DHCPv6

a different beast than DHCPv4

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CREATED: 2025-01-30 THU 09:39

Agenda

- DHCPv6 vs DHCPv4
- DHCPv6 High Availability
- DHCPv6 server

DHCPv6

DHCPv6

- From a birds-eye view, DHCPv6 works the same way as DHCPv4
  - In the details, it is very different
  - DHCPv6 is not an upgrade to DHCPv4, it is a protocol of its own

DHCPv6 IP based vs. DHCPv4 Layer2/Ethernet based (use of link-local addresses)

- DHCPv6 is solely a Layer 3 protocol
  - A DHCPv6 client already has a working link-local IPv6 address (`fe80::`) when sending the first DHCPv6 request
  - No "low-level kernel trickery" required

DHCPv6 protocol (port numbers, communication)

- DHCPv6 Servers and Relay-Agents listen on Port 547 (UDPv6)
- DHCPv6 clients listen on Port 546 (UDPv6)

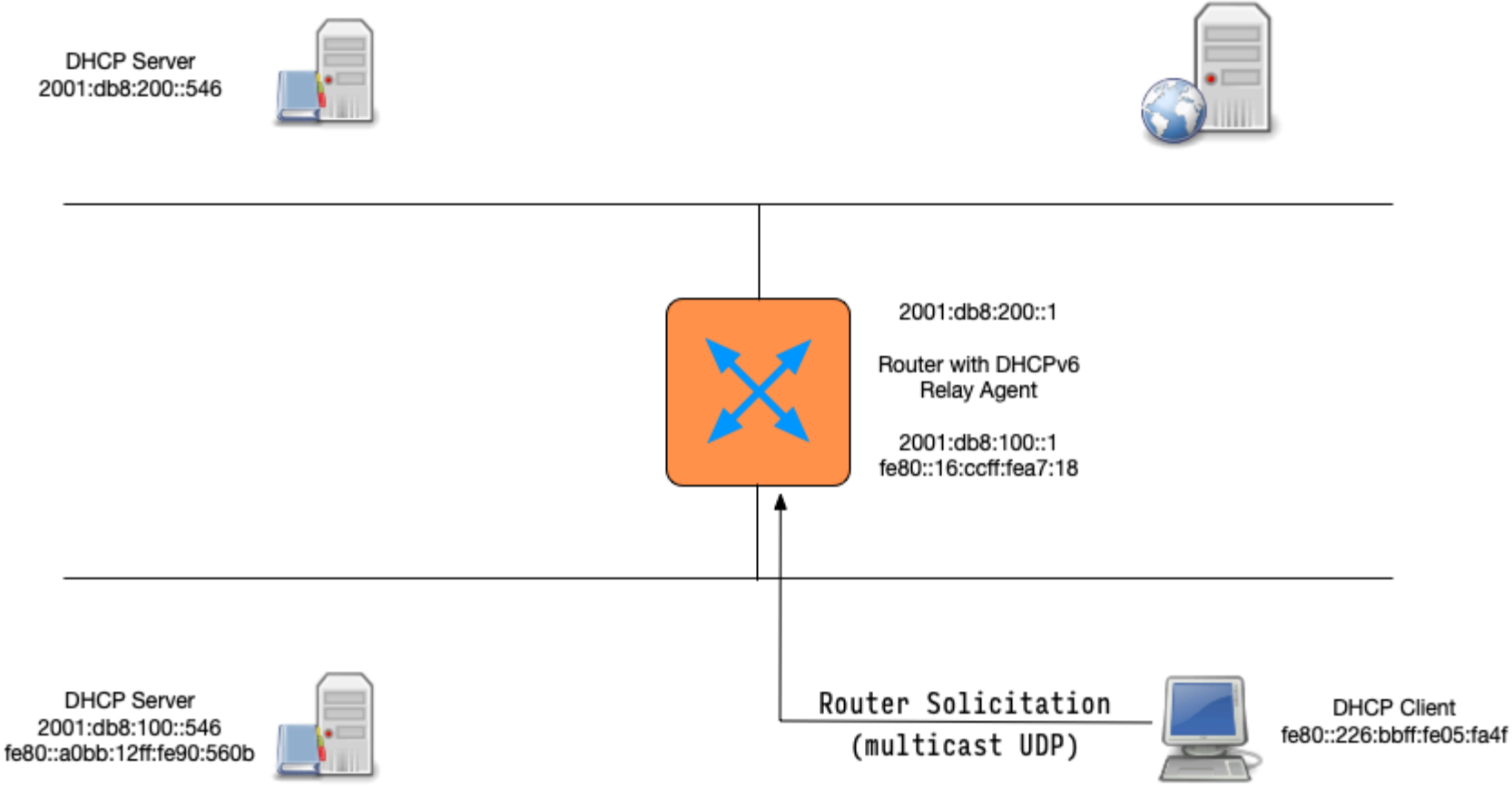
DHCPv6 multicast usage and addresses

- DHCPv6 clients communicate using link-local multicast addresses
  - All-DHCP-Relay-Agents-and-Servers (`ff02::1:2`)
  - All-DHCP-Servers (`ff05::1:3`)

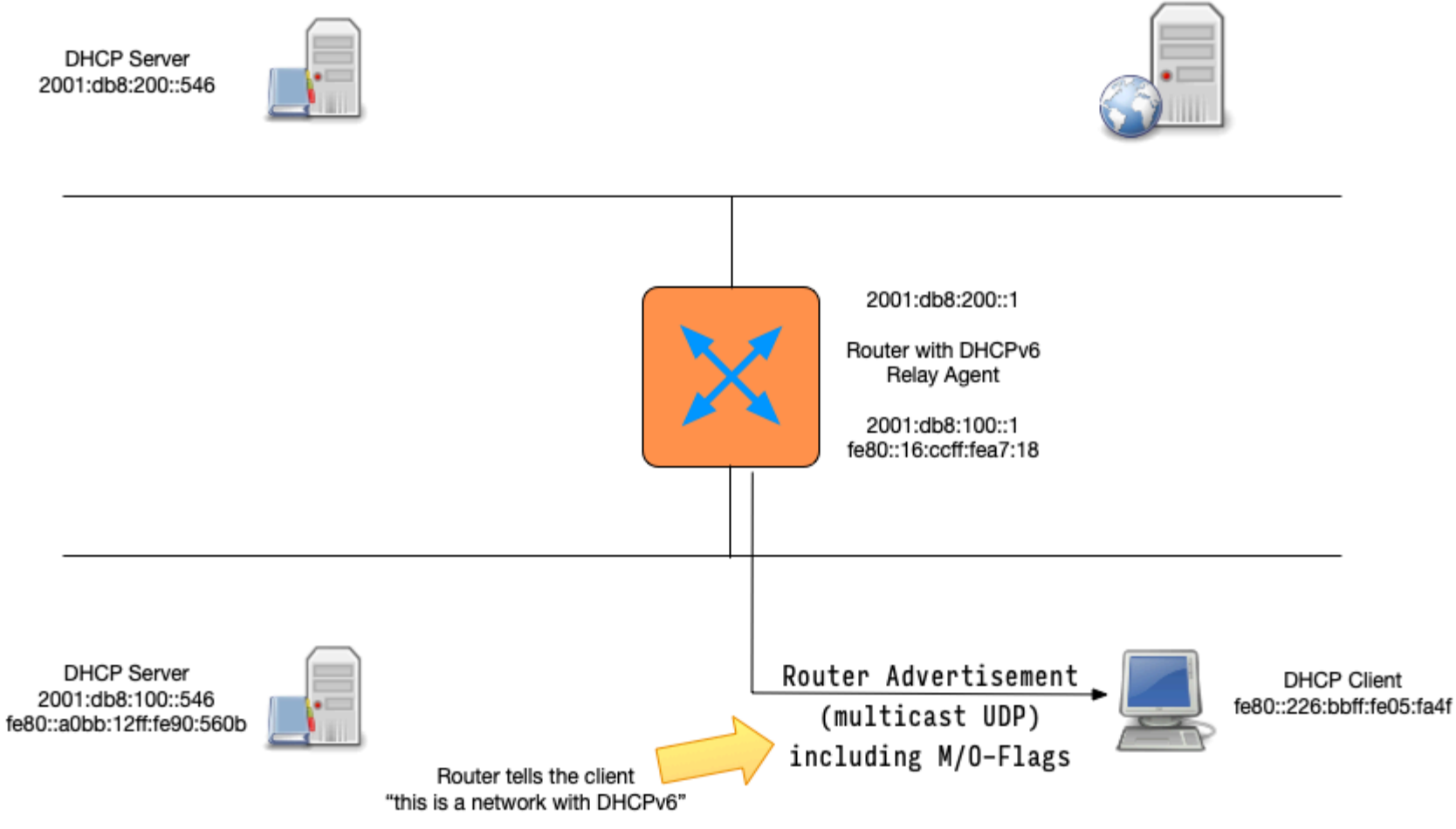
the role of router in DHCPv6

- DHCPv6 has been designed to provide it's service in cooperation with the local router(s)
  - DHCPv6 must be enabled in the router configuration (`M–Flag` or `O–Flag`)
  - The Default-Gateway Address will be retrieved from a router and **not** from the DHCPv6 Server

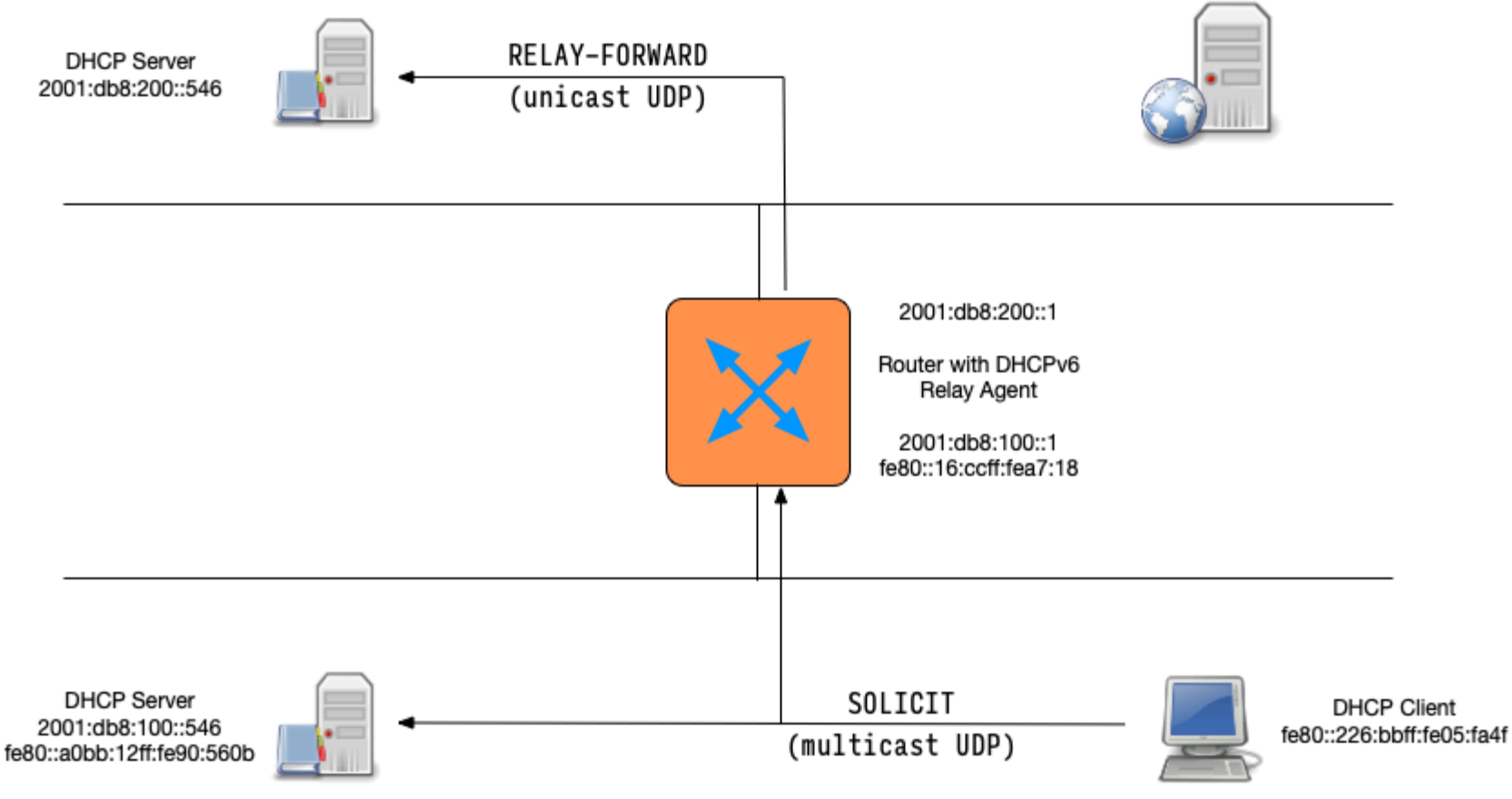
Router and DHCPv6 (1/2)



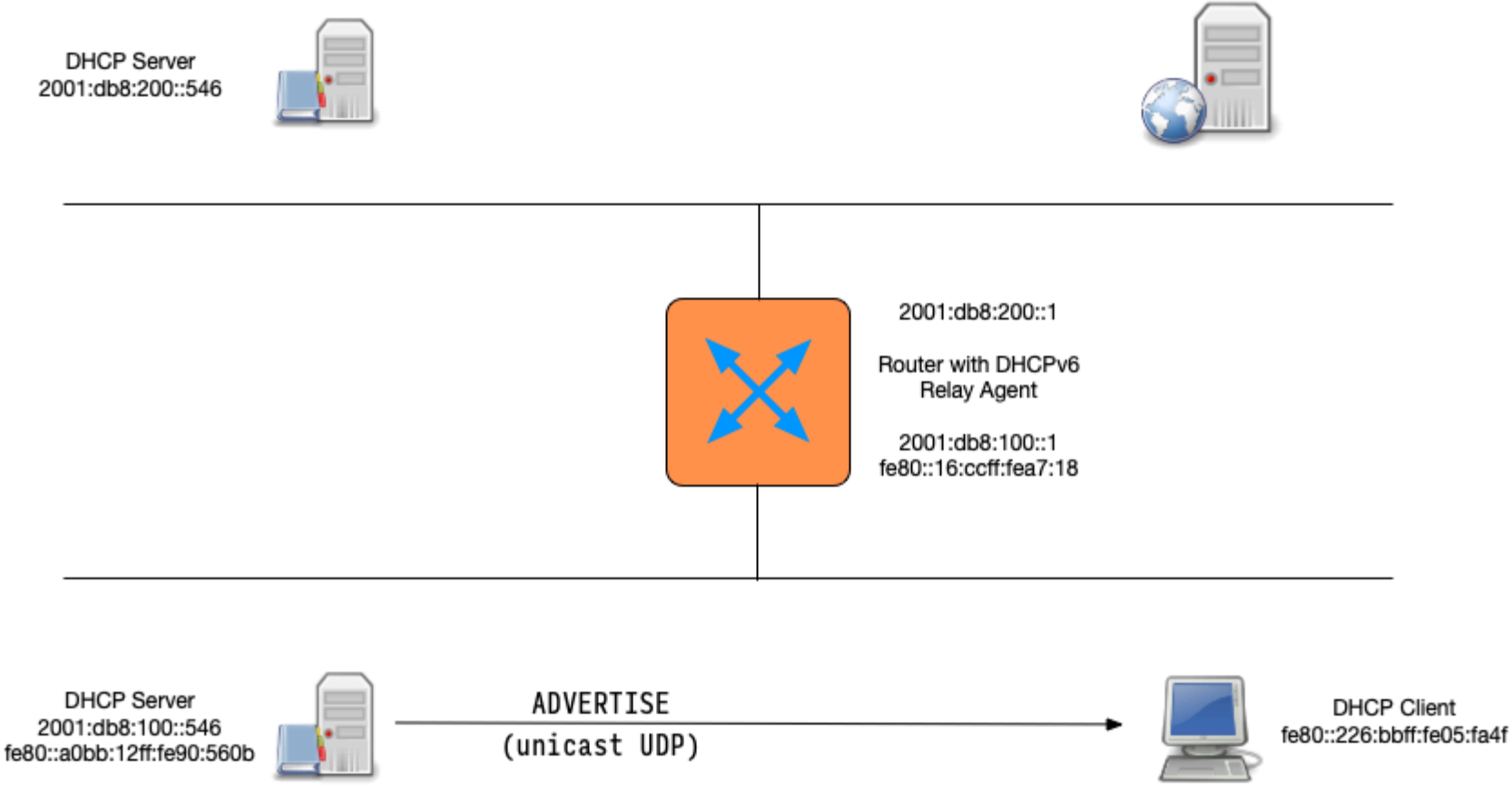
Router and DHCPv6 (2/2)



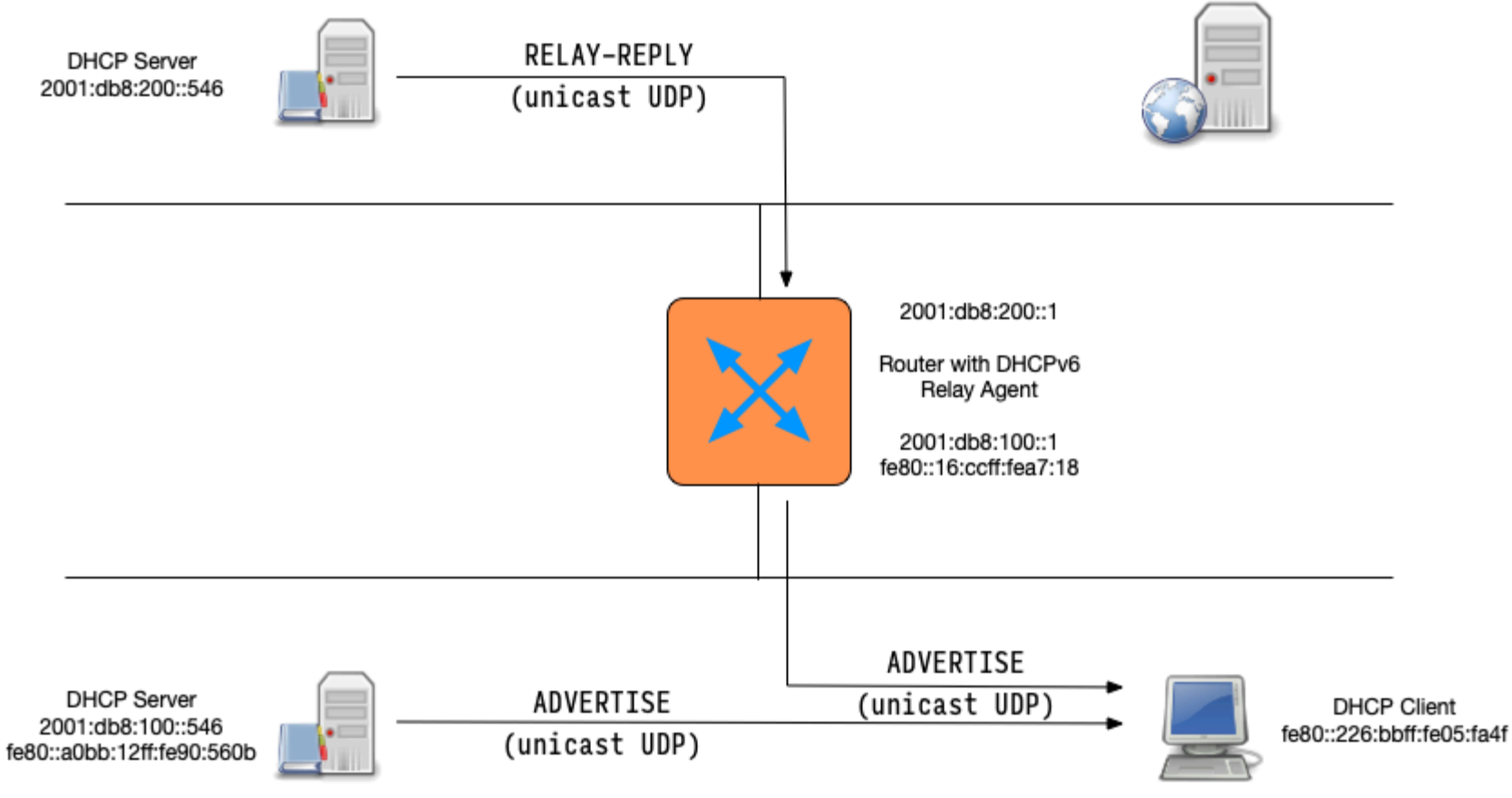
DHCPv6 solicit message



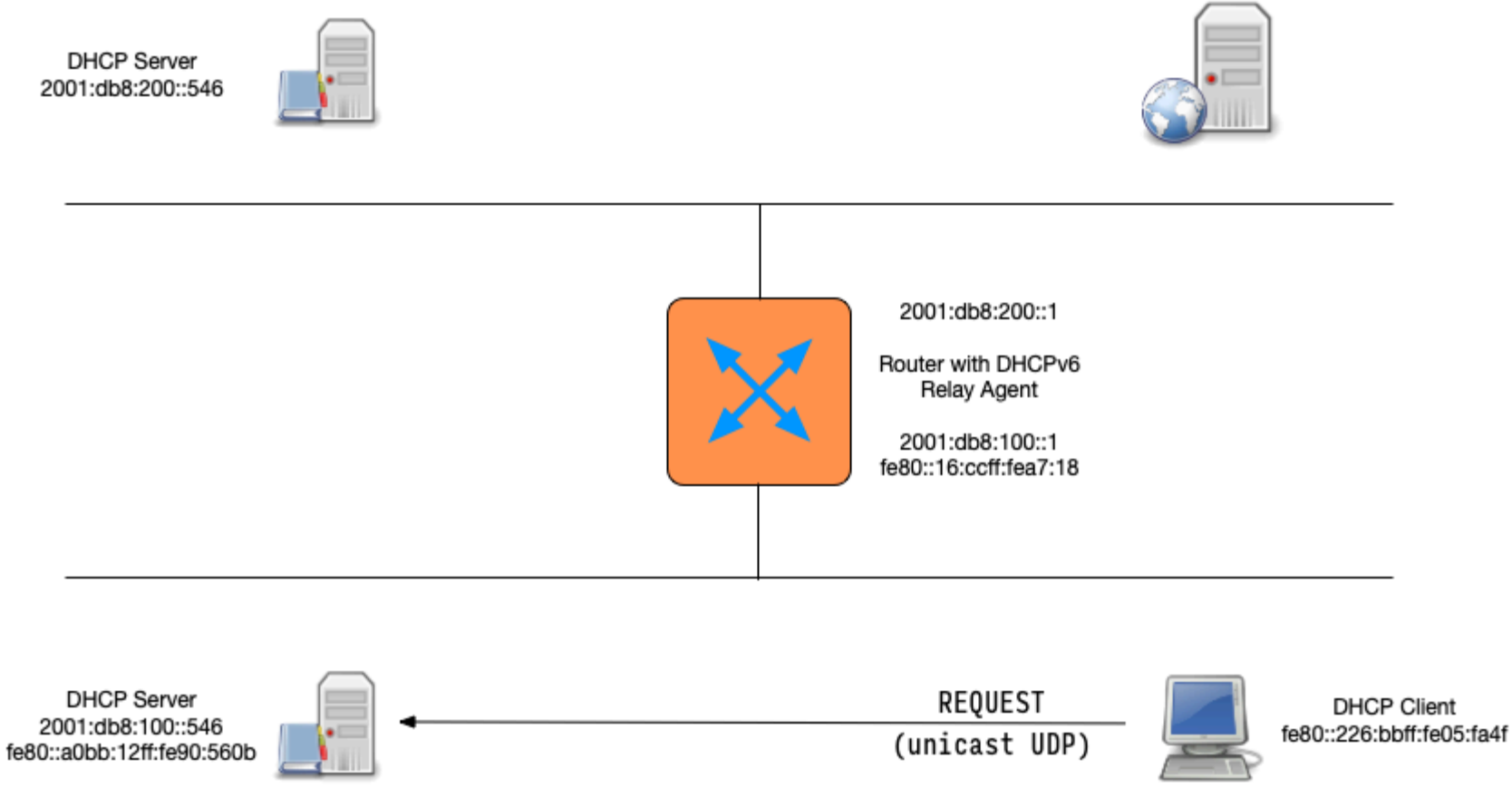
DHCPv6 advertise message



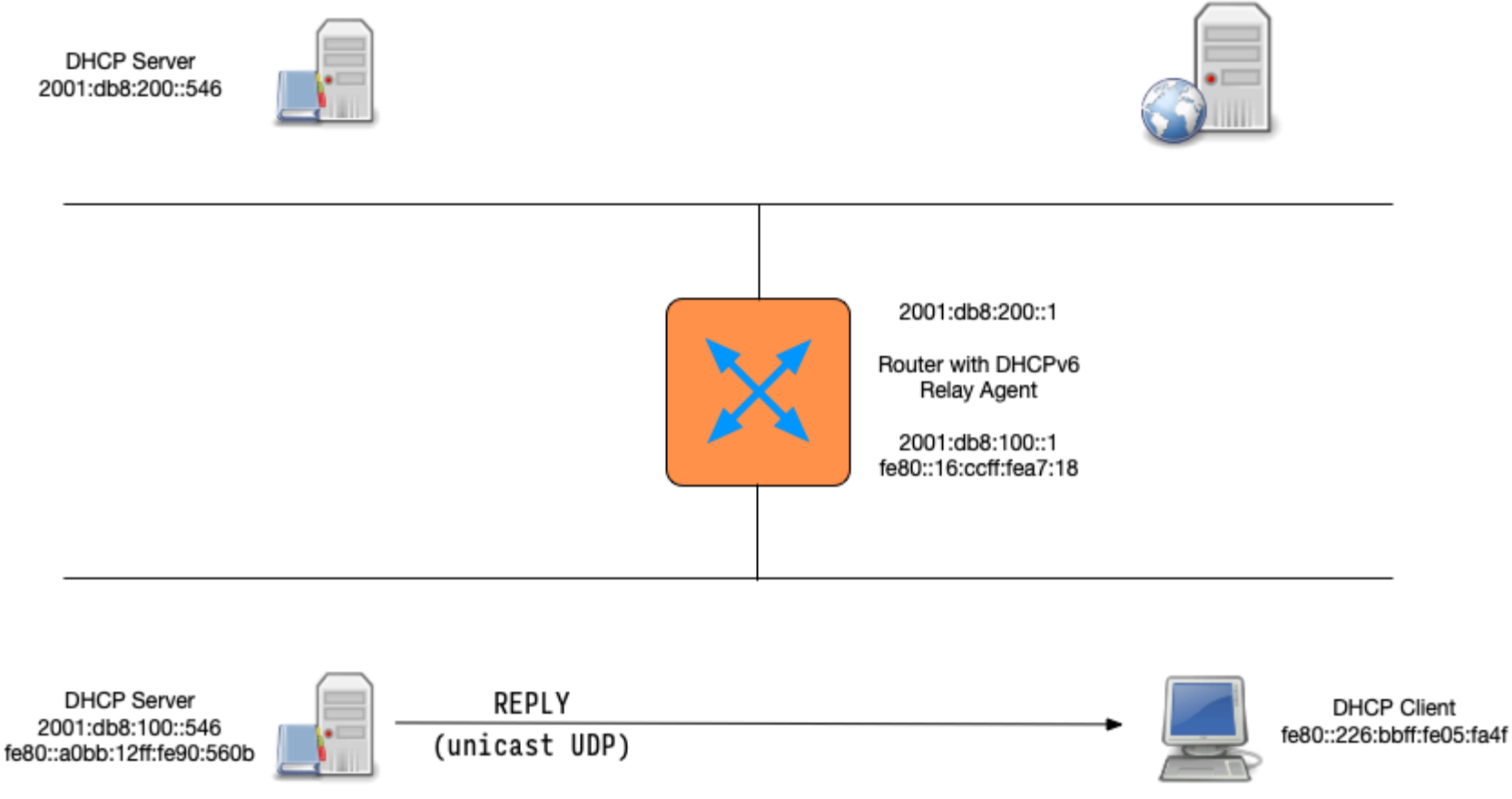
DHCPv6 advertise (via relay)



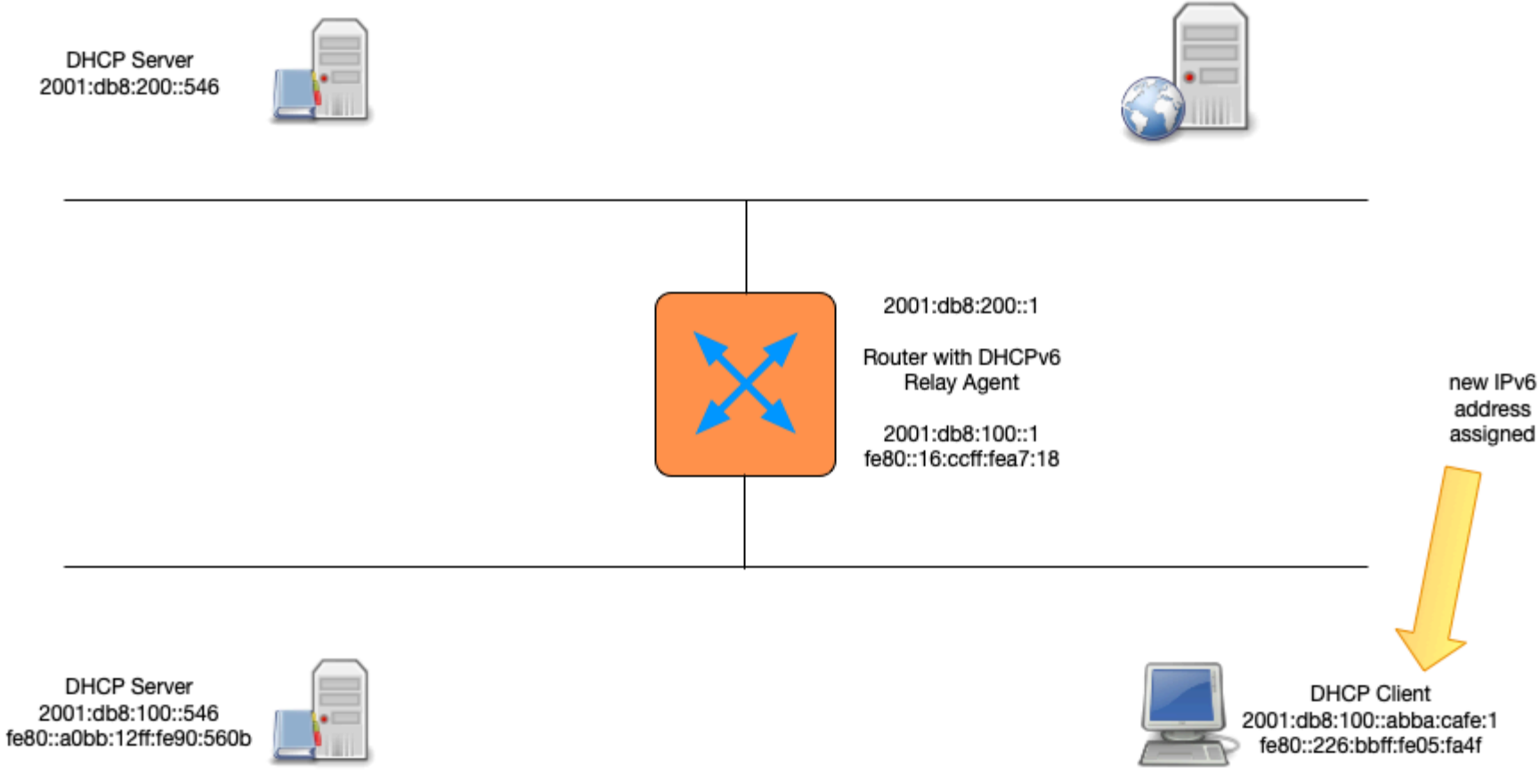
DHCPv6 request



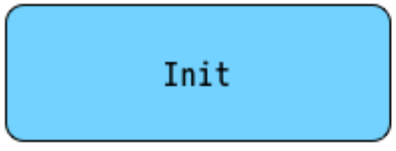
DHCPv6 reply



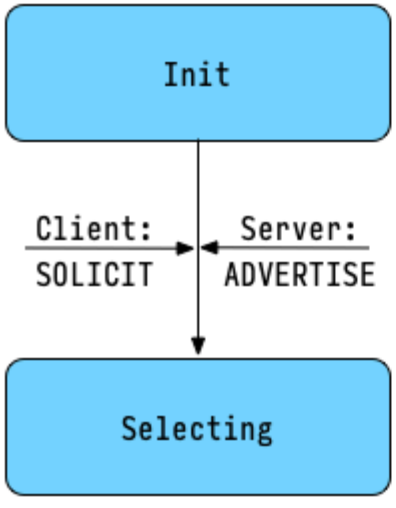
DHCPv6 client assigns new IPv6 address



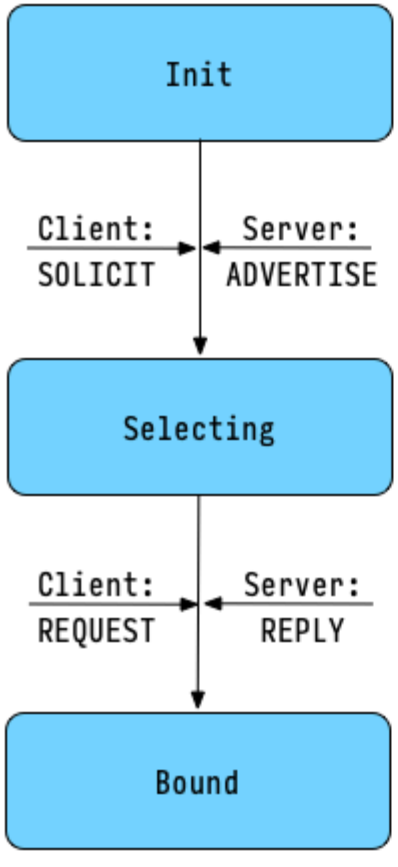
DHCPv6 client states (1/8)



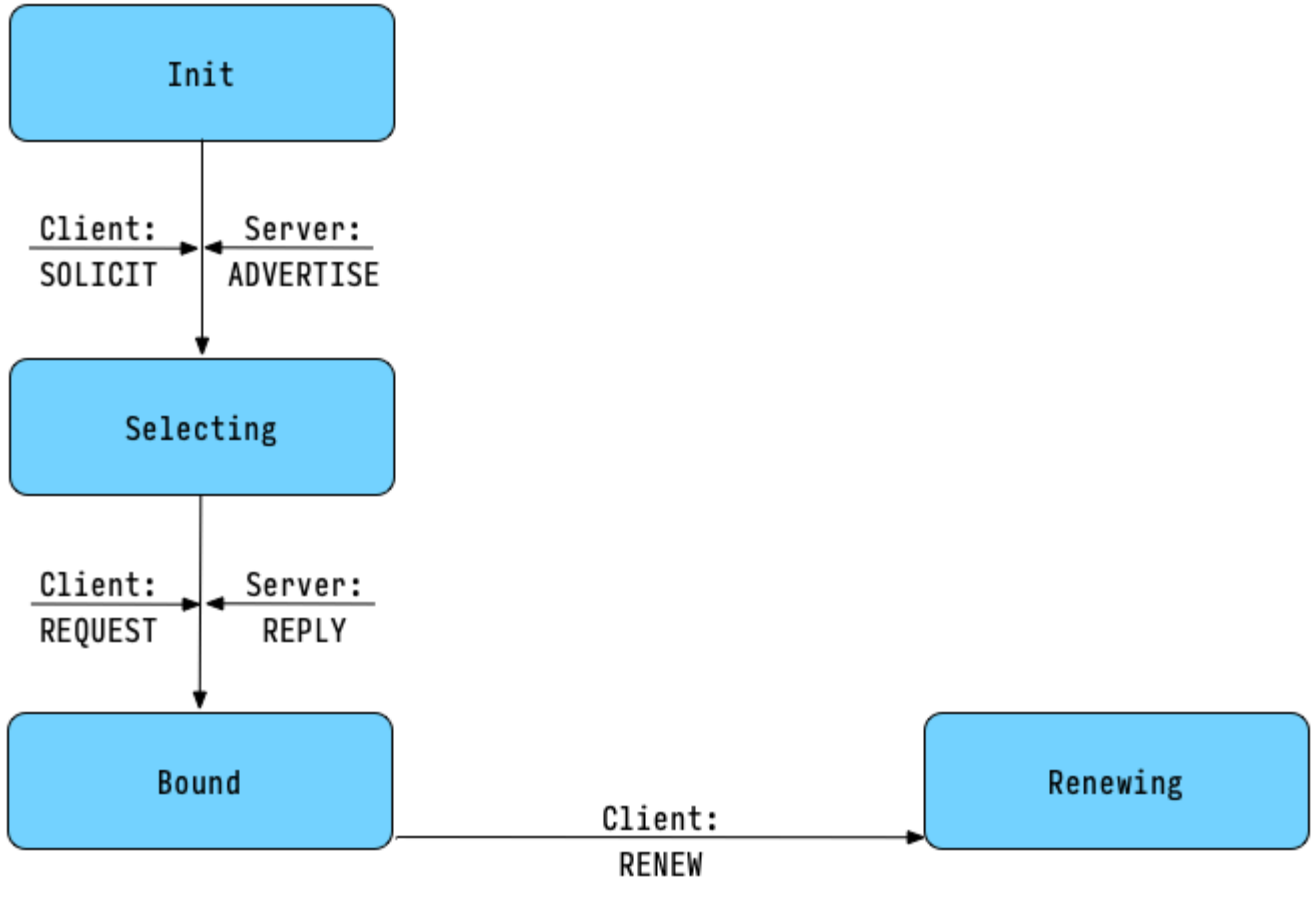
DHCPv6 client states (2/8)



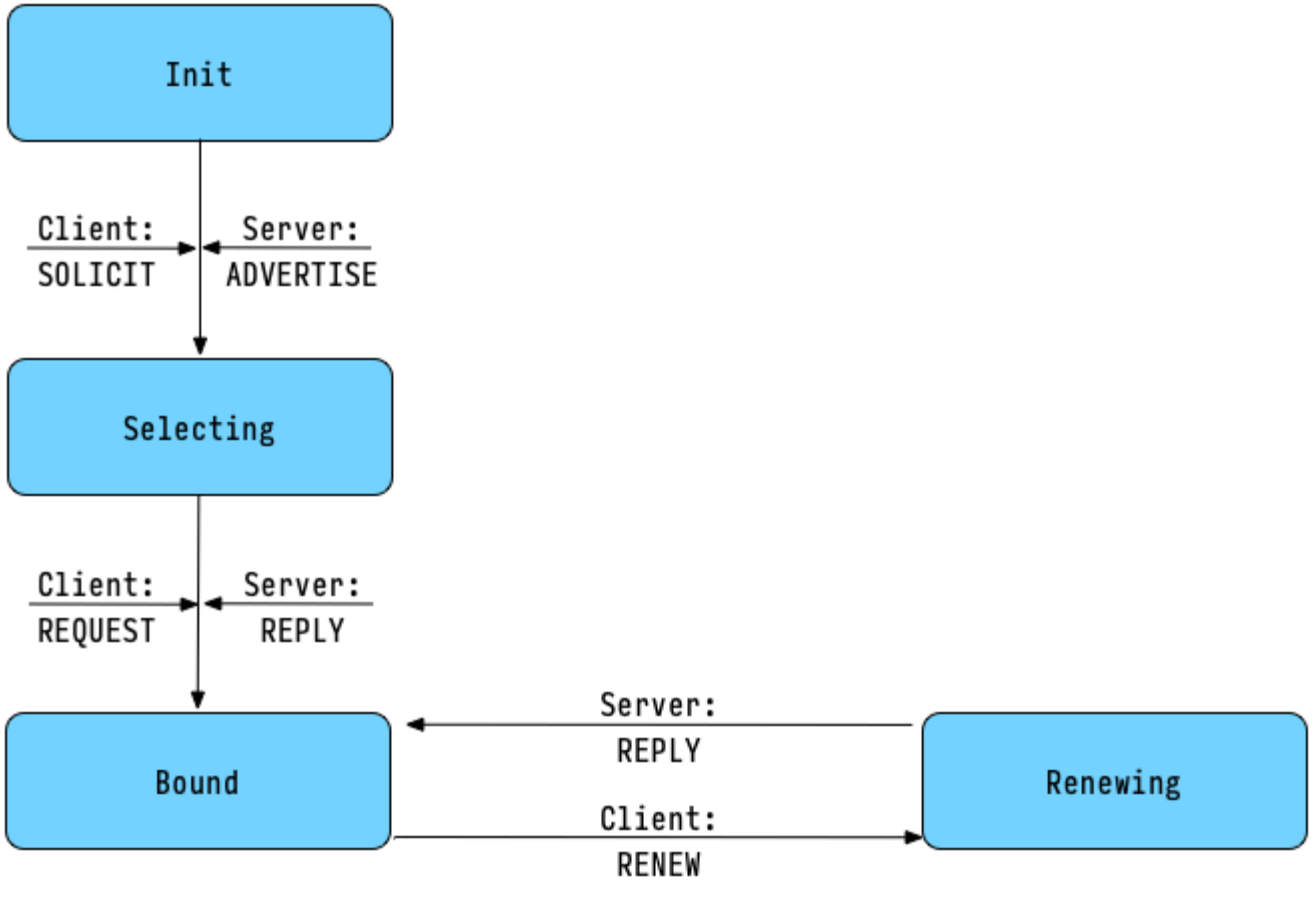
DHCPv6 client states (3/8)



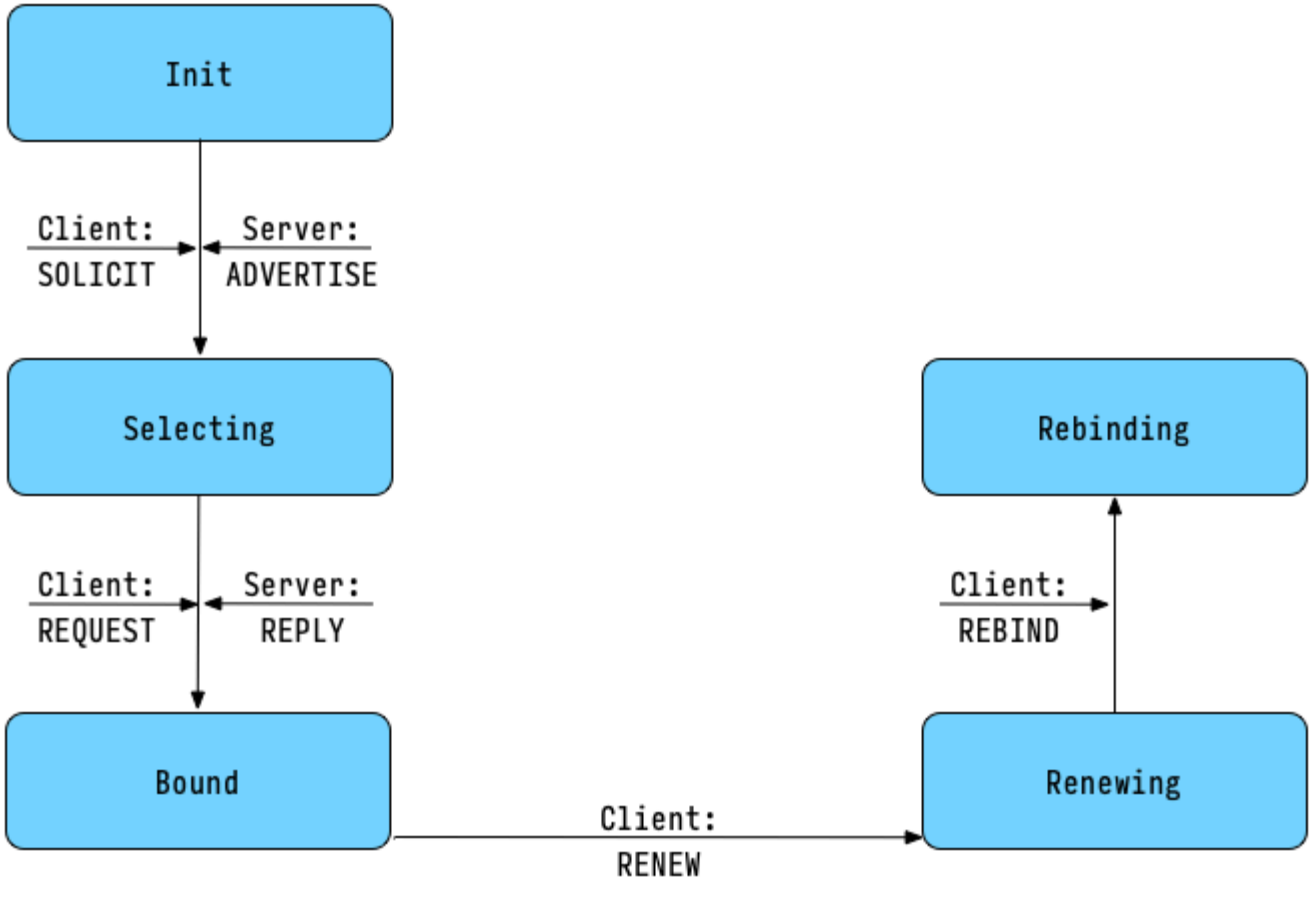
DHCPv6 client states (4/8)



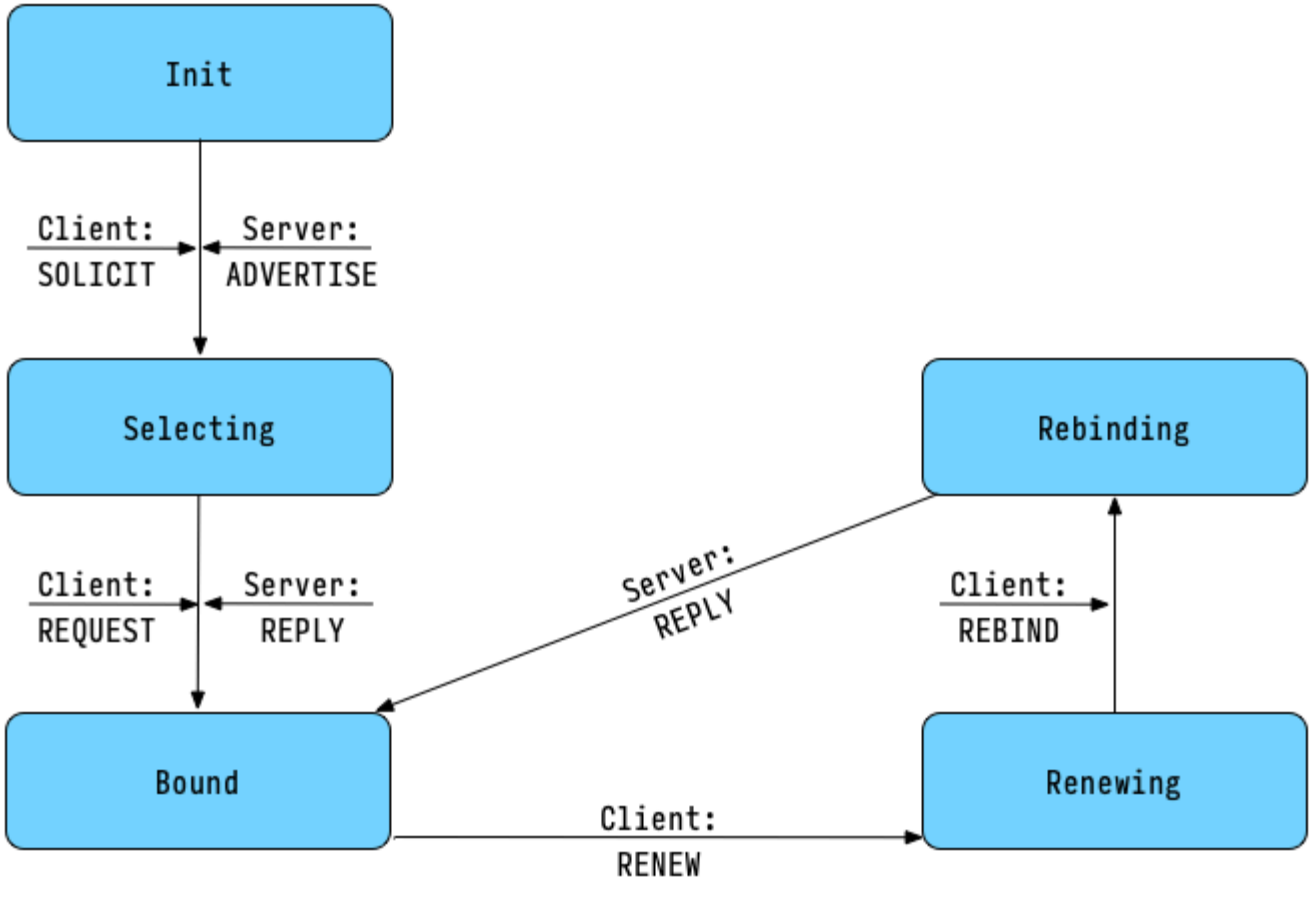
DHCPv6 client states (5/8)



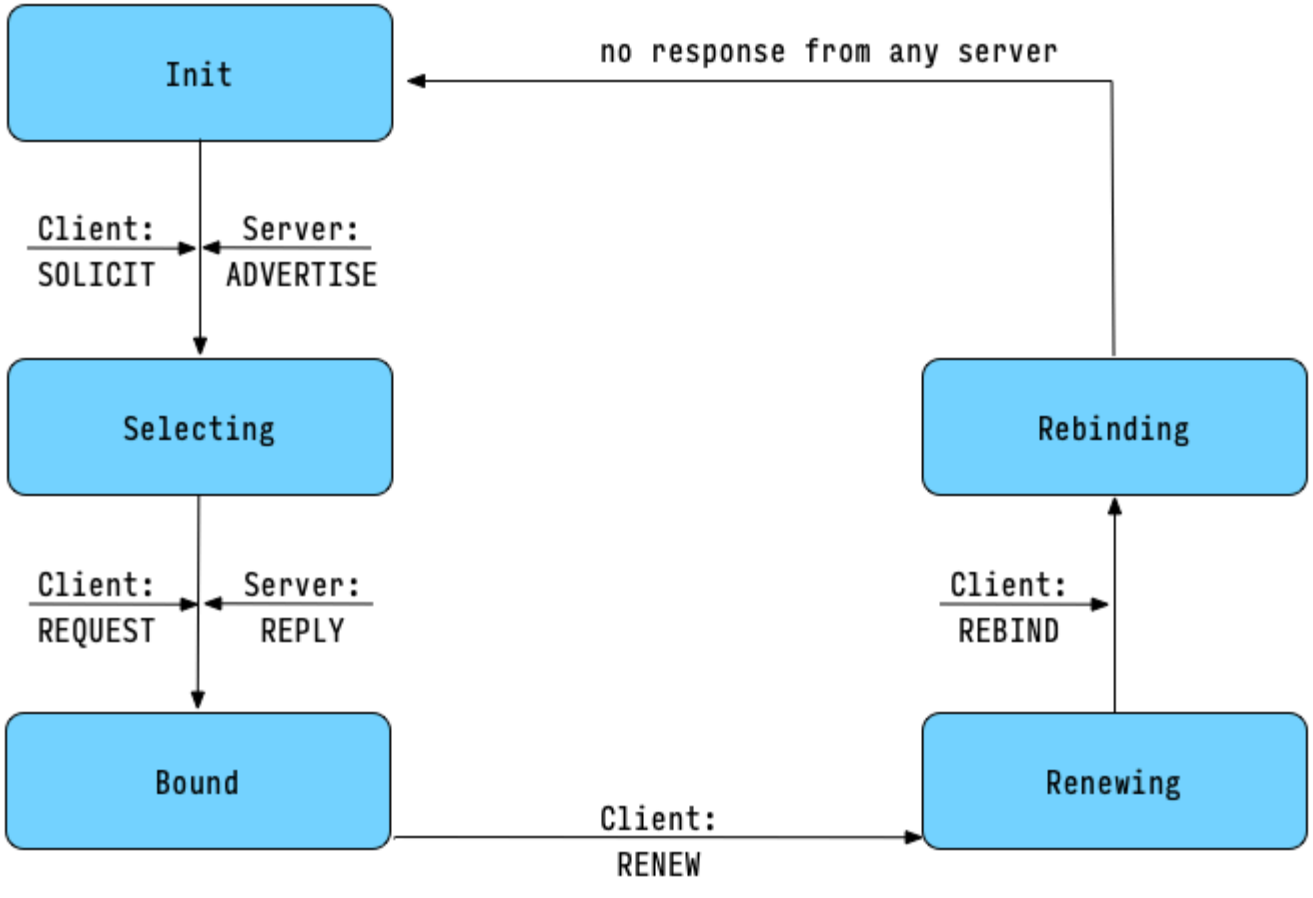
DHCPv6 client states (6/8)



DHCPv6 client states (7/8)



DHCPv6 client states (8/8)



DHCPv6 address allocation vs. DHCPv4 address allocation

- DHCPv6 server must issue IP Addresses randomly from the available address pool
    - Some DHCPv4 server products issue IP Addresses continuously
- The DHCPv6 scheme makes it harder to guess an IP Address or scan a network segment

DHCPv6 in combination with SLAAC

- IPv6 support *Stateless Automatic Address Configuration* aka **SLAAC**
- SLAAC can be used as an alternative to DHCPv6
- SLAAC and DHCPv6 can be combined

Register Static or SLAAC IPv6 addresses in DHCPv6

- ↪RFC 9686 - Registering Self-Generated IPv6 Addresses Using DHCPv6 (December 2024)
  - Supports the use of SLAAC while still maintaining the DHCPv6 servers lease database or logs as an tool to track IP-address assignments
  - Client and DHCPv6-Server support currently not available in common operating systems

DHCPv6 - stateless vs. stateful

- There are two different ways to get an IPv6 address for a IPv6 enabled device
  - Stateless configuration
  - Stateful configuration

DHCPv6 - stateless vs. stateful

- Stateless configuration
  - The IPv6 address will be determined without a DHCP Server (IPv6 auto-configuration = SLAAC)
- Stateful configuration
  - The IPv6 address will be received from a DHCPv6 Server
- In both cases additional configuration parameters (DNS Server etc) can be retrieved by DHCPv6

Identity Association (IA)

- An Identity Association (IA) is a construct through which a server and a client can identify, group, and manage a set of related IPv6 addresses (or delegated prefixes)
- Each `IA` consists of an `IAID` (Identity Association ID) and associated configuration information
- If a client has more than one network interface, every interface will be associated with one distinct `IAID`

Identity Association (IA)

- DHCPv6 clients can receive temporary and non- temporary addresses
  - Temporary addresses are used for communication with outside, untrusted networks (like the Internet)
  - Temporary addresses make it difficult to track a client, they are created randomly and change often
  - Non-temporary addresses are stable and can be used to track a client machine (non-temporary addresses are used in trusted, internal networks)

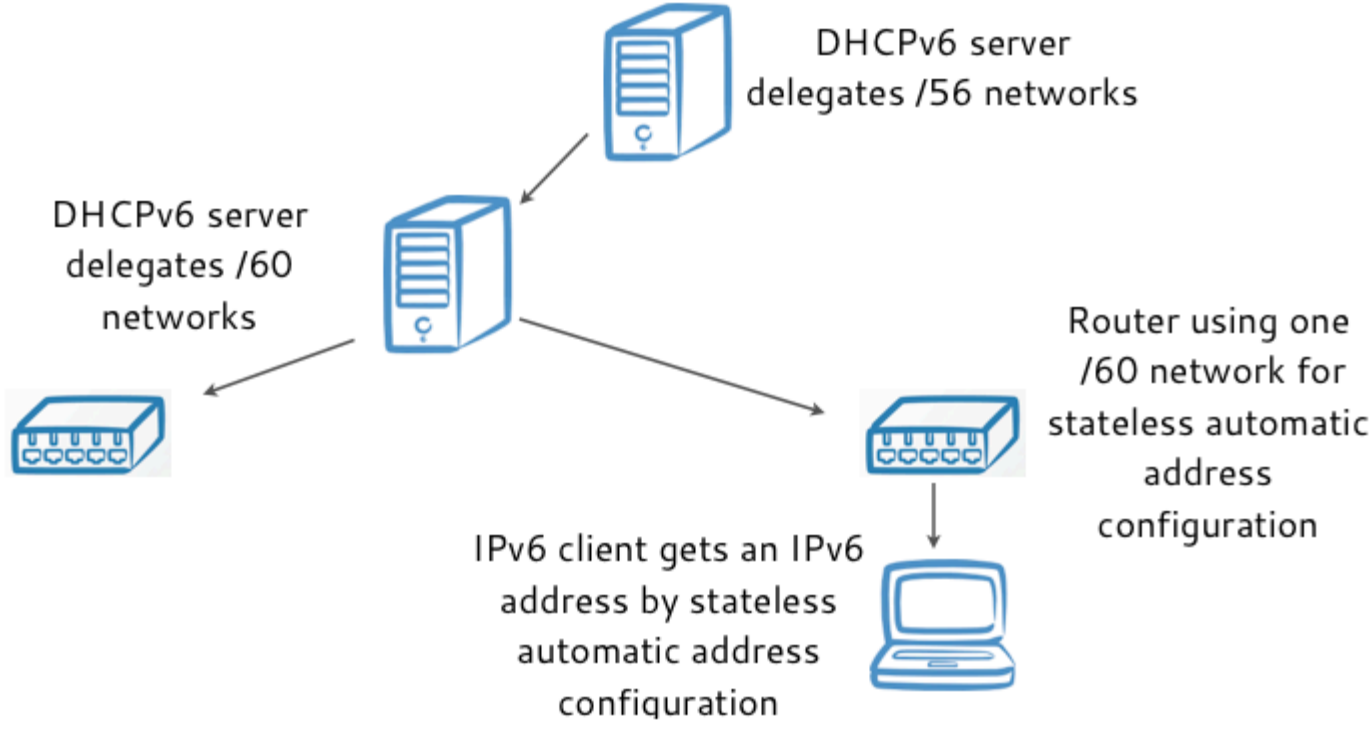
- Temporary and non-temporary (stable) IPv6 addresses are managed with the help of IAIDs

DHCPv6 Prefix Delegation

Prefix Delegation

- A DHCPv6 server can distribute whole networks (prefixes) to DHCPv6 clients (Router, DSL-CPEs, downstream DHCPv6 server)
    - A DHCPv6 server in the headquarter distributes networks to a network in a subsidiary
    - A DHCPv6 server at an ISCP distributes IPv6-Networks to customers CPE (DSL-Router), which in turn will give out IPv6 prefixes for stateless autoconfiguration

Prefix Delegation



Prefix Delegation

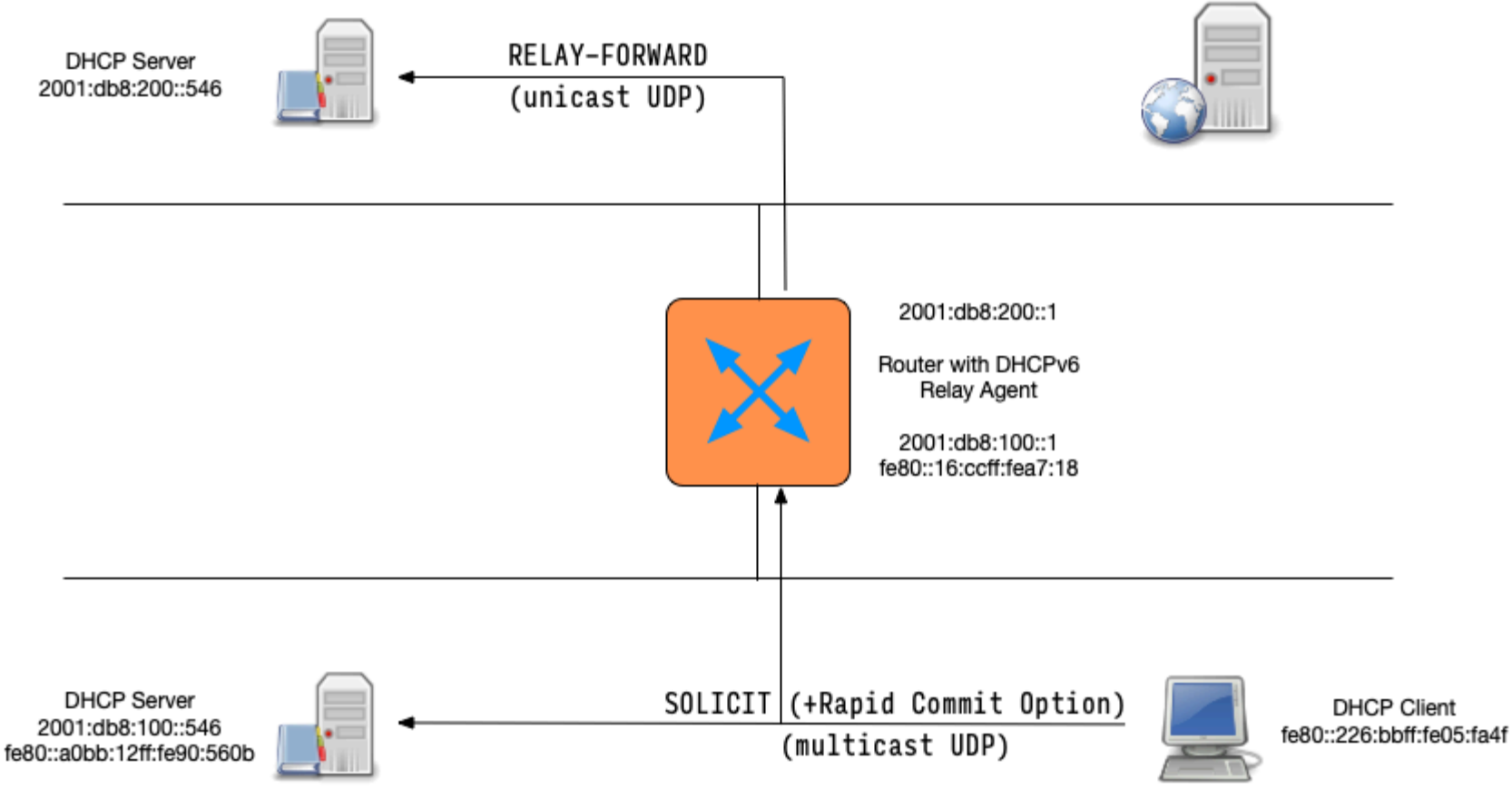
- ↪RFC 9663 - Using DHCPv6 Prefix Delegation (DHCPv6-PD) to Allocate Unique IPv6 Prefixes per Client in Large Broadcast Networks (October 2024)
  - Better scalability on large broadcast networks
  - Ability to extend the network (sub-devices or IP-Addresses per service on the device)
    - USB/Bluetooth-Tethered device behind smartphone on WiFi that does not itself have WiFi capabilities

DHCPv6 rapid commit

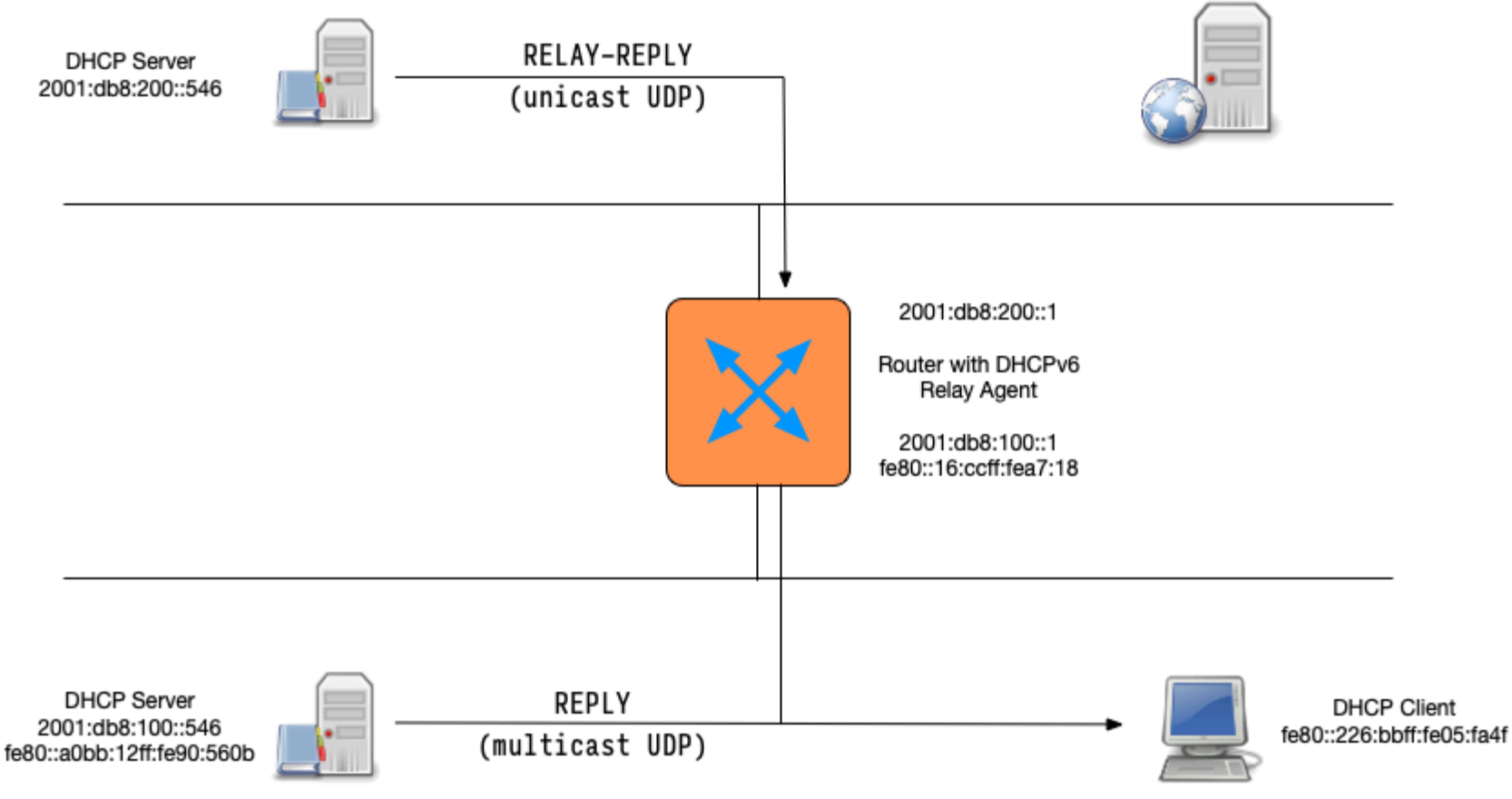
DHCPv6 rapid commit

- *Rapid commit* speeds up the process of joining a network (only one packet exchange)
- With *rapid commit* there is no information send to the DHCPv6 server telling the server whether the client is using the advertised IPv6 address
    - The DHCPv6 server must reserve the IPv6 address for the full lease time
        - This (temporary) squandering of IPv6 addresses is usually not a problem because of the large size of IPv6 subnets (/64 prefixes)

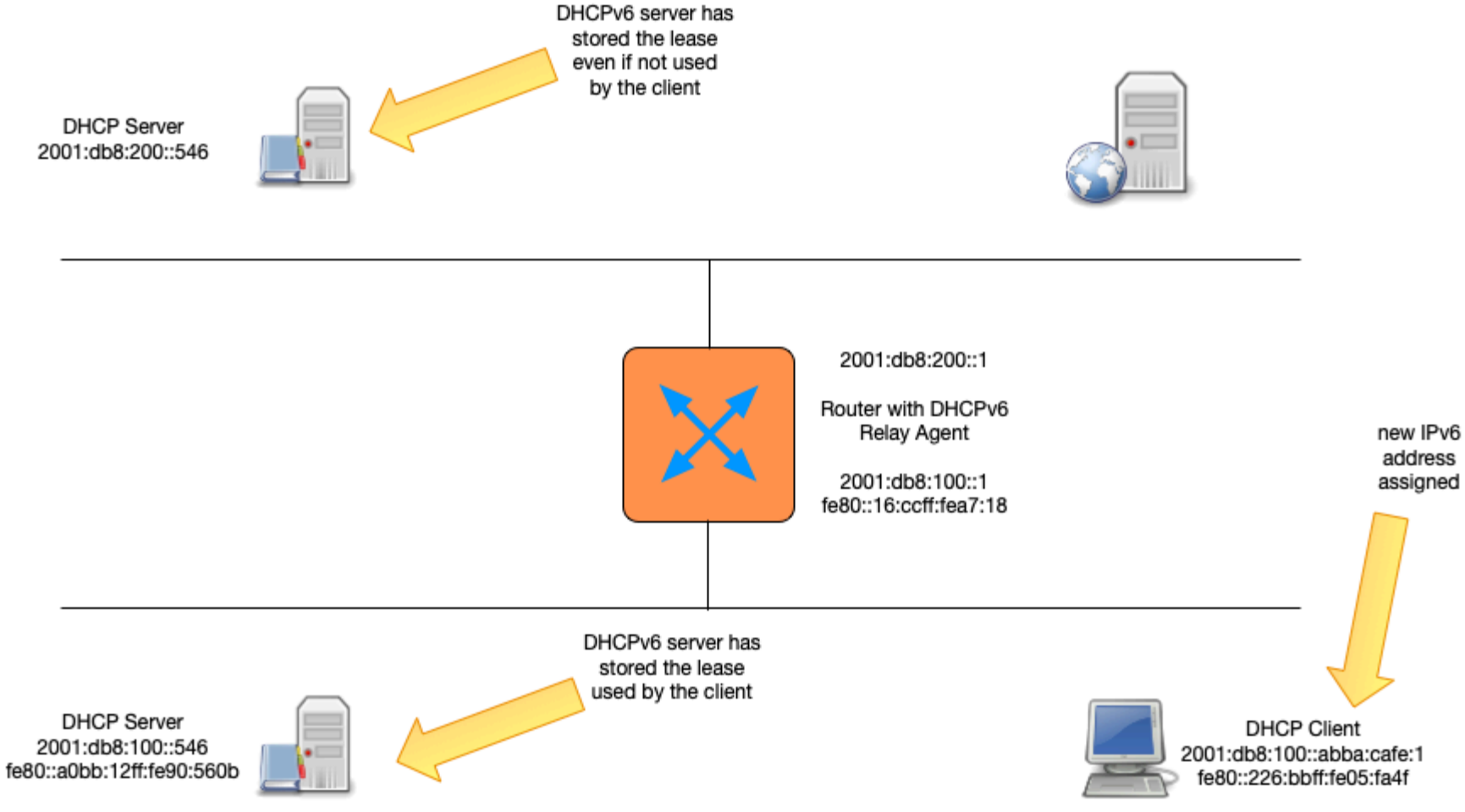
DHCPv6 rapid commit



DHCPv6 rapid commit



DHCPv6 rapid commit



High Availability

DHCP High-Availability

- DHCP is a critical resource in most networks
  - If the DHCP service is down, machines and computers cannot join the network
- DHCP administrators like to make the DHCP service redundant and high-available

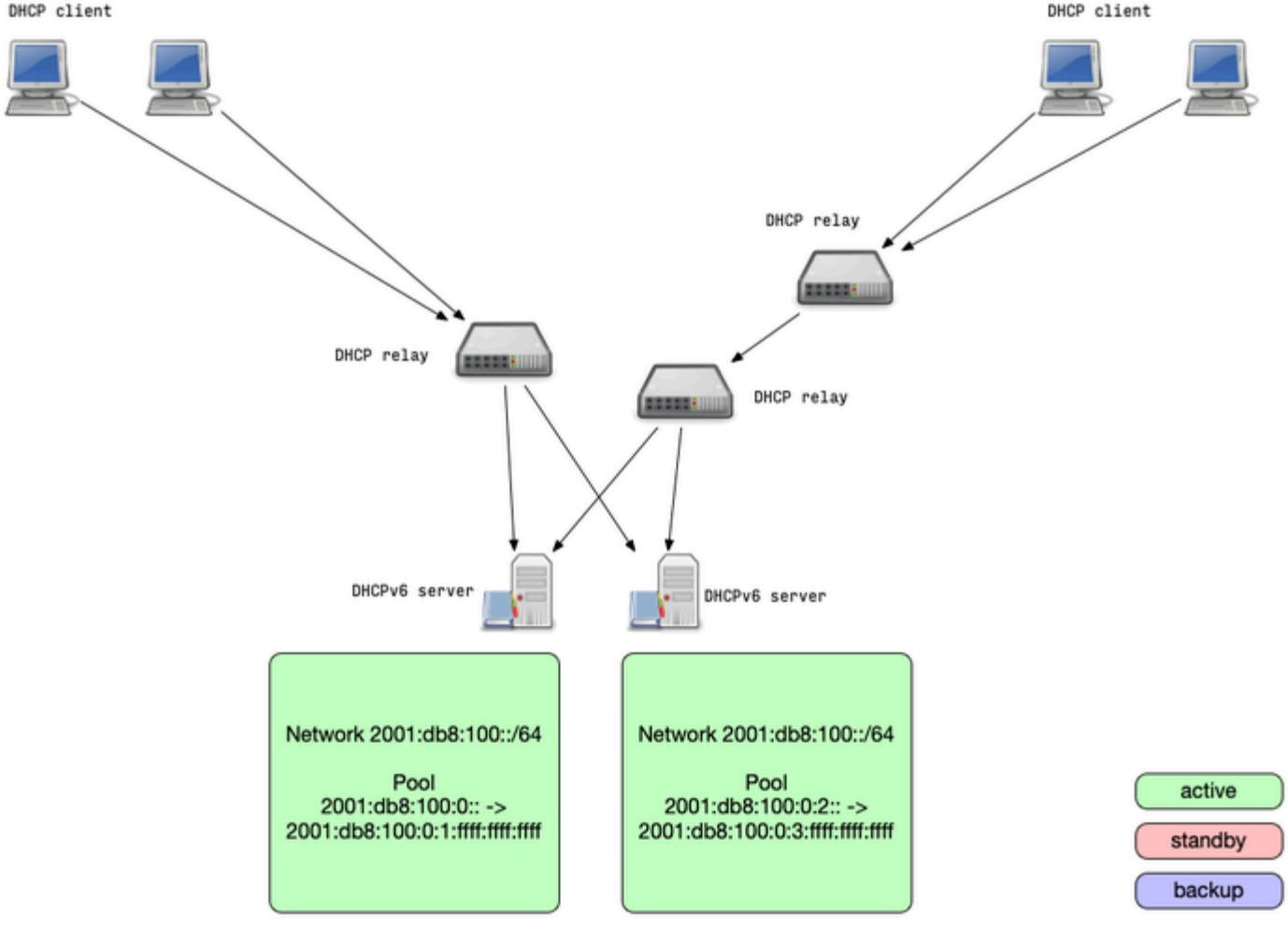
DHCPv6 Split Pool / Shared Pool

- The DHCPv6 split pool or shared pool HA solution are independent from the DHCPv6 server implementation
- These HA solutions do not require any synchronization between the DHCP server
- These solutions make use of the vast address space available in one IPv6 /64 subnet
- Does not work for DHCPv4, because the address space in IPv4 is too small

DHCPv6 Split Pool

- Split-Pool: because one IPv6 /64 is so large, it usually can be split in two parts that are served by two independent DHCPv6 servers
  - The pools are not overlapping, it is impossible that the two DHCPv6 servers will return the same lease address to different clients
  - If one DHCPv6 server stops responding, the clients will receive a new lease from the remaining DHCPv6 server (after lease expiry)

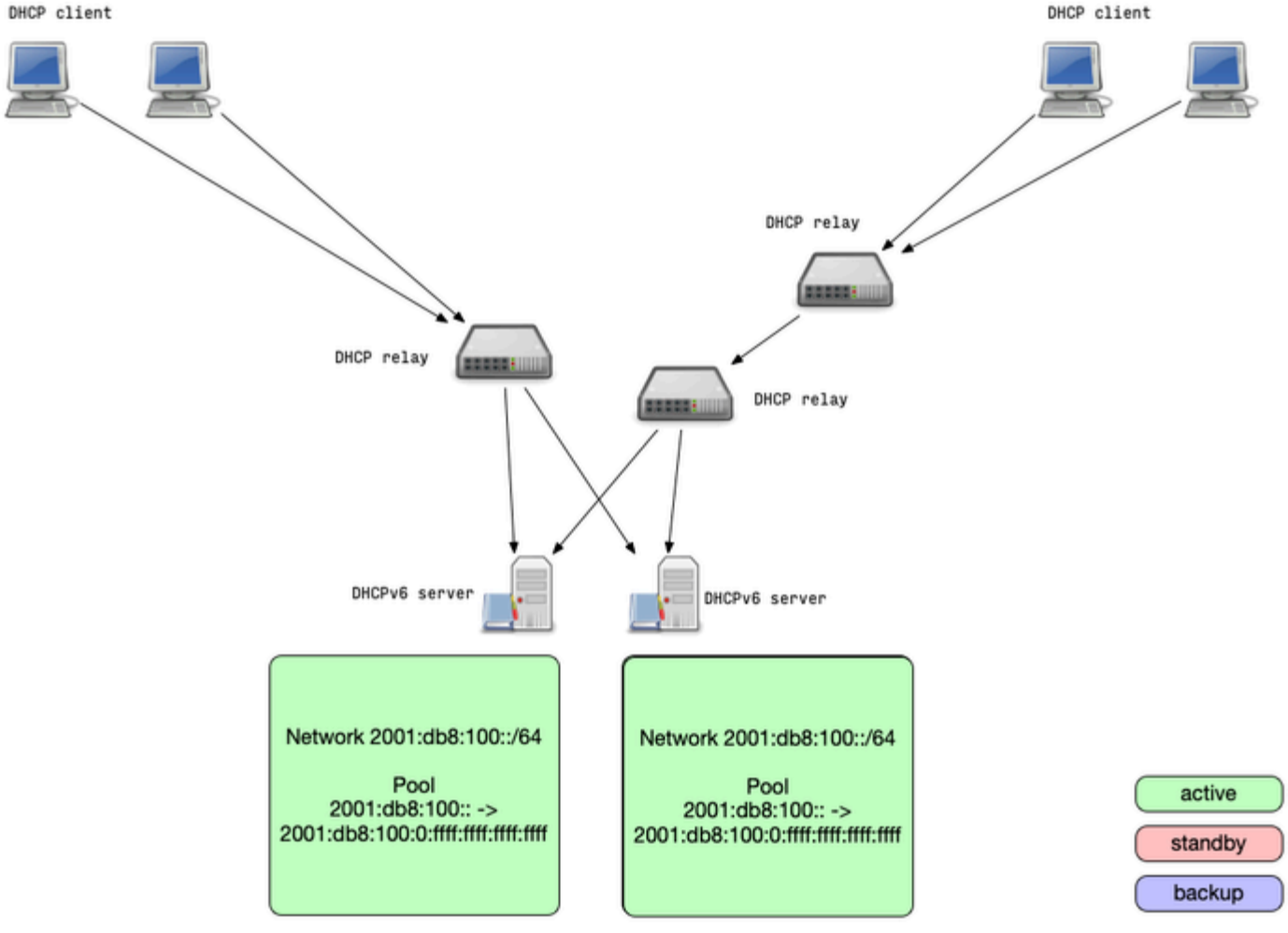
DHCPv6 Split Pool



DHCPv6 Shared Pool

- Shared-Pool: two DHCPv6 server are authoritative for the same addresses from a pool
  - For the shared pool setup, the DHCPv6 servers should allocate new IPv6 addresses non-continuously (random, hash-based etc)
  - Because of the size of one IPv6 /64 subnet, the chance that both servers give out the same address to different clients is statistically very low
  - And if they did, IPv6 duplicate address detection (DAD) will cover this rare edge case
  - If one DHCPv6 server stops responding, the clients will receive a new lease from the remaining DHCPv6 server (after lease expiry)

DHCPv6 Shared Pool

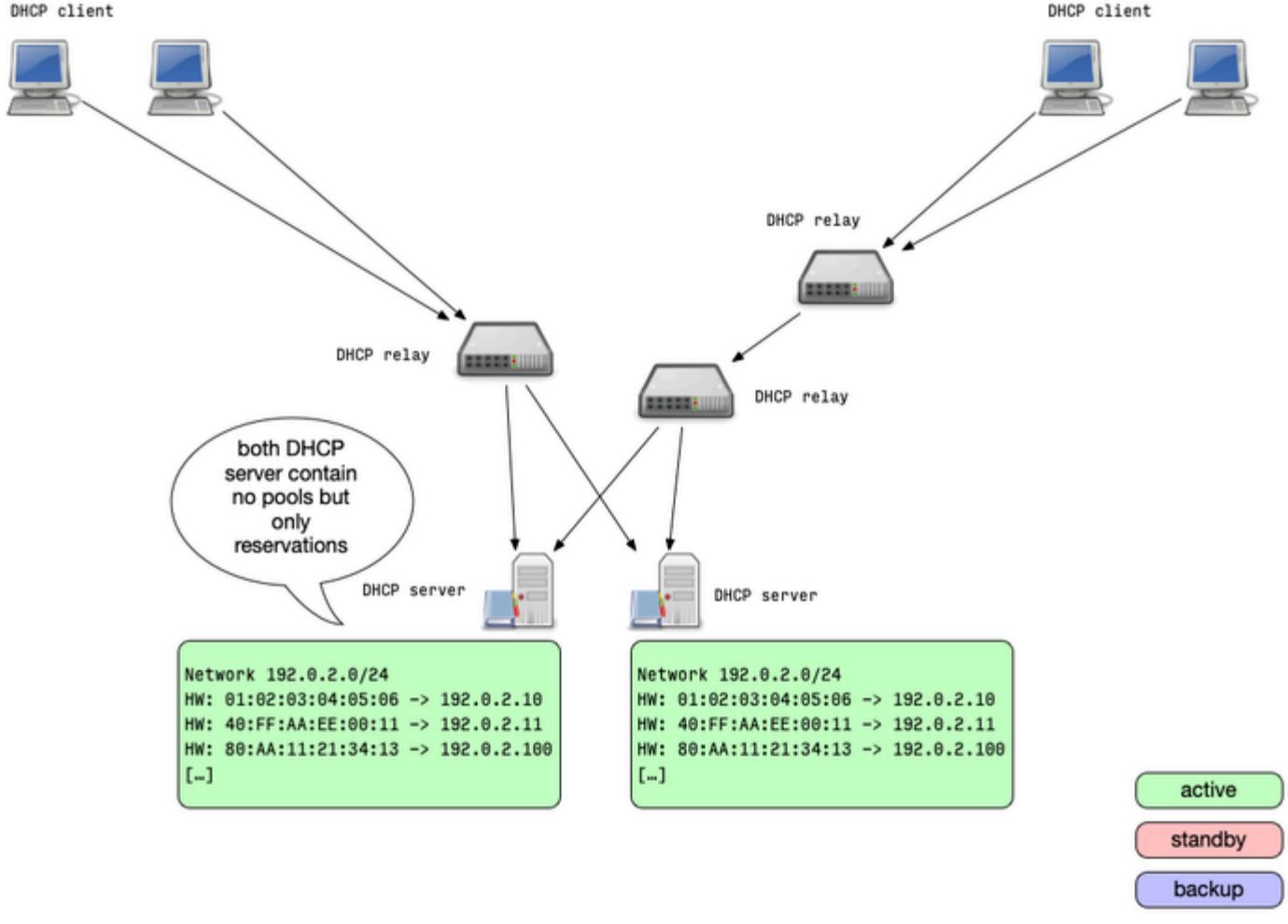


IPv4/IPv6 pure static DHCP

- The *pure static* solution also works with any DHCP server, in IPv4 and IPv6 networks
  - The idea is to not use dynamic allocation of addresses, but only static reservations
  - Two or more DHCP server are equipped with the same reservation configuration
  - Each server will always return the same IP address lease to the same client

- This solution requires an *out-of-band* synchronization of the reservation
  - This could be done on the database level with a shared host reservation database

IPv4/IPv6 pure static DHCP

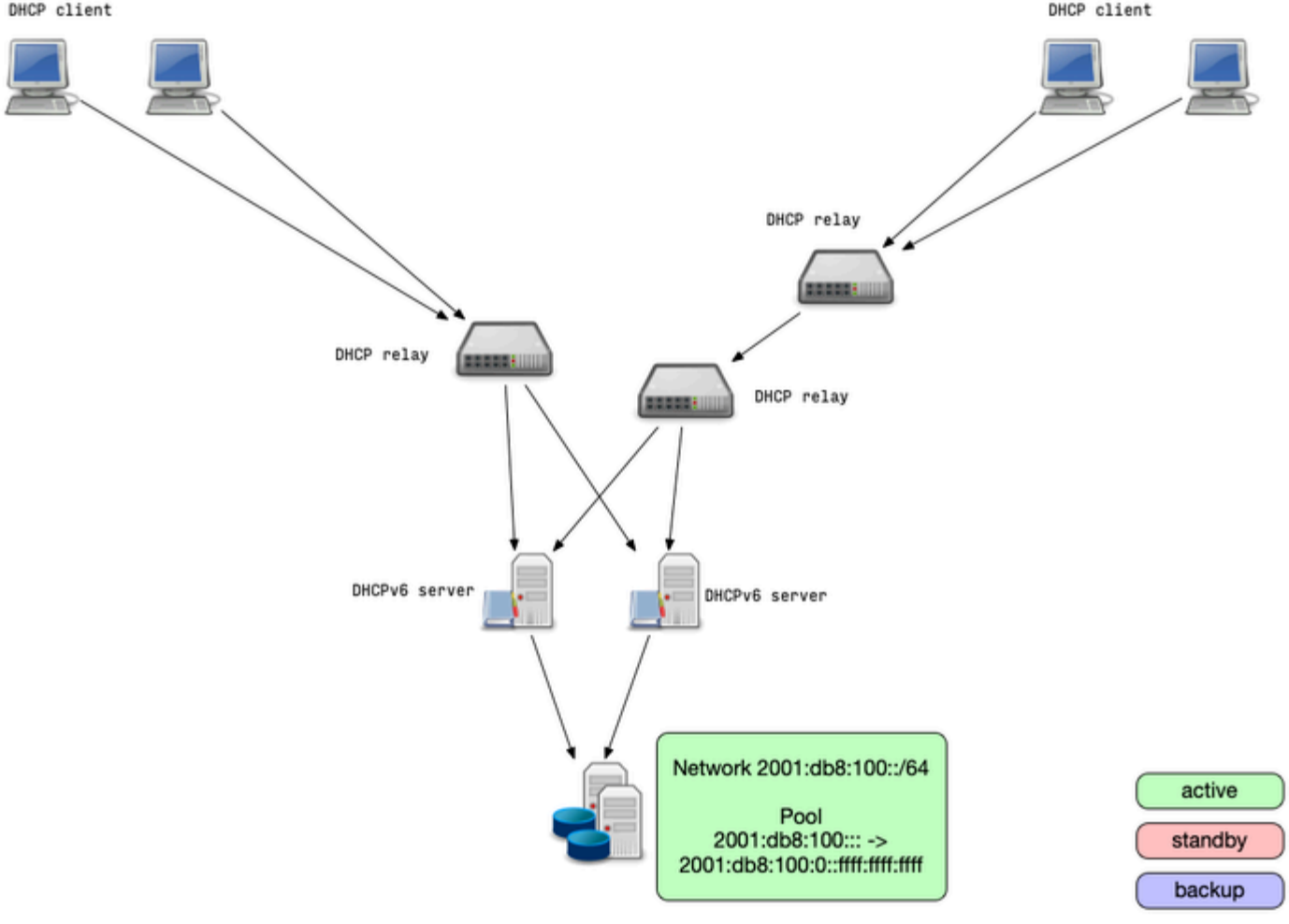


IPv4/IPv6 shared database

- The *shared database* solution moves the redundancy to the database level
  - This solutions allows high availability with more than two DHCP server nodes
  - Two or more DHCP server are connected to the same (logical) database containing the lease information
  - The database itself should be made high available
  - All DHCP servers read and write lease information from/to the same database

- Database locking can lead to performance degradation(!) on high rate of leases/renewals

IPv4/IPv6 shared database

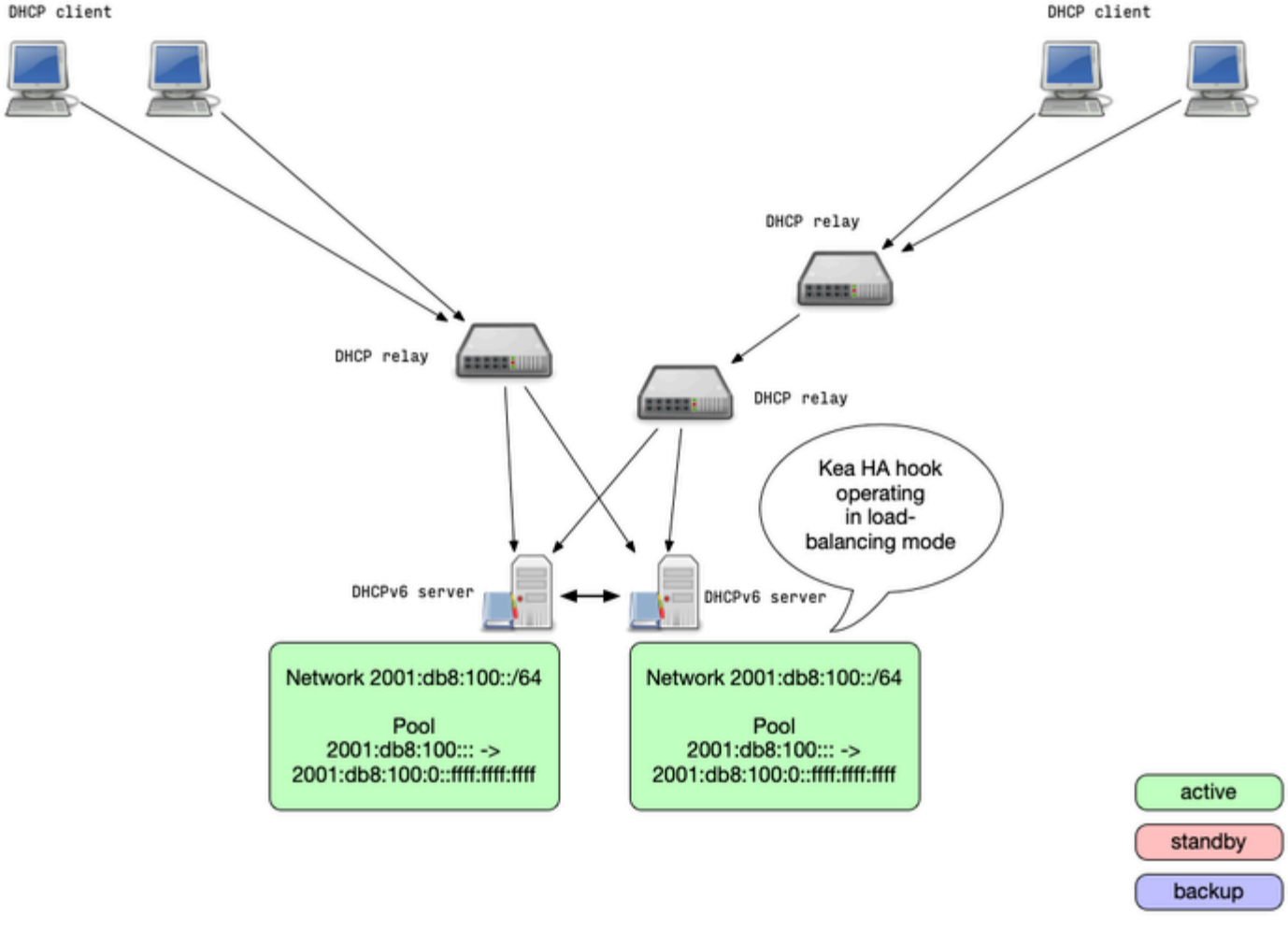


Kea DHCP - High Availability Hook

- Using the Kea DHCP High-Availability extension (HA hook) is the most feature rich high availability solution
- The HA hook offers different operation modes
  - Load-balancing: all DHCP server are active and return leases
  - Hot-standby: all DHCP server are in sync but only one is active and returns leases
  - Passive-backup: one DHCP server is active and send lease database updates to a number of backup servers.

Kea HA Mode: load-balancing

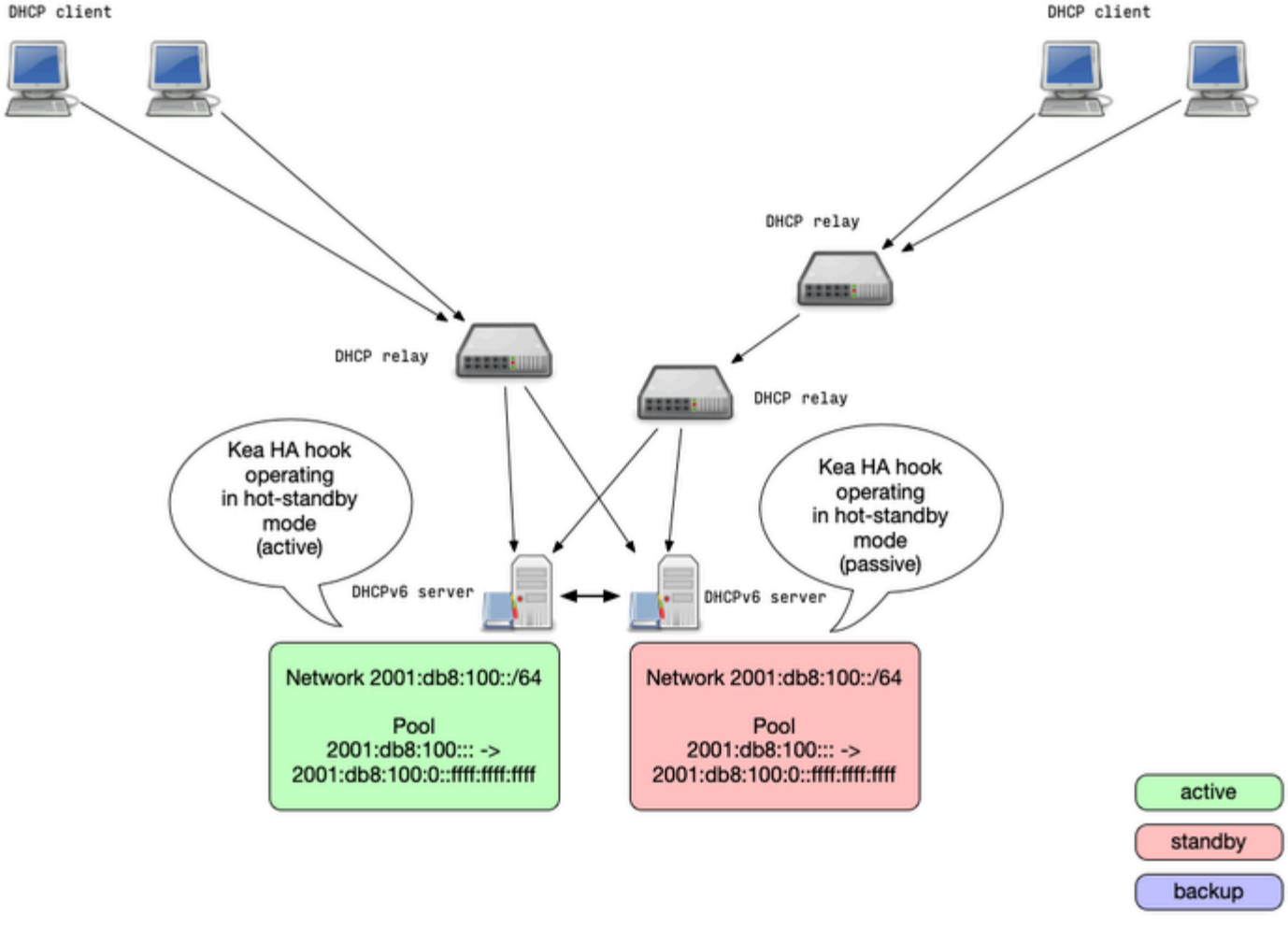
Kea HA Mode: load-balancing



Kea HA Mode: hot-standby

- A Kea DHCP cluster configured for the *hot-standby* mode will have the primary node serving DHCP clients and another node (secondary) only receiving the lease-database updates, but not serving clients
    - If the secondary server detects the failure of the primary, it starts responding to all DHCP queries

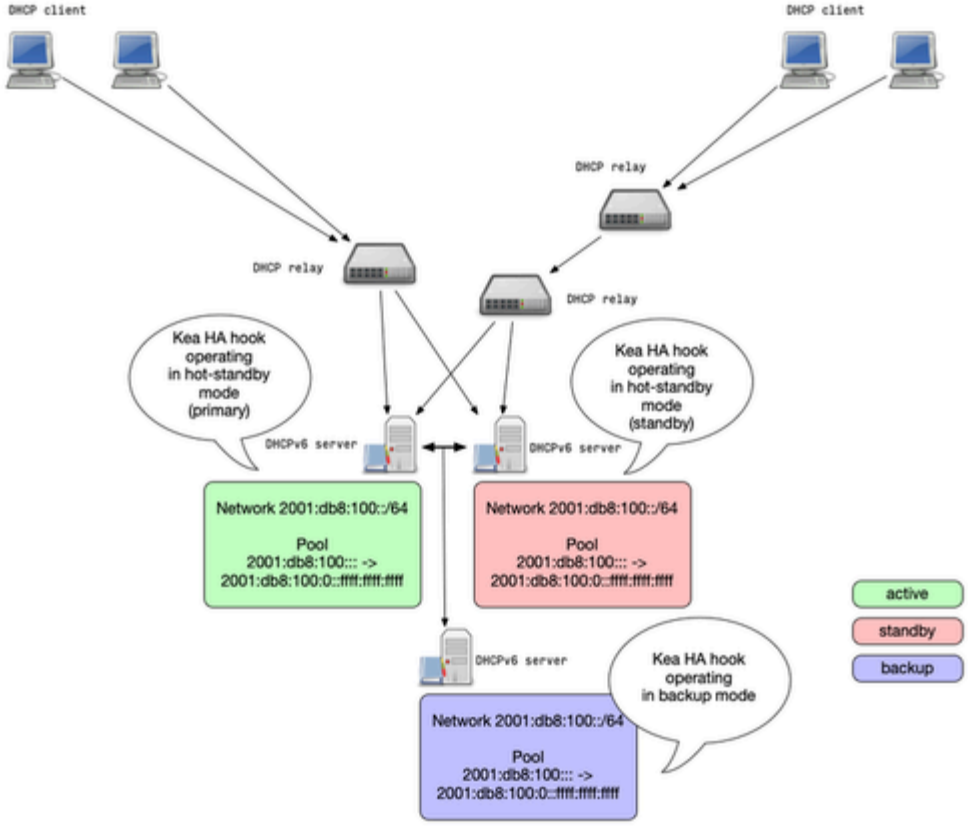
Kea HA Mode: hot-standby



Kea HA Mode: Backup Servers

- Kea DHCP supports any number of *backup* servers
  - Backup server receive lease database updates but are not an active part of an HA setup
  - Backup server can be deployed in addition to the other Kea HA modes

Kea HA Mode: Backup Server

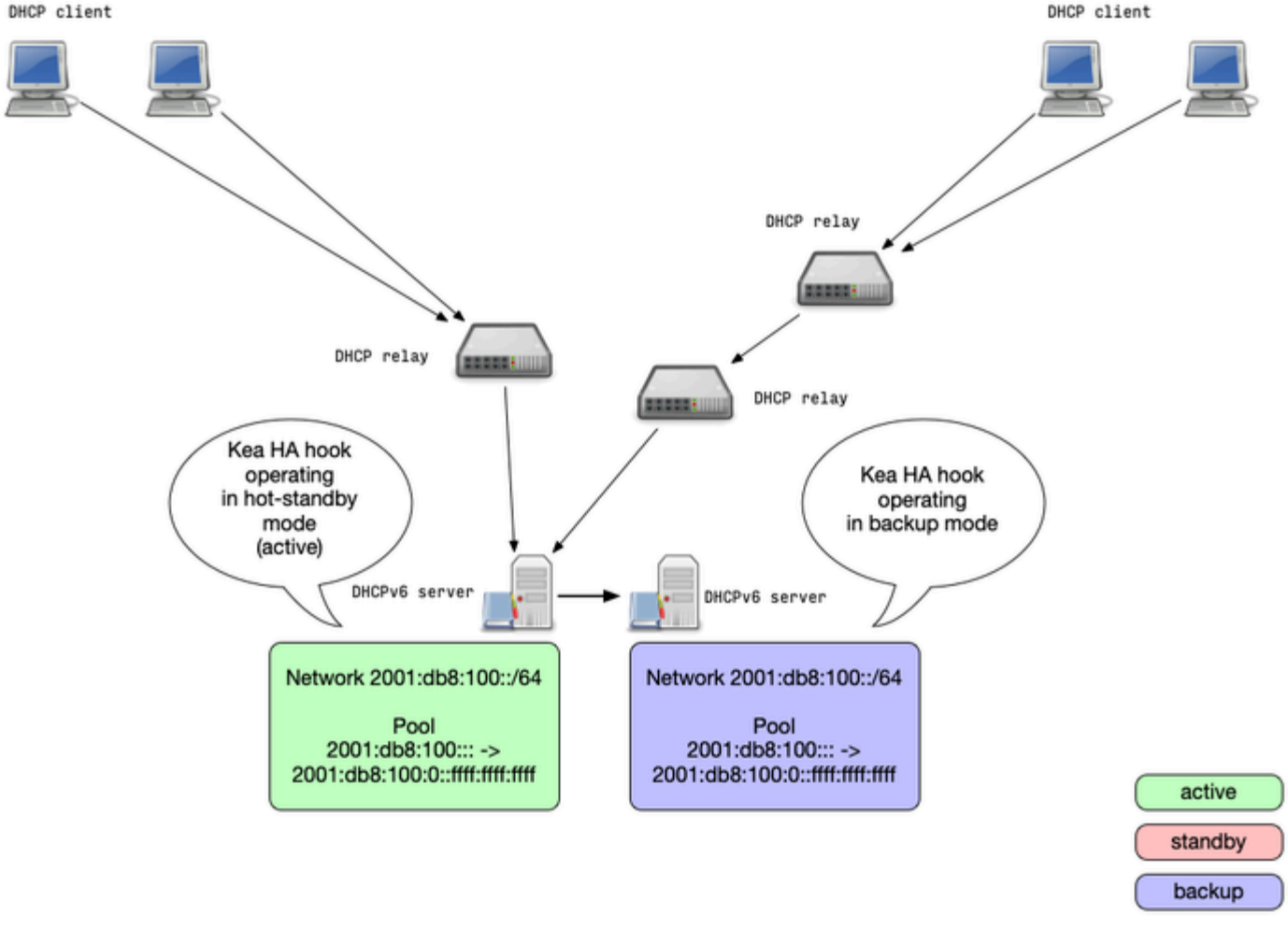


Kea HA Mode: passive-backup

- In the *passive-backup* configuration, only one Kea server is active and is serving leases to the clients
  - Any number of passive (not answering to clients) backup servers receive lease database backups
  - Since Kea 1.7.8, the active server does not need to wait for a lease update confirmation from the backup servers before giving the lease to a client
    - this reduces the latency compared to the other HA modes

- In case of an failure of the active server, a backup server needs to be manually promoted to be active
  - This could be automated outside of Kea with API calls from a monitoring system

Kea HA Mode: passive-backup



DHCPv6 Server

ISC DHCPv6

- the ISC DHCP server supports DHCPv6 since Version 4.0.0
  - Source: ↪http://isc.org
  - License: BSD
  - The ISC DHCP Server is deprecated and development has stopped
    - The last version of the ISC DHCP server is 4.4.3 (March 2022)

Kea DHCPv6

- ISC KEA DHCP is the successor of ISC DHCP
- It was designed for DHCPv6 (and DHCPv4) from the beginning
- Supports modern standards like DHCPv4-over-DHCPv6
- HA Support for DHCPv6 (and DHCPv4)
- Website: ↪https://kea.isc.org/

Microsoft DHCP Server

- DHCPv6 since Windows Server 2008R2
  - License: Microsoft EULA
  - Information: ↪https://blogs.technet.com/b/teamdhcp/
  - HA via Microsoft Server Cluster

Dibbler DHCPv6

- DHCPv6 Server for Linux, macOS and Windows XP/2003
  - Current version: 1.0.1 (2015)
  - License: GNU GPL v2
  - Source: ↪https://github.com/tomaszmrugalski/dibbler
    - The developer of this DHCPv6 server (Tomasz Mrugalski) now works for ISC on the KEA DHCP Server
    - Development is halted, the project currently has no active maintainer

WIDE DHCPv6 Server

- Was the first available DHCPv6 server
  - Has been part of the KAME project (IPv6 for BSD Unix)
  - License: BSD
  - Source: ↪https://sf.net/projects/wide-dhcpv6/
    - development has stopped

dhcpy6d

- DHCPv6 server written in Python
- Current release: 1.6.0 (July 2024)
- License: GPL-2.0
- Source: ↪https://github.com/HenriWahl/dhcpy6d
  - Actively maintained
  - Easy to extend (Python)
  - MAC address aware

Udhcpc

- DHCPv4/DHCPv6 server for embedded systems, part of BusyBox
- License: GPL
- Current release: BusyBox 1.37.0 (September 2024)
- Source: ↪https://busybox.net/

Jagornet DHCP Server

- An open source DHCPv4/DHCPv6 Server in Java
- License: GPLv3
- Current release: 4.0.1
- Source: ↪https://www.jagornet.com
- Features: HA, dynamic DNS, multithreaded architecture, flexible XML/JSON/YAML configuration file format

CoreDHCP

- Fast, multithreaded, modular and extensible DHCP server written in Go
- License: MIT
- Source: ↪https://coredhcp.io/
    - Modular design, possible to extend with plugins
    - Work in Progress

DHCPv6 in Router Hardware

Many IPv6 router devices from vendors like Cisco or Juniper include DHCPv6 server.

Questions