Kea DHCP

Kea lease allocation, client classification and option assignment

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In this Chapter

- Lease allocation
- Client classification
- DHCP options
- DHCP reservations
- Shared subnets
- Questions & Answers

DHCP options

DHCP options

- DHCP options can be configured in different scopes in the Kea configuration
    - Global
    - Class
    - Subnet
    - Pools
    - Reservations

Global DHCP options (1/2)

```
"Dhcp4": {
    "option-data": [{
           "name": "domain-name-servers",
           "code": 6,
           "space": "dhcp4",
           "csv-format": true,
           "data": "192.0.2.1, 192.0.2.2"
        },
        ...
    ]}
```

Global DHCP options (2/2)

- If the default values are used, the fields `code`, `space` and `csv-format` can be omitted

```
"Dhcp4": {
    "option-data": [{
            "name": "domain-name-servers",
            "data": "192.0.2.1, 192.0.2.2"
        },
        ...
    ]}
```

Subnet specific DHCP option

```
[...]
   "subnet4": [ {
            "subnet": "192.0.2.0/24",
            "pools": [ { "pool": "192.0.2.100 - 192.0.2.200" } ],
            "option-data": [{
                    "name": "routers",
                    "data": "192.0.2.1" },
                {
                    "name": "domain-name",
                    "data": "a.example.com" }
            ]},
[...]
```

Client class options

```
"client-classes": [{
        "name": "Zimbutsio-Server",
        "test": "option[vendor-class-identifier].text == 'Zimbutsio'",
        "option-data": [ {
                "name": "log-servers",
                "data": "192.0.2.42"
            }]
    }],
[...]
```

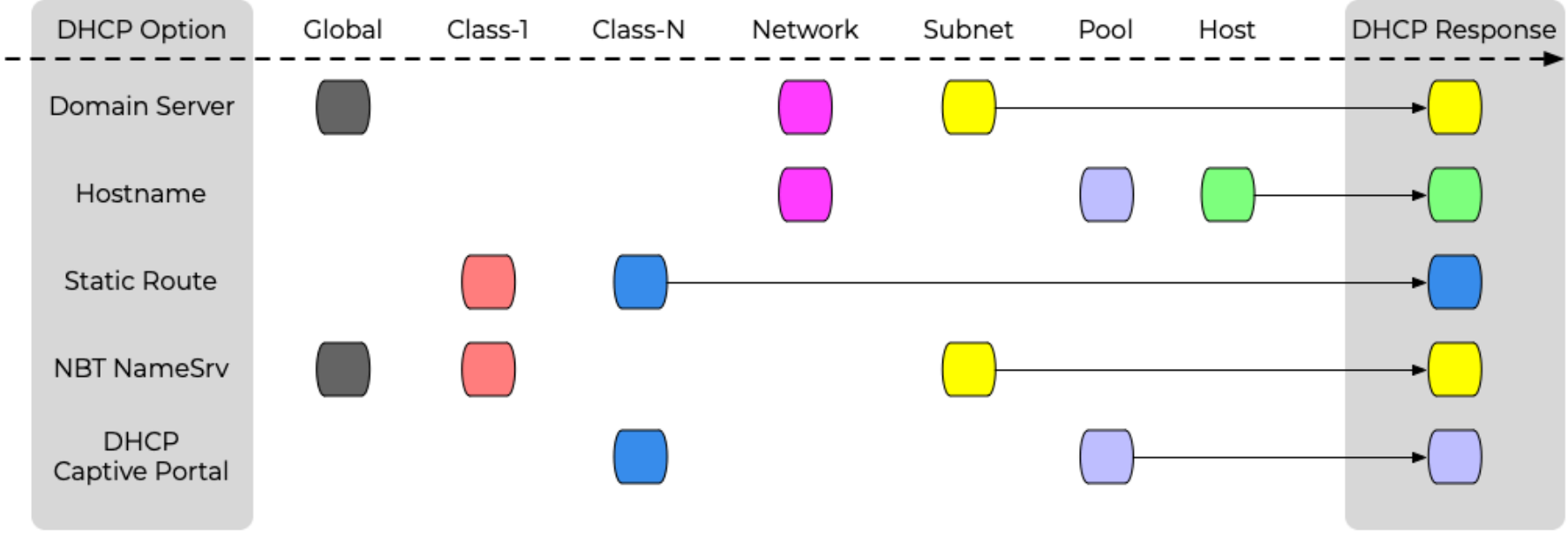
Defining custom DHCPv4 options (1/2)

- Sometimes it is required to define custom DHCP options that are not part of the DHCP standards.
    - These can be vendor specific options, or new DHCP options that are not yet implemented in Kea DHCP

Defining custom DHCPv4 options (2/2)

```
{
    "Dhcp4": {
        "option-def": [{
                "name": "my-message",
                "code": 234,
                "type": "string",
                "array": false,
                "record-types": "",
                "space": "dhcp4",
                "encapsulate": "" }],
        "option-data": [{
                "name": "my-message",
                "space": "dhcp4",
                "csv-format": true,
                "data": "Hello World" }],
[...]
```

Option assignment order



(Client-class options are assigned in the order in which the client classes are evaluated (specified in the configuration))

DHCP reservations

Why DHCP reservations

- Security policies
- Stable addressing (server)
- IP bound licenses
- Captive portal (*KNOWN* vs. *UNKNOWN* clients)

DHCP reservations

- Kea DHCP supports reservations of client leases based on
  - Hardware interface address (MAC-Address)
  - DHCP Unique ID (DUID)
  - Relay-Circut-ID (DHCPv4)
  - Client-ID / Hostname (DHCPv4)
  - flex.id

DHCP reservation parameter

- Alongside IP-Address leases, reservations can also reserve a number of DHCP parameters for a client
    - Hostname
    - DHCP options
    - Reservation-client-classes
    - Boot-file-name (BOOTP/DHCPv4)
    - Next-server (BOOTP/DHCPv4)
    - Server-hostname (BOOTP/DHCPv4)

Global vs. Subnet reservations

- DHCP reservations can optionally be defined on a global scope
  - Global reservations can be used to assign a fixed hostname or other options to a client
  - Kea does not prevent the definition of DHCP parameters on the global level that are only useful in an subnet scope (like IP address or IPv4 default route). Be careful!

- The common case is to have reservations in the subnet or shared-subnet scope
  - Kea 1.9+ does allow for reservations to be defined on a global and subnet level (at the same time)

Example of global reservation

```
"Dhcp4:" {
    # This specifies global reservations. They will apply to all subnets that
    # have global reservations enabled.

    "reservations": [
    {  "hw-address": "aa:bb:cc:dd:ee:ff",  "hostname": "hw-host-dynamic"  },
    {  "hw-address": "01:02:03:04:05:06",  "hostname": "hw-host-fixed",  "ip-address": "192.0
    {  "circuit-id": "'office042'",        "hostname": "circuit-id-host"  },
[...]
```

in-pool vs *out-of-pool* reservations

- Host reservations can be inside a dynamic DHCP pool or outside a dynamic DHCP pool
- Reservations that are inside a pool can lead to DHCP conflicts (https://kea.readthedocs.io/en/latest/arm/dhcp4-srv.html#conflicts-in-dhcpv4-reservations) and also might result in a performance loss (see DHCP tuning)

Dynamically manage DHCP reservations

- Small Kea deployments (small = a few hundred client machines) can have the DHCP reservations inside the Kea configuration file
- Larger deployments might want to change the DHCP reservations dynamically and programatically via the API
    - The *Host Commands* hook adds a number of new commands to Kea used to query and manipulate host reservations

Dynamically manage DHCP reservations

- The *Host Commands* hook requires a database for storing the host reservations
- If reservations are specified in both file and database, file reservations take precedence over the ones in the database.

Host Commands

COMMAND	DESCRIPTION
reservation-add	add a new reservation to the Kea DB
reservation-get-all	get all reservation information (can be huge)
reservation-get	get information on a single reservation (by address or identifier)
reservation-get-page	get all reservation information from a subnet by pages (used for GUI display)
reservation-get-by-hostname	get the reservation information for one host by its hostname
reservation-get-by-id	get the reservation information for one host by its identifier (global, since 1.9.0)
reservation-del	delete a reservation from the database

Example command file to add a reservation (1/2)

- This command snippet can be used to create a new reservation inside the Kea Host database

```
$ cat reservation-add.json
{
  "command": "reservation-add",
  "service": [ "dhcp6" ],
  "arguments": {
    "reservation": {
      "duid": "01:02:03:04:05:06:07:08:09:0A",
      "hostname": "foo.example.com",
      "ip-addresses": [ "2001:db8:1::1" ],
      "option-data": [{
          "data": "4491",
          "name": "vendor-opts"
        },{
          "data": "3000:1::234",
          "name": "tftp-servers",
          "space": "vendor-4491"
        }],
      "subnet-id": 1
    }
```

```
    }
}
```

Example command file to add a reservation (2/2)

- The `curl` command can be used to send the request towards the Kea API

```
$ curl -s -X POST -H "Content-Type: application/json" \
  -d @reservation-add.json http://127.0.0.1:8000/ | jq
[
  {
    "result": 0,
    "text": "Host added."
  }
]
```

Example command file retrieving all reservations

- This command snippet can be used to retrieve all reservations from the Kea Host database

```
$ cat reservation-get-all.json
{
  "service": [
    "dhcp6"
  ],
  "command": "reservation-get-all",
  "arguments": {
    "subnet-id": 1
  }
}
$ curl -s -X POST -H "Content-Type: application/json" \
  -d @reservation-get-all.json http://127.0.0.1:8000/ | jq
```

Client classing in reservations

- Clients can be associated to a client-class using a reservation (using the Hardware-Address, DUID, Client-ID, Relay-ID)

```
[...]
  "subnet4": [
  {
     "subnet": "10.0.0.0/24",
     "pools": [ { "pool": "10.0.0.10-10.0.0.200" } ],
     "reservations": [{
          "hw-address": "01:02:03:04:05:06",
          "client-classes": [ "windows", "staff" ]
      }]
  }],
[...]
```

Performance tuning DHCP reservations (1/4)

- Kea DHCP must check for every lease request for conflicts with reservations. This can slow down the DHCP lease assignment process
    - In some cases, where reservations are not in use or used only in certain scopes, some of these checks can be disabled with the `reservation-mode` configuration parameter
    - The parameter can be specified at global, subnet, and shared-network levels.

```
"Dhcp4": {
    "subnet4": [{
        "subnet": "192.0.2.0/24",
        "reservation-mode": "disabled",
        ...
```

```
    }]
}
```

Performance tuning DHCP reservations (2/4)

RESERVATION-MODE	DESCRIPTION
all	Reservations can be on global, subnet or inside pool scope, all checks enabled (default)
out-of-pool	Reservations in subnets are always outside the pool
global	Only global reservations allowed, not subnet/pool reservations
disabled(*)	Host reservation support is disabled, no checks for collisions

(*) the best performance is achieved when host reservations are disabled (if no reservations are used). In that case Kea can skip all the checks and lookups.

Performance tuning DHCP reservations (3/4)

- Kea currently supports four types of identifiers:
  - `hw-address`
  - `duid`
  - `client-id`
  - `circuit-id`
  - `flex-id`
- For each incoming packet, Kea has to extract each identifier type and then query the database to see if there is a reservation by this particular identifier.

Performance tuning DHCP reservations (4/4)

- A parameter called **`host-reservation-identifiers`** takes a list of identifier types that Kea will check
    - For best performance the number of identifier types should be kept to a minimum, ideally one.

```
"host-reservation-identifiers": [ "circuit-id", "hw-address" ],
"subnet4": [{
        "subnet": "192.0.2.0/24",
        ...
    }]
```

Shared networks

Shared networks

- A shared subnet is a physical subnet with multiple IP networks
  - One shared subnet definition can contain two or more subnet definitions
  - Options can be defined on the shared-network, subnet and pool level
  - Without client classification, Kea might choose an IP address from any pool of all subnets inside the shared network

When to use shared networks

- Shared Subnets are adding complexity to a DHCP server configuration and should only be used if there is a good use case
    - Shared subnet are sometimes created if a larger number of IP addresses are needed in a network, but because of IPv4 address shortage no continuous range of IPv4 addresses are available
    - Another use case of shared subnets is a network where addresses from different IPv4 subnets (and possibly different network configuration) should be given to different network devices

Kea configuration shared network example

```
[...]
        "shared-networks": [
            {
                "name": "kea-lab01",
                "relay": { "ip-address": "192.0.2.1" },
                "subnet4": [{
                        "subnet": "192.0.2.0/24",
                        "option-data": [
                            { "name": "routers", "data": "192.0.2.1" }],
                        "pools": [{ "pool": "192.0.2.20 - 192.0.2.190" }]
                    }, {
                        "subnet": "10.0.0.0/24",
                        "option-data": [
                            { "name": "routers", "data": "10.0.0.1" }],
                        "pools": [{ "pool": "10.0.0.10 - 10.0.0.200"  }]
                    }]
        ],
[...]
```

Client classification

DHCP client classes

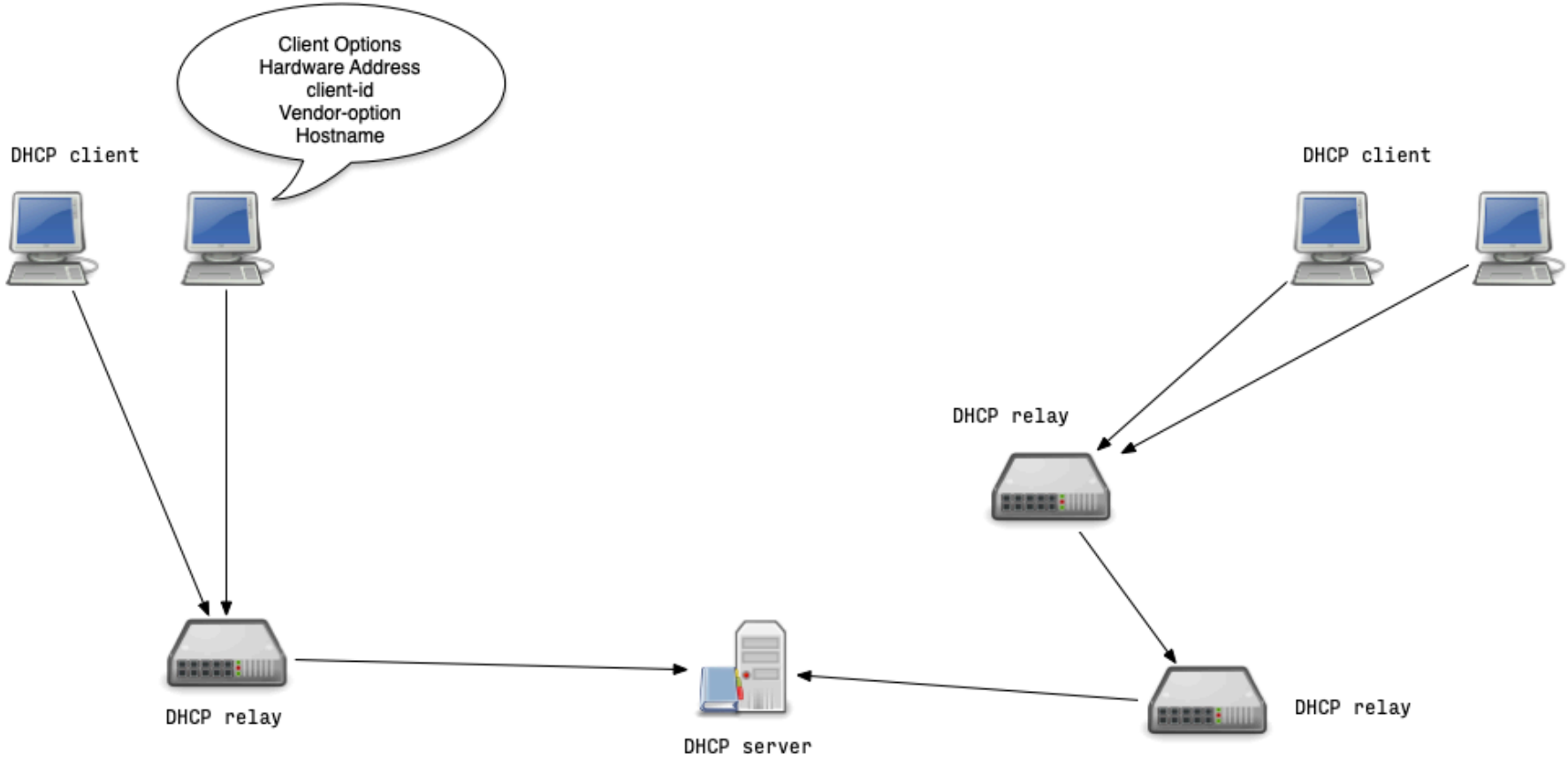
- Kea DHCP can assign one or more client classes to client requests
- Depending on the client classes, different DHCP information can be send to the client:
    - DHCP-Options
    - IP-Addresses
    - BOOTP-Parameter inside DHCP responses

- Kea can select from multiple subnets / pools with the help of client classes

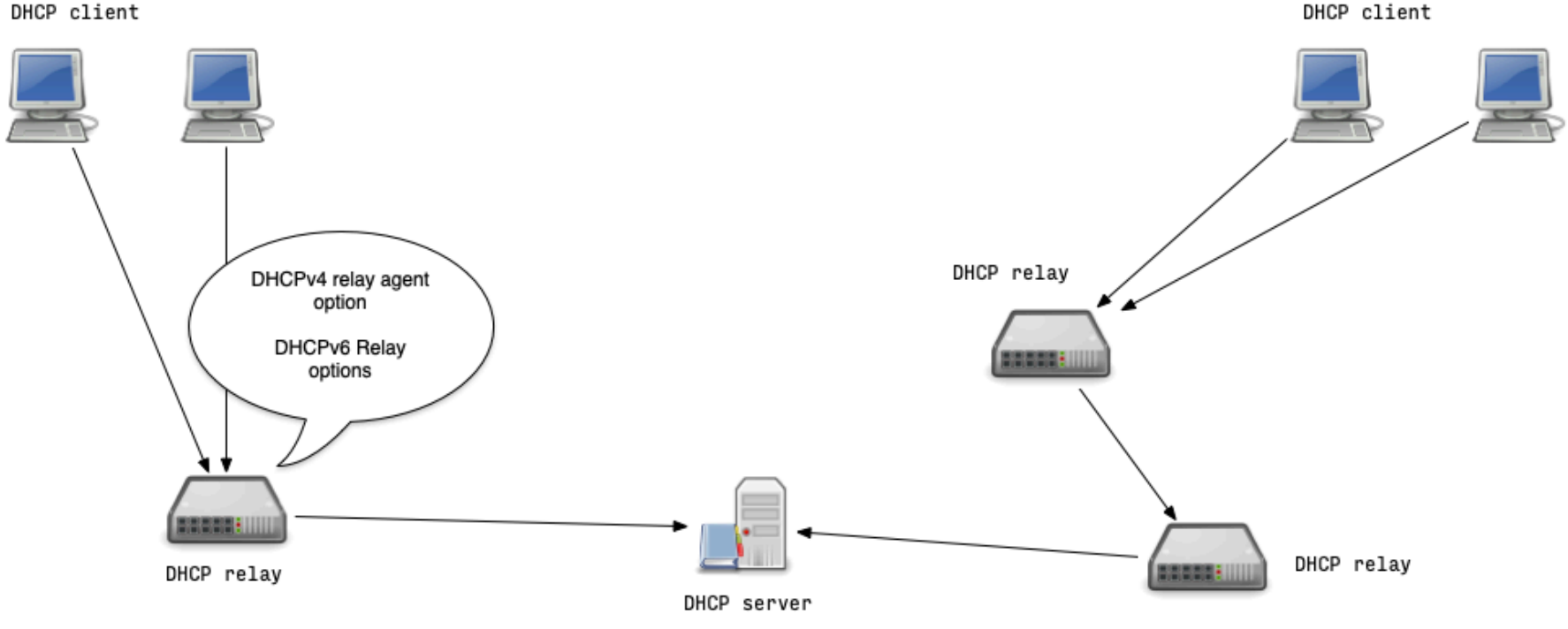
DHCP client classes

- Client classes can be built from various DHCP identifiers
    - Information from the client host
    - Information from the DHCP relay
    - Information from the DHCP packet path towards the DHCP server
- Client classification examines the incoming DHCP packet's contents and selects one or more class(es) based on configuration criteria

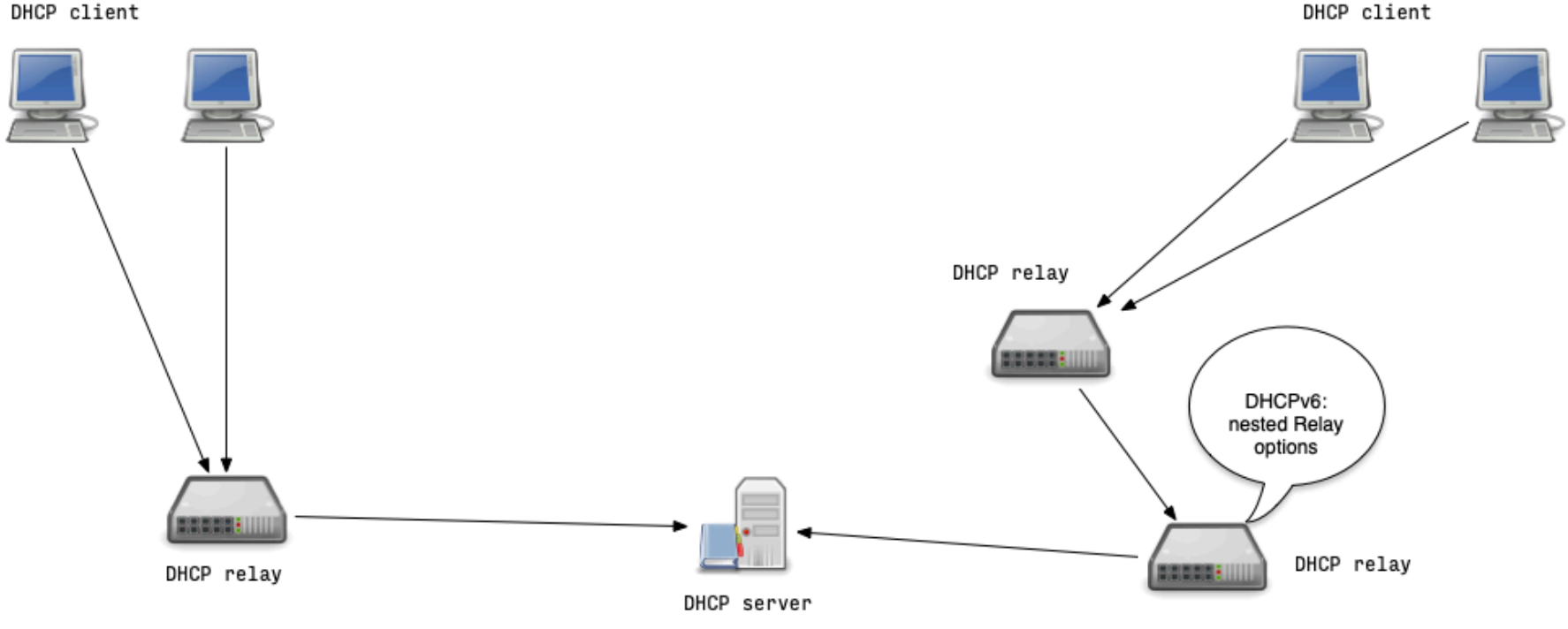
Where do DHCP identifiers come from (1/4)



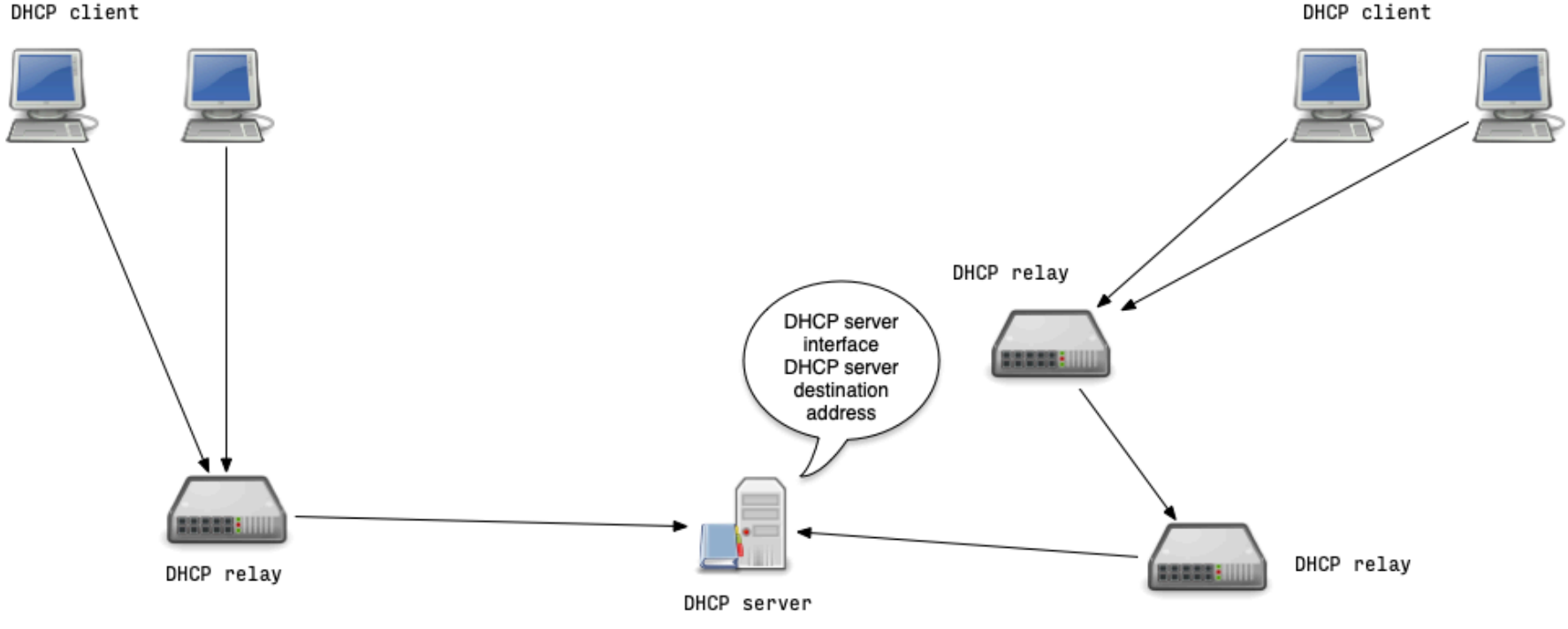
Where do DHCP identifiers come from (2/4)



Where do DHCP identifiers come from (3/4)



Where do DHCP identifiers come from (4/4)



Automatic vendor classing

- Kea DHCP automatically assigns a vendor client class if a vendor option (DHCPv4 option 60 or DHCPv6 option 16) is set in the DHCP request
- The content of that option is prepended with `VENDOR_CLASS_` and the result is interpreted as a class
    - For example, modern cable modems send this option with value `docsis3.0`, so the packet belongs to class `VENDOR_CLASS_docsis3.0`

Automatic vendor classing example

- Example subnet selection based on the vendor option
  - A client **must** be in any of the client classes listed to get a lease from this subnet
  - The vendor options used in this exercise are examples and not the real-world vendor option values:

```
"shared-networks": [
    {
        "name": "kea-net01",
        "relay": { "ip-address": "192.0.2.1" },
        "subnet4": [
            {
                "subnet": "192.0.2.0/24",
                "client-class": "VENDOR_CLASS_windowsCE", # <-- Windows CE Clients wi
                                                          # an IP from this subnet
                "option-data": [{
                        "name": "routers", "data": "192.0.2.1" }],
                "pools": [{
                        "pool": "192.0.2.60 - 192.0.2.220" }]
            },
            {
```

```
                        "subnet": "10.0.0.0/24",
                        "client-class": "VENDOR_CLASS_fedoraLinux", # <-- Fedora-Linux Client
                                                                    # get an IP from this sub
                        "option-data": [
[...]
```

The KNOWN and UNKNOWN classes

- Kea automatically assigns classes based on host reservations
  - All clients **with** a host reservation will be in the `KNOWN` class
  - All client **without** reservation will be in the `UNKNOWN` class

- For example, these classes can be used to separate *guests* from *staff* clients

```
{
    "client-classes": [{
            "name": "dependent-class",
            "test": "member('KNOWN')",
            "only-if-required": true
    }]
}
```

Dynamic client classing based on expressions

- DHCP requests can be assigned one or more client classes
  - Expressions can be used to extract information from the DHCP request message
  - Logical and conditional expressions can be used to assign classes to the DHCP request

- List of available expressions
  https://kea.readthedocs.io/en/latest/arm/classify.html#using-expressions-in-classification@@html:%3C/div%3E@@

Dynamic client classing based on expressions

List of Classification Values

Name	Example expression	Example value
String literal	‘example’	‘example’
Hexadecimal string literal	0x5a7d	‘Z}’
IP address literal	10.0.0.1	0x0a000001
Integer literal	123	‘123’
Binary content of the option	option[123].hex	‘(content of the option)’
Option existence	option[123].exists	‘true’
Binary content of the sub-option	option[12].option[34].hex	‘(content of the sub-option)’
Sub-Option existence	option[12].option[34].exists	‘true’
Client class membership	member(‘foobar’)	‘true’
Known client	known	member(‘KNOWN’)
Unknown client	unknown	not member(‘KNOWN’)
DHCPv4 relay agent sub-option	relay4[123].hex	‘(content of the RAI sub-option)’
DHCPv6 Relay Options	relay6[nest].option[code].hex	(value of the option)
DHCPv6 Relay Peer Address	relay6[nest].peeraddr	2001:DB8::1
DHCPv6 Relay Link Address	relay6[nest].linkaddr	2001:DB8::1
Interface name of packet	pkt.iface	eth0
Source address of packet	pkt.src	10.1.2.3
Destination address of packet	pkt.dst	10.1.2.3
Length of packet	pkt.len	513
Hardware address in DHCPv4 packet	pkt4.mac	0x010203040506
Hardware length in DHCPv4 packet	pkt4.hlen	6

Client classification example (1/2)

- Configuration for dynamic client classing based on the vendor option (Option 60) content

```
"Dhcp4": {
   "client-classes": [
        {   "name": "windows",
            "test": "substring(option[60].hex,0,3) == 'win'",
            "option-data": [{
                    "name": "domain-name", "data": "win.example.com" }]
        },
        {   "name": "other",
            "test": "not(substring(option[60].hex,0,3) == 'win')",
            "option-data": [{
                    "name": "domain-name", "data": "other.example.com" }]
        }
    ],
[...]
```

Client classification example (2/2)

- The client class is used to select a subnet inside a shared network
  - Windows clients get IP addresses from the 1st subnet
  - Client with other operating systems get IP addresses from the 2nd subnet

```
"shared-networks": [
    {
        "name": "kea-lab01",
        "relay": { "ip-address": "192.0.2.1" },
        "subnet4": [
            {
                "subnet": "192.0.2.0/24",
                "client-class": "windows", # <-- all Windows Clients will
                                           # get IP addresses from this subnet
                "option-data": [{
                        "name": "routers", "data": "192.0.2.1" }],
                "pools": [{
                        "pool": "192.0.2.60 - 192.0.2.250" }]
            },
            {
                "subnet": "10.0.0.0/24",
                "client-class": "other", # <-- non Windows Clients will
```

```
                                                # get IP addresses from this subnet
                        "option-data": [
[...]
```

Client Classes with regular expressions

- Since Kea-DHCP Version 3.0 client classes can be selected based on regular expressions
- The following client class looks into the OUI-part of the hardware address and tests if they are from Apple Computers range of OUI-Adresses:

```
"client-classes": [
      {
        "name": "Apple-Computer",
        "test": "match('5c-1b-f4|a8-5b-b7|58-55-95|00-19-b8',hexstring(substring(pkt4.mac, 0,
      },
      [...]
```

- Client-Classing tests run for each incoming DHCP request
    - Complex regular expressions can be CPU intensive and can slow down the DHCP server

Classification via hooks

- Client classification via complex expressions can hurt the DHCP server performance
- Alternative: writing a custom hook for client classification

Debugging client classing (1/3)

- To debug client classing based on expressions, enable debug logging inside the Kea DHCP server
- Quick option: start Kea DHCP4 in debug mode from the command line. This will automatically enable the highest debugging level
    - on a busy server, this will create too much debug information (see next slide for an alternative)

```
[kea-server]# systemctl stop kea-dhcp4
[kea-server]# kea-dhcp4 -d -c /etc/kea/kea-dhcp4.conf
```

Debugging client classing (2/3)

- Alternative: enable the special **`kea-dhcp4.eval`** or **`kea-dhcp6.eval`** debug logger in the Kea configuration file

```
"Logging": {
    "loggers": [ {
        "name": "kea-dhcp4.eval",
        "output_options": [ {
            "output": "/var/log/kea-dhcp4-eval.log"
        } ],
        "severity": "DEBUG",
        "debuglevel": 55
    } ]
}
```

Debugging client classing (3/3)

- Watch for the test evaluation results in the Kea Eval DHCP4 log file

```
[kea-server]# tail -f /var/log/kea-dhcp4-eval.log
```

Resources

- Understanding Client Classification
- Do I need to use shared-networks or not with Kea DHCP?
- Host Reservation in DHCPv4
- Standard DHCP Options Defined in ISC DHCP and Kea