Network Layer
Part 5

Mark Allman
mallman@case.edu

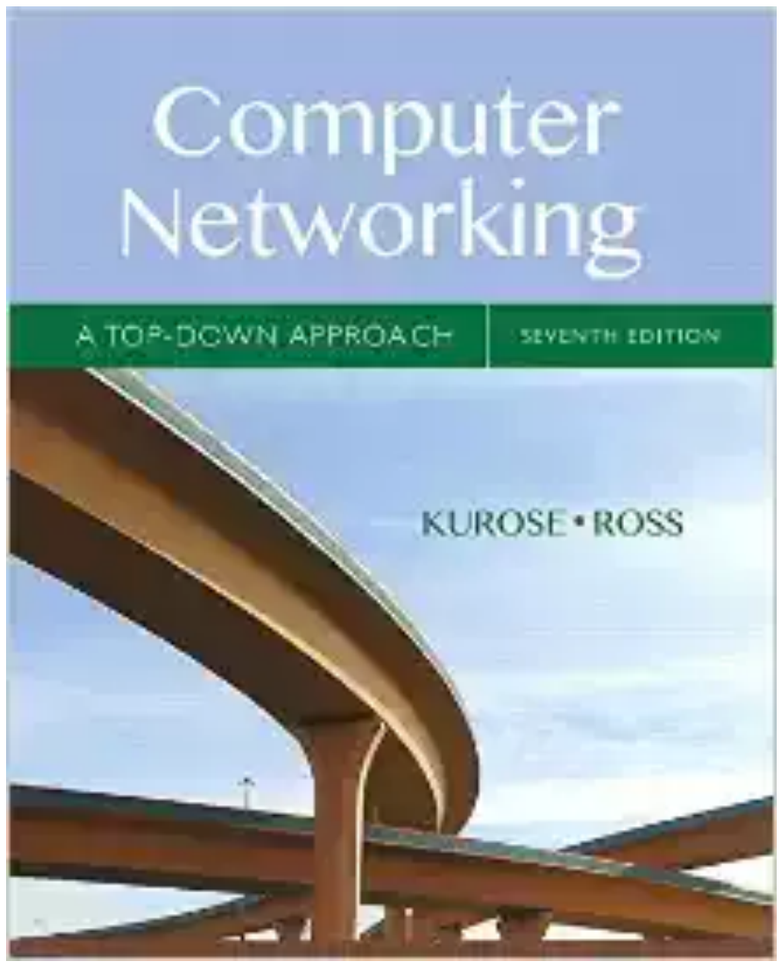
EECS 325/425
Fall 2018

"We goin' downtown in the middle of the night,
We laughin' and I'm jokin' and we feelin' alright."

These slides are more-or-less directly from the slide set developed by Jim Kurose and Keith Ross for their book "Computer Networking: A Top Down Approach, 5th edition".

The slides have been lightly adapted for Mark Allman's EECS 325/425 Computer Networks class at Case Western Reserve University.

Reading Along ...



- Network layer is chapters 4 & 5
  - IPv4 addressing

IP addresses: how to get one?

IP addresses: how to get one?

Q: How does network get subnet part of IP addr?

IP addresses: how to get one?

Q: How does network get subnet part of IP addr?

A: gets allocated portion of its provider ISP's address space

IP addresses: how to get one?

Q: How does network get subnet part of IP addr?

A: gets allocated portion of its provider ISP's address space

ISP's block 11001000 00010111 00010000 00000000 200.23.16.0/20

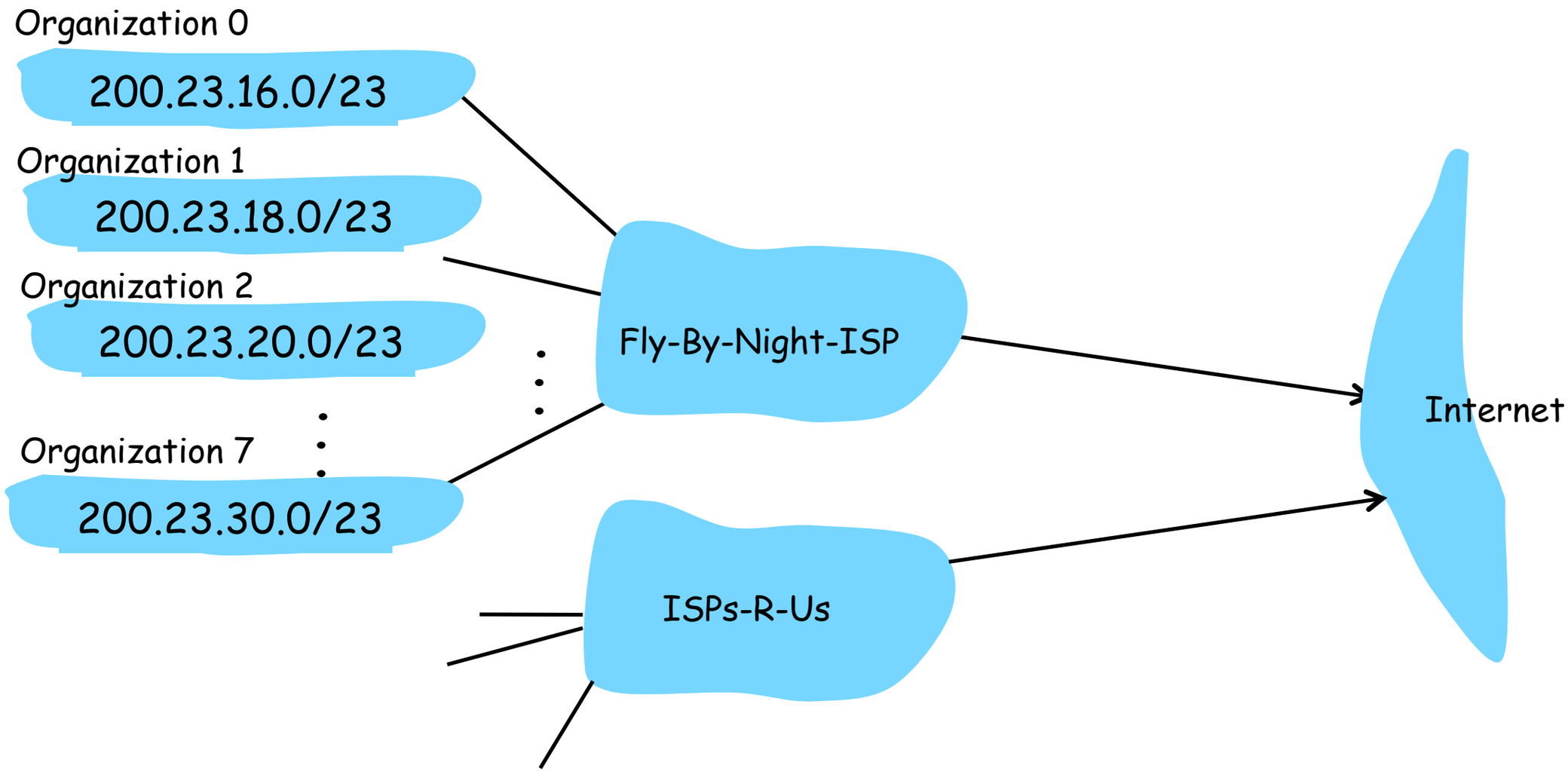
IP addresses: how to get one?

Q: How does network get subnet part of IP addr?

A: gets allocated portion of its provider ISP's address space

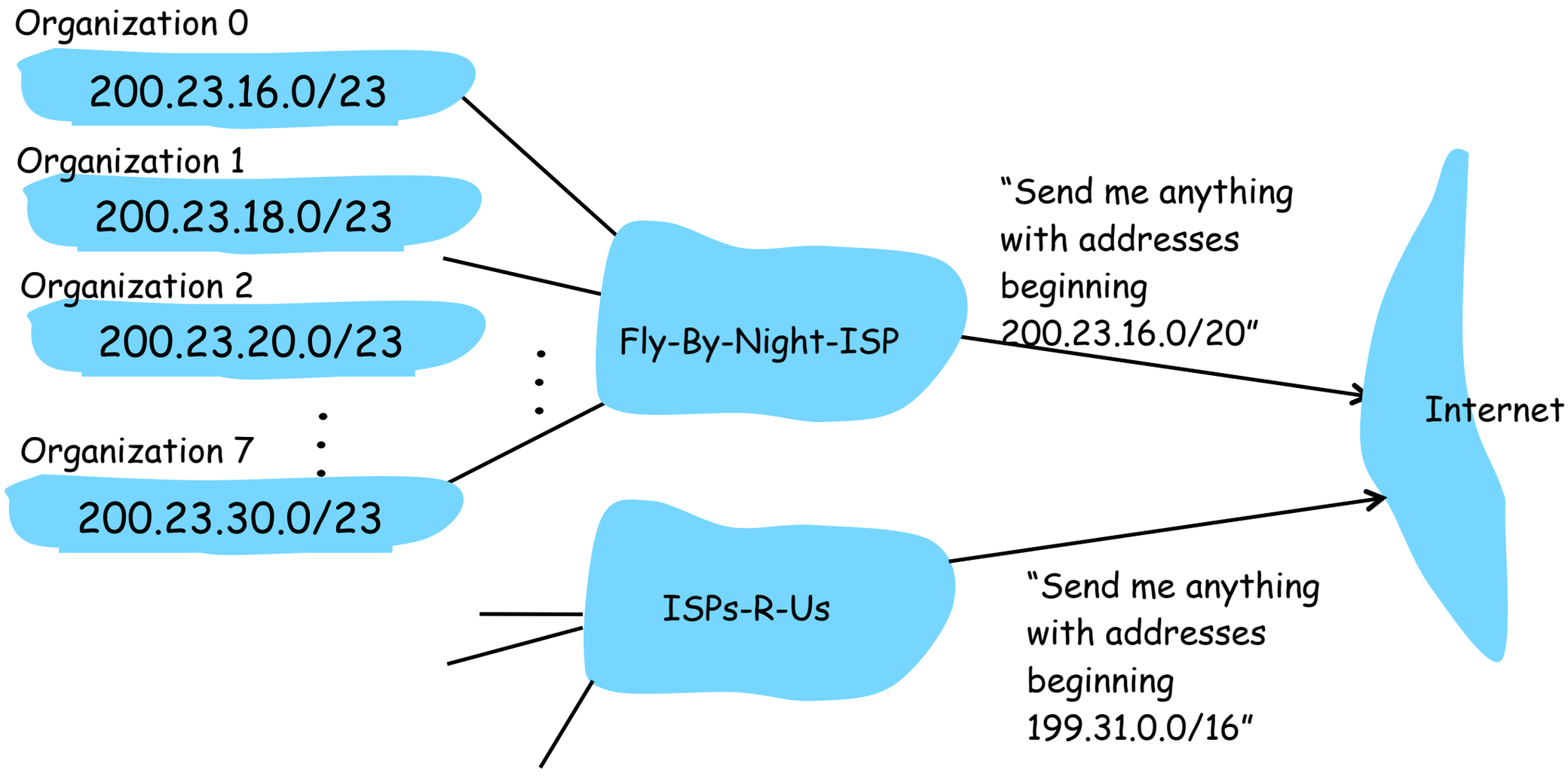
ISP's block	11001000 00010111 00010000	00000000	200.23.16.0/20
Organization 0	11001000 00010111 00010000	00000000	200.23.16.0/23
Organization 1	11001000 00010111 00010010	00000000	200.23.18.0/23
Organization 2	11001000 00010111 00010100	00000000	200.23.20.0/23
...	.....	....	....
Organization 7	11001000 00010111 00011110	00000000	200.23.30.0/23

Hierarchical addressing: route aggregation

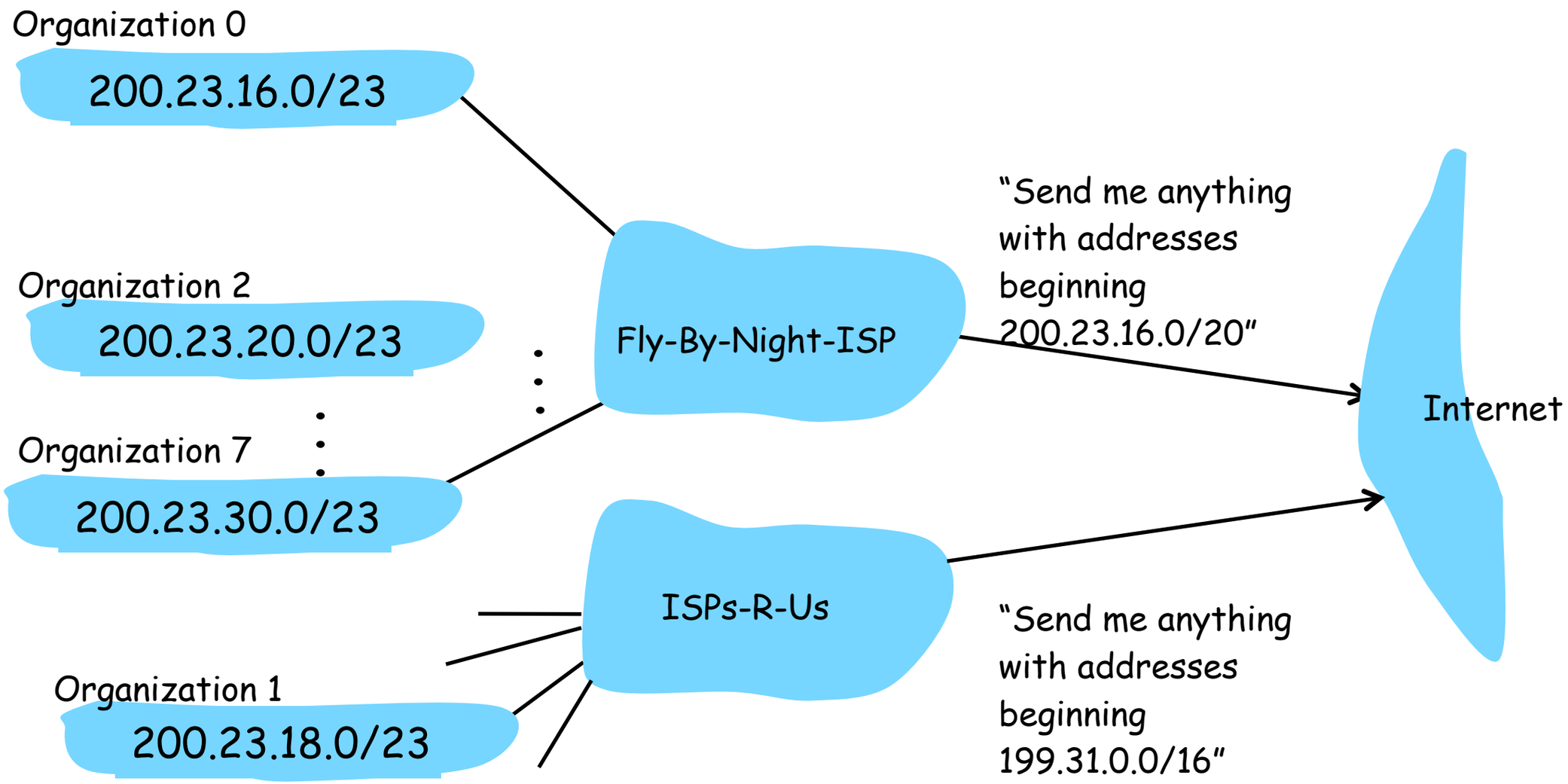


Hierarchical addressing: route aggregation

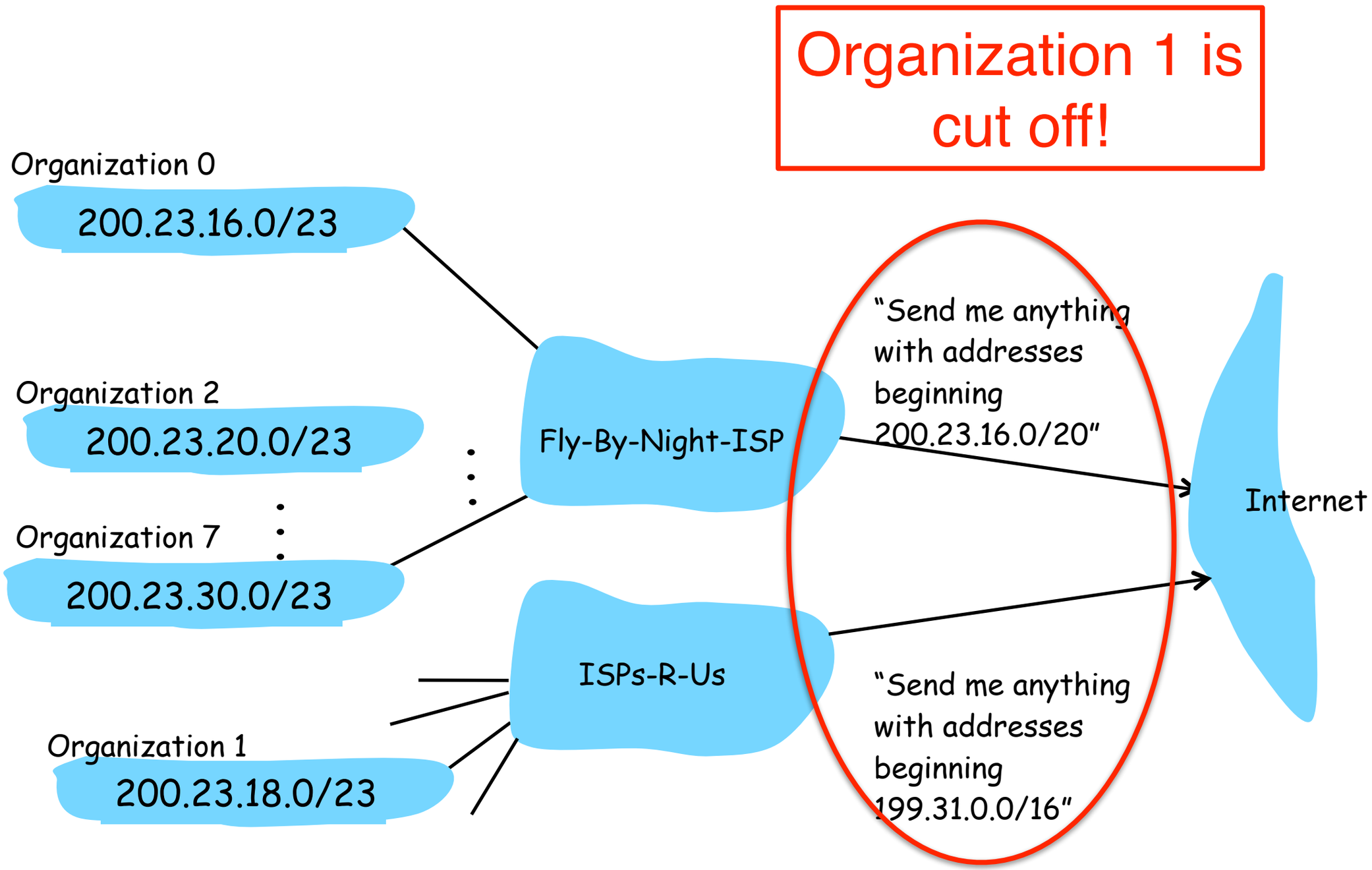
Hierarchical addressing allows efficient advertisement of routing information:



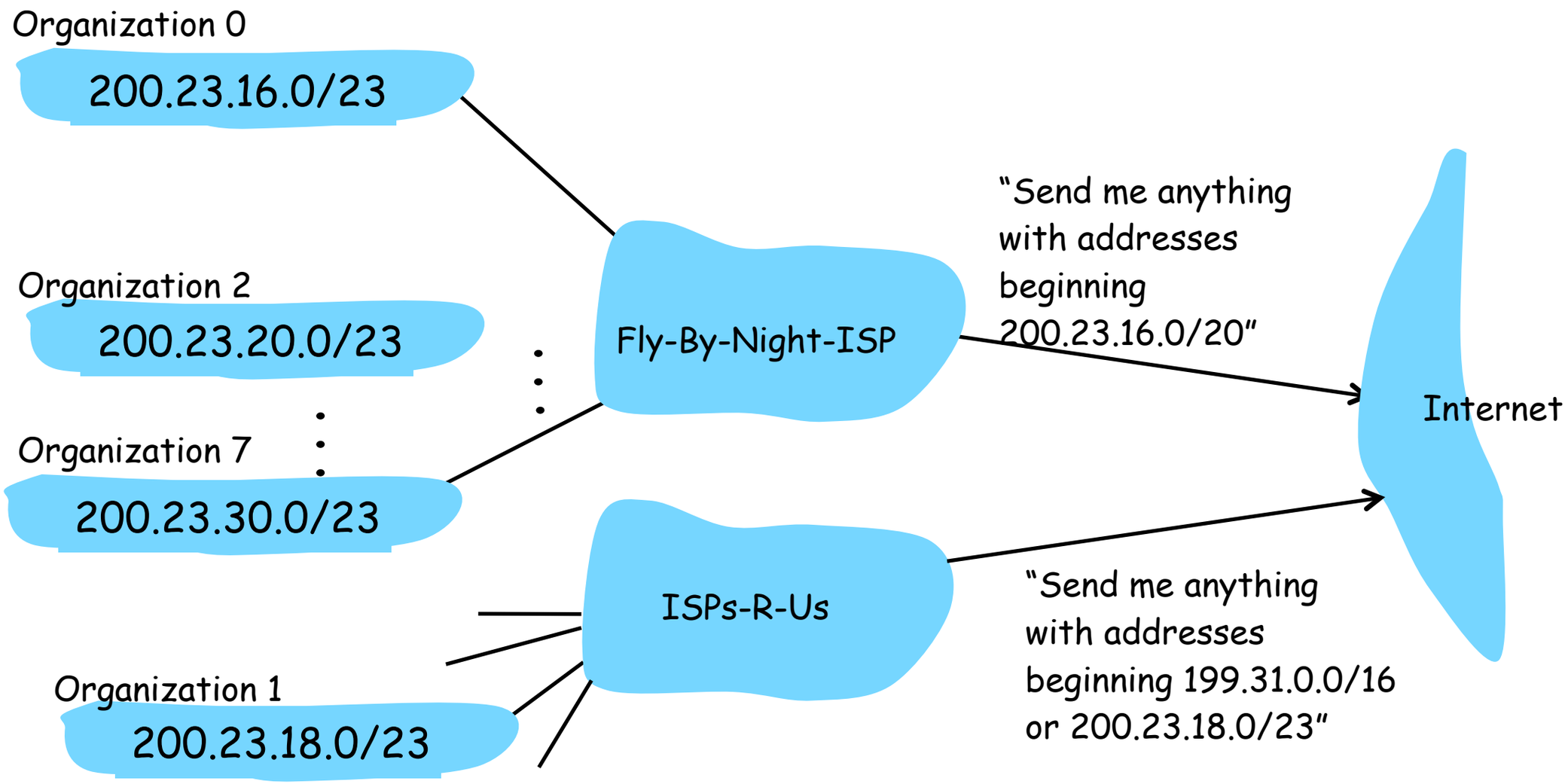
Hierarchical addressing



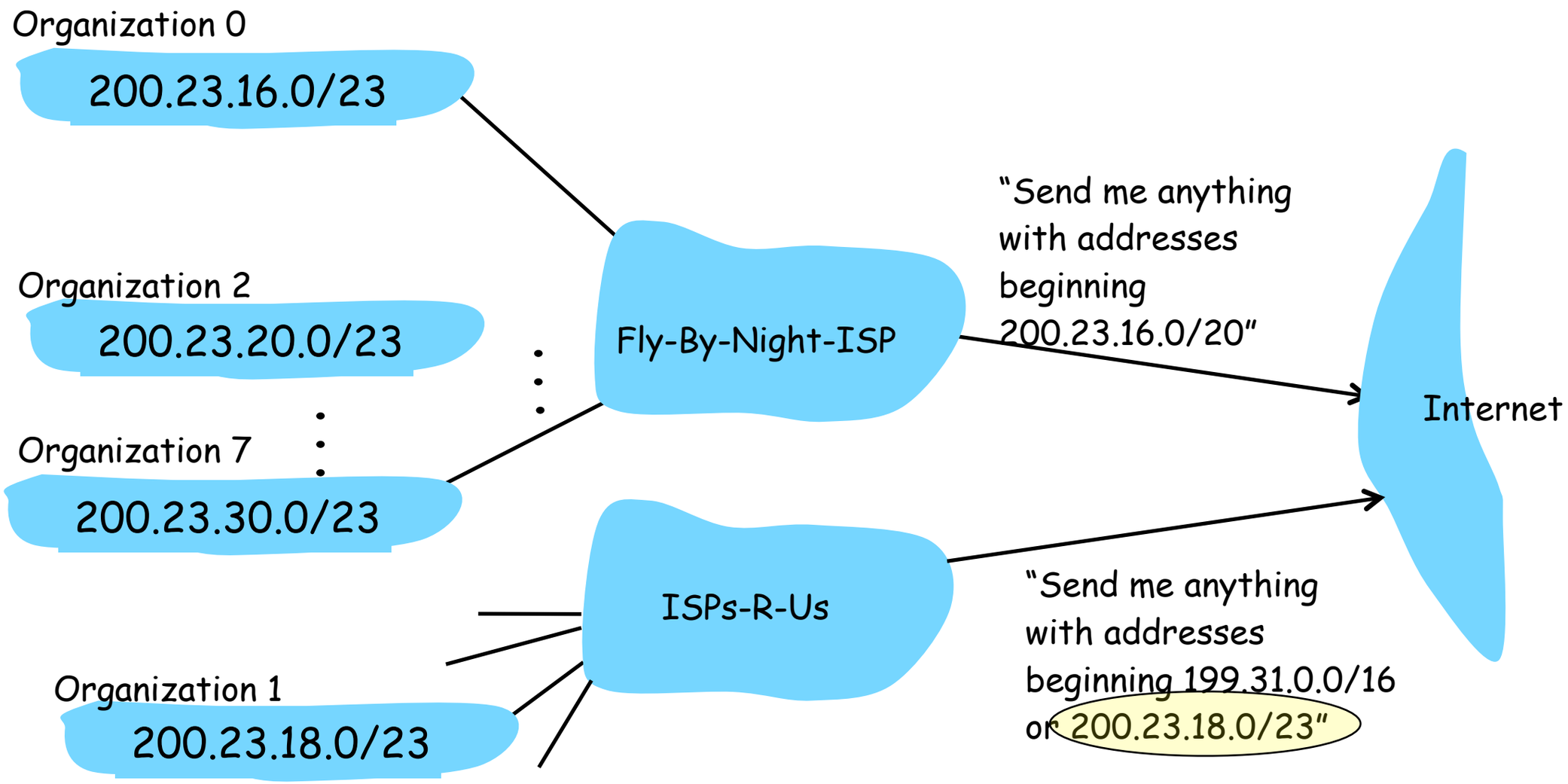
Hierarchical addressing



Hierarchical addressing

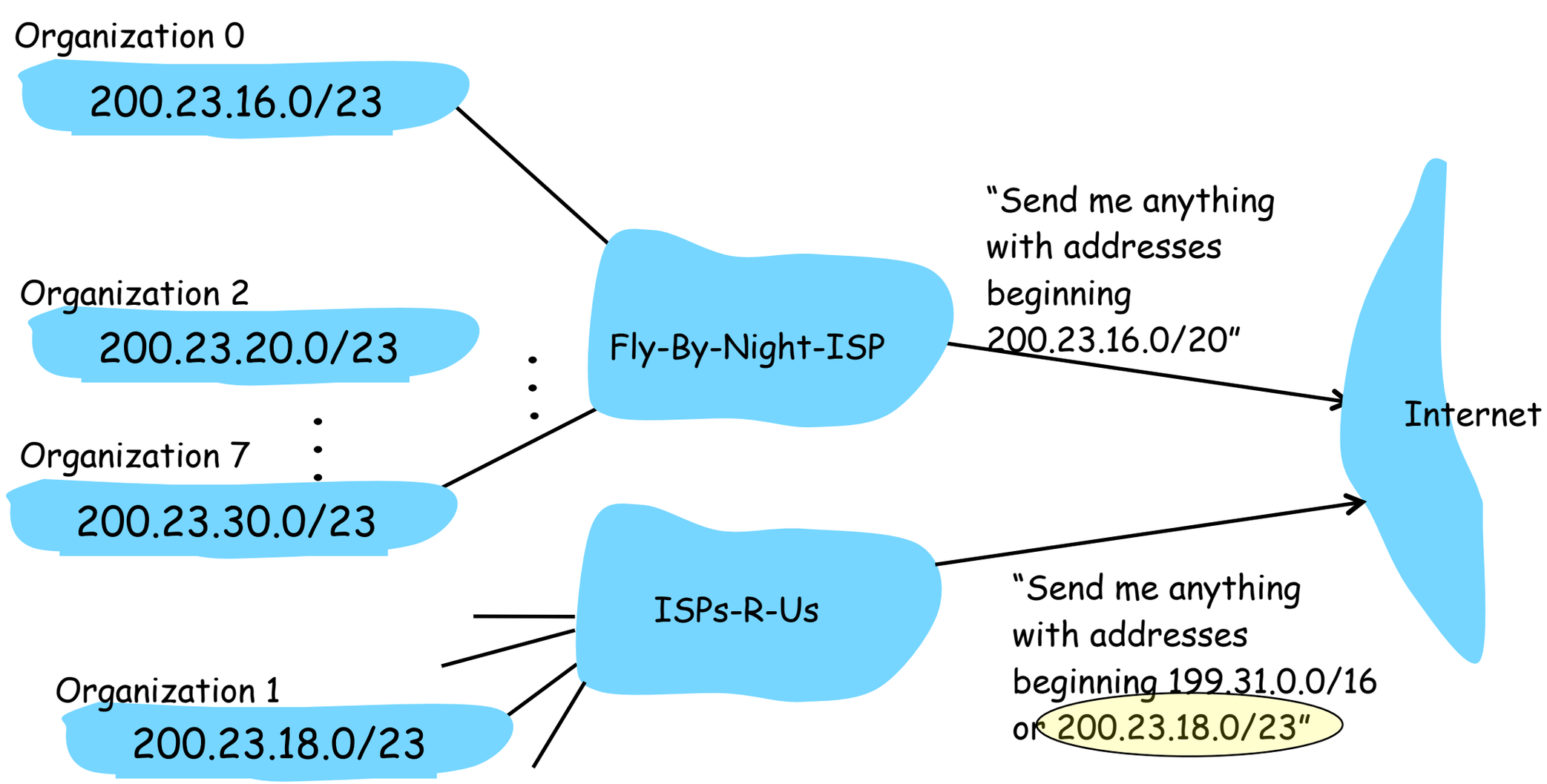


Hierarchical addressing



Hierarchical addressing

ISPs-R-Us has a more specific route to Organization 1



IP addresses: how to assign?

Q: How do we assign a host an IP address?

IP addresses: how to assign?

Q: How do we assign a host an IP address?

- hard-coded by system admin in a file
  - Windows: control-panel->network->configuration->tcp/ip->properties
  - UNIX: /etc/rc.config

IP addresses: how to assign?

Q: How do we assign a host an IP address?

- hard-coded by system admin in a file
  - Windows: control-panel->network->configuration->tcp/ip->properties
  - UNIX: /etc/rc.config
- DHCP: Dynamic Host Configuration Protocol: dynamically get address from as server
  - "plug-and-play"

DHCP: Dynamic Host Configuration Protocol

DHCP: Dynamic Host Configuration Protocol

Goal: allow host to dynamically obtain its IP address from network server when it joins network

DHCP: Dynamic Host Configuration Protocol

Goal: allow host to dynamically obtain its IP address from network server when it joins network

Why?

DHCP: Dynamic Host Configuration Protocol

Goal: allow host to dynamically obtain its IP address from network server when it joins network

Why?

- Ease admin burden
- Can renew its lease on address in use
- Allows reuse of addresses (only hold address while connected and "on")
- Support for mobile users who want to join network

DHCP: Dynamic Host Configuration Protocol

DHCP: Dynamic Host Configuration Protocol

- Conundrum: if we don't have an IP address, how can we communicate over the network?
  - who do we ask for an address?
  - who do they tell about an available address?

DHCP: Dynamic Host Configuration Protocol

- Conundrum: if we don't have an IP address, how can we communicate over the network?
  - who do we ask for an address?
  - who do they tell about an available address?

- Bootstrap using broadcast
  - i.e., messages destined for everyone on a network instead of a single server

DHCP: Dynamic Host Configuration Protocol

- Conundrum: if we don't have an IP address, how can we communicate over the network?
  - who do we ask for an address?
  - who do they tell about an available address?

- Bootstrap using broadcast
  - i.e., messages destined for everyone on a network instead of a single server
- Communication between two specific hosts is referred to as unicast

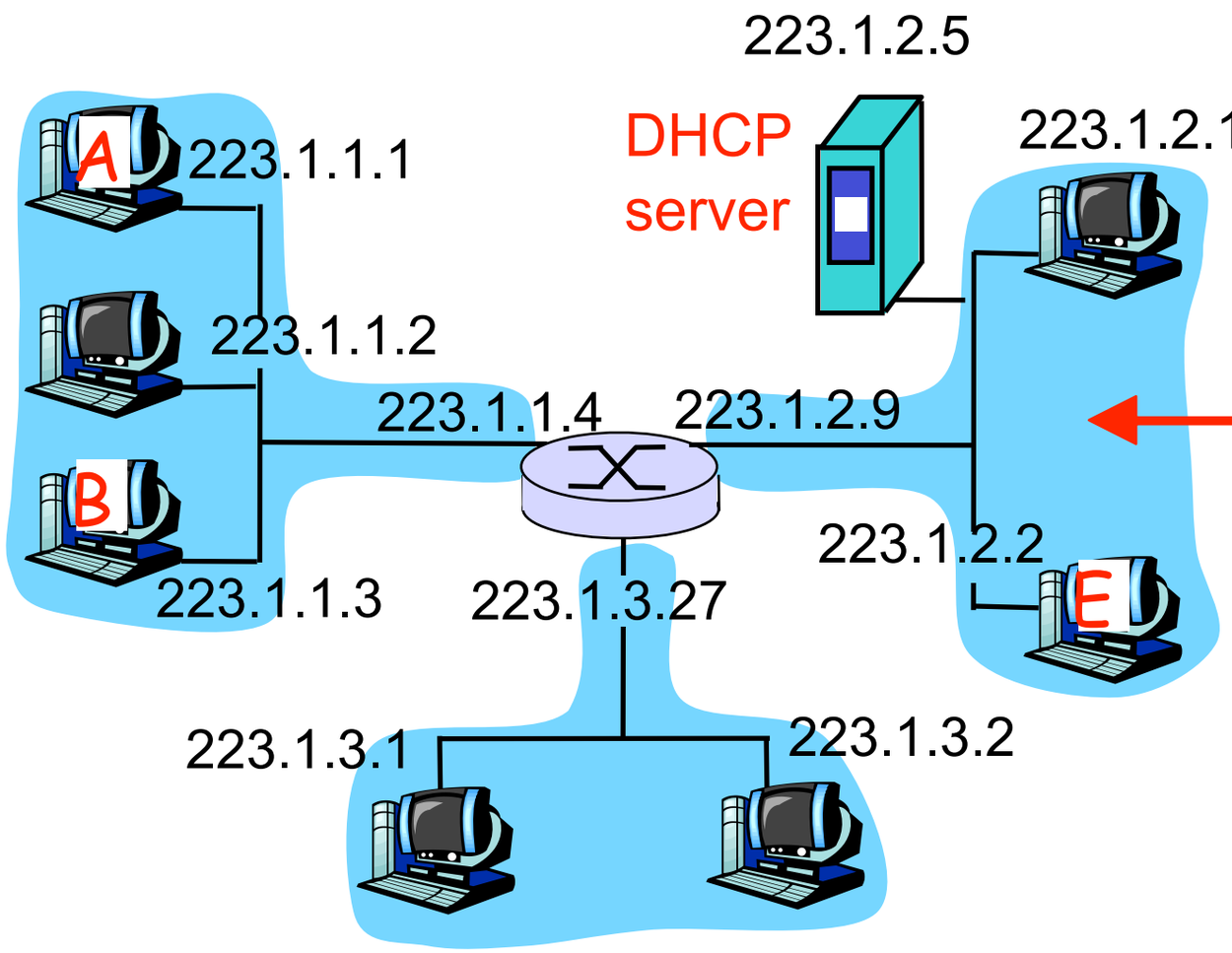
DHCP: Dynamic Host Configuration Protocol

DHCP: Dynamic Host Configuration Protocol

DHCP overview:

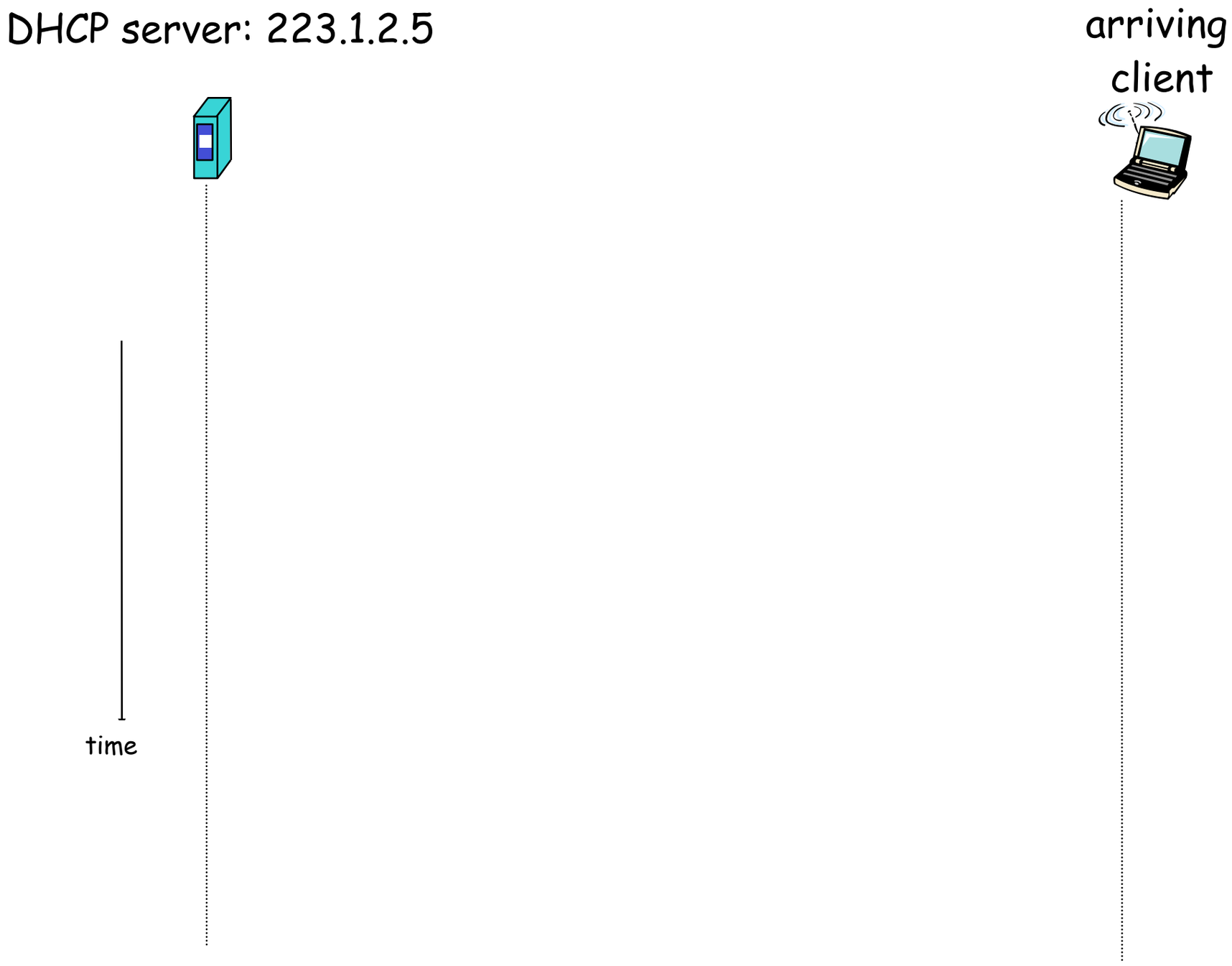
- host broadcasts "DHCP discover" msg [optional]
- DHCP server responds with "DHCP offer" msg [optional]
- host requests IP address: "DHCP request" msg
- DHCP server sends address: "DHCP ack" msg

DHCP client-server scenario

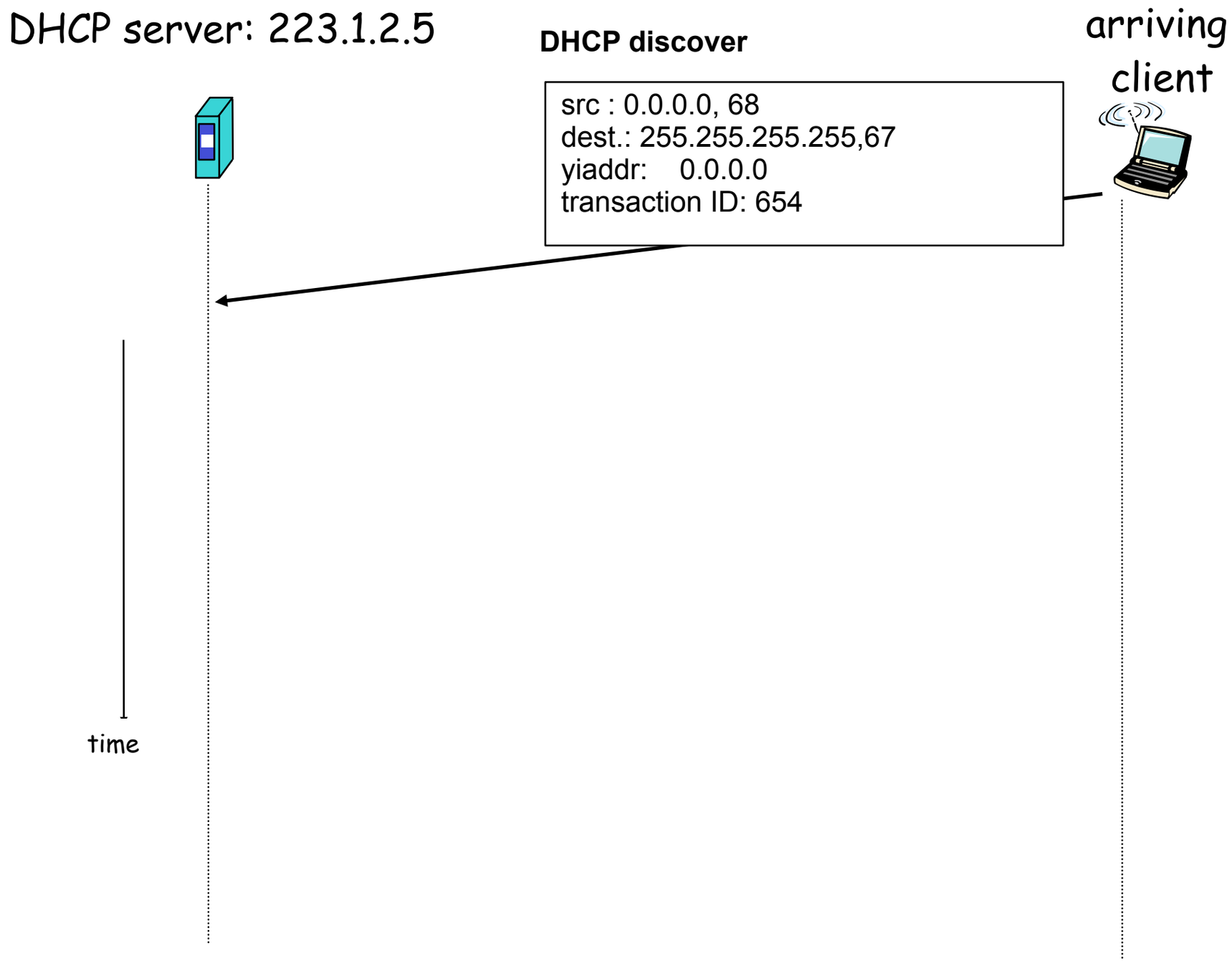


arriving DHCP client needs address in this network

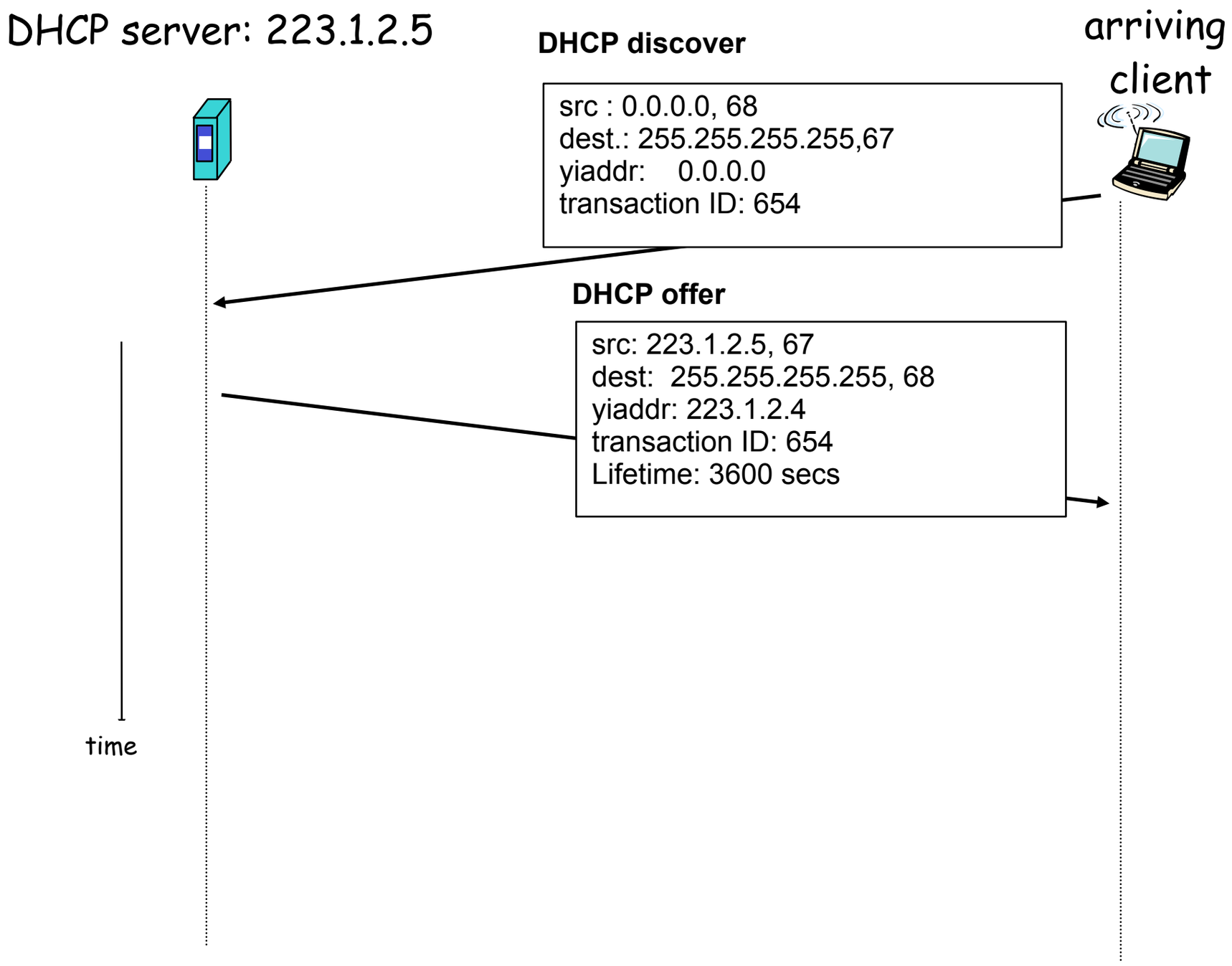
DHCP client-server scenario



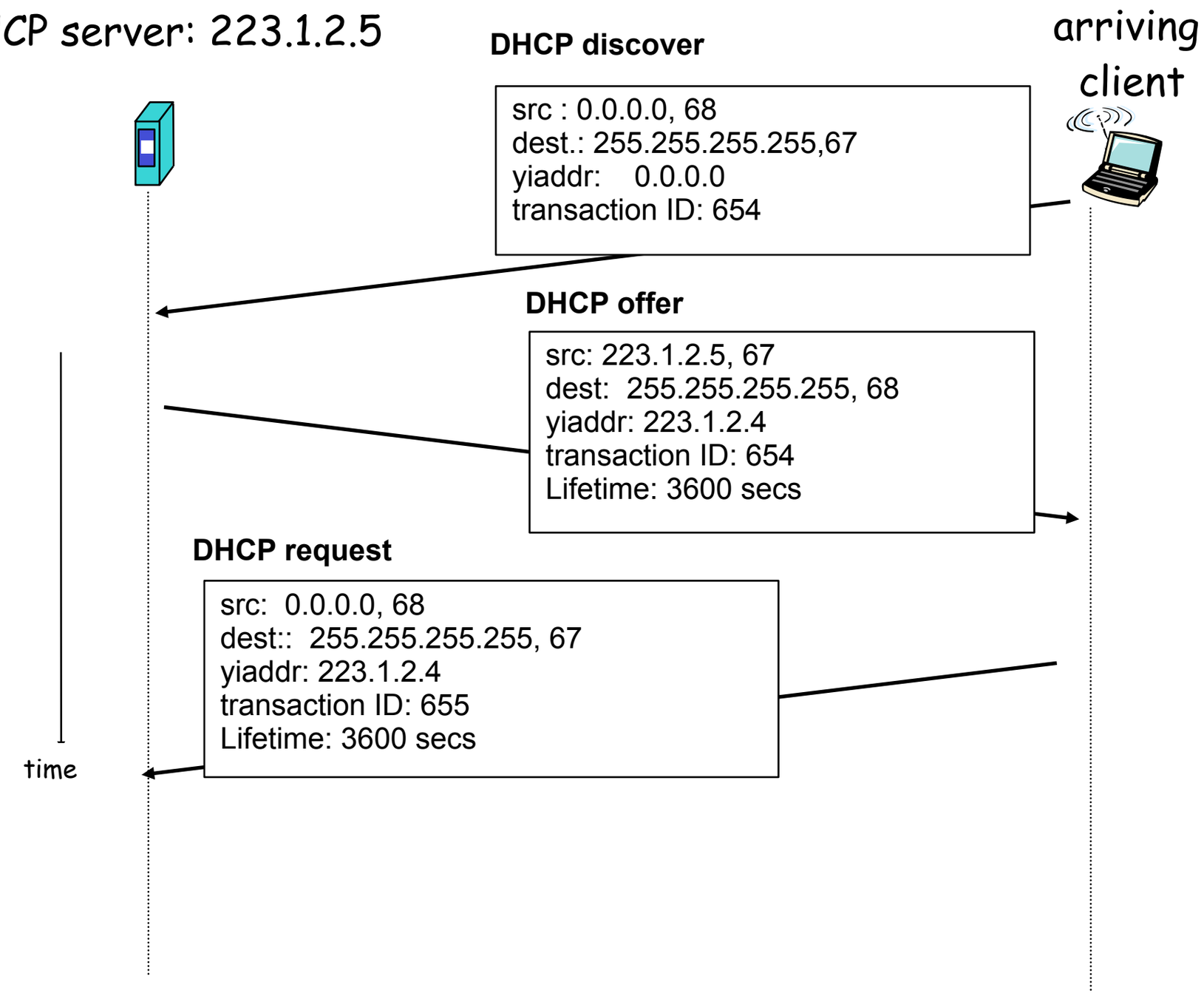
DHCP client-server scenario



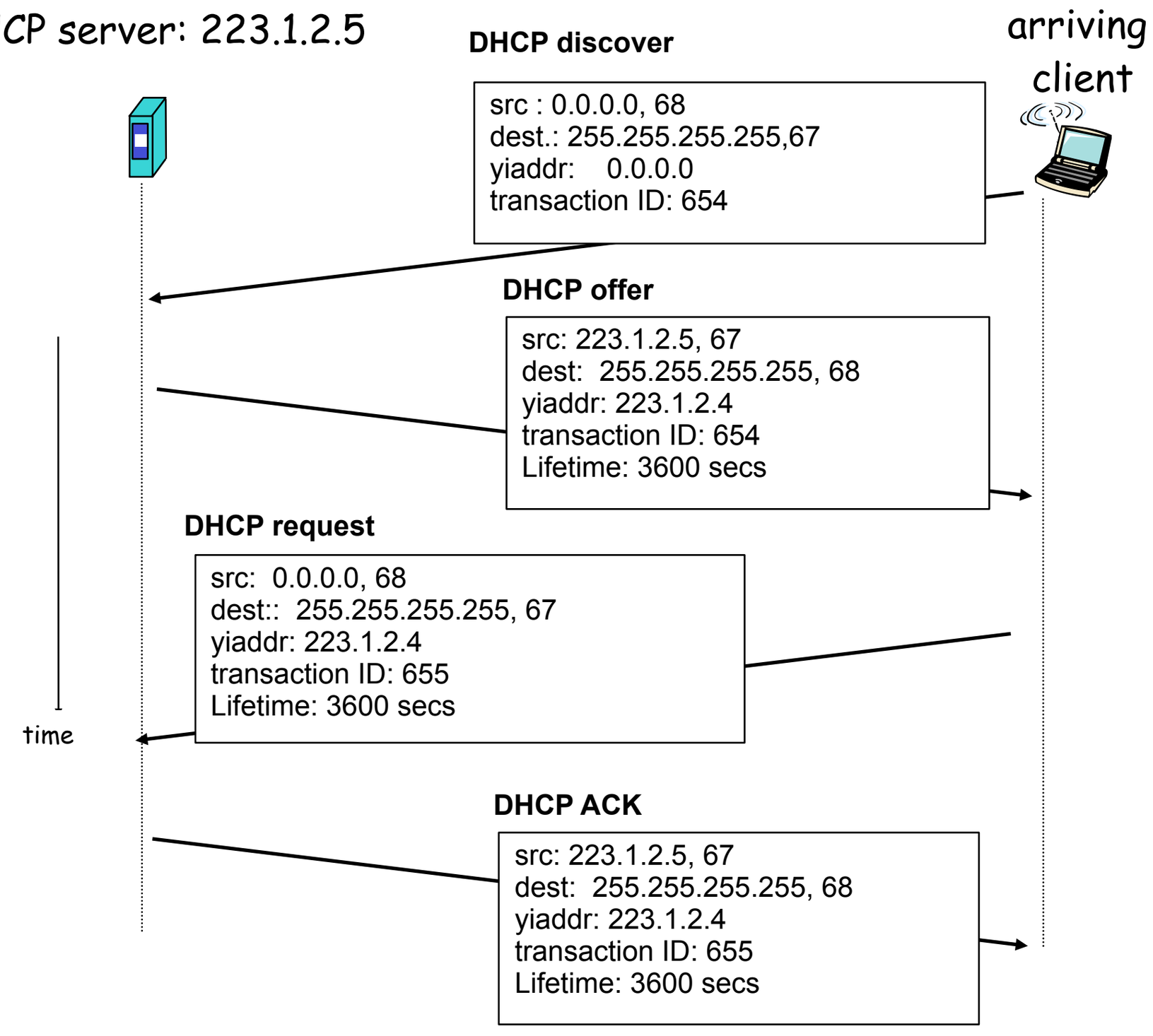
DHCP client-server scenario



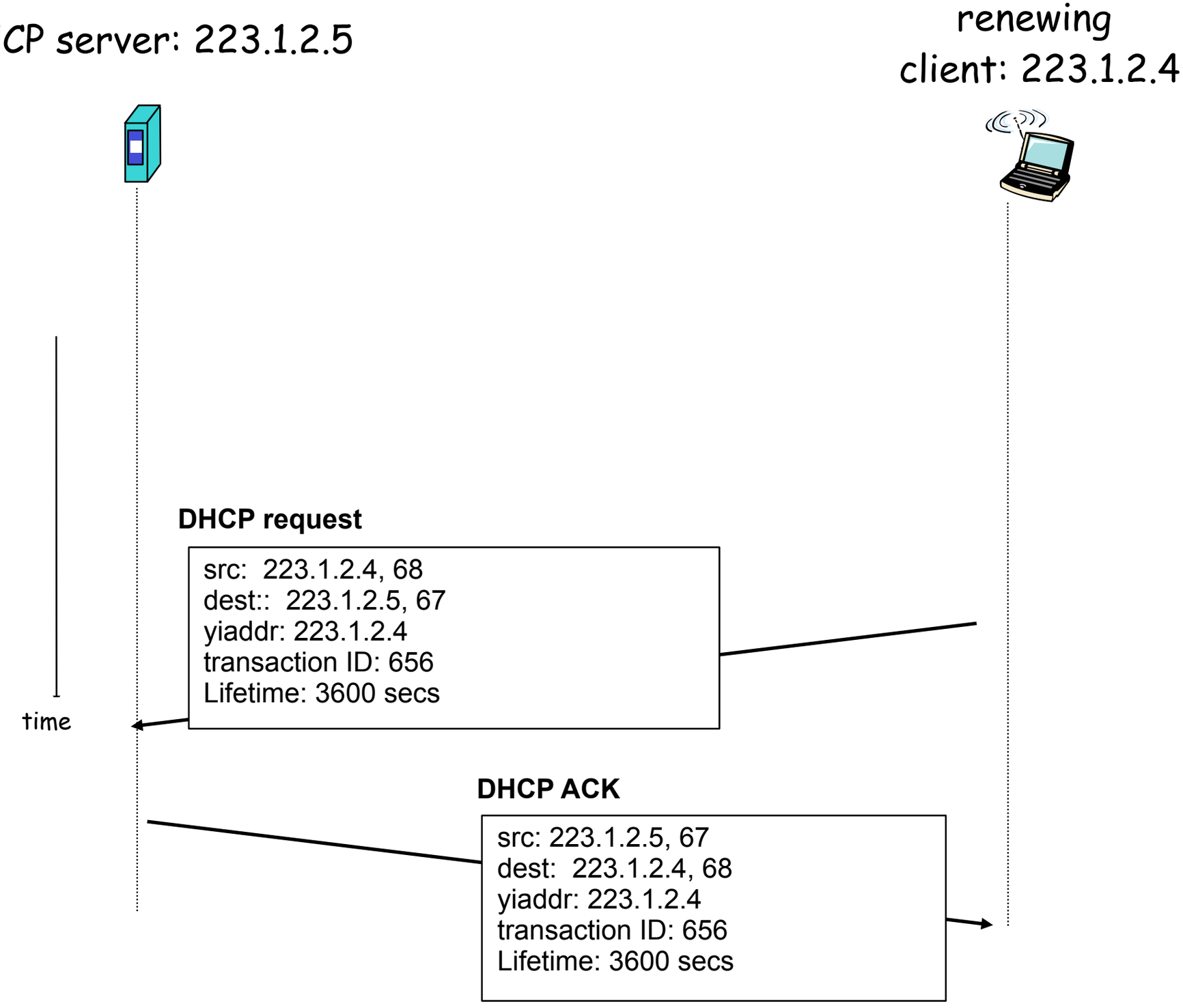
DHCP client-server scenario



DHCP client-server scenario



DHCP renewal process



DHCP: more than IP address

DHCP: more than IP address

DHCP can return more than just allocated IP address on subnet:

- address of first-hop router for client
- name and IP address of DNS sever
- network mask (indicating network versus host portion of address)

DHCP: Thought questions

DHCP: Thought questions

- What if you already have a DHCP address and ask for another?

DHCP: Thought questions

- What if you already have a DHCP address and ask for another?
- How long should the lease be?

DHCP: Thought questions

- What if you already have a DHCP address and ask for another?
- How long should the lease be?
- How do you know to believe the server that answers?

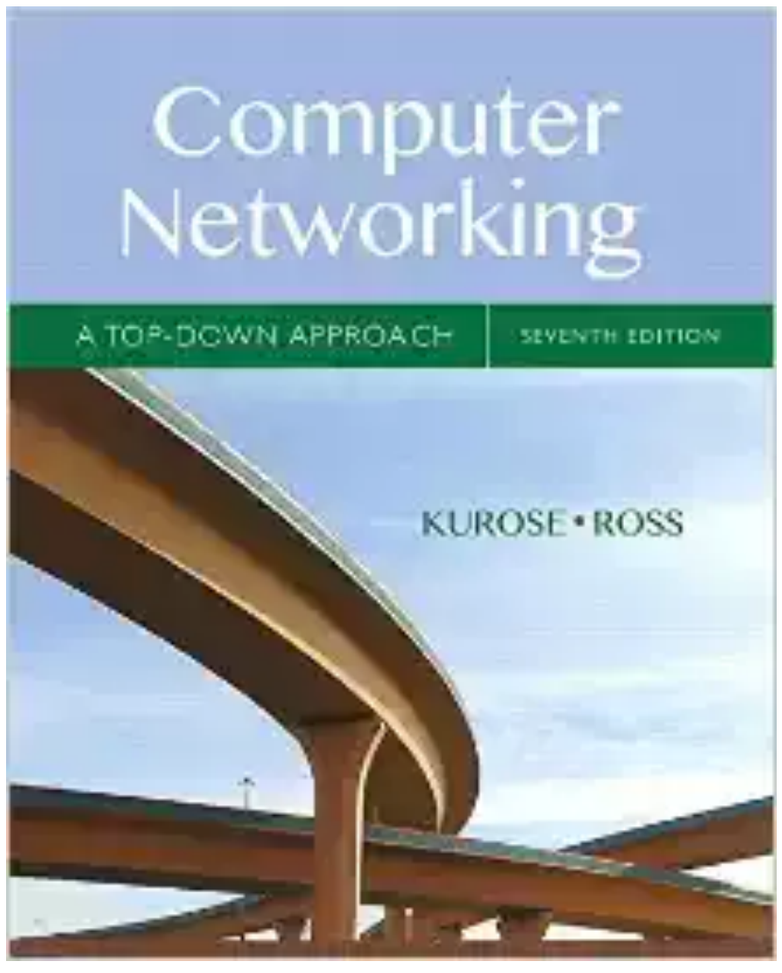
DHCP: Thought questions

- What if you already have a DHCP address and ask for another?
- How long should the lease be?
- How do you know to believe the server that answers?
- What if someone statically configures IP address X and then a DHCP server gives out the same address?

DHCP: Thought questions

- What if you already have a DHCP address and ask for another?
- How long should the lease be?
- How do you know to believe the server that answers?
- What if someone statically configures IP address X and then a DHCP server gives out the same address?
- Doesn't DHCP hinder accountability?

Reading Along ...



- Network layer is chapters 4 & 5
  - Address shortage

Addresses

Addresses

- Crucial resource within networks
  - original vision: every host would have a globally unique network layer address
  - a peer-to-peer network

Addresses

- Crucial resource within networks
  - original vision: every host would have a globally unique network layer address
  - a peer-to-peer network
- But, addresses grew scarce

Addresses

Addresses

- What to do about address scarcity?

Addresses

- What to do about address scarcity?

- CIDR
  - Allocate addresses we have more intelligently

Addresses

- What to do about address scarcity?

- CIDR
  - Allocate addresses we have more intelligently

- IPv6
  - Invent more addresses

Addresses

- What to do about address scarcity?

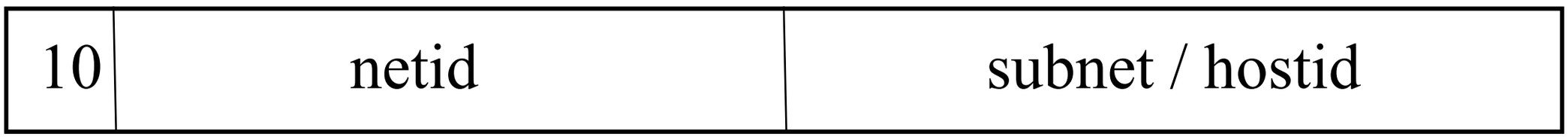
- CIDR
  - Allocate addresses we have more intelligently
- IPv6
  - Invent more addresses
- NAT / CGN
  - Share addresses we have

Classful Address Allocation

Class A: /8

16.7M addrs

Class B: /16

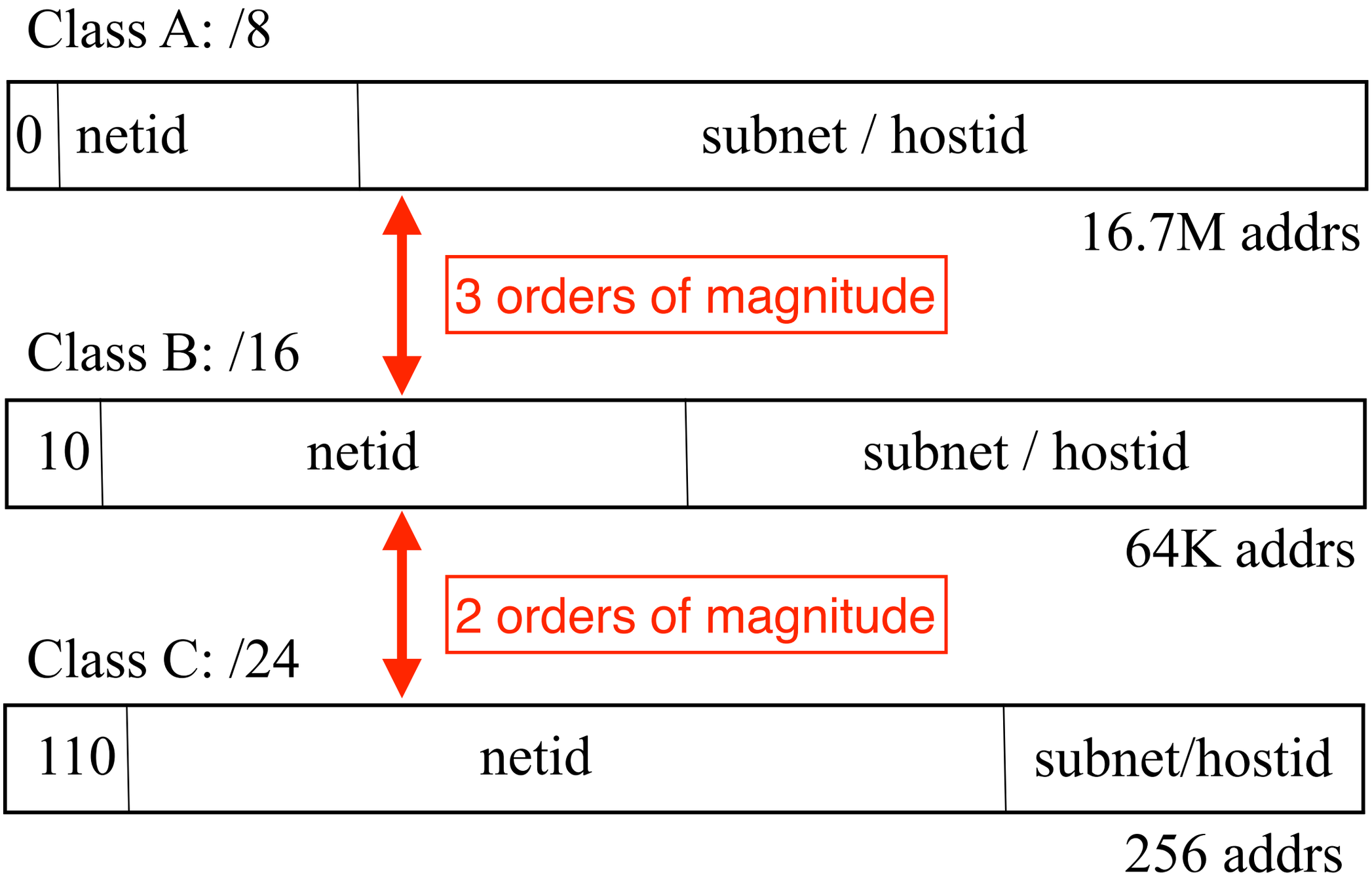


64K addrs

Class C: /24

256 addrs

Classful Address Allocation



IP addressing: CIDR

CIDR: Classless InterDomain Routing

- stopped massively coarse IP block assignment
- netid portion of address of arbitrary length
- address format: a.b.c.d/x, where x is # bits in netid portion of address

200.23.16.0/23

CIDR

- CIDR helped
  - a lot!
- CIDR bought us a bunch of time

IPv6

IPv6

- Initial motivation: 32-bit address space was growing thin

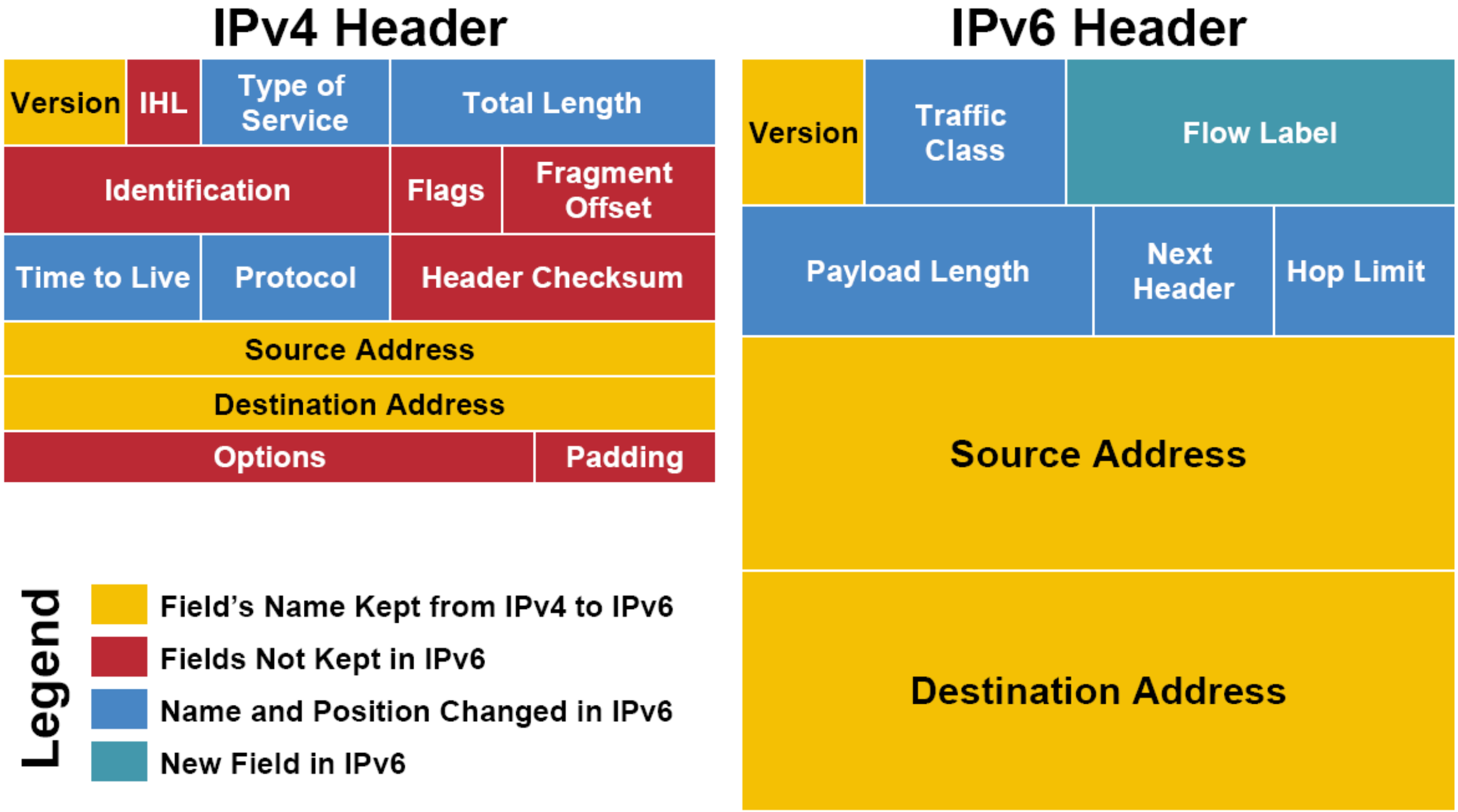
IPv6

- Initial motivation: 32-bit address space was growing thin
- Now: 32-bit IPv4 address space is completely allocated

IPv6

- Initial motivation: 32-bit address space was growing thin
- Now: 32-bit IPv4 address space is completely allocated
- Additional motivation:
  - while we're at it, let's incorporate some lessons we learned from IPv4

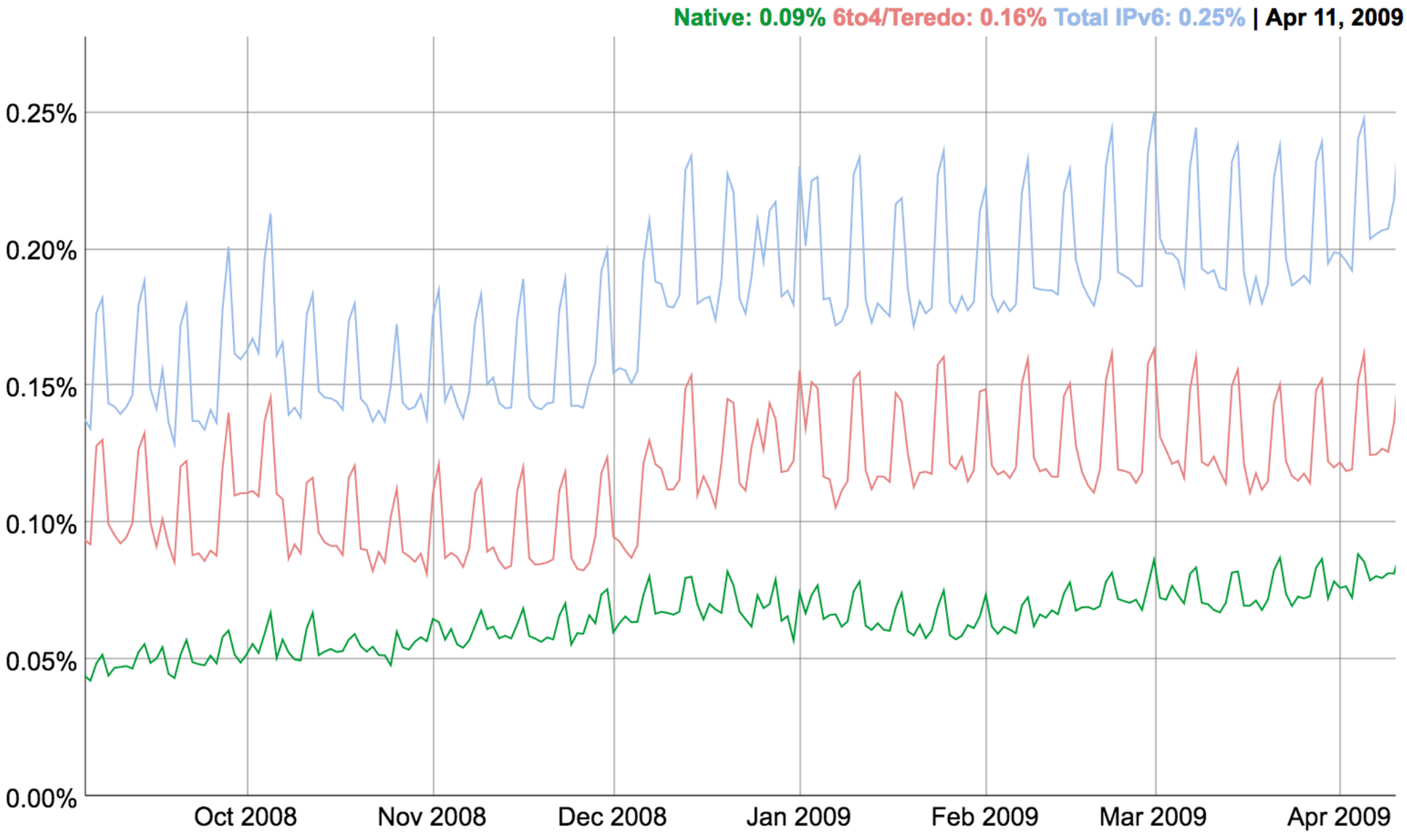
IPv4 vs. IPv6


IPv4 Header
Version
IHL
Type of Service
Total Length
Identification
Flags
Fragment Offset
Time to Live
Protocol
Header Checksum
Source Address
Destination Address
Options
Padding
IPv6 Header
Version
Traffic Class
Flow Label
Payload Length
Next Header
Hop Limit
Source Address
Destination Address
Legend
Field's Name Kept from IPv4 to IPv6
Fields Not Kept in IPv6
Name and Position Changed in IPv6
New Field in IPv6

Transition From IPv4 To IPv6

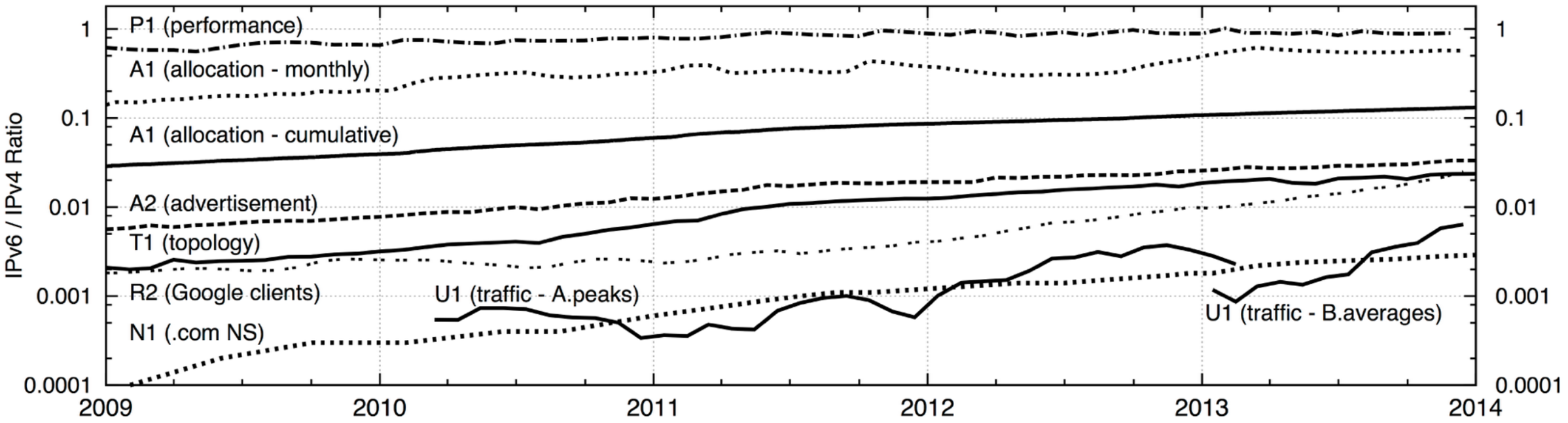
- Not all routers can be upgraded simultaneous
  - no "flag days"
  - How will the network operate with mixed IPv4 and IPv6 routers?
- Initial strategy: tunneling
  - IPv6 carried as payload in IPv4 datagram among IPv4 routers

IPv6 Roll Out



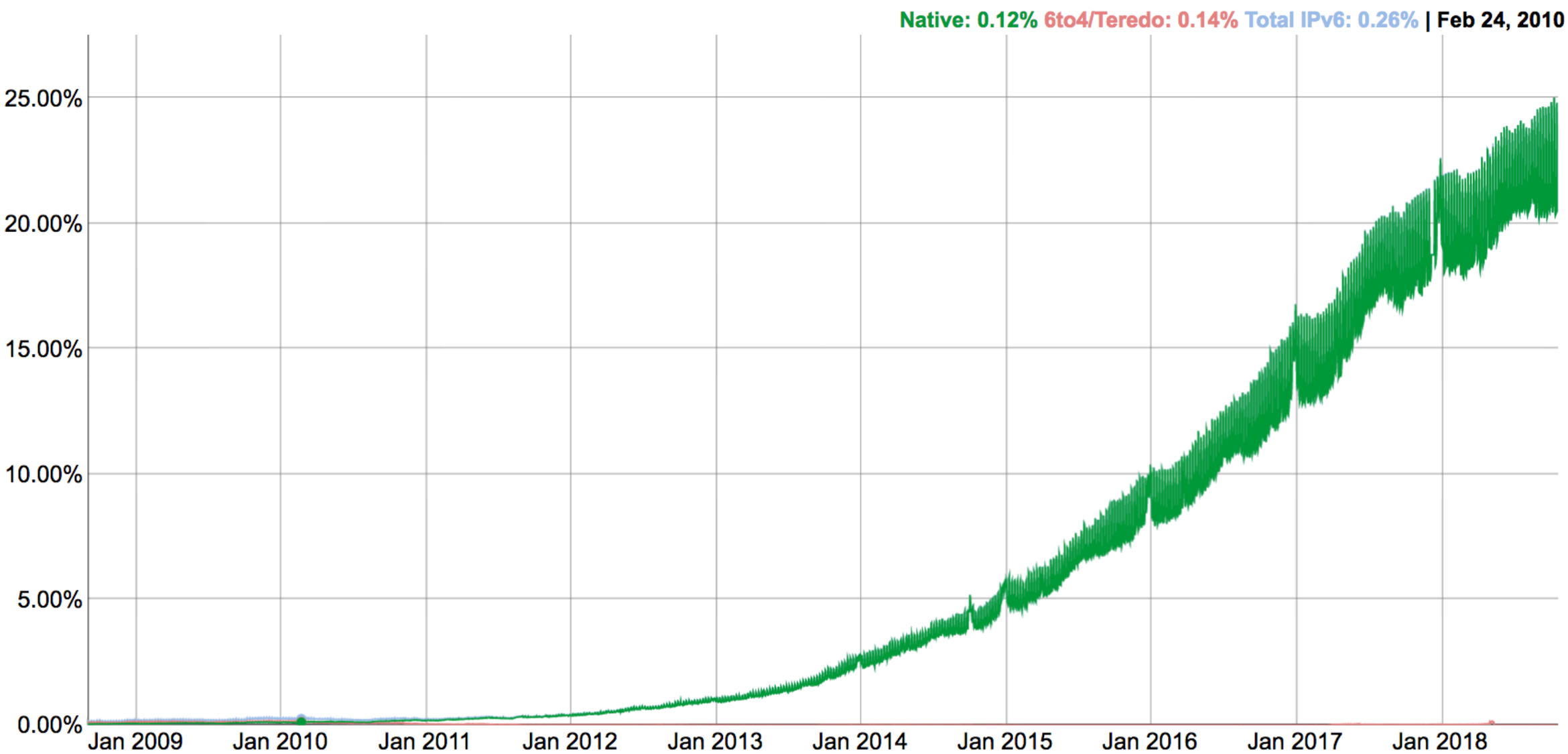
Google

State of IPv6



Czyz, et.al., *Measuring IPv6 Adoption*, SIGCOMM 2014

IPv6 Current Availability



Google

IPv6 Lesson

- It is difficult to change the tires while the car is moving

- We need to think hard about transition to new technology

- We need to think about planning for transition when we build technology

Can We Better Use 32-bit Addresses?

- IPv6 is not yet ubiquitous
  - after 20+ years!

- And, now we're out of IPv4 addresses for real

- So, how can we cope?