

Lecture 13:

NAT and Routing

CSE 123: Computer Networks

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Lecture 13 Overview

- Wrap up discussion of naming
- Overview of routing
- Intra vs. Inter-domain routing
- Link-state routing protocols



Private Address Space

- Sometimes you can't get/don't want IP addresses
 - ◆ An organization wants to change service providers without having to renumber its entire network
 - ◆ A network may be unable obtain (or cannot afford) enough IP addresses for all of its hosts
- IP provides **private address space** anyone can use
 - ◆ 10/8, 192.168/16, 172.16.0/20
 - ◆ These addresses are not routable—Internet routers should drop packets destined to these so-called **bogons**
- What good are they if can't use them on the Internet?

Network Address Translation



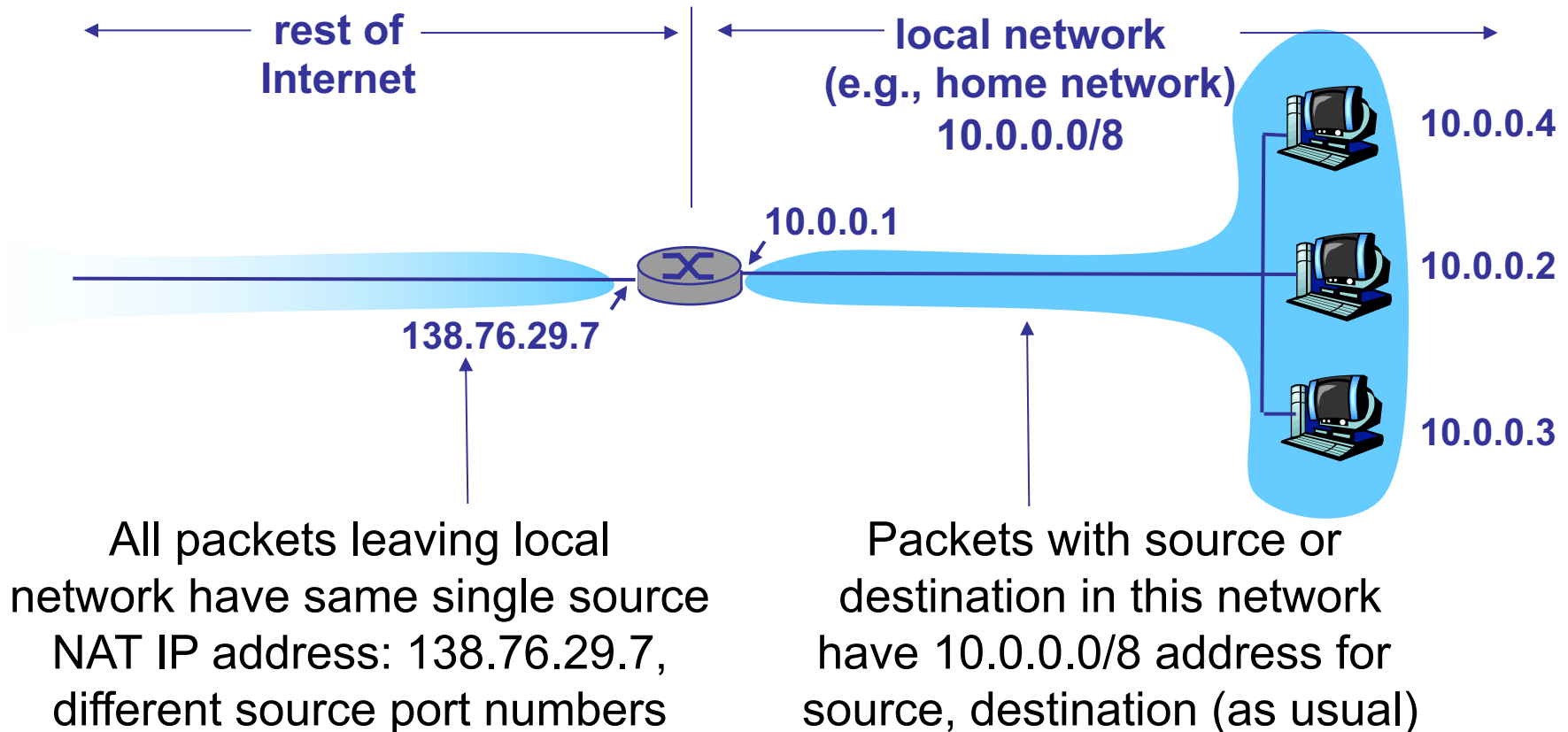
- Gateway router can rewrite IP addresses as packets leave or enter a given network
 - ◆ I.e., replace private addresses with public ones
 - ◆ Router needs to see and update every packet
- Maintains a mapping of private-to-public addresses
 - ◆ Simple case is a one-to-one mapping
 - ◆ Anytime network changes provider, just update mapping table
 - ◆ In more clever scenarios, can map a set of private addresses to a smaller set of public addresses
 - ◆ In the extreme map the entire private network to one public IP!



IP Masquerading

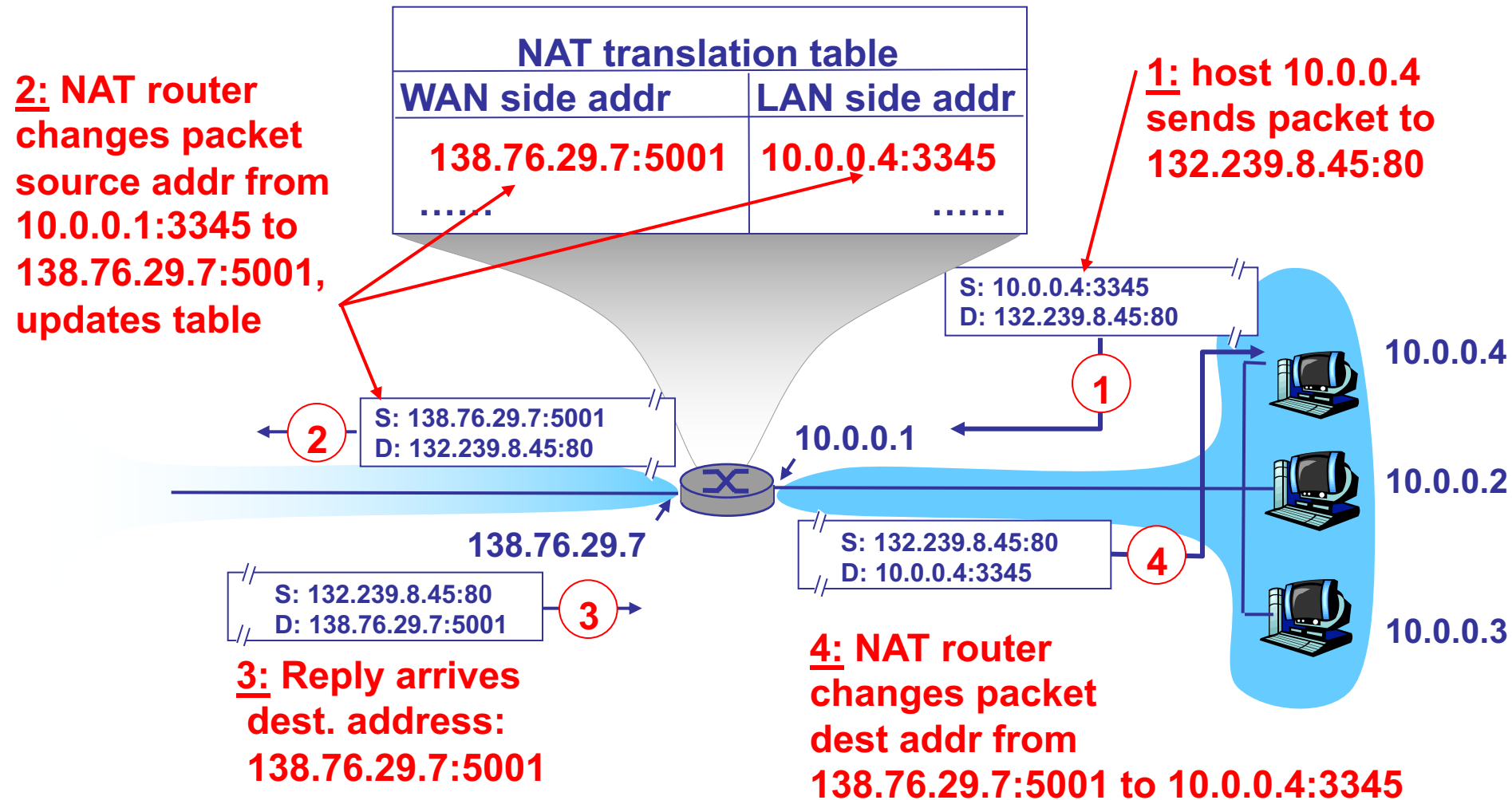
- A.K.A. Network Address and port Translation (NAT), Port Address Translation (PAT), or, colloquially, just NAT.
- Entire local network uses just one IP address as far as outside world is concerned:
 - ◆ can change addresses of devices in local network without notifying outside world
 - ◆ can change ISP without changing addresses of devices in local network
 - ◆ devices inside local net not explicitly addressable, visible by outside world (a security plus).

A NAT'd Network





NA(p)T Example





NAT Challenges

- End hosts may not be aware of external IP address
 - ◆ Some applications include IP addresses in application data
 - ◆ Packets will contain private IP addresses inside payload
 - ◆ Many NATs will inspect/rewrite certain protocols, e.g., FTP
- NAT'd end hosts are not reachable from the Internet
 - ◆ All connections must be initiated from within private network
 - ◆ Alternative is to configure fixed forwarding in NAT
 - ◆ Many protocols for [NAT traversal](#) to get around this



Router Tasks

- Forwarding
 - ◆ Move packet from input link to the appropriate output link
 - ◆ Purely local computation
 - ◆ Must go be very fast (executed for every packet)
- Routing
 - ◆ Make sure that the next hop actually leads to the destination
 - ◆ Global decisions; distributed computation and communication
 - ◆ Can go slower (only important when topology changes)



Forwarding Options

- Source routing
 - ◆ Complete path listed in packet
- Virtual circuits
 - ◆ Set up path out-of-band and store path identifier in routers
 - ◆ Local path identifier in packet
- Destination-based forwarding
 - ◆ Router looks up address in forwarding table
 - ◆ Forwarding table contains (address, next-hop) tuples



Source Routing

- Routing
 - ◆ Host computes path
 - » Must know global topology and detect failures
 - ◆ Packet contains complete ordered path information
 - » I.e. node A then D then X then J...
 - ◆ Requires variable length path header
- Forwarding
 - ◆ Router looks up next hop in packet header, strips it off and forwards remaining packet
 - » Very quick forwarding, no lookup required
- In practice
 - ◆ ad hoc networks (DSR), some HPC networks (Myrinet), and for debugging on the Internet (LSR,SSR)



Virtual Circuits

- Routing
 - ◆ Hosts sets up path out-of-band, requires connection setup
 - ◆ Write (input id, output id, next hop) into each router on path
 - ◆ Flexible (one path per flow)
- Forwarding
 - ◆ Send packet with path id
 - ◆ Router looks up input, swaps for output, forwards on next hop
 - ◆ Repeat until reach destination
 - ◆ Table lookup for forwarding (why faster than IP lookup?)
- In practice
 - ◆ ATM: fixed VC identifiers and separate signaling code
 - ◆ MPLS: ATM meets the IP world (why? *traffic engineering*)

Destination-based Forwarding



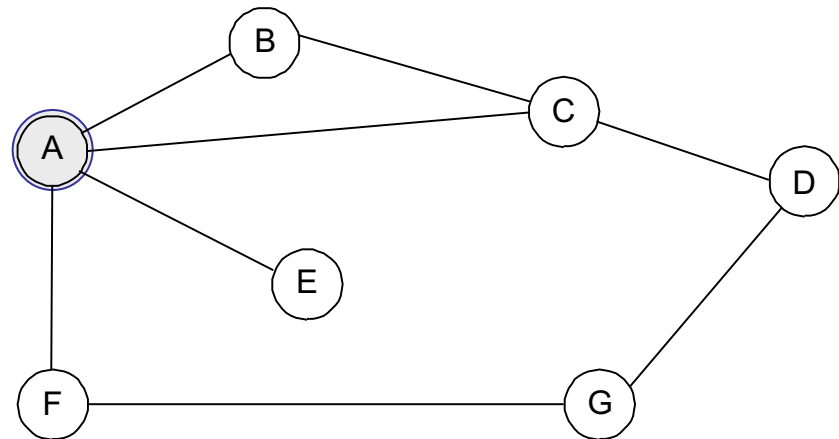
- Routing
 - ◆ All addresses are globally known
 - » No connection setup
 - ◆ Host sends packet with destination address in header
 - » No path state; only routers need to worry about failure
 - ◆ Distributed routing protocol used to routing tables
- Forwarding
 - ◆ Router looks up destination in table
 - » Must keep state proportional to destinations rather than connections
 - ◆ Lookup address, send packet to next-hop link
 - » All packets follow same path to destination
- In Practice: IP routing



Routing Tables

- The routing table at A, lists – *at a minimum* – the next hops for the different destinations

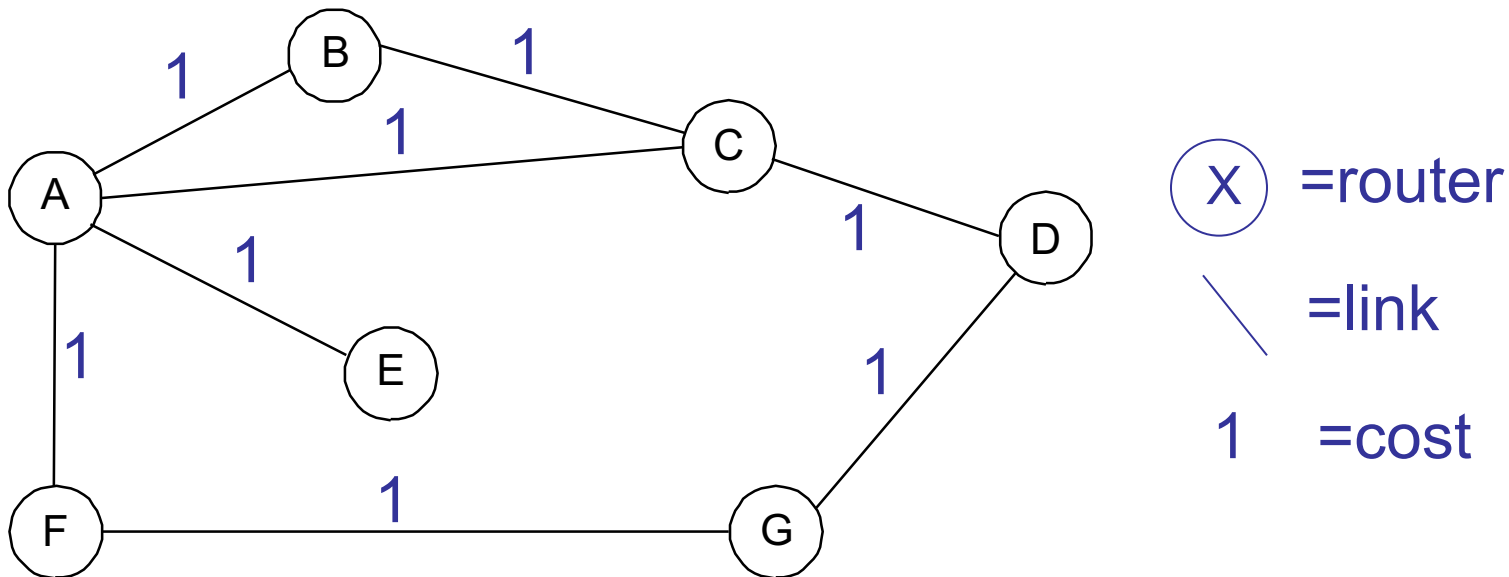
Dest	Next Hop
B	B
C	C
D	C
E	E
F	F
G	F





Routing on a Graph

- Essentially a graph theory problem
 - ◆ Network is a directed graph; routers are vertices
- Find “best” path between every pair of vertices
 - ◆ In the simplest case, best path is the shortest path





Routing Challenges

- How to choose best path?
 - ◆ Defining “best” can be slippery
- How to scale to millions of users?
 - ◆ Minimize control messages and routing table size
- How to adapt to failures or changes?
 - ◆ Node and link failures, plus message loss



Intra-domain Routing

- Routing within a network/organization
 - ◆ A single administrative domain
 - ◆ The administrator can set edge costs
- Overall goals
 - ◆ Provide intra-network connectivity
 - ◆ Adapt quickly to failures or topology changes
 - ◆ Optimize use of network resources
- Non-goals
 - ◆ Extreme scalability
 - ◆ Lying, and/or disagreements about edge costs

For next time...



- Read Chapter 3.3.2 in P&D