IP Host Configuration
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Acknowledgements

- The presentation builds upon material from
  - Previous slides by Markus Hidell, Björn Knutsson and Peter Sjödin
  - *Computer Networking: A Top Down Approach*, 5th ed. Jim Kurose, Keith Ross. Addison-Wesley.
  - *TCP/IP Protocol Suite*, 4th ed, Behrouz Foruzan. McGraw-Hill.

Outline

- Introduction
- Automating IP Configuration
- Stateful configuration - DHCP
- Stateless configuration – SLAAC
- Further reading

Basic Question

- IP (Internet Protocol):
  - what packets look like and how to interpret IP addresses
- Routing protocols:
  - calculate paths through the network
- DNS (Domain Name System):
  - how to translate between names and IP addresses

But how do we get an IP address for a network interface?

Manual IP Address Configuration

- System administrator:
  - Manually select an IP address from currently unassigned addresses in the subnet
  - Assign to host machine
  - Manually edit configuration file on host machine
- Statically assigned address
  - require work to change address
- *What if...*
  - Sysadmin forgets to mark address as assigned?
  - Subnet changes address?

Manual IP address configuration is not a practical solution

IP Configuration Information

- Just IP address is **not enough** information for hosts
  - Need to know subnet mask for local traffic
    - CIDR notation: 10.1.1.0/24
  - Need to know IP address of gateway for non-local traffic
    - Gateway: the router that connects our subnet to the Internet (default gateway)

- **What else** might we want to tell a local host?
  - DNS server
  - Host name
  - Other services (Print server, log server, etc)

Automating IP Configuration

We know the information needed – let's build a protocol to do the work!

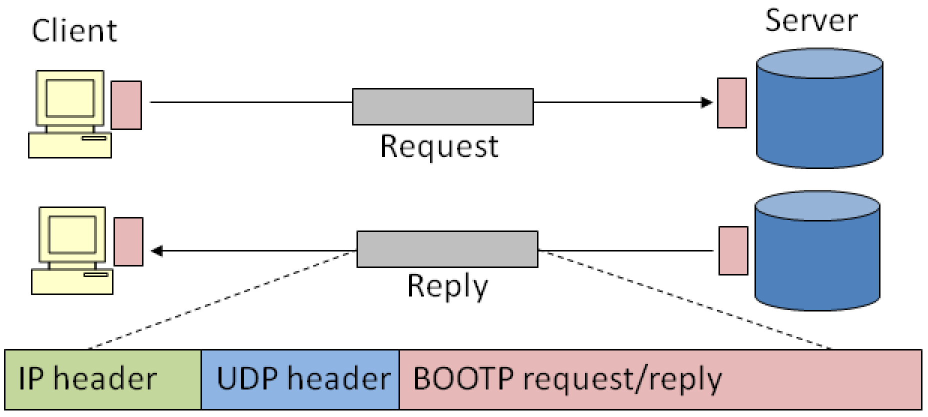
- BOOTP (Bootstrap Protocol)
  - Static, stateful, client-server
- DHCP (Dynamic Host Configuration Protocol)
  - Dynamic, stateful, client-server
- SLAAC (Stateless Address Autoconfiguration)
  - Dynamic, stateless
  - RFC 4862: *IPv6 Stateless Address Autoconfiguration*
- Zeroconf
  - Autoconfiguration completely without servers?

RARP—Reverse ARP

- How to get your own IP address, when all you know is your link address
  - Diskless clients (with no config files)
- RARP request:
  - Broadcast on subnet: “Who knows my IP address?”
- RARP reply
  - Sent by RARP server: “I know that address!”
- Client
  - receives the RARP reply, and learns its own IP addr
- RARP packet has the same format as ARP packet
- RARP limitations
  - Server must be on local subnet, only IP address given

BOOTP—Bootstrap Protocol

- BOOTP (RFC 951) is a lot more powerful than RARP
- BOOTP sends requests/replies over UDP
  - Easy to write a user space server
  - Client does not need a full TCP/IP stack to run BOOTP
- BOOTP is not dynamic
  - static binding between MAC and IP addresses



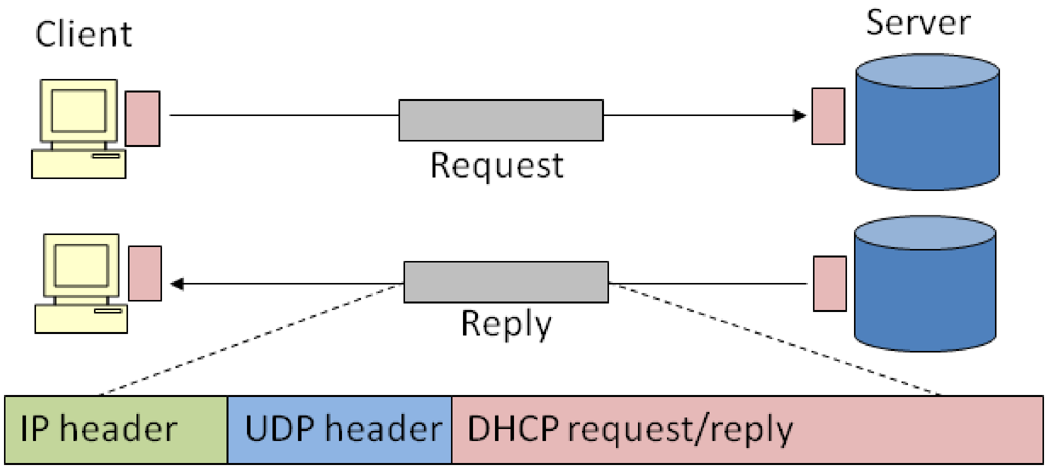
DHCP—Dynamic Host Configuration

- Main innovation: Dynamic configuration
  - Hosts can be assigned temporary IP addresses from a pool
    - Allows reuse of addresses
  - A subnet can thus support more hosts than available IP addresses (not all at the same time of course…)
    - Like KTH wireless LAN

- Also defines standard for additional information to clients
  - DNS server, time server, printers etc

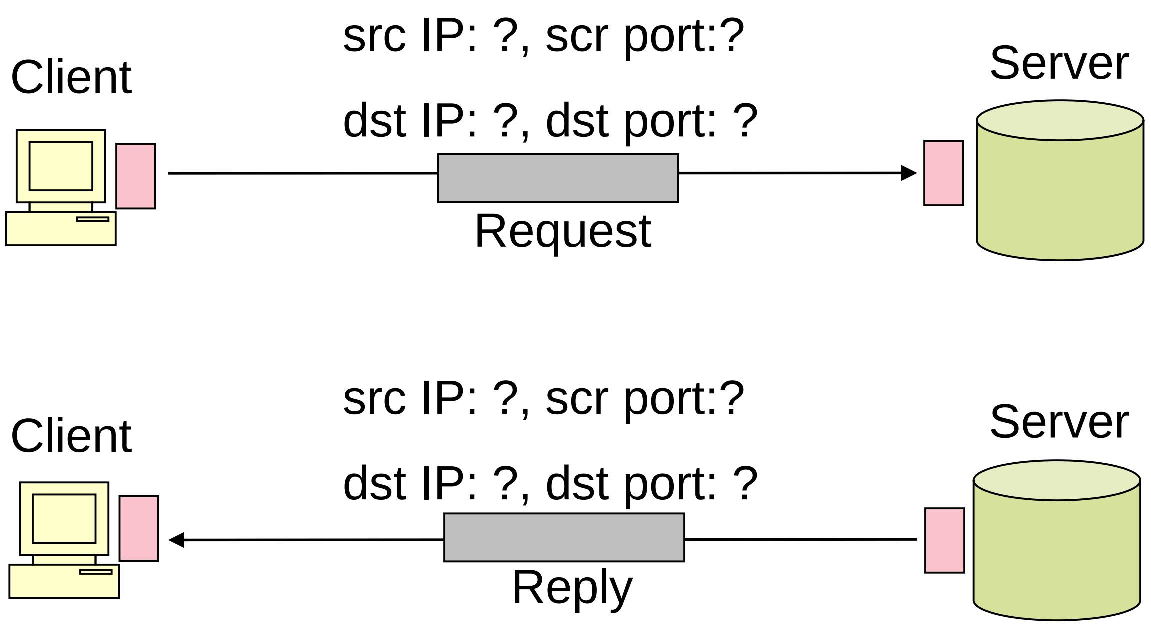
DHCP—Successor to BOOTP

- Backwards compatible with BOOTP
  - BOOTP clients can use DHCP server

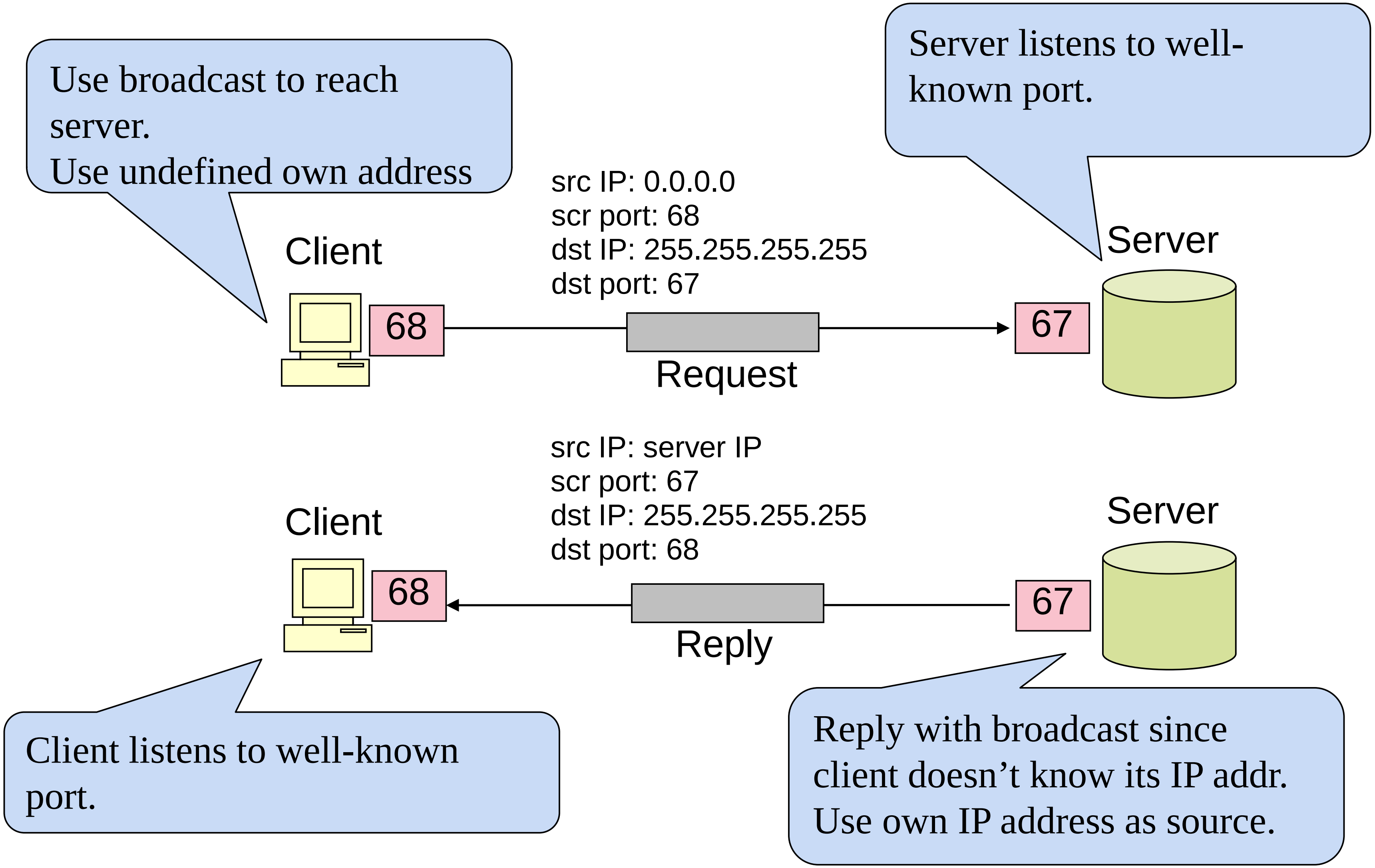


DHCP Addressing

Client has neither its own IP address, nor the server's.
How do we then address Request/Reply?
Think and discuss for 5 minutes…..



DHCP Addressing (Protocol Operation Simplified)



Well-known Client Port Number

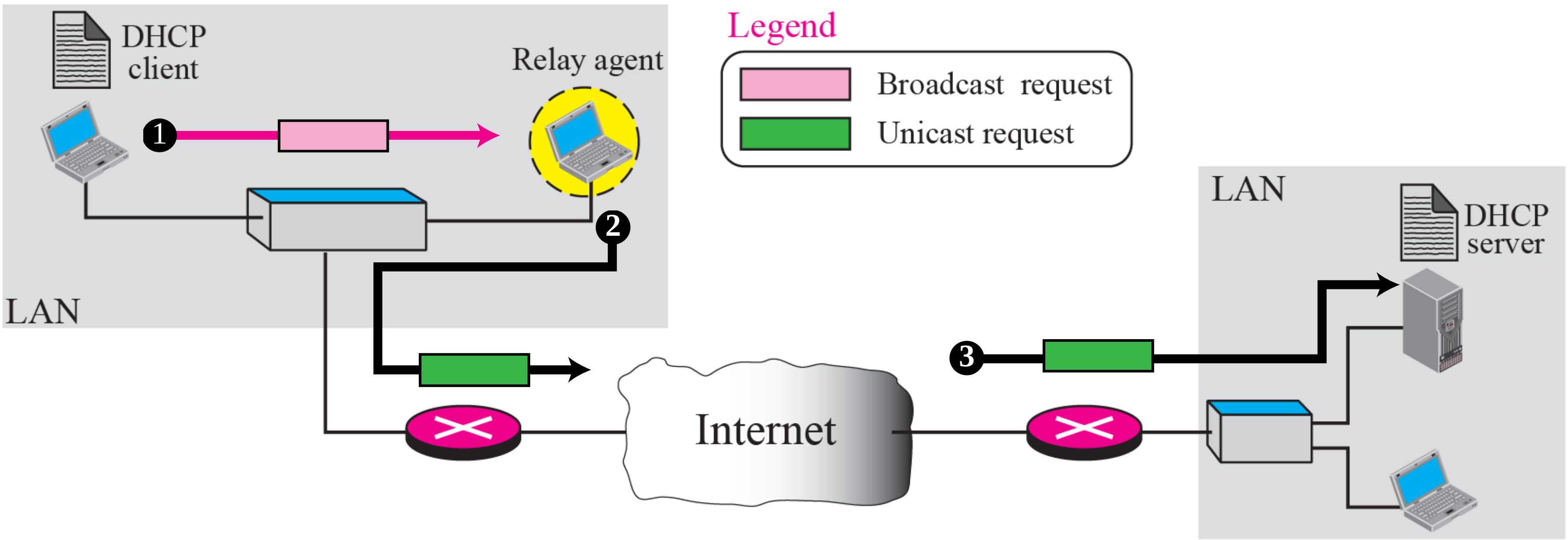
Why does DHCP not use ephemeral port number on the client side?

- The reply from the server can be broadcast
- Broadcast response will reach all hosts on the subnet
- It is considered bad manner to broadcast to a random port number

- What if two clients are using DHCP simultaneously?
  - A Transaction ID will help recognizing the reply message
  - Transaction ID is chosen randomly

DHCP Relay

- What if the DHCP client and the DHCP server are on different subnets?
  - We can use a relay agent!



DHCP Relay, cont´d

- DHCP traffic can be relayed to a central DHCP server
  - Only the relay agent needs to be on local subnet
    - Just tunnels DHCP traffic to/from server, little complexity
  - Simplifies management of large networks
    - No need for a distributed database of valid mappings
    - Completely transparent to the clients

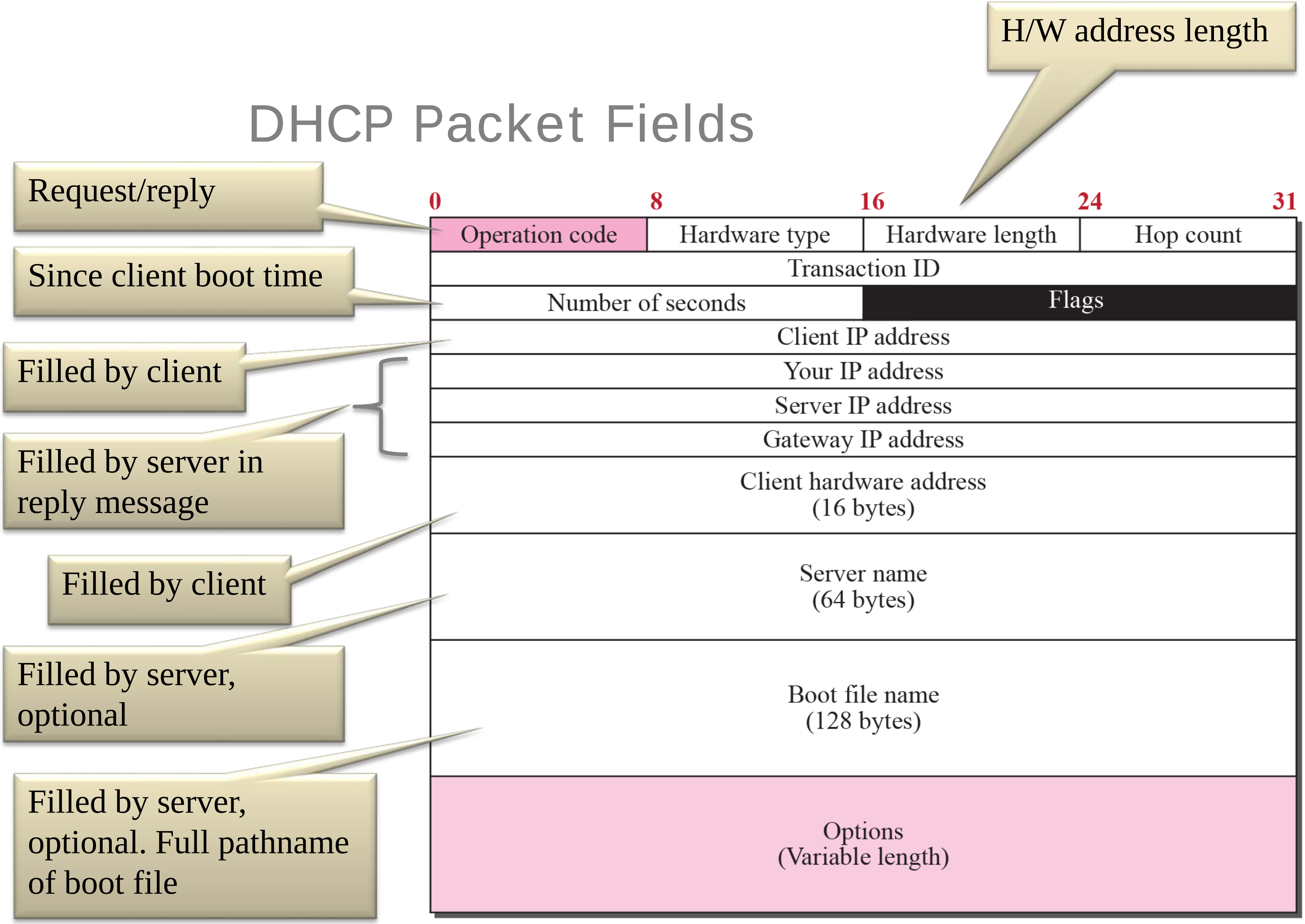
DHCP Packet Format

In reality, DCHP is more complex than seen in the previous slides.

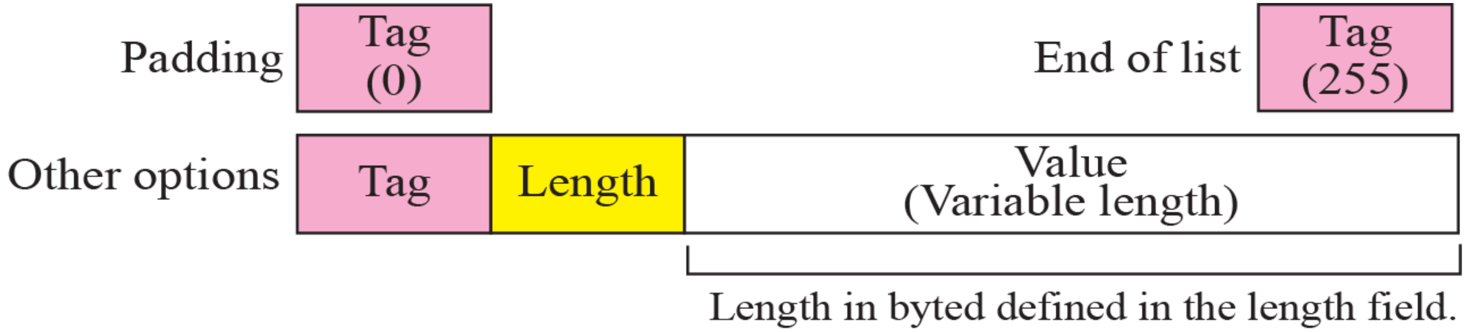
Not only one type of request/reply

0	8	16	24 31
Operation code	Hardware type	Hardware length	Hop count
Transaction ID			
Number of seconds		Flags	
Client IP address			
Your IP address			
Server IP address			
Gateway IP address			
Client hardware address (16 bytes)			
Server name (64 bytes)			
Boot file name (128 bytes)			
Options (Variable length)			

DHCP Packet Fields



DHCP Option Format



DHCP Options

Lots of things can be configured with DHCP.

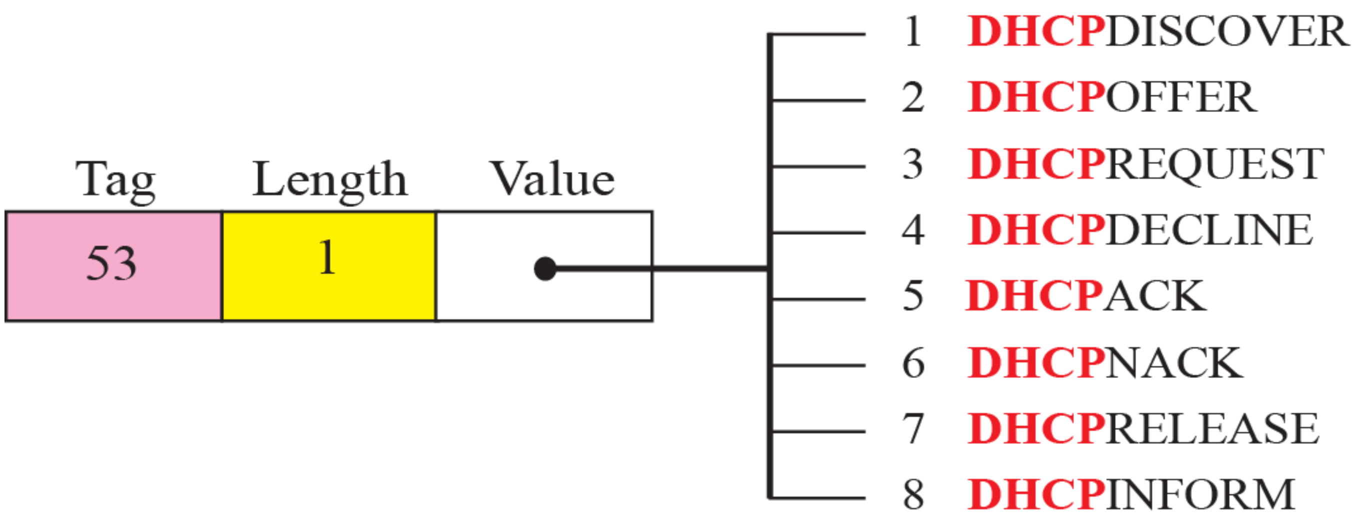
This is where dynamicity is added, compared to BOOTP.

Table 18.1 *Options for DHCP*

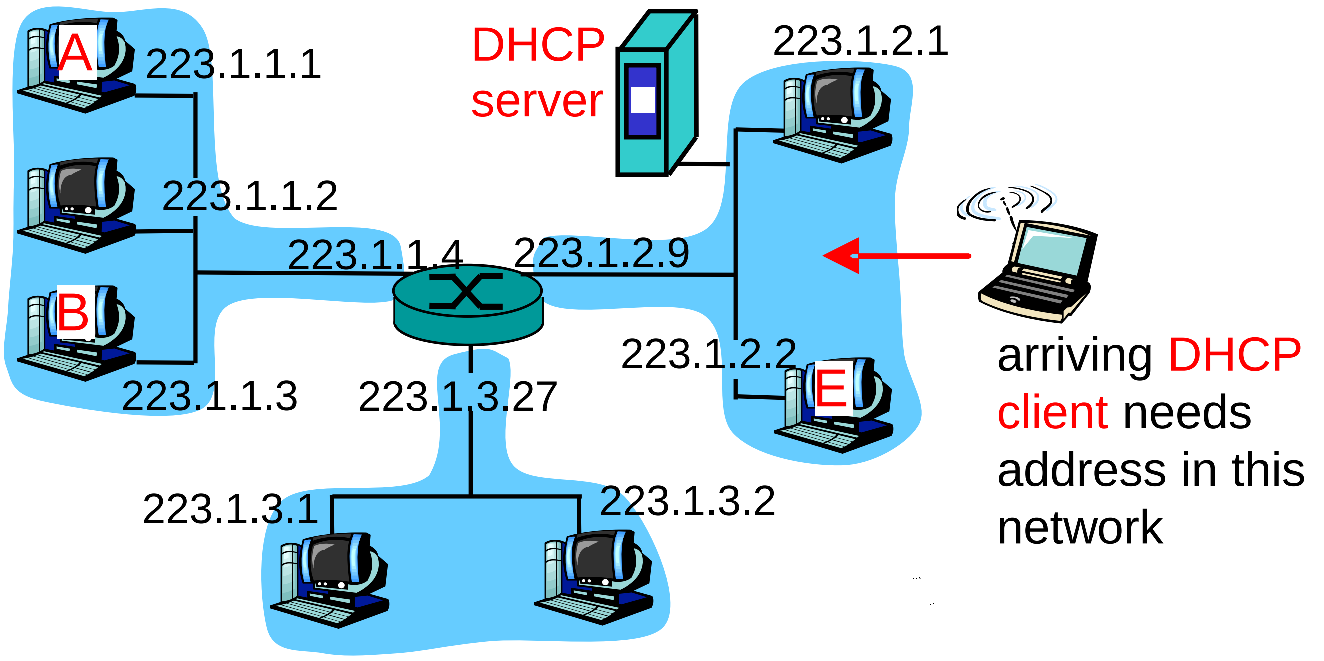
Tag	*Length*	*Value*	*Description*
0			Padding
1	4	Subnet mask	Subnet mask
2	4	Time of the day	Time offset
3	Variable	IP addresses	Default router
4	Variable	IP addresses	Time server
5	Variable	IP addresses	IEN 16 server
6	Variable	IP addresses	DNS server
7	Variable	IP addresses	Log server
8	Variable	IP addresses	Quote server
9	Variable	IP addresses	Print server
10	Variable	IP addresses	Impress
11	Variable	IP addresses	RLP server
12	Variable	DNS name	Host name
13	2	Integer	Boot file size
53	1	Discussed later	Used for dynamic configuration
128–254	Variable	Specific information	Vendor specific
255			End of list

DHCP Operation

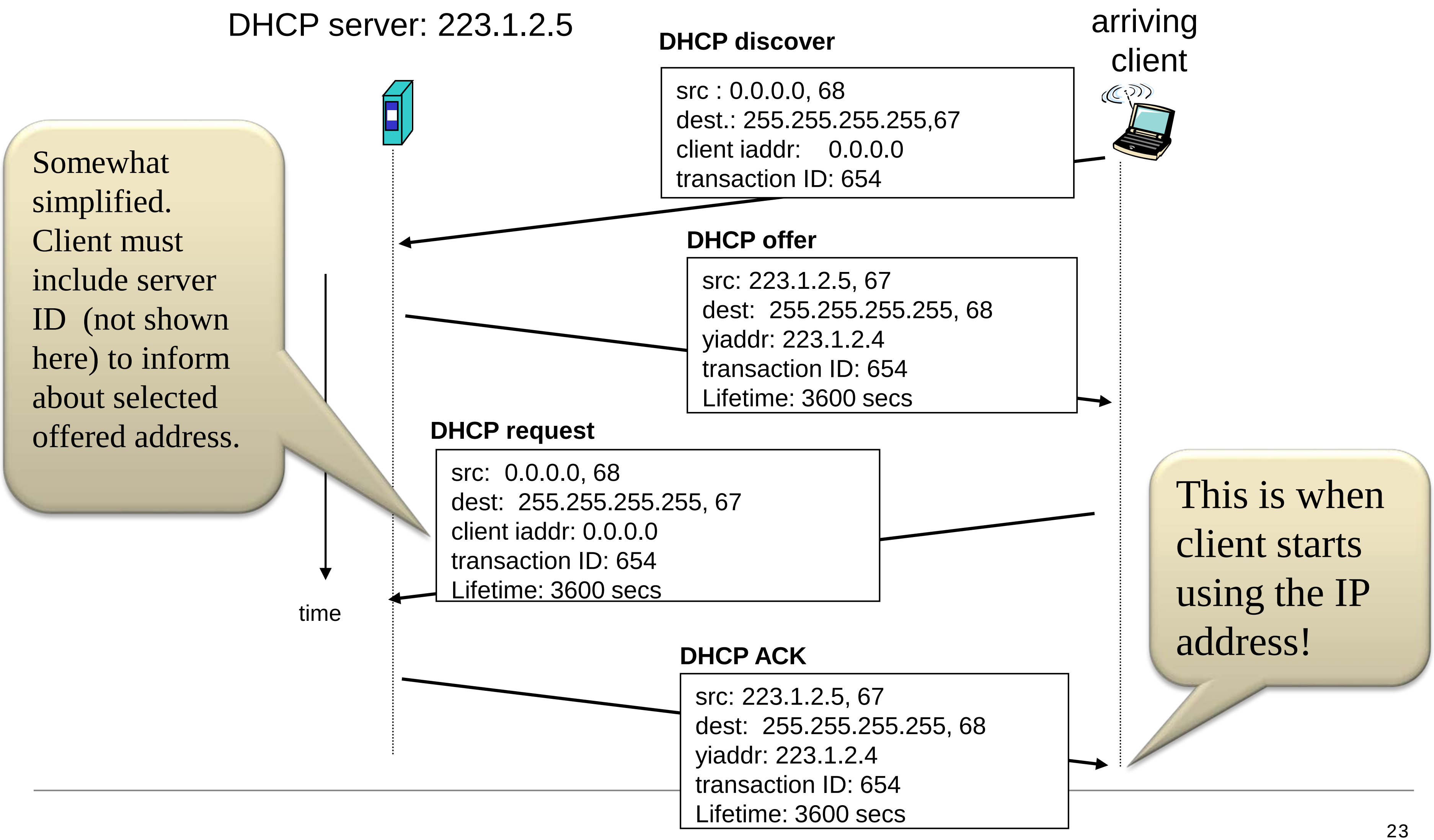
- Dynamic address allocation requires more messages
  - DHCP defines a set of states and semantic (tag 53)
- Simplest case requires clients to perform two steps:
  - First discover available DHCP servers
  - Then request IP address from one of them



DHCP Scenario



DHCP Scenario, Message Exchange



DHCP Client State Diagram

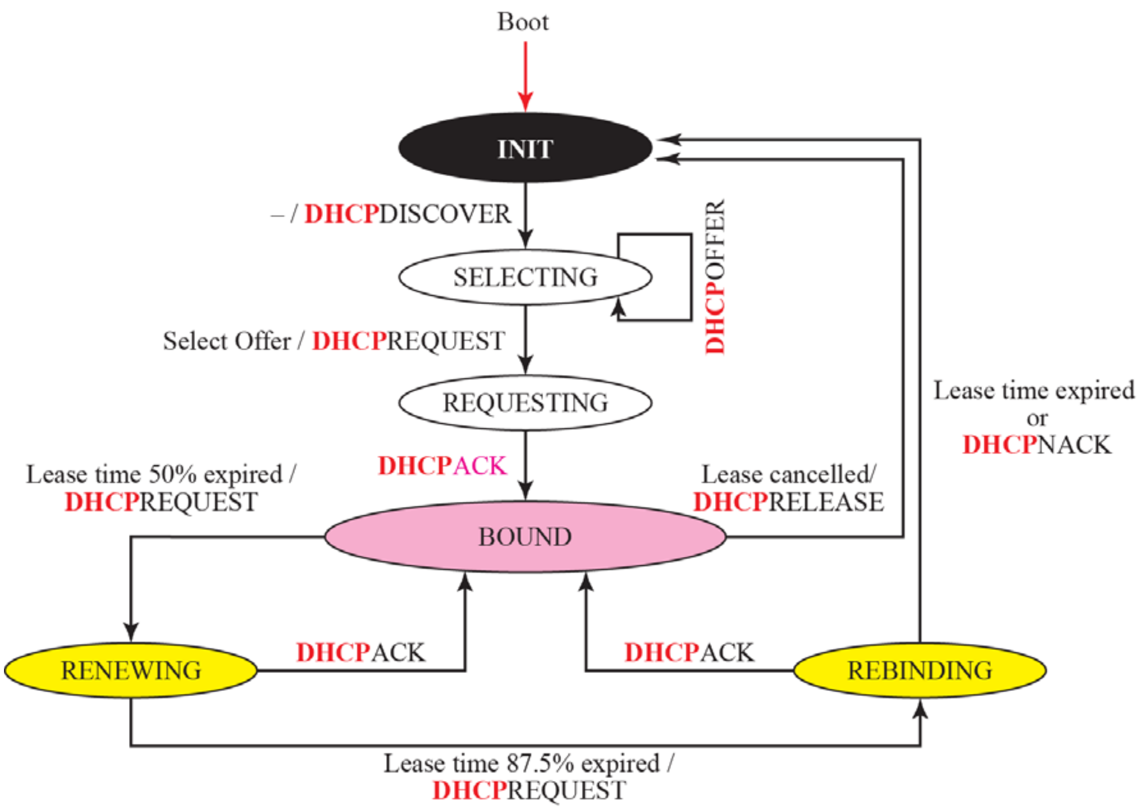
Clients need to renew their lease periodically.

If lease expires, client is assumed to have left network without release.

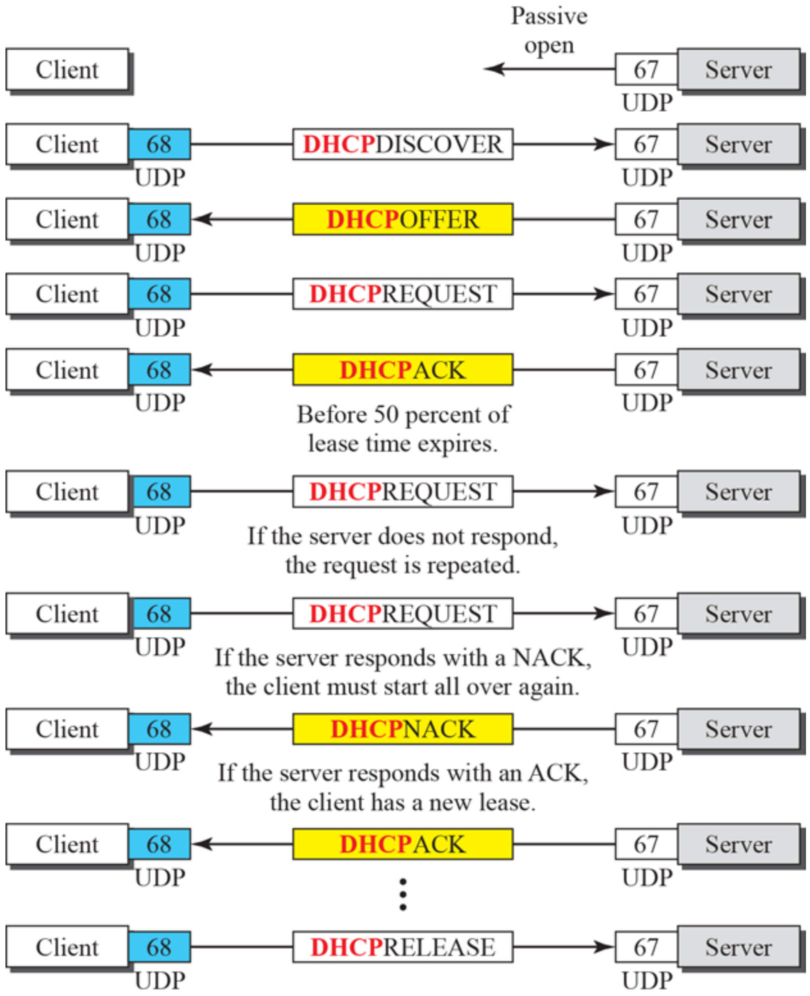
DHCP servers tend to reuse addresses in LRU order.

If client releases and comes back before reuse, it often gets the old IP address back.

Full protocol is slightly more complex



DHCP—Full Packet Exchange



Host Configuration—SLAAC

- Stateless Autoconfiguration
  - Initially developed for IPv6, but later designed also for IPv4
  - Server keeps no state about hosts, only non-host state
    - Like global unicast prefix and subnet prefix
  - Uses IPv6 concept of link local addresses to enable client to communicate on local subnet before having a global address
  - Client does not explicitly request address from server
    - Does not even explicitly inform the server of address selected

IPv6 Autoconfiguration—Plug and Play

- Remember that IPv6 development started in the 1990s
- Idea: automatically discover parameters used to connect to the Internet
  - Address, netmask, router, nameserver, ...
- Two scenarios: stateless and stateful
  - “Dentist’s office”
  - “Thousand computers on the dock”

Dentist’s Office

Dentists are rich enough to buy several computers, but they have been trained in dentistry, not computer networks, so they can do little else other than take the machine out of the box, plug in the various connectors, switch it on, and expect it to work.

A requirement of IPv6 is that is should indeed be sufficient, even if the dentist is not connected to the Internet and even if there is no router in the office’s network.

C. Huitema “IPv6 – the new Internet protocol

Thousand Computers on the Dock

Network managers often have a dream, a bad dream. A thousand computers have just been delivered and are waiting on the unloading dock. It is 2 P.M. on Friday and the company expects the entire network will be available by the end of the afternoon.

This certainly implies that we will not have much time to configure each of these computers. It should be as automatic as possible.

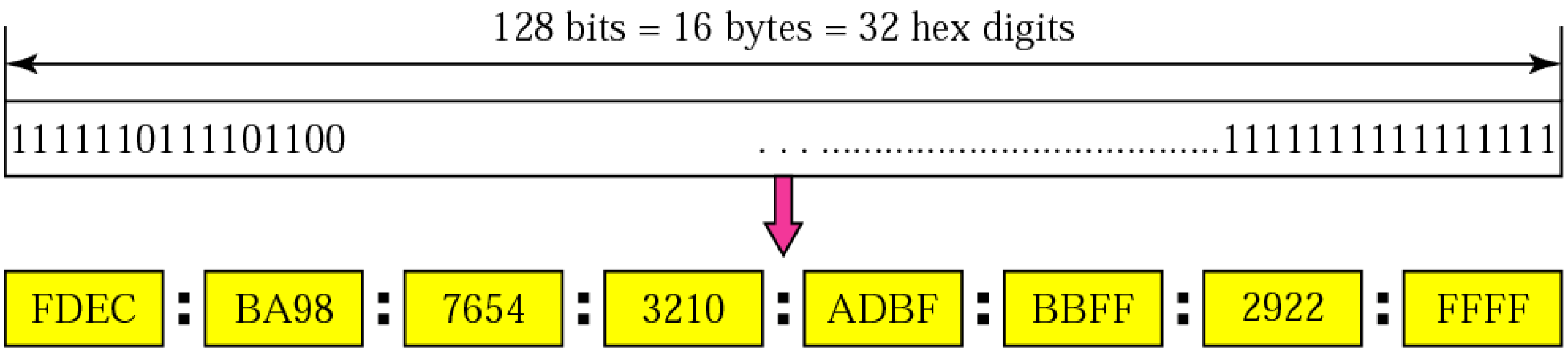
C. Huitema “IPv6 – the new Internet protocol

Stateful and Stateless Autoconfiguration

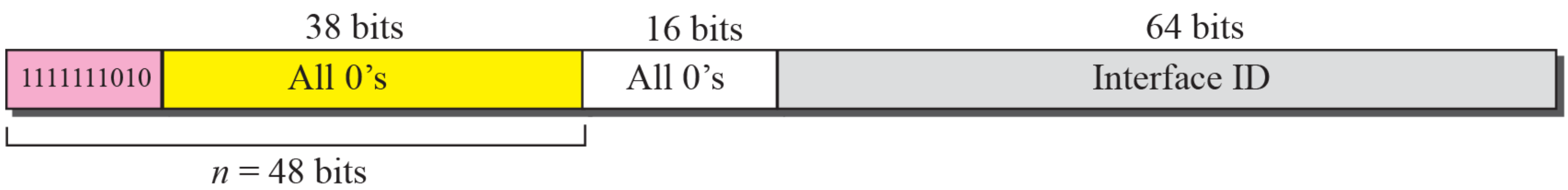
- Stateless autoconf
  - Scenario: “Dentist’s office”
  - Small networks
  - Nodes can start communicating directly
- Stateful autoconf
  - Scenario: “Thousand computers on the dock”
  - Larger networks
  - Centralized management
- Combination (Stateless DHCP)

IPv6 Addressing, Revisited

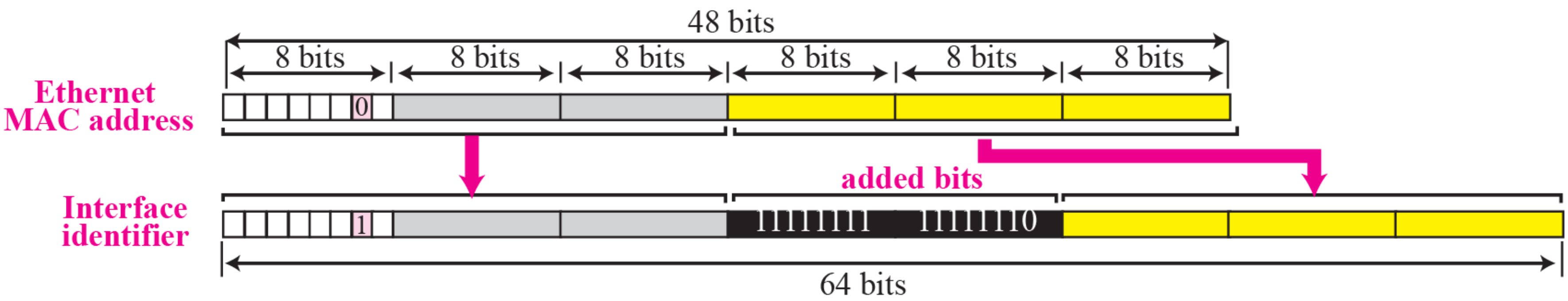
- An IPv6 unicast address identifies an interface connected to an IP subnet (as is the case in IPv4)
- IPv6 routinely allows each interface to be identified by several addresses
  - facilitates management
- Colon hexadecimal notation (eight 16 bit hexadecimal integers)



IPv6 Link Local Address in SLAAC



- Host generates link local address (LLA)
  - From the interface MAC address
  - Or using random number (privacy extensions, next slide)
- Use ICMP messages to probe local subnet and detect if generated LLA already in use



Privacy Extensions

- MAC-derived interface-ids is an easy way to ensure unique addresses
  - And get rid of L2/L3 address resolution
- But, you know many things about the origin of the packet
  - IEEE 802 addresses have encoded data
    - The identity and vendor of the interface card
    - You can derive which equipment you use
    - E.g., exploit bugs in that equipment
  - You can track the node when netid is changed (dhcp/mobile IP)
- Privacy extensions
  - Randomly assigned interface-id
  - Changes over time (temporal addresses)
- Protects users
- You need to make L2/L3 address resolution

SLAAC, cont’d

- Once unique LLA is established, this can be used to communicate with other hosts on same subnet
- Routers on local subnet broadcast periodic Router Advertisements (RA) ICMP messages
  - Hosts can also send an ICMP message to solicit announcements from routers on local subnet
  - RA contains the global unicast prefix and subnet prefix
- Client combines LLA with prefixes to create its unique global address and directly starts using it

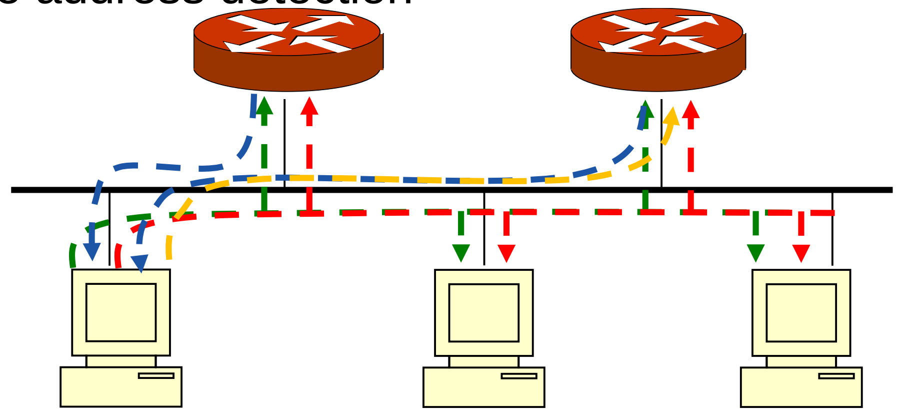
SLAAC vs DHCP

- Unfortunately, RA:s contain only limited information
  - Prefixes and router address
- Hosts often need other configuration information
  - E.g., DNS server, Time server, Printer server
- For these, we still need DHCP servers
  - Good news is that we can use SLAAC for setting up the IP address, and use *stateless DHCP for everything else*

Stateless Autoconfiguration—Example

1 (green). Host forms link-local tentative address.
Sends neighbor solicitation:
Duplicate address detection

4 (orange). Optionally: proceed with stateful configuration



2 (red). Assign link-local address to interface.
Send router solicitation to all routers

3 (blue). Get router advertisement from Routers. Get prefixes, form addresses, default nexthop.

Host Configuration, Further Reading

- Forouzan
  - Chapter 18
  - Chapter 26.4
  - Chapter 28.4
- Wikipedia entries
  - DHCP
  - Link-local address
  - Mobile IP—host configuration and mobility
  - Zeroconf
    - Autoconfiguration completely without servers
    - Allow hosts to configure themselves and find resources without needing a server to tell addresses

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Thanks for listening