CSE 43: Computer Networks
NAT, ICMP, IPv6

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November 9, 2017

Recall: IPv4 Addresses

- 32-bit number, must be *globally unique*
- 2^{32} => 4,294,967,296 possible addresses
- How many do you have?

Address Scarcity

RIPE NCC Begins to Allocate IPv4 Address Space From the Last /8

14 Sep 2012

On Friday 14 September, 2012, the RIPE NCC, the Regional Internet Registry (RIR) for Europe, the Middle East and parts of Central Asia, distributed the last blocks of IPv4 address space from the available pool.

This means that we are now distributing IPv4 address space to Local Internet Registries (LIRs) from the last /8 according to section 5.6 of "IPv4 Address Allocation and Assignment Policies for the RIPE NCC Service Region".

This section states that an LIR may receive one /22 allocation (1,024 IPv4 addresses), even if they can justify a larger allocation. This /22 allocation will only be made to LIRs if they have already received an IPv6 allocation from an upstream LIR or the RIPE NCC. No new IPv4 Provider Independent (PI) space will be assigned.

It is now imperative that all stakeholders deploy IPv6 on their networks to ensure the continuity of their online operations and the future growth of the Internet.

More information on IPv6 and its deployment, advice from experts and where to get training

More information on reaching the last /8

CORE NETWORKING AND SECURITY

By Scott Hogg

About

Scott Hogg is the CTO for Global Technology Resources, Inc. (GTRI). Scott provides network engineering, security consulting, and training services to his clients.

OPINION

ARIN Finally Runs Out of IPv4 Addresses

IPv4 Address Cupboards are Bare in North America.

Network World | Sep 22, 2015 7:25 AM PT

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ARIN's registry and transfer policies can help bridge the gap from IPv4 to IPv6

on IDG Answers

If I buy a Chromebook and can't get to grips with OS can I convert to windows?

It is often said, "the Internet is running out of phone numbers," as a way to express that the Internet is running out of IPv4 addresses, to those who are unfamiliar with Internet technologies. IPv4 addresses, like phone numbers are assigned hierarchically, and thus, have inherent inefficiency. The world's Internet population has been growing and the number of Internet-connected devices continues to rise, with no end in sight. In the next week, the American Registry for Internet Numbers (ARIN) will have exhausted their supply of IPv4 addresses. The metaphorical IPv4 cupboards are bare. This long-predicted Internet historical event marks opening a new chapter of the Internet's evolution. However, it is somehow anti-climactic now that this date has arrived. The Internet will continue to operate, but all organizations must now accelerate their efforts to deploy IPv6.

INSIDER

Network jobs are hot; salaries expected to rise in 2016

Wireless network

ARIN IPv4 Address Exhaustion

The Internet Assigned Numbers Authority (IANA) delegates authority for Internet resources to the five RIRs that cover the world. The American Registry for Internet Numbers (ARIN) is the Regional Internet Registry (RIR) for the United States, Canada, the Caribbean, and North Atlantic islands. ARIN has been managing the assignment of IPv4 and IPv6 addresses and Autonomous System (AS) numbers for several decades. Each RIR has been managing their limited IPv4 address stores and going through their various phases of exhaustion policies. ARIN has been in Phase 4 of their IPv4 depletion plan for more than a year now. ARIN will soon announce that they have completely extinguished their supply of IPv4 addresses.

Seriously, we're done now. We're done

Exhausted with never-ending internet exhaustion

By Kieren McCarthy in San Francisco 15 Feb 2017 at 23:07 214 SHARE ▼

You may have heard this before, but we are really, really running out of public IPv4 addresses.

This week, the regional internet registry responsible for Latin America and the Caribbean, LACNIC, announced it has moved to "phase 3" of its plan to dispense with the remaining network addresses, meaning that only companies that have not received any IPv4 space are eligible. There is no phase 4.

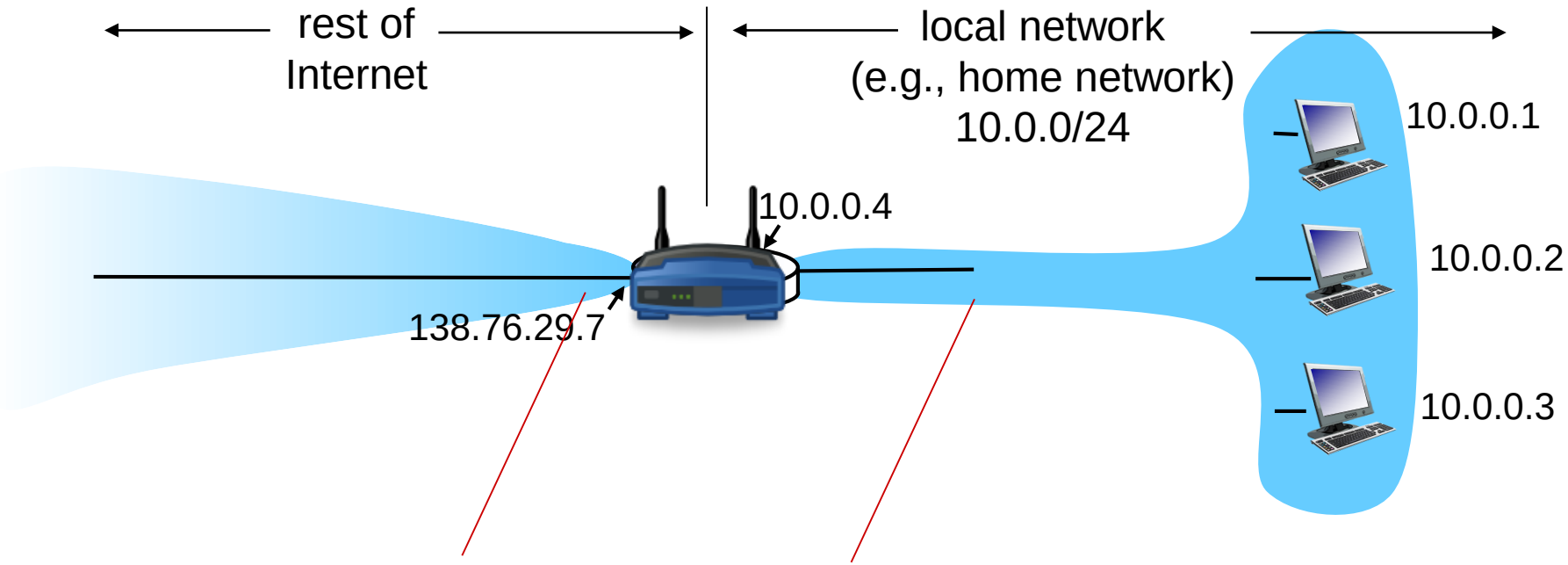
That means LACNIC is down to its last 4,698,112 public IPv4 addresses (although that may increase as it recovers a little bit of space over time).

Private Addresses

- Defined in RFC 1918:
  - 10.0.0.0/8 (16,777,216 hosts)
  - 172.16.0.0/12 (1,048,576 hosts)
  - 192.168.0.0/16 (65536 hosts)

- These addresses shouldn’t be routed.
  - Anyone can use them.
  - Often adopted for use with NAT.

NAT: Network Address Translation



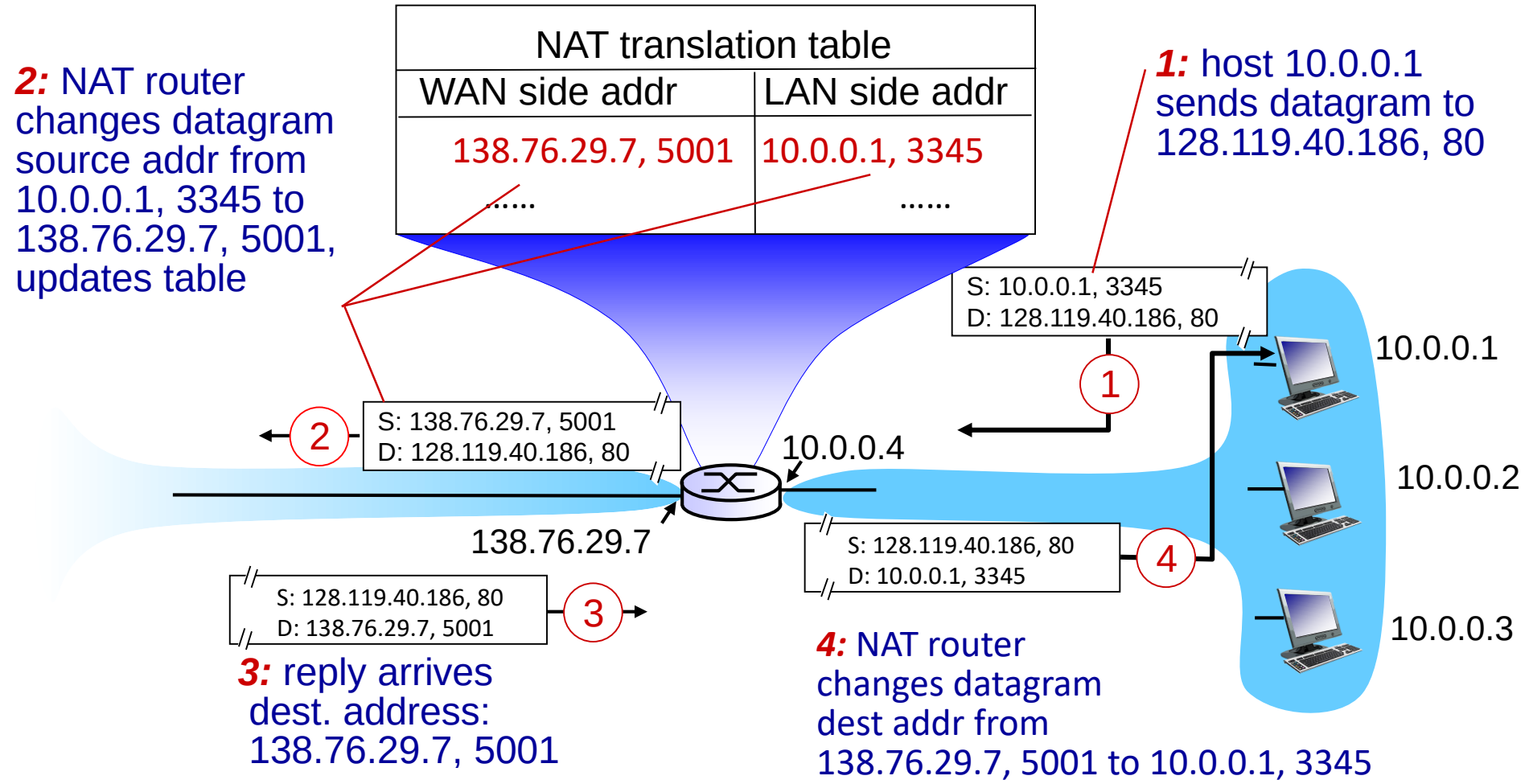
all datagrams *leaving* local network have *same* single source NAT IP address: 138.76.29.7,different source port numbers

datagrams with source or destination in this network have 10.0.0/24 address for source, destination (as usual)

Implementing NAT

- *Outgoing datagrams: replace* (source IP address, port #) of every outgoing datagram to (NAT IP address, new port #)
  - remote clients/servers will respond using (NAT IP address, new port #) as destination address
- *Record (in NAT translation table)* every (source IP address, port #) to (NAT IP address, new port #) translation pair
- *Incoming datagrams: replace* (NAT IP address, new port #) in dest fields of every incoming datagram with corresponding (source IP address, port #) stored in NAT table

NAT: network address translation



NAT: network address translation

NAT translation table	
WAN side addr	LAN side addr
138.76.29.7, 5001	10.0.0.1, 3345

Neither the sender nor receiver need to know that NAT is happening…

10.0.0.1

10.0.0.2

10.0.0.3

D: 138.76.29.7, 5001

4: NAT router changes datagram dest addr from 138.76.29.7, 5001 to 10.0.0.1, 3345

NAT Advantages

- Organizations need fewer IP addresses from their ISP.
  - With a 16-bit port field, we can put 65535 connections behind one external IP address!

- Organizations can change internal network IPs without having to change outside world IPs.

What about the following statement?

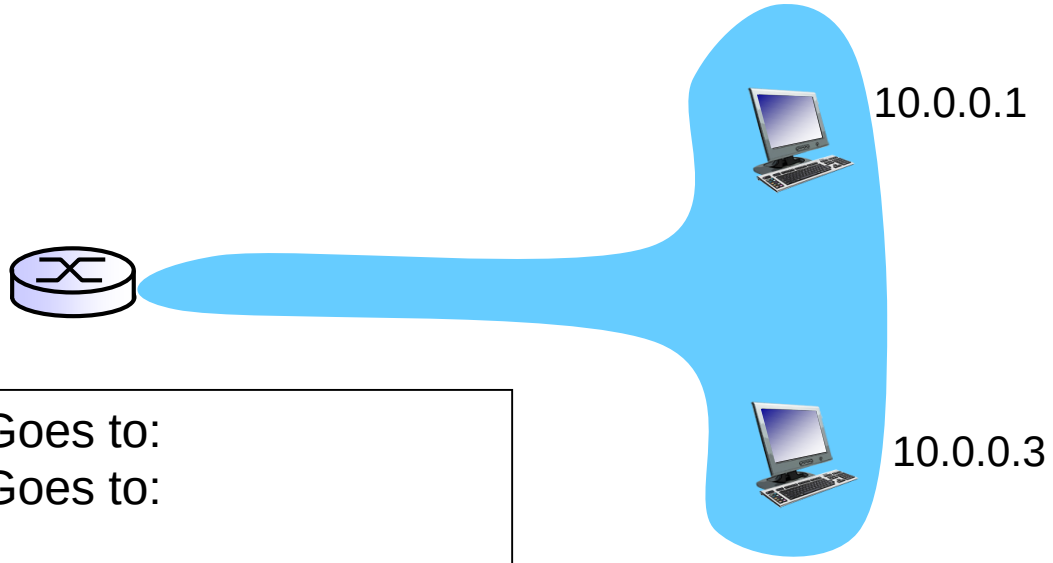
Devices inside the local network are not explicitly addressable or visible to the outside world.

A. This is an advantage.

B. This is a disadvantage.

Port Forwarding

- What if we wanted to run a web server on both these hosts?



In port:	Goes to:
In port:	Goes to:
…	

How do we feel about NAT?

A. NAT is great! It conserves IP addresses and makes it harder to reach non-public machines.

B. NAT is mostly good, but has a few negative features. No big deal.

C. NAT is mostly bad, but in some cases, it's a necessary evil.

D. NAT is an abomination that violates the end to end principle, and we should not use it!

IPv6

- *Initial motivation:* 32-bit address space soon to be completely allocated, any day now™.

- Additional motivation:
  - header format helps speed processing/forwarding
  - header changes to facilitate QoS

IPv6 datagram format:

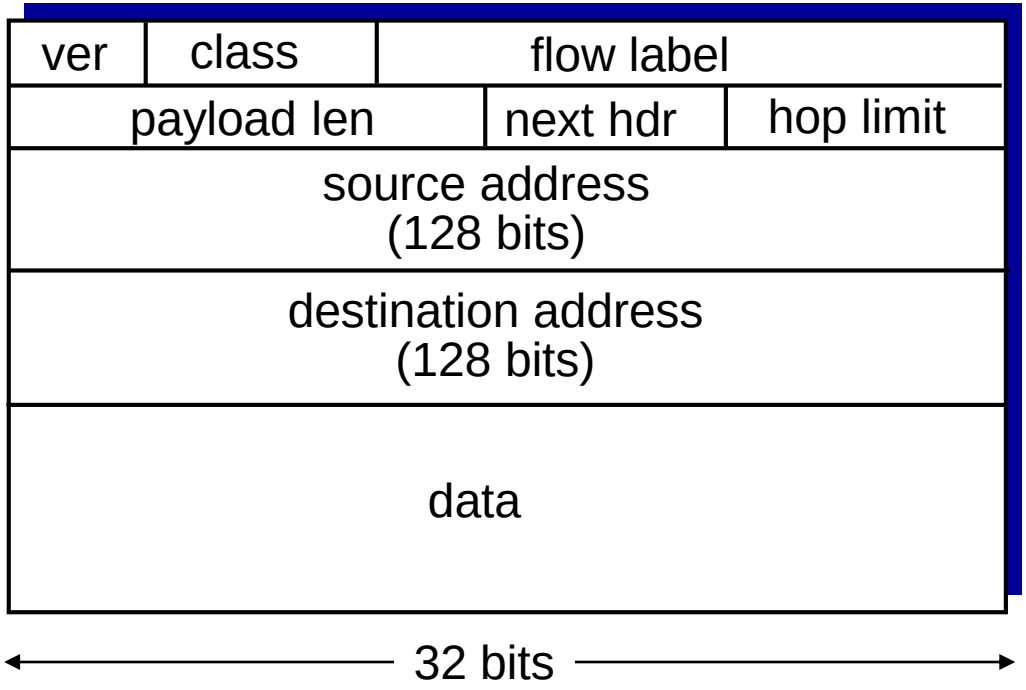
  - fixed-length 40 byte header
  - no fragmentation allowed

IPv6 datagram format

class: identify class/priority of packet

flow label: identify datagrams in same "flow." (purpose of "flow" not well defined).

next header: identify upper layer protocol for data



Other changes from IPv4

- *checksum*: removed entirely to reduce processing time at each hop
- *options:* allowed, but outside of header, indicated by "Next Header" field
- *ICMPv6:* new version of ICMP
  - additional message types, e.g. "Packet Too Big"
  - multicast group management functions

IPv6 (vs. IPv4)

- Simpler, faster, better
- How much traffic on the Internet is IPv6?
- Why!?

IPv6 celebrates its 20th birthday by reaching 10 percent deployment

All I want for my birthday is a new IP header.

ILJITSCH VAN BEIJNUM - 1/3/2016, 12:00 PM

Twenty years ago this month, RFC 1883 was published: Internet Protocol, Version 6 (IPv6) Specification. So what's an Internet Protocol, and what's wrong with the previous five versions? And if version 6 is so great, why has it only been adopted by half a percent of the Internet's users each year over the past two decades?

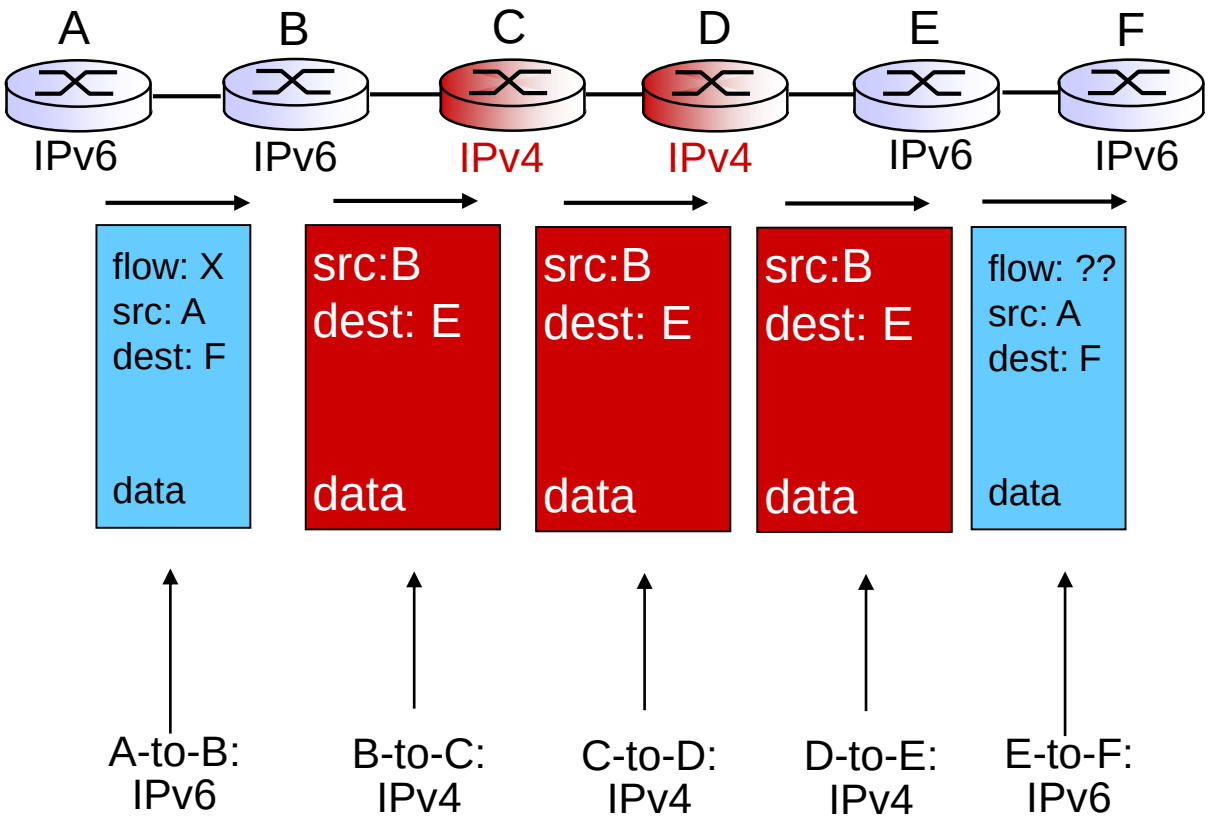
10 percent!

First the good news. According to Google's statistics, on December 26, the world reached 9.98 percent IPv6 deployment, up from just under 6 percent a year earlier. Google measures IPv6 deployment by having a small fraction of their users execute a Javascript program that tests whether the computer in question can load URLs over IPv6. During weekends, a tenth of Google's users are able to do this, but during weekdays it's less than 8 percent. Apparently more people have IPv6 available at home than at work.

Transitioning to IPv6

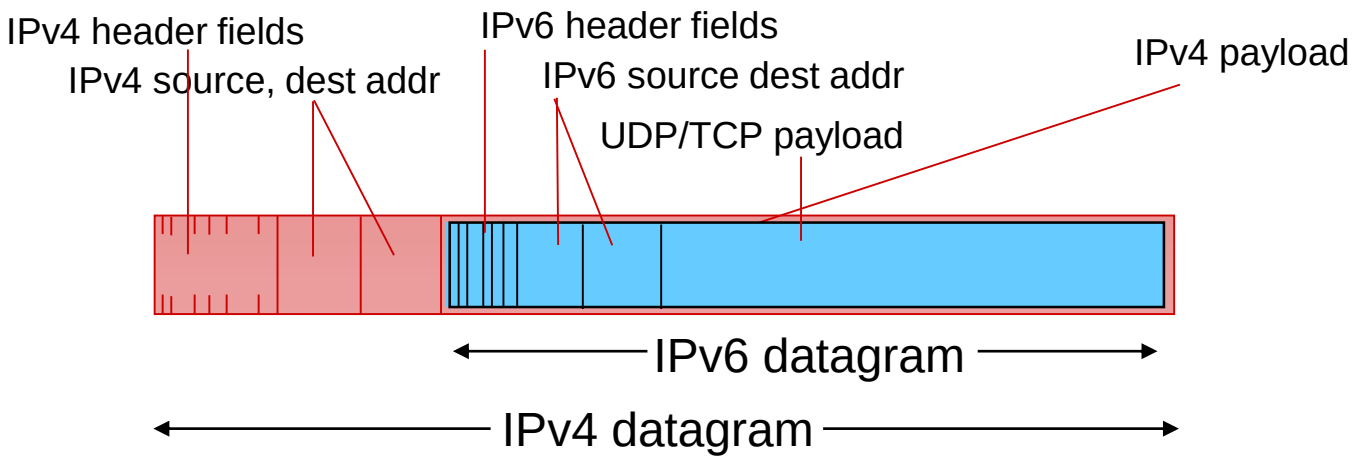
- Option 1: “Flag day”
  - How do we get *everyone* on the Internet to agree?
  - Whose authority to decide when?
  - Can you imagine how much would break?
- Option 2: Slow transition
  - Some hosts/routers speak both versions
  - Must have some way to deal with those who don’t
  - Lack of incentive to switch

Dual Stack

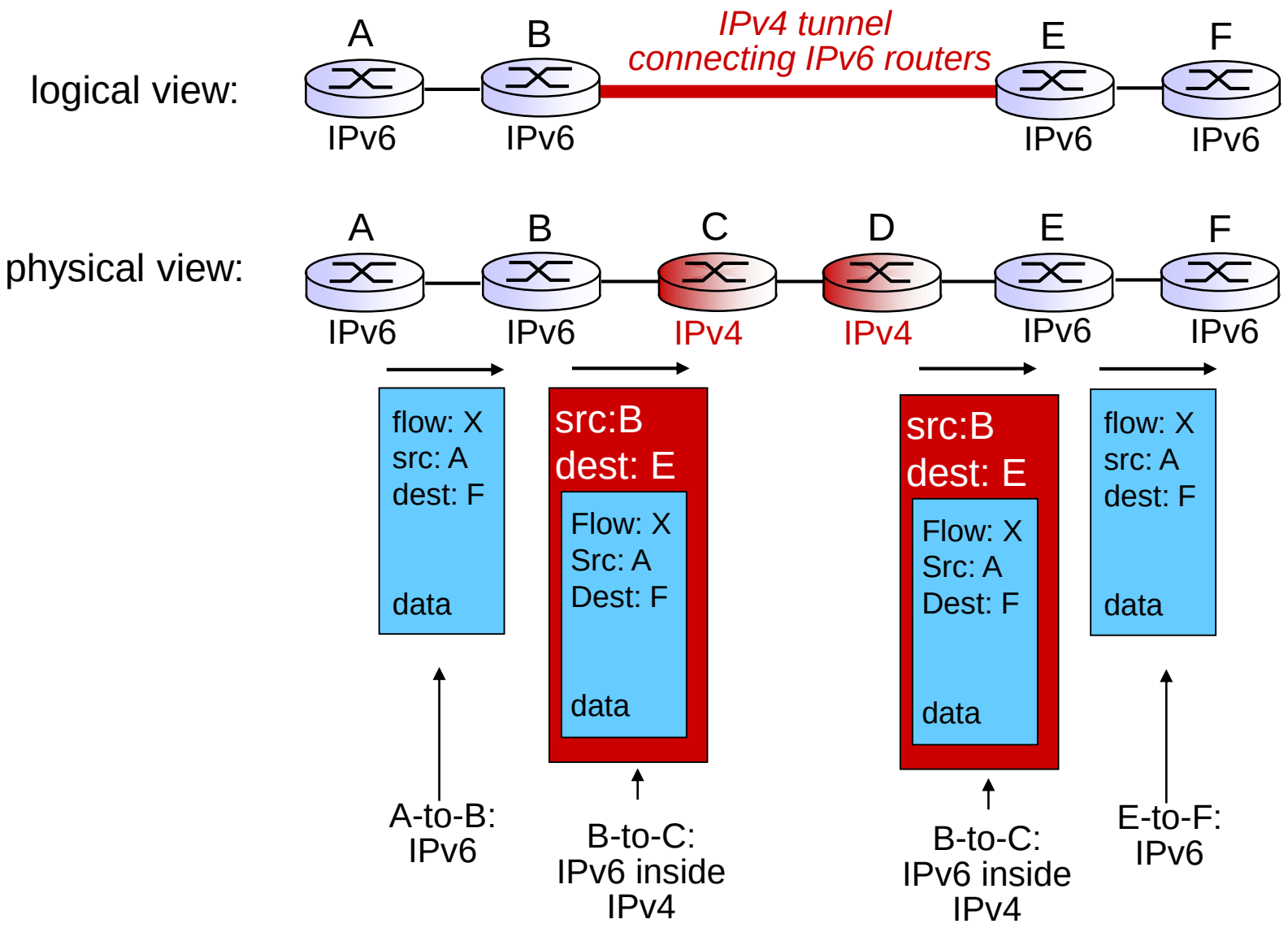

A
B
C
D
E
F
IPv6
IPv6
IPv4
IPv4
IPv6
IPv6
flow: X
src: A
dest: F
data
src:B
dest: E
data
src:B
dest: E
data
src:B
dest: E
data
flow: ??
src: A
dest: F
data
A-to-B:
IPv6
B-to-C:
IPv4
C-to-D:
IPv4
D-to-E:
IPv4
E-to-F:
IPv6

Tunneling

- IPv6 datagram carried as *payload* in IPv4 datagram among IPv4 routers



Tunneling


logical view:
A
B
IPv4 tunnel
connecting IPv6 routers
E
F
IPv6
IPv6
IPv6
IPv6
physical view:
A
B
C
D
E
F
IPv6
IPv6
IPv4
IPv4
IPv6
IPv6
flow: X
src: A
dest: F
data
src:B
dest: E
Flow: X
Src: A
Dest: F
data
src:B
dest: E
Flow: X
Src: A
Dest: F
data
flow: X
src: A
dest: F
data
A-to-B:
IPv6
B-to-C:
IPv6 inside
IPv4
B-to-C:
IPv6 inside
IPv4
E-to-F:
IPv6

ICMP: Internet Control Message Protocol

- Used to communicate network information
  - "Control messages", i.e., not data themselves
  - Error reporting
    - Unreachable host
    - Unreachable network
    - Unreachable port
    - TTL expired
  - Test connectivity
    - Echo request/response (ping)

ICMP: Internet Control Message Protocol

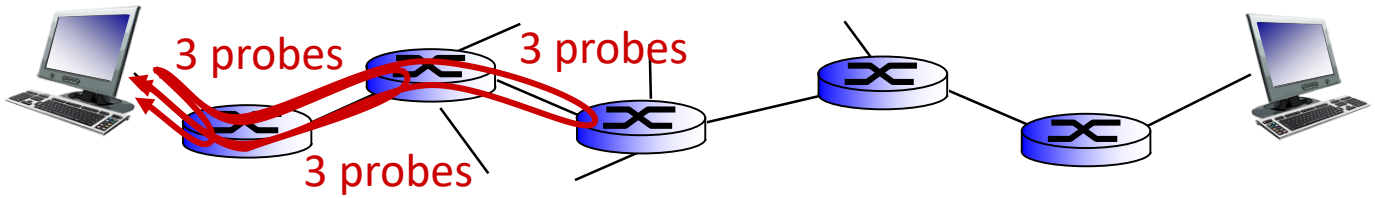
- Header:
  - 1-byte type
  - 1-byte code
  - 2-byte checksum
  - 4 bytes vary by type
- Sits above IP
  - Type 1 in IP header
  - Usually considered part of IP

Type	Code	Description
0	0	echo reply (ping)
3	0	dest. network unreachable
3	1	dest host unreachable
3	2	dest protocol unreachable
3	3	dest port unreachable
3	6	dest network unknown
3	7	dest host unknown
4	0	source quench (congestion control - not used)
8	0	echo request (ping)
9	0	route advertisement
10	0	router discovery
11	0	TTL expired
12	0	bad IP header

Ping Demo

Traceroute and ICMP

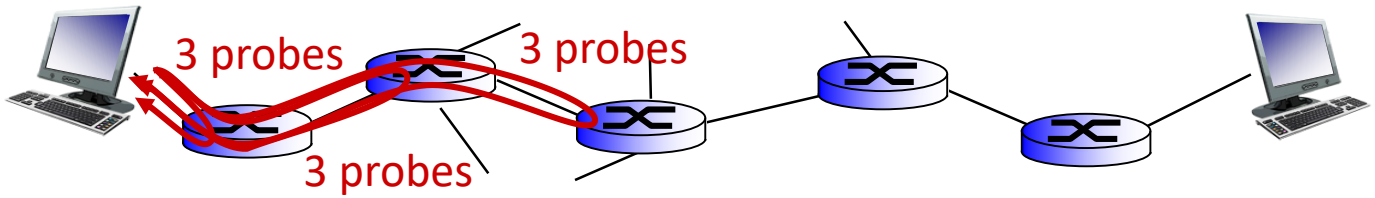
- Source sends sets of UDP segments (usually 3) to dest
  - first set has TTL =1
  - second set has TTL=2, etc.
  - unlikely port number
- When *n*th set of datagrams arrives to nth router:
  - router discards datagrams
  - and sends source ICMP messages (type 11, code 0)
  - ICMP messages includes name of router & IP address
- When ICMP messages arrives, source records RTTs



Traceroute and ICMP

stopping criteria:

- UDP segment eventually arrives at destination host
- destination returns ICMP "port unreachable" message (type 3, code 3)
- source stops



Traceroute Demo

```
 6  Episode.IV (206.214.251.1)  68.642 ms  67.307 ms  67.005 ms
 7  A.NEW.HOPE (206.214.251.6)  65.986 ms  68.502 ms  68.708 ms
 8  It.is.a.period.of.civil.war (206.214.251.9)  67.067 ms  70.139 ms  66.52
 9  Rebel.spaceships (206.214.251.14)  70.214 ms  70.192 ms  71.622 ms
10  striking.from.a.hidden.base (206.214.251.17)  71.427 ms  74.206 ms
11  have.won.their.first.victory (206.214.251.22)  71.665 ms  70.434 ms  7
12  against.the.evil.Galactic.Empire (206.214.251.25)  69.218 ms  70.621
13  During.the.battle (206.214.251.30)  69.059 ms  68.931 ms  69.981 ms
14  Rebel.spies.managed (206.214.251.33)  77.247 ms  72.757 ms  77.61
15  to.steal.secret.plans (206.214.251.38)  71.224 ms  71.164 ms  69.543
16  to.the.Empires.ultimate.weapon (206.214.251.41)  68.744 ms  68.824
17  the.DEATH.STAR (206.214.251.46)  72.316 ms  74.551 ms  66.354 ms
18  an.armored.space.station (206.214.251.49)  69.413 ms  70.334 ms  6
19  with.enough.power.to (206.214.251.54)  66.182 ms  66.627 ms  71.23
20  destroy.an.entire.planet (206.214.251.57)  71.926 ms  71.266 ms  70.
21  Pursued.by.the.Empires (206.214.251.62)  67.298 ms  65.956 ms  66.
22  sinister.agents (206.214.251.65)  65.020 ms  67.806 ms  70.508 ms
23  Princess.Leia.races.home (206.214.251.70)  68.894 ms  71.147 ms  71
24  aboard.her.starship (206.214.251.73)  72.130 ms  71.093 ms  74.026
25  custodian.of.the.stolen.plans (206.214.251.78)  68.568 ms  67.939 ms
26  that.can.save.her (206.214.251.81)  67.063 ms  69.874 ms  68.889 m
27  people.and.restore (206.214.251.86)  70.395 ms  70.144 ms
28  freedom.to.the.galaxy (206.214.251.89)  66.098 ms  65.432 ms
29  0------------------0 (206.214.251.94)  75.931 ms  74.159 ms  80.012
30  0-----------------0 (206.214.251.97)  73.026 ms  73.403 ms  73.256
31  0----------------0 (206.214.251.102)  83.602 ms  82.079 ms  70.743
32  0---------------0 (206.214.251.105)  70.459 ms  69.403 ms  68.782 m
33  0--------------0 (206.214.251.110)  68.516 ms  72.472 ms  71.811 ms
34  0-------------0 (206.214.251.113)  69.056 ms  65.981 ms  68.202 ms
35  0------------0 (206.214.251.118)  66.790 ms  71.556 ms  74.292 ms
36  0-----------0 (206.214.251.121)  68.286 ms  71.042 ms  71.587 ms
37  0----------0 (206.214.251.126)  72.702 ms  71.785 ms  72.442 ms
38  0---------0 (206.214.251.129)  78.143 ms  74.411 ms  72.828 ms
39  0--------0 (206.214.251.134)  69.692 ms  66.187 ms  67.369 ms
40  0-------0 (206.214.251.137)  69.184 ms  70.678 ms  67.445 ms
41  0------0 (206.214.251.142)  70.383 ms  68.220 ms  67.543 ms
42  0-----0 (206.214.251.145)  67.593 ms  72.970 ms  73.220 ms
43  0----0 (206.214.251.150)  70.964 ms  69.082 ms  70.831 ms
44  0---0 (206.214.251.153)  73.856 ms  71.848 ms  70.311 ms
45  0--0 (206.214.251.158)  71.517 ms  69.204 ms  69.538 ms
46  0-0 (206.214.251.161)  68.076 ms  68.179 ms  67.620 ms
47  00 (206.214.251.166)  68.738 ms  70.518 ms  68.757 ms
48  I (206.214.251.169)  68.281 ms  70.225 ms  74.811 ms
49  By.Ryan.Werber (206.214.251.174)  70.203 ms  71.668 ms  71.672 ms
50  When.CCIEs.Get.Bored (206.214.251.177)  68.900 ms  71.461 ms  72.297 ms
51  read.more.at.beaglenetworks.net (206.214.251.182)  75.816 ms  73.957 ms  71.333 ms
52  (206.214.251.185)  70.254 ms  73.799 ms
```

IPsec – Security at the Network Layer

- Encryption
- Data Authentication
  - Verify the data was not modified in transit
- Host Authentication
  - Verify the data comes from who it says it comes from

Two Modes

- Works entirely on end hosts
- Transport
  - Payload is encrypted, IP header is normal
- Tunneling
  - Entire packet is encrypted, stuck inside a different IP packet
  - Can be used to create Virtual Private Networks

Summary

- IPv6: solution to IP address scarcity
  - Low adoption so far, but improving
- Lots of mechanisms surrounding IP
  - NAT: translate routable IP address to multiple private IP addresses using ports/header rewriting
  - ICMP: small status messages, usually report errors
  - IPsec: encryption service for transport data