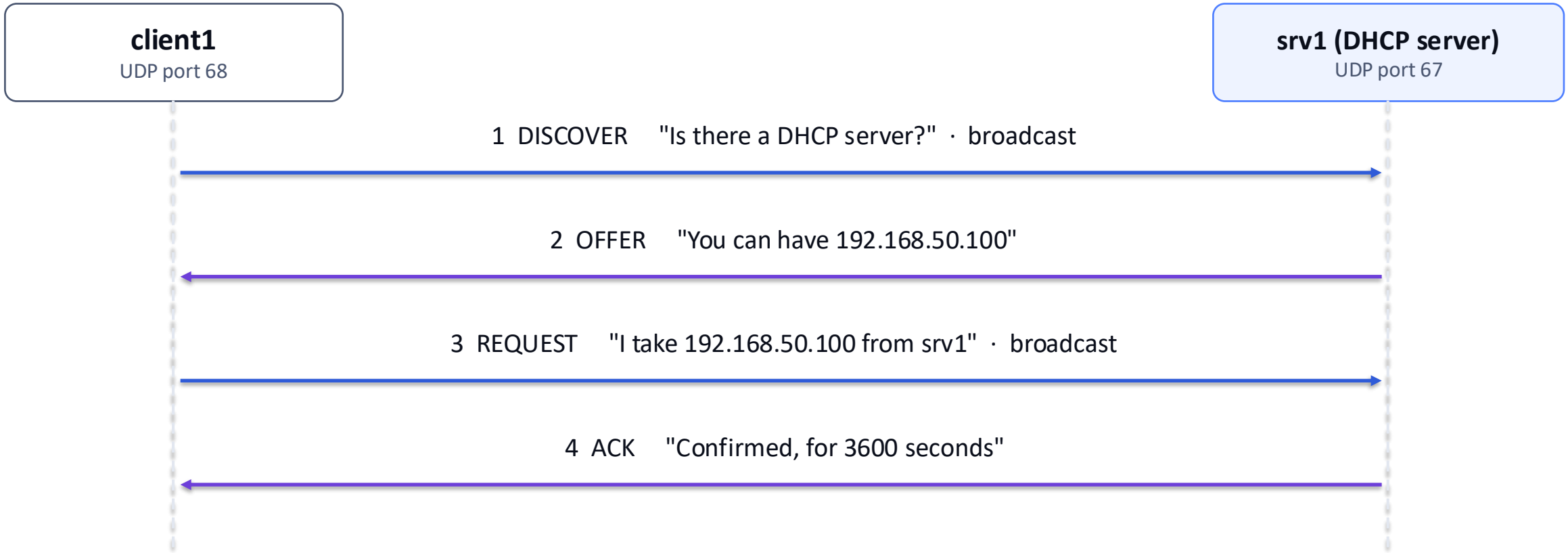


Figure 2. The four DHCP messages between client1 and srv1, in order. Legend: arrows show the direction of each message.

Who sends what, to which address

Message	Sent by	Source IP:port	Destination IP:port
DISCOVER	client1	`0.0.0.0:68`	`255.255.255.255:67`
OFFER	srv1	`192.168.50.1:67`	`192.168.50.100:68`
REQUEST	client1	`0.0.0.0:68`	`255.255.255.255:67`
ACK	srv1	`192.168.50.1:67`	`192.168.50.100:68`

Table 2. Addresses observed in a real capture (tcpdump) of a client obtaining a lease from a Kea DHCP server. The client did not set the broadcast flag.

A real DISCOVER, seen with tcpdump

BASH · SRV1

```
$ sudo tcpdump -i enp0s8 -n -v \
    port 67 or port 68

0.0.0.0.68 > 255.255.255.255.67:
BOOTP/DHCP, Request from
  36:5d:64:a3:24:7f, xid 0x23286965
  DHCP-Message (53): Discover
  Parameter-Request (55):
    Subnet-Mask, Default-Gateway,
    Domain-Name-Server, Domain-Name
  Hostname (12): "client1"
```

LINES 1-2

-i which card, -n numbers not names, -v show DHCP details

LINE 4

From 0.0.0.0 port 68 to the broadcast address, port 67

LINES 6-11

MAC address, transaction ID, message type and the settings requested

The OFFER: everything the client asked for

TCPDUMP OUTPUT

```
192.168.50.1.67 > 192.168.50.100.68:
BOOTP/DHCP, Reply, xid 0x23286965
  Your-IP 192.168.50.100
  DHCP-Message (53): Offer
  Subnet-Mask (1): 255.255.255.0
  Default-Gateway (3): 192.168.50.254
  Domain-Name-Server (6): 192.168.50.2
  Domain-Name (15): "lab.internal"
  Lease-Time (51): 3600
  Server-ID (54): 192.168.50.1
```

WHAT TO NOTICE

Same xid as the DISCOVER: this reply belongs to that request

Your-IP: the proposed address

Server-ID: which server makes this offer

The ACK that follows carries the same values

How each machine knows a message is for it

DEFINITION

Every DHCP message carries a transaction ID (xid), chosen at random by the client, and the client's MAC address (chaddr).

ON THE CLIENT

A reply is for me if it has my MAC address and the xid I chose. Everything else is ignored.

ON THE SERVER

The REQUEST names a Server-ID. A server whose ID is not named puts its offered address back in the pool.

"The server always broadcasts its OFFER"

✗ INCORRECT APPROACH

Expecting the OFFER and the ACK to always go to 255.255.255.255

✓ CORRECTION

The server broadcasts only if the client set the broadcast flag. Otherwise it sends the reply directly to the client's MAC address.

WHY IT MATTERS

When you read a capture, a unicast OFFER is normal, not a fault. The client still uses 0.0.0.0 until the ACK.

The other DHCP messages

Message	Sent by	When
DHCPNAK	Server	The client asks for an address that is no longer valid, e.g. after moving to another network
DHCPDECLINE	Client	The offered address is already used by another host (detected with ARP)
DHCPRELEASE	Client	The client gives its address back before the lease ends
DHCPINFORM	Client	A host with a static address asks only for other settings, such as DNS servers

Table 3. Message types defined in RFC 2131, section 3.1. After a NAK, the client starts again from DISCOVER.

Knowledge check

QUESTION

Why does client1 broadcast its REQUEST instead of sending it to srv1 only?

A

Because it does not know srv1's address

B

So that every server that made an offer learns which one was chosen

C

Because UDP cannot send unicast packets

D

To check that no other host uses the address

03

CHAPTER

Leases, pools and reservations

An address is lent, not given: how long, what happens next, and how to plan the addresses

A lease: an address on loan

DEFINITION

A lease is the permission to use an address for a limited time. The client must renew it to keep the address.

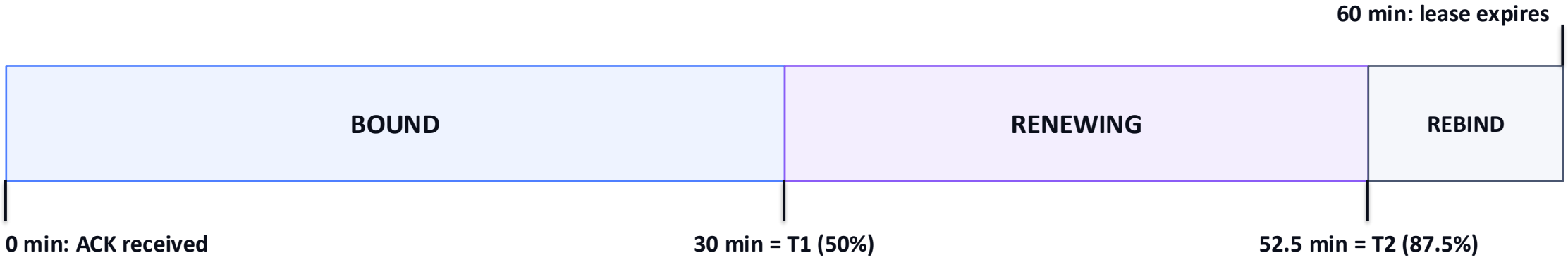
EXAMPLE

Like a library book: you borrow it for two weeks, you can extend the loan, and if you never return, the library can lend it to someone else.

WHY NOT FOREVER?

Devices leave without saying goodbye. Leases let the server reuse the addresses of machines that are gone.

The life of a one-hour lease



BOUND

The client uses its address normally.

RENEWING (AFTER T1)

It sends a REQUEST directly to srv1. An ACK restarts the clock.

REBINDING (AFTER T2)

srv1 did not answer: it broadcasts a REQUEST to any server.

Figure 3. Lease timers for a 3600 s lease, drawn to scale. T1 and T2 use the default values of RFC 2131 (50% and 87.5% of the lease).

Computing T1 and T2

PROBLEM

An office server gives 8-hour leases. A PC receives its ACK at 08:00. When does it try to renew, when does it rebind, and when does the lease expire?

REASONING

1. T1 = 0.5 × 8 h = 4 h after 08:00
2. T2 = 0.875 × 8 h = 7 h after 08:00
3. Expiry = 8 h after 08:00

RESULT

Renew at 12:00

Rebind at 15:00

Expires at 16:00

When the DHCP server is down

Situation of the client	What happens
Has a valid lease	Keeps working; renewals fail silently until the lease expires
Lease expires, server still down	Loses its address; it can only reach the local link
Windows client, no answer at all	Picks a 169.254.x.x address (APIPA): no gateway, no Internet
New client booting	Gets nothing; the user sees "no network"

Table 4. 169.254.0.0/16 is the IPv4 link-local range (RFC 3927). Seeing such an address on a PC almost always means that DHCP failed.

An address plan for labnet

Addresses	Use	Configured how
`192.168.50.1 - .9`	Servers (srv1 = .1, DNS = .2, web = .3)	Static, on each server
`192.168.50.10 - .99`	Reservations (printers, special hosts)	DHCP, fixed per MAC address
`192.168.50.100 - .199`	Pool for clients	DHCP, dynamic
`192.168.50.254`	Default gateway (router)	Static, on the router

Table 5. Example plan for the 192.168.50.0/24 lab network. A pool must never contain addresses already used by static hosts.

Knowledge check

QUESTION

A client has a 2-hour lease. srv1 crashes 10 minutes after the ACK. When does the client lose its address?

A

Immediately

B

At T1, one hour after the ACK

C

At T2, 1 h 45 min after the ACK

D

Two hours after the ACK, if no server answers

04

CHAPTER

A DHCP server on Fedora with Kea

Choosing the software, writing the configuration, starting the service and checking the result

Which DHCP server software in 2026?

Software	Status	On Fedora 44	Configuration
ISC DHCP (dhcpd)	End of life since December 2022; no more updates	dhcp-server 4.4.3, "not for production"	/etc/dhcp/dhcpd.conf
ISC Kea	Maintained; 3.0 is a long-term support version (June 2025)	kea 3.0.3 (Fedora 45: 3.2)	/etc/kea/kea-dhcp4.conf (JSON)
Windows Server DHCP	Maintained by Microsoft	Not applicable	Graphical console or PowerShell
Cisco IOS DHCP	Built into routers	Not applicable	ip dhcp pool commands

Table 6. Sources: ISC, ISC DHCP end of life; ISC, Kea 3.0 announcement (25 Jun 2025); Fedora packages pages for dhcp-server and kea. Checked 12 Oct 2026.

Five steps to a working DHCP server

01

Install

sudo dnf install kea

02

Configure

Edit /etc/kea/kea-dhcp4.conf

03

Check

kea-dhcp4 -t finds syntax errors before starting

04

Open the firewall

Allow the dhcp service (UDP 67)

05

Start and enable

systemctl enable --now kea-dhcp4

Reading JSON: the format of Kea's configuration

The building blocks

- { } an object: a set of "name": value pairs
- [ ] a list of values, in order
- "text" in double quotes; numbers and true/false without quotes

Rules that cause most errors

- A comma between two items, never after the last one
- Every { and [must be closed
- Names are case-sensitive: "subnet4", not "Subnet4"

kea-dhcp4.conf, part 1: where and how long

JSON · /ETC/KEA/KEA-DHCP4.CONF

```
{
  "Dhcp4": {
    "interfaces-config": {
      "interfaces": [ "enp0s8" ]
    },
    "lease-database": {
      "type": "memfile",
      "persist": true
    },
    "valid-lifetime": 3600,
```

LINE 2

Everything belongs to the DHCPv4 server

LINES 3-5

Listen only on the labnet card, never on the NAT card

LINES 6-9

Save leases in a file so they survive a restart

LINE 10

Lease time in seconds

kea-dhcp4.conf, part 2: the subnet and its pool

JSON · CONTINUED

```
    "subnet4": [ {
      "id": 1,
      "subnet": "192.168.50.0/24",
      "pools": [ { "pool":
        "192.168.50.100 - 192.168.50.199" } ],
      "option-data": [
        { "name": "routers",
          "data": "192.168.50.254" },
        { "name": "domain-name-servers",
          "data": "192.168.50.2" },
        { "name": "domain-name",
          "data": "lab.internal" }
      ] } ] } }
```

LINES 1-3

One subnet, with a unique number and its network address

LINES 4-5

The pool from our address plan

LINES 6-12

Options 3, 6 and 15: gateway, DNS server, domain

LINE 13

Close everything that was opened

Install, check, open, start

BASH · SRV1

```
sudo dnf install kea
sudo cp /etc/kea/kea-dhcp4.conf{,.orig}
sudo nano /etc/kea/kea-dhcp4.conf

sudo kea-dhcp4 -t /etc/kea/kea-dhcp4.conf

sudo firewall-cmd --permanent --add-service=dhcp
sudo firewall-cmd --reload
sudo systemctl enable --now kea-dhcp4
systemctl status kea-dhcp4
```

LINE 2

Keep a copy of the example file

LINE 5

Nothing printed: syntax correct

LINES 7-8

Allow DHCP, then apply

LINES 9-10

Look for active (running) and enabled

When the check fails: two real error messages

Mistake in kea-dhcp4.conf	What kea-dhcp4 -t prints
No comma at the end of line 5 ("valid-lifetime": 3600)	`kea-dhcp4.conf:6.5-13: syntax error, unexpected subnet4, expecting "," or }`
"interfaces": ["enp0s8"] on a machine with no card of that name	`Failed to select interface: interface 'enp0s8' doesn't exist in the system (kea-dhcp4.conf:3:44)`

Table 7. Messages obtained by running kea-dhcp4 -t (Kea 2.4) on this session's configuration after introducing each error.

On client1: ask for an address

BASH · CLIENT1

```
sudo nmcli connection add type ethernet \
    ifname enp0s3 con-name labnet \
    ipv4.method auto
sudo nmcli connection up labnet

ip -br address show enp0s3
nmcli -f IP4 device show enp0s3
nmcli -f DHCP4 device show enp0s3
```

LINES 1-4

ipv4.method auto = use DHCP. This is the opposite of manual from Session 01

LINES 6-7

Expect 192.168.50.100/24, gateway .254, DNS .2

LINE 8

All options received, including the lease time

On srv1: the lease file

BASH · SRV1

```
$ sudo cat /var/lib/kea/kea-leases4.csv
address,hwaddr,client_id,
valid_lifetime,expire,subnet_id,
fqdn_fwd,fqdn_rev,hostname,state,...

192.168.50.100,36:5d:64:a3:24:7f,
01:36:5d:64:a3:24:7f,3600,
1791819517,1,0,0,client1,0,...
```

LINES 2-4

The first line names the fields

LINES 6-8

One lease: address, MAC address, client ID, lease time, expiry time, subnet id, hostname

Troubleshooting: client1 gets no address

What you see	Likely cause	How to check
Nothing in tcpdump on srv1	client1 not on labnet, or network name misspelt	VirtualBox settings of both VMs
DISCOVER seen, no OFFER	Kea stopped, firewall closed, or wrong interface in the config	systemctl status kea-dhcp4; firewall-cmd --list-all
Kea refuses to start	Syntax error in kea-dhcp4.conf	kea-dhcp4 -t; journalctl -u kea-dhcp4
client1 gets 10.0.2.x	Its card is on NAT, not labnet	VirtualBox network mode of client1
Address OK, no Internet	Normal today: router .254 does not exist yet	ip route on client1

Table 8. Work from the cable up, as in Session 01: first the VirtualBox network, then the server, then the client.

Knowledge check

QUESTION

tcpdump on srv1 shows DISCOVER messages from client1 but no OFFER. Which cause can you rule out?

A

The kea-dhcp4 service is stopped

B

client1 is attached to a different internal network

C

The firewall on srv1 blocks UDP 67

D

Kea listens on enp0s3 instead of enp0s8

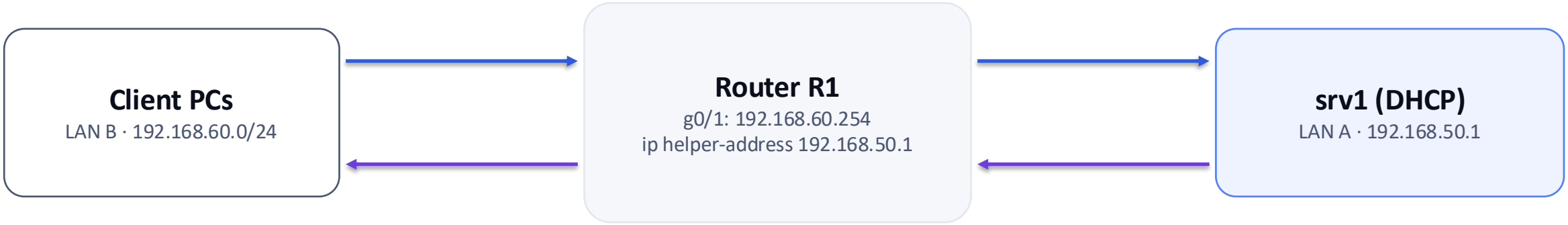
05

CHAPTER

Beyond one LAN

One DHCP server for several subnets, and how to stop a DHCP server that should not be there

A relay agent carries DHCP across a router



1. The client broadcasts its DISCOVER. Without help, it stops at R1.

2. R1 forwards it to 192.168.50.1 as unicast, adding its own address (giaddr).

3. srv1 picks the pool matching giaddr and replies through R1.

Figure 4. The router relays DHCP messages between LAN B and the server. Legend: blue arrows = towards the server, violet arrows = replies.

The two sides of a relay configuration

IOS ON R1 · KEA ON SRV1

```
R1(config)# interface g0/1
R1(config-if)# ip helper-address 192.168.50.1

# kea-dhcp4.conf: add a second subnet
{ "id": 2,
  "subnet": "192.168.60.0/24",
  "pools": [ { "pool":
    "192.168.60.100 - 192.168.60.199" } ],
  "option-data": [ { "name": "routers",
    "data": "192.168.60.254" } ] }
```

LINES 1-2

On the interface facing the clients, name the DHCP server

LINES 4-10

One subnet per LAN, each with its own pool and its own gateway

DHCP and security

Threats

- A rogue DHCP server answers first and gives a wrong gateway, so traffic passes through the attacker
- Starvation: an attacker requests every address in the pool with fake MAC addresses
- A home router plugged in by mistake does the same as a rogue server

Protections

- DHCP snooping on switches: server replies are accepted only on trusted ports
- Limit the number of MAC addresses per switch port
- In the lab: keep DHCP servers on internal networks, never on bridged mode

Knowledge check

QUESTION

Clients on LAN B get no address. srv1 is on LAN A behind router R1. What is most likely missing?

A

A second DHCP server on LAN A

B

A relay (ip helper-address) on R1's LAN B interface

C

A bigger pool for 192.168.50.0/24

D

A shorter lease time

Recap

KEY TAKEAWAYS

- DHCP gives hosts their address, mask, gateway and DNS server
- DORA: the client broadcasts from 0.0.0.0; the ACK makes it official
- A lease is renewed at 50% (T1), rebound at 87.5% (T2)
- Kea: JSON config, kea-dhcp4 -t, firewall dhcp, enable --now
- Routers stop broadcasts: other subnets need a relay

NEXT

- Practical: srv1 becomes the DHCP server of labnet; client1 receives its address
- Session 03 (masterclass): DNS, turning names into addresses

References

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SH

Thank you · Questions?

Next: build the DHCP server of labnet in the practical session

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