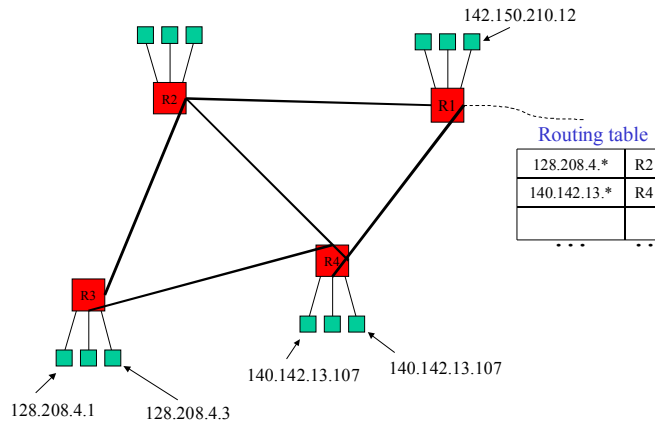


## IP Routing: Routing Tables



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## Topic 2: Discovering MAC's from IP's

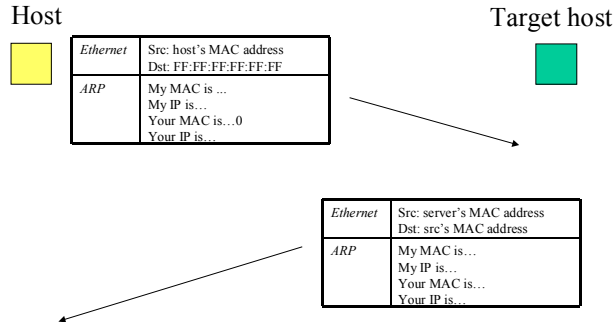
- Host has an IP (e.g., for the gateway). It needs a MAC address to send a frame to it.
- Solution: Address Resolution Protocol (ARP)
- Exploits the physical multicast of Ethernet

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## ARP: The IP->MAC Problem Solution

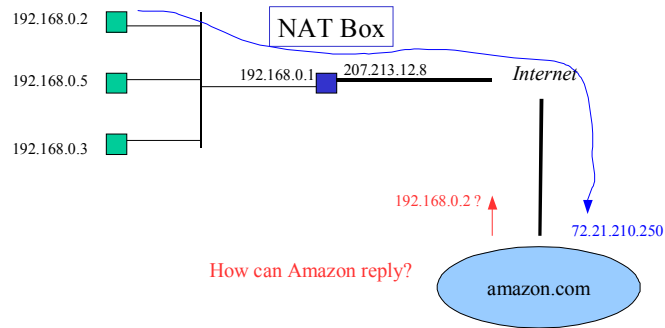


*(As always, the actual protocol is richer than what is shown here.)*

## Topic 3: Network Address Translation (NAT)

- Turns out that there aren't all that many 32-bit strings (i.e., IP addresses)
  - The world needs more...
  - An individual network needs more...
  - You need more...
    - Your ISP will give you only one (using DHCP), but you want to connect five machines to the Internet
- NAT exploits *non-routable addresses* to let you build your own private network "behind the NAT box"
  - Non-routable addresses are, well, never routed
  - Do not have to be globally unique (just locally unique)
    - 10.0.0.0 - 10.255.255.255
    - 172.16.0.0 - 172.31.255.255
    - 192.168.0.0 - 192.168.255.255
- The NAT box substitutes its own IP address for outgoing packets, and the local address of the actual destination for incoming packets

## NAT: The Primary Goal



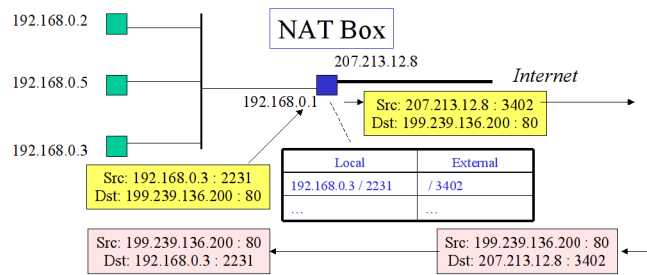
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## NAT Overview

- Recall that IP addresses are 32-bits (e.g., 192.168.10.3)
- Recall that TCP addresses are IP addresses plus a port number

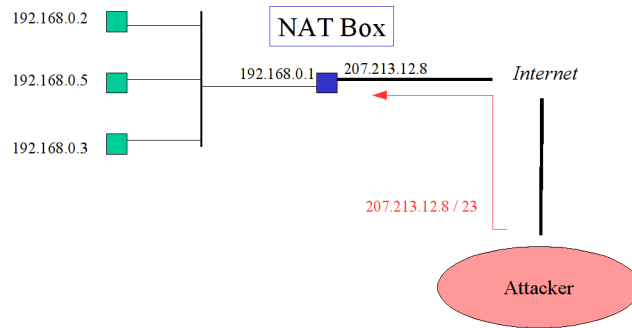


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## Bonus Feature: NATs As Firewalls



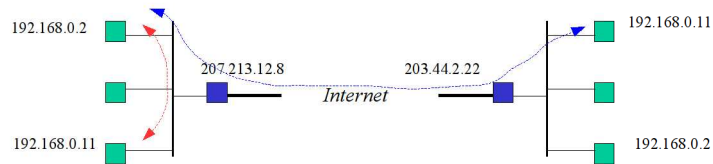
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## Bonus Problem: NAT and Peer-to-Peer (P2P)

Wants to send along blue path.  
Ends up sending along red path.



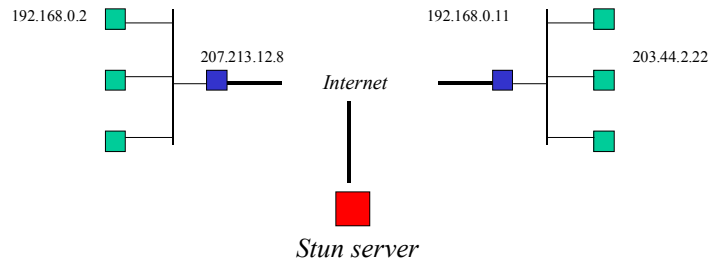
It doesn't help to start the communication  
from this end.

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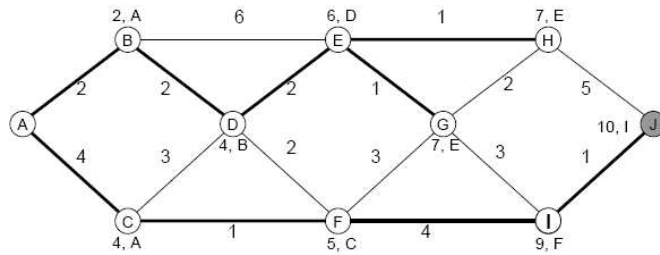
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## STUN: Simple Traversal of UDP over NATs



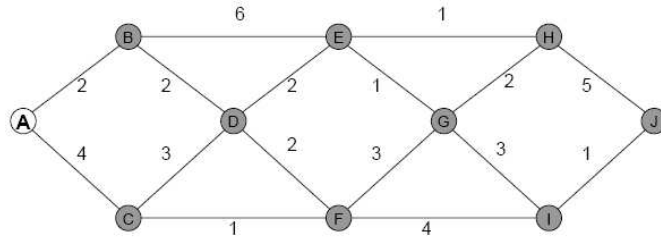
- Heuristic designed to discover “routable” address (NAT entry) for hosts behind NATs
- IETF RFC 3489 (<http://tools.ietf.org/html/rfc3489>)
  - Updated by RFC 5389

## Routing: Minimum Cost Spanning Tree



Let's interpret this as A's view of its outgoing paths  
(i.e., it's own routing table).

## Each router has a routing table



Construct minimum cost spanning trees rooted at C, D, and F.  
What important property do they have?