Internet Technology

15. VoIP, NAT Traversal, and auto configuration

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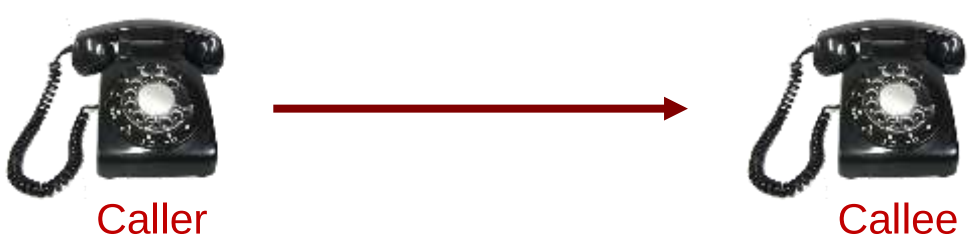
Session Initiation Protocol (SIP)

- Dominant protocol for Voice over IP (VoIP): RFC 3261
- Allows a call to be established between multiple parties
  - Notify a callee of a call request
  - Agree on media encodings
  - Allow a participant to end the call
  - Determine IP address of callee
    - No assumption on the callee having a fixed IP address
  - Add new media streams, change encoding, add/drop participants
- Messages are HTTP style (line-oriented text) using UDP or TCP



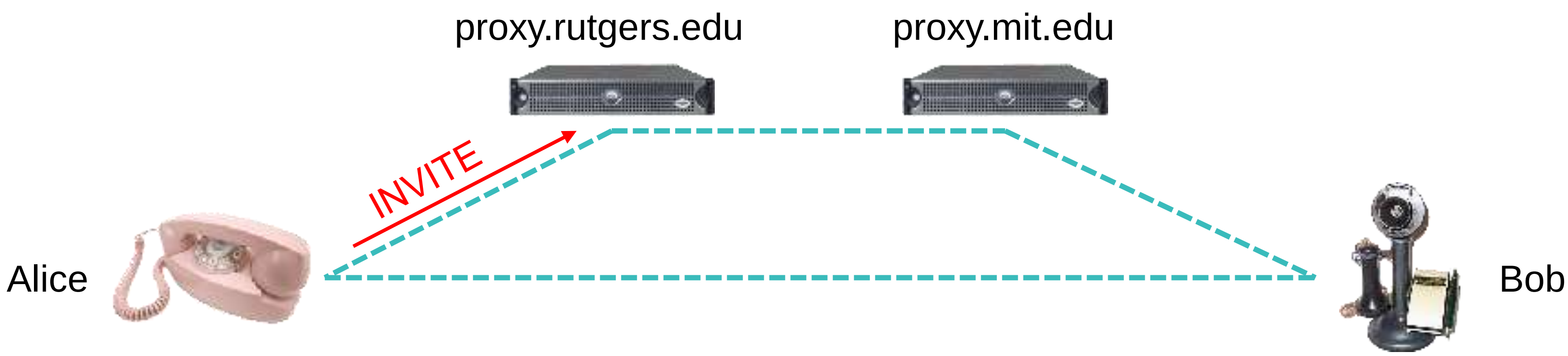
Proxies

- SIP proxy server
  - Helps route requests
  - Forwards requests to one or more destinations and sends responses to the requester
  - Contacts remote registrar to look up addresses
  - Often run on the same server as a registrar
- Usually a proxy at each SIP domain

Registration

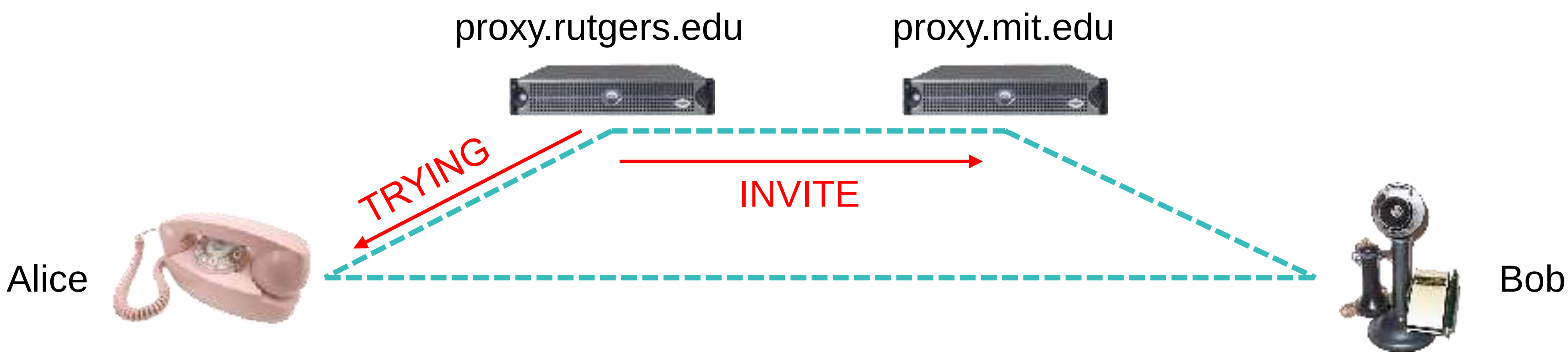
- A user's SIP address is an IP address & port number
  - In many cases, this changes over time
- Registration
  - When a phone is switched on (or phone software is run)
  - A registration process takes place
  - Registrations expire, so re-register periodically
- Location Server
  - Stores a mapping between the user's address and the address of their phone
    - user's address = Address of Record (AOR): sip:alice@sip.rutgers.edu
- SIP Registrar:
  - Accepts REGISTER requests and interacts with the Location Server
- SIP proxy, registrar, & location server normally run on the same system

SIP Example



- Alice wants to call `bob@sip.mit.edu`
- She sends an INVITE message to her proxy server
  - HTTP-style
  - Identifies destination: Bob (`bob@sip.mit.edu`)
  - Specifies:
    - Alice's current IP address
    - Media type (e.g., PCM-encoded audio via RTP)
    - Port on which she'd like to receive the message

SIP Example

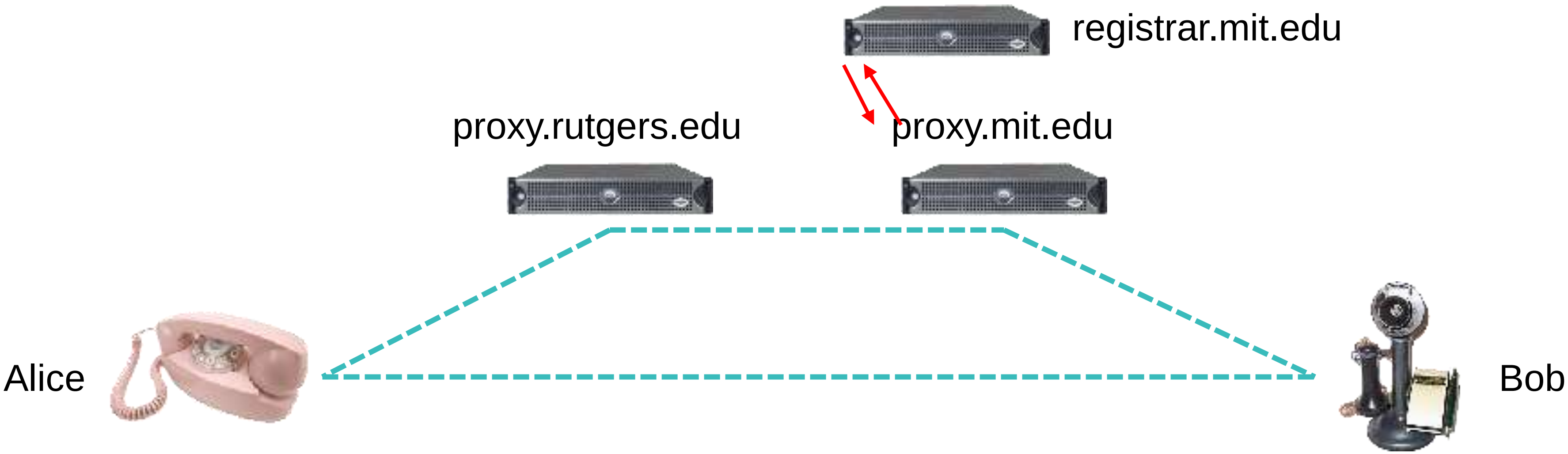


- Alice's SIP proxy server needs to look up `bob@sip.mit.edu`
  - Uses DNS to look up Bob's SIP server (NAPTR and/or SVR records)
  - Forwards the Alice's INVITE to Bob's SIP proxy
  - Tells Alice that it's TRYING to contact the party

NAPTR = Name Authority Pointer
– designed to get a list of protocols and regular expression rewrite rule to create a SIP URN

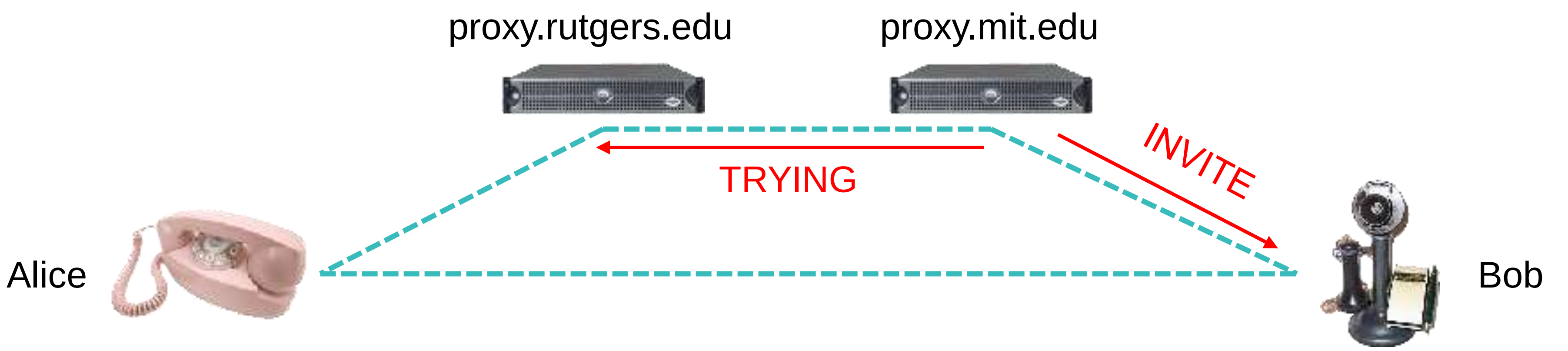
SVR = Service Record – designed to map service names to hostname:port

SIP Example



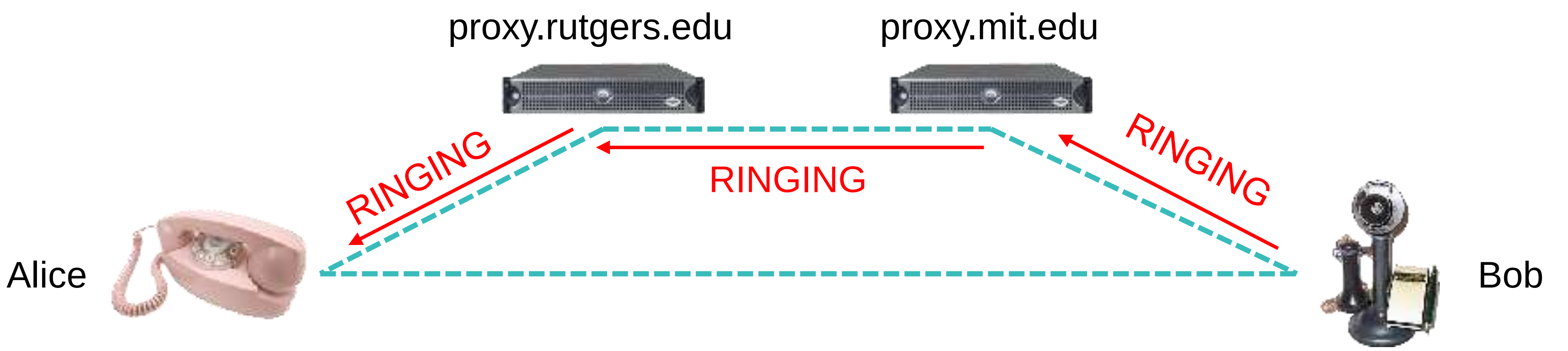
- Routing
  - SIP INVITE requests are sent from proxy to proxy until it reaches one that knows the location of the callee
  - A Proxy may respond with a REDIRECT message

SIP Example



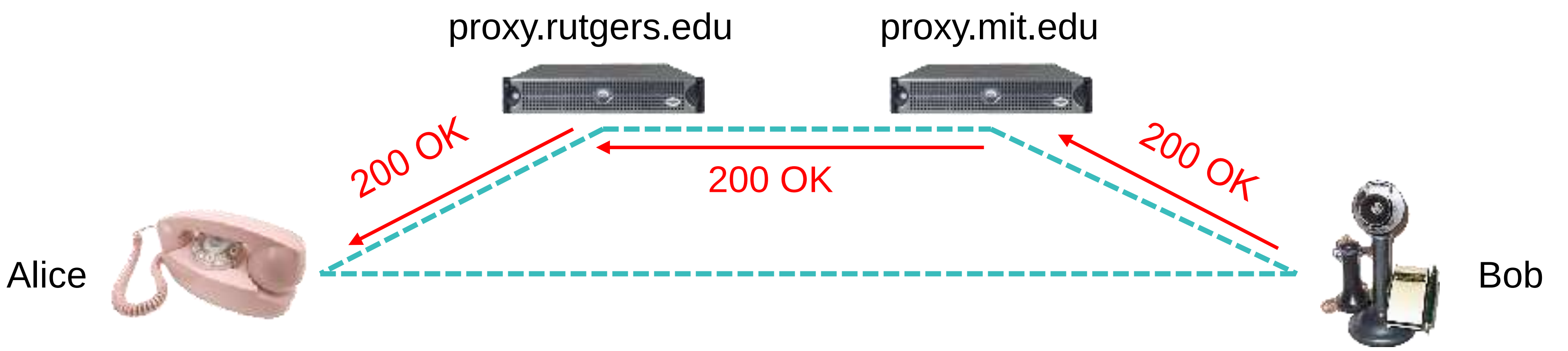
- Bob's proxy server
  - Forwards the INVITE to Bob's phone
  - Tells Alice's proxy server that it's trying to reach Bob

SIP Example



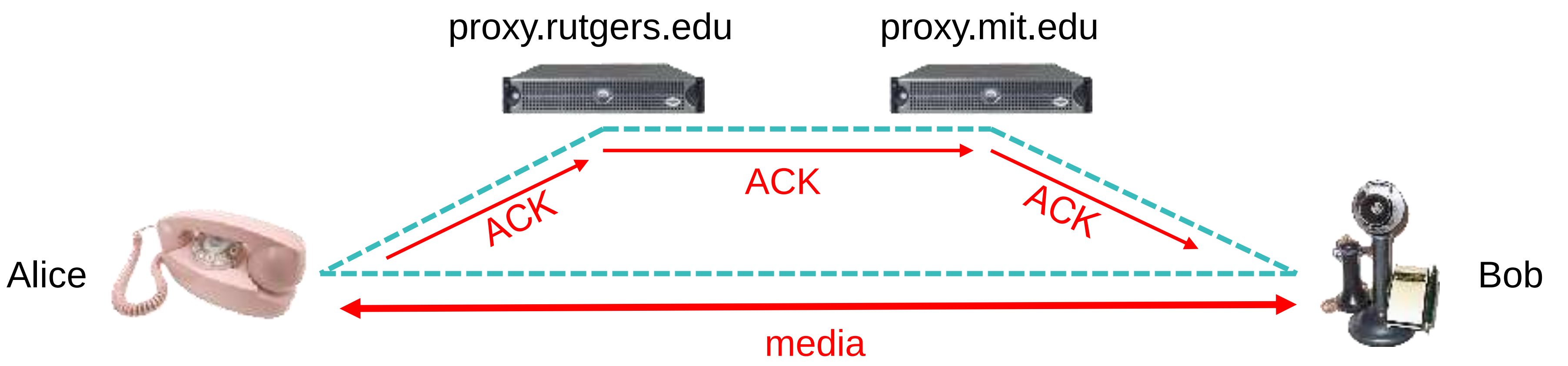
- Bob’s phone gets the INVITE message
  - Starts ringing
  - Sends RINGING response

SIP Example



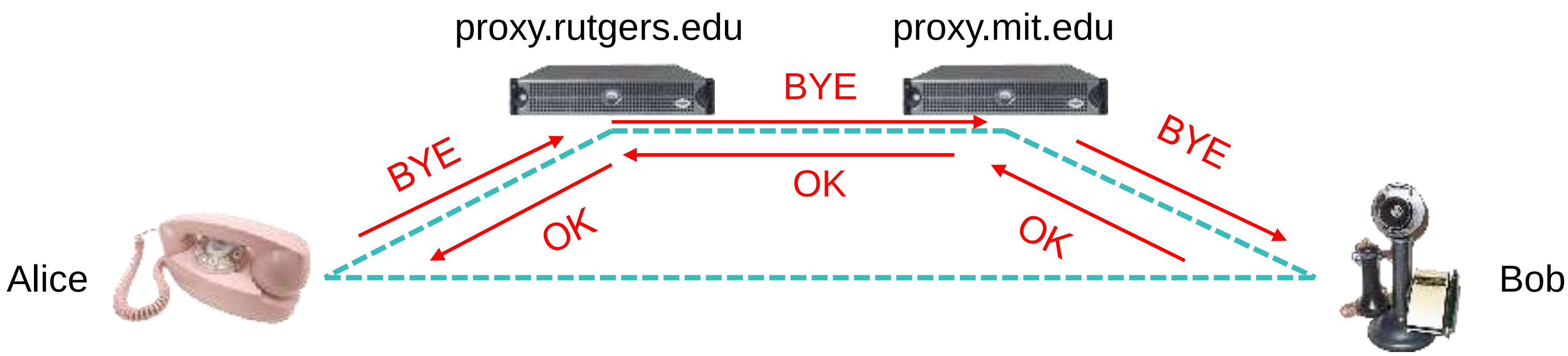
- Bob can accept or decline the call
  - If he accepts it, the INVITE is acknowledged with a 200 OK
  - INVITE feedback is propagated back to Alice

SIP Example



- Now Alice & Bob talk point-to-point
  - Alice sends an ACK to confirm setup
  - Both sides exchange media streams (usually RTP)

SIP Example



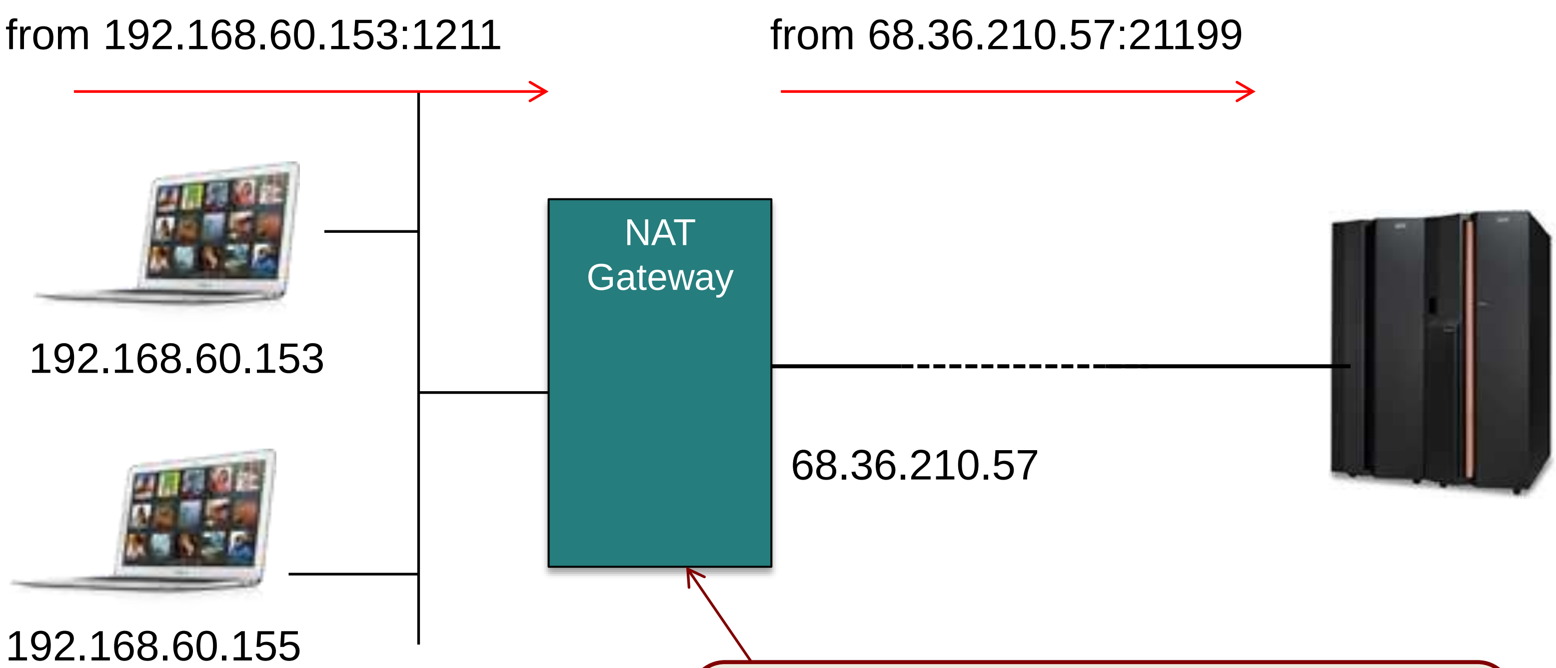
- To disconnect, one party sends a BYE message
- The other side confirms with a
  200 OK
- SIP is an out-of-band protocol
  - SIP messages are sent on different sockets than media data
  - All messages are acknowledged, so either TCP or UDP can be used

NAT Traversal

NAT traversal & why do we need it?

- Remember NAT?
  - Private IP addresses
  - NAT gateway (usually on a gateway router)
    - Translates between internal addresses/ports & external ones
- It's awesome!
  - Cut down on lots of wasted addresses – usually, you need just one
- But it breaks end-to-end connectivity!
  - What if you want to contact a service behind NAT?
  - Consider two VoIP clients that want to communicate
  - *No foolproof solution*

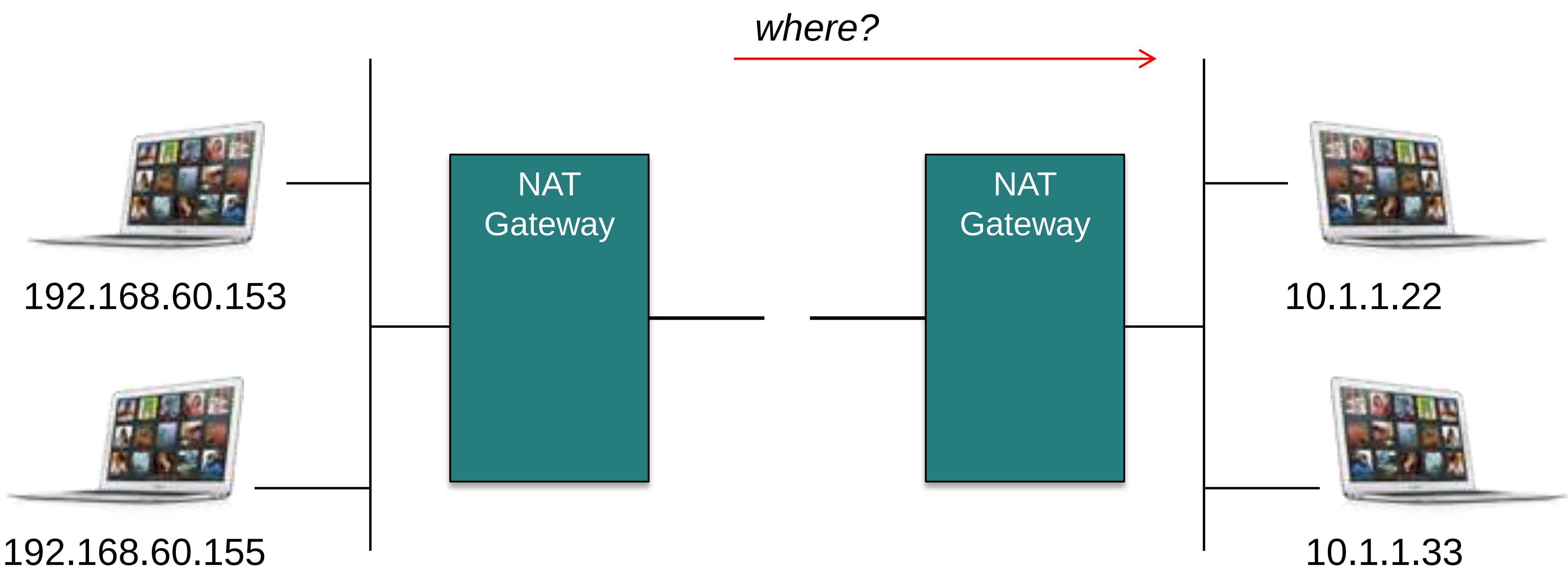
NAT: This is easy



Translation Table

Inside	Outside
192.168.60.153:1211	68.36.210.57:21199

NAT: This is tricky

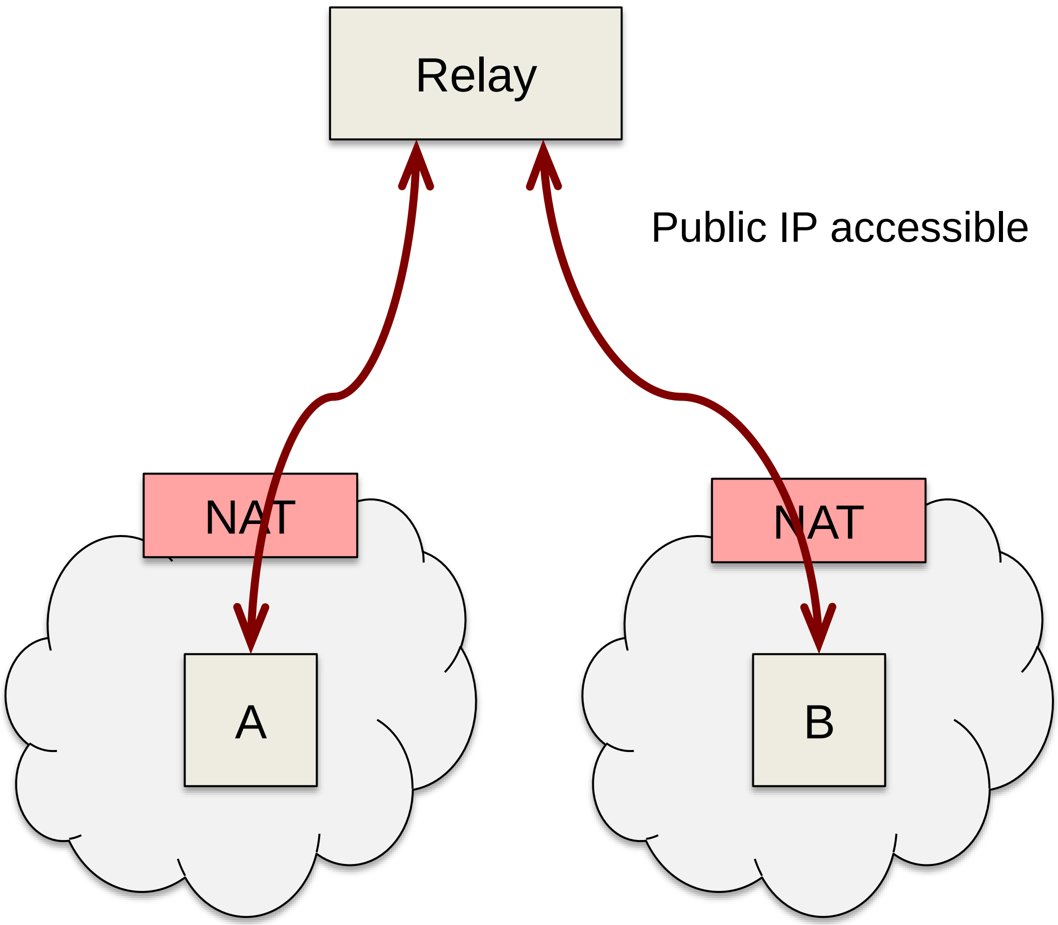


NAT Traversal Techniques

Relay all messages

- Hosts A & B want to communicate
- Have an Internet-accessible proxy, P
- A connects to P and waits for messages on the connection
- B talks to P; P relays messages to A
- Most reliable but not very efficient
  - Extra message relaying
  - Additional protocols needed (e.g., B needs to state what it wants)
  - Proxy can become a point of congestion (network links & CPU)

Relay all messages

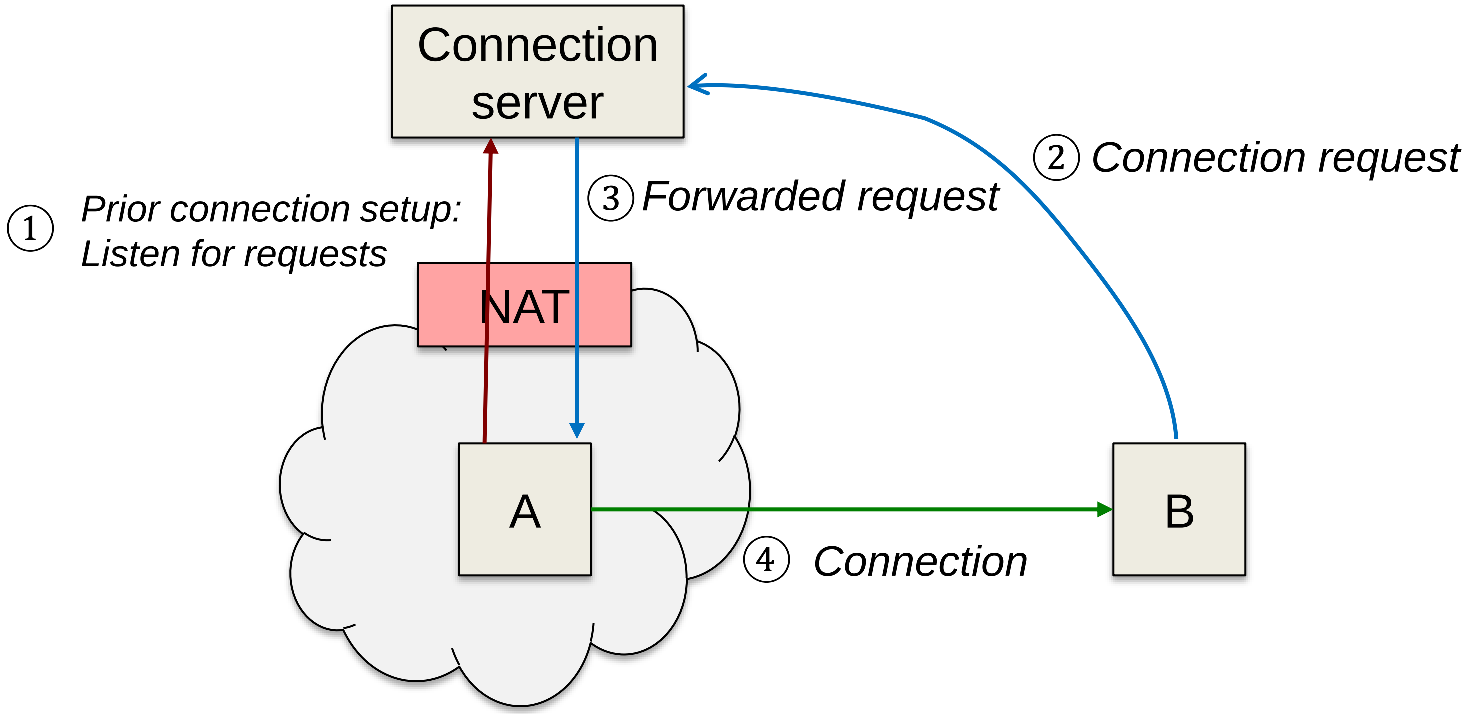


Connection reversal

- B wants to connect to A
  - But A is behind a NAT
- *Somehow* get B to send a message to A,
  - Ask A to open a connection to B
- Two approaches
  - Relay the request via a server (but A must be connected to the server)
  - As with passive FTP
    Assume an existing connection exists between A & B and ask for a new one

Connection reversal

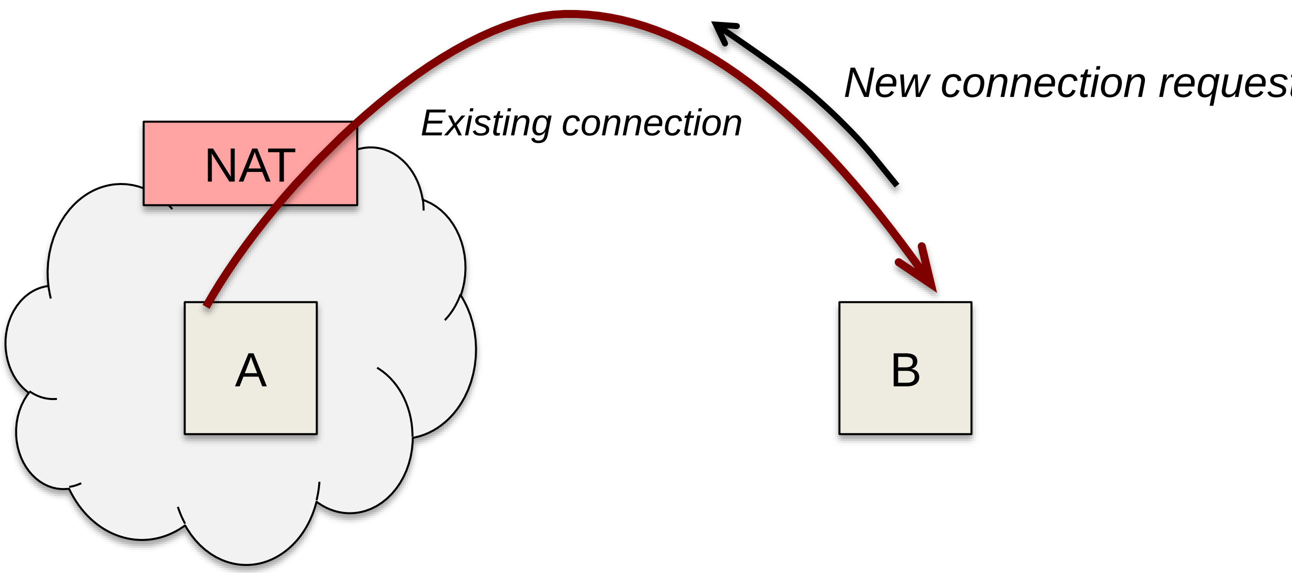
Use a server for sending only connection requests



Connection reversal

B wants to talk to A

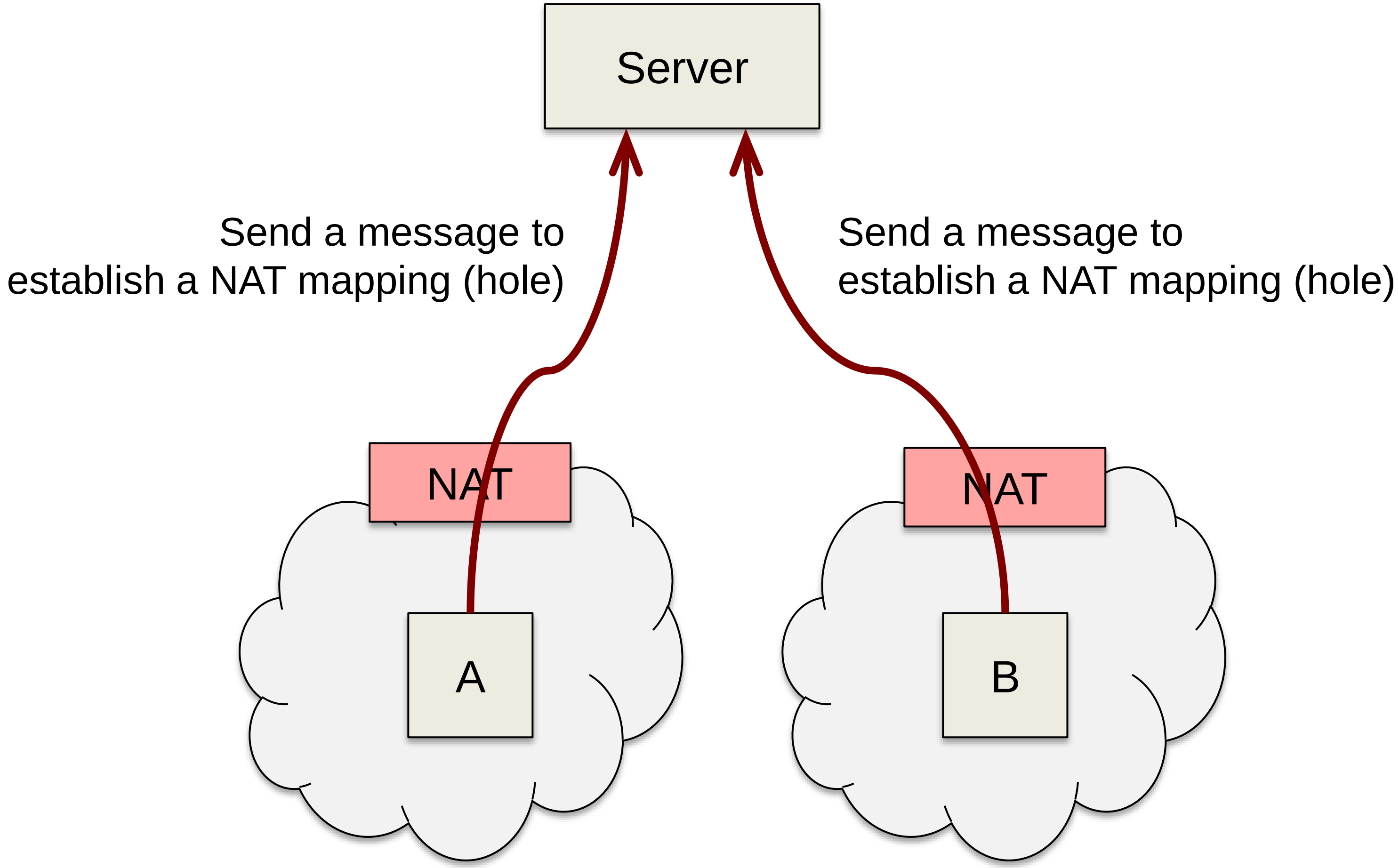
Existing connection between A & B (set up by B)



UDP hole punching

- Hosts A & B want to communicate
- Have an Internet-accessible rendezvous server, S
- Host A sends a message to S
  - That sets up a NAT translation on A's NAT gateway
  - S now knows the external host & port
- Host B sends a message to S
  - That sets up a NAT translation on B's NAT gateway
  - S also knows the external host & port on B
- S tells B: *talk on A's IP address & port*
- S tells A: *talk to B's IP address & port*

UDP hole punching



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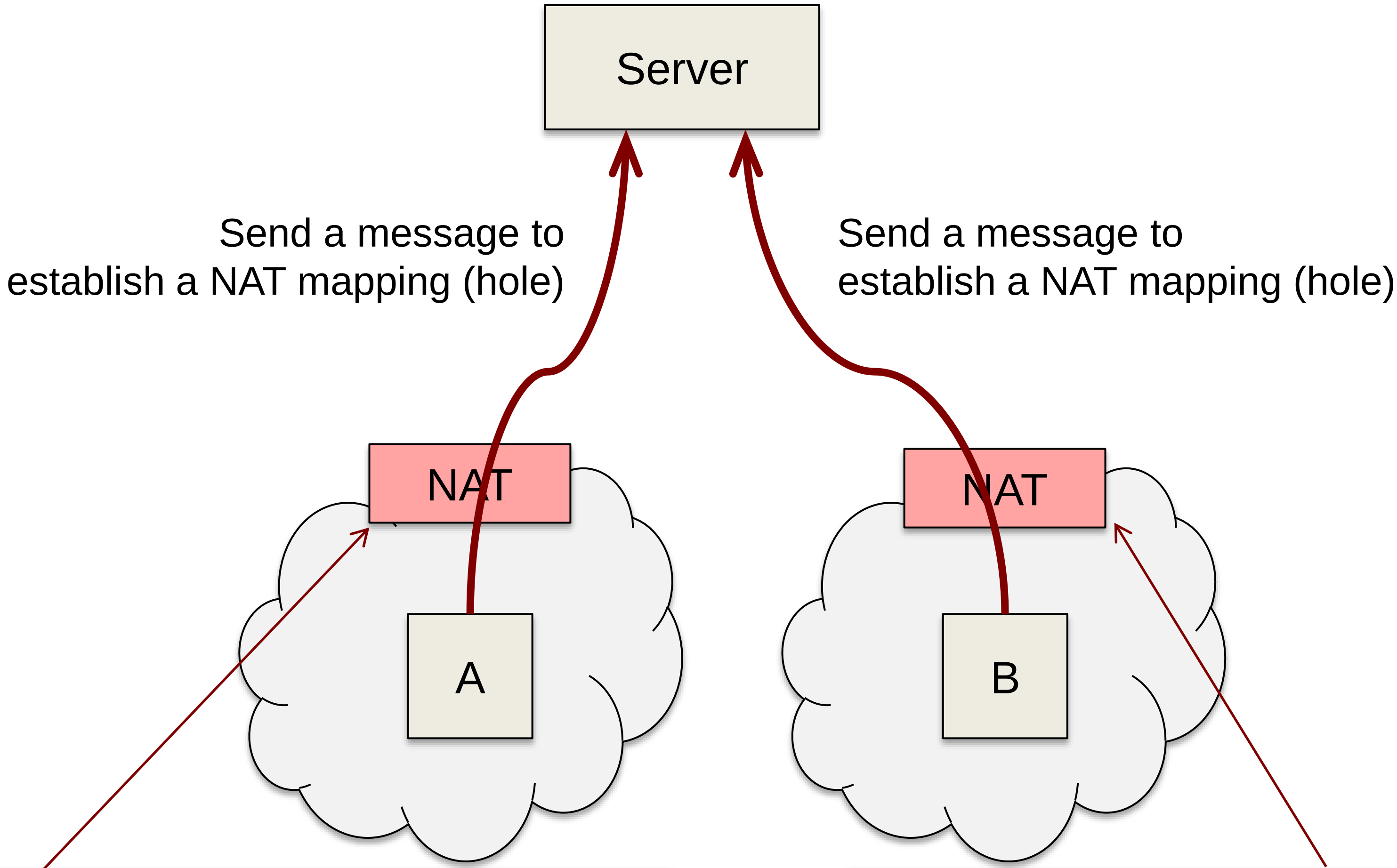

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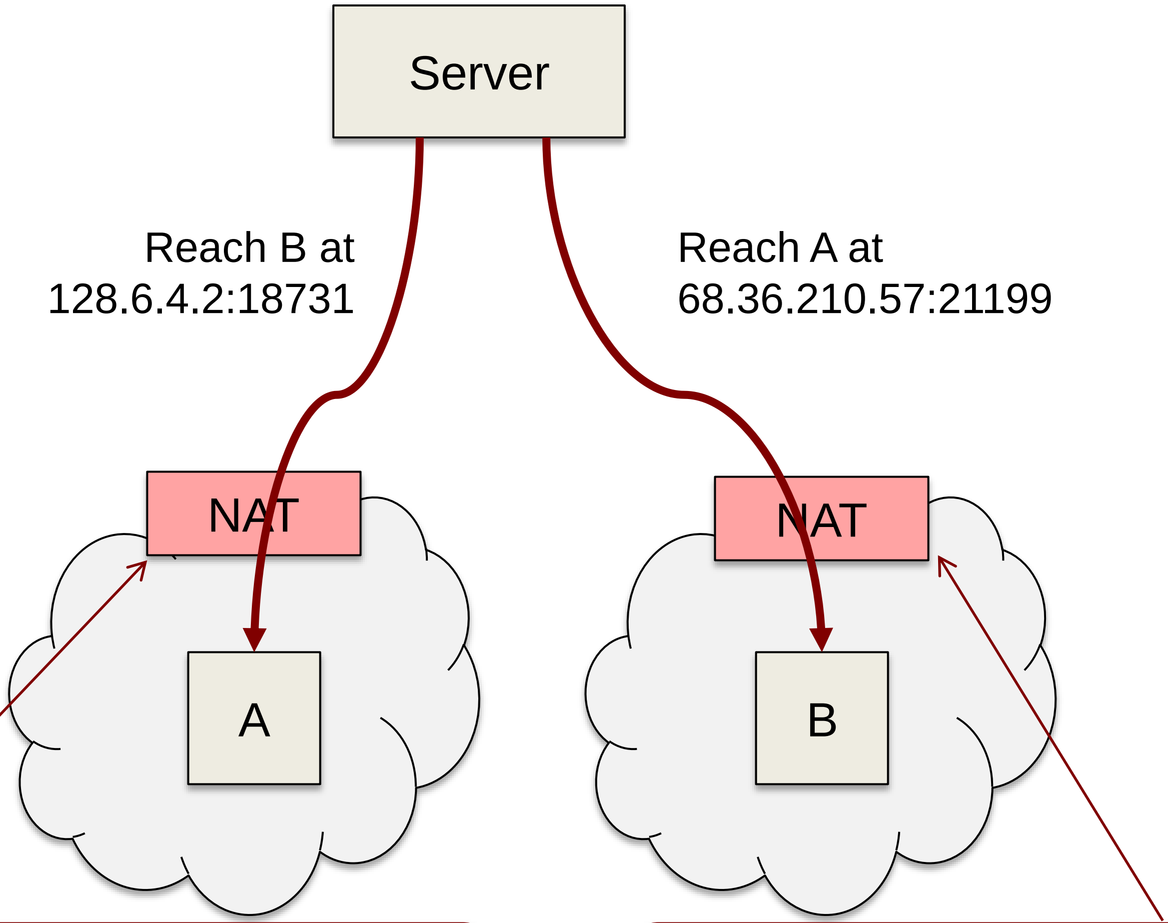

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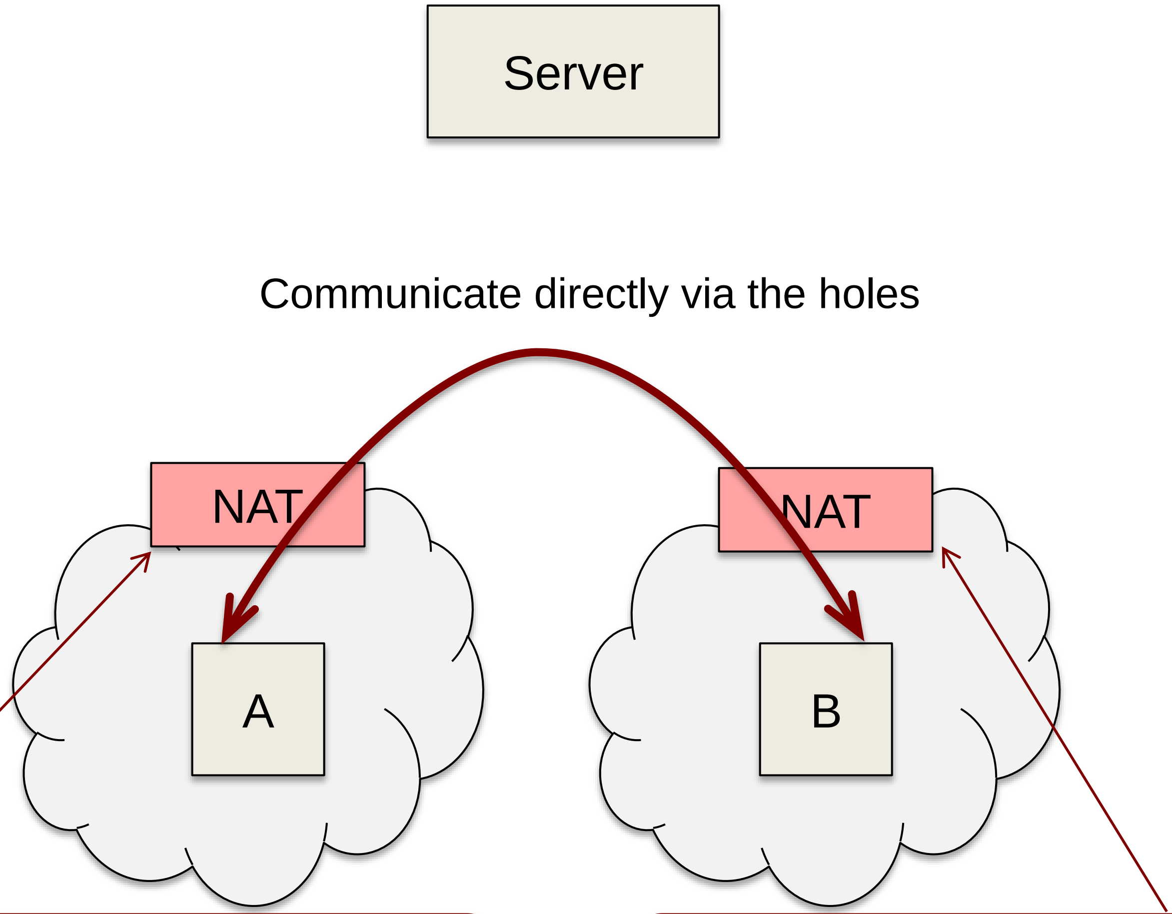

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TCP hole punching

- Same principle (tell other host of your address:port) – BUT
  - Use TCP Simultaneous Open
    - Both hosts will try to connect to each other
    - Each NAT creates a translation rule
    - At least one of the SYN messages during connection set up will go through the NAT translation on the other side
      - The remote side will send a SYN-ACK
  - Need to re-use the same port # that the remote side knows about
    - Socket option to reuse an address:
      SO_REUSEADDR
  - Not guaranteed to work with all NAT systems

NAT Traversal Protocols

STUN

- Session Traversal Utilities for NAT; RFC 5389
  - Allows clients to discover whether they are in a NAT environment
    - Discover public IP address
    - Send a message to a STUN server on the Internet
    - STUN server returns the source IP address and port number
  - A client can share this external address/port
    - If both peers are behind NAT, they will need to find a way to share this information

Hole punching

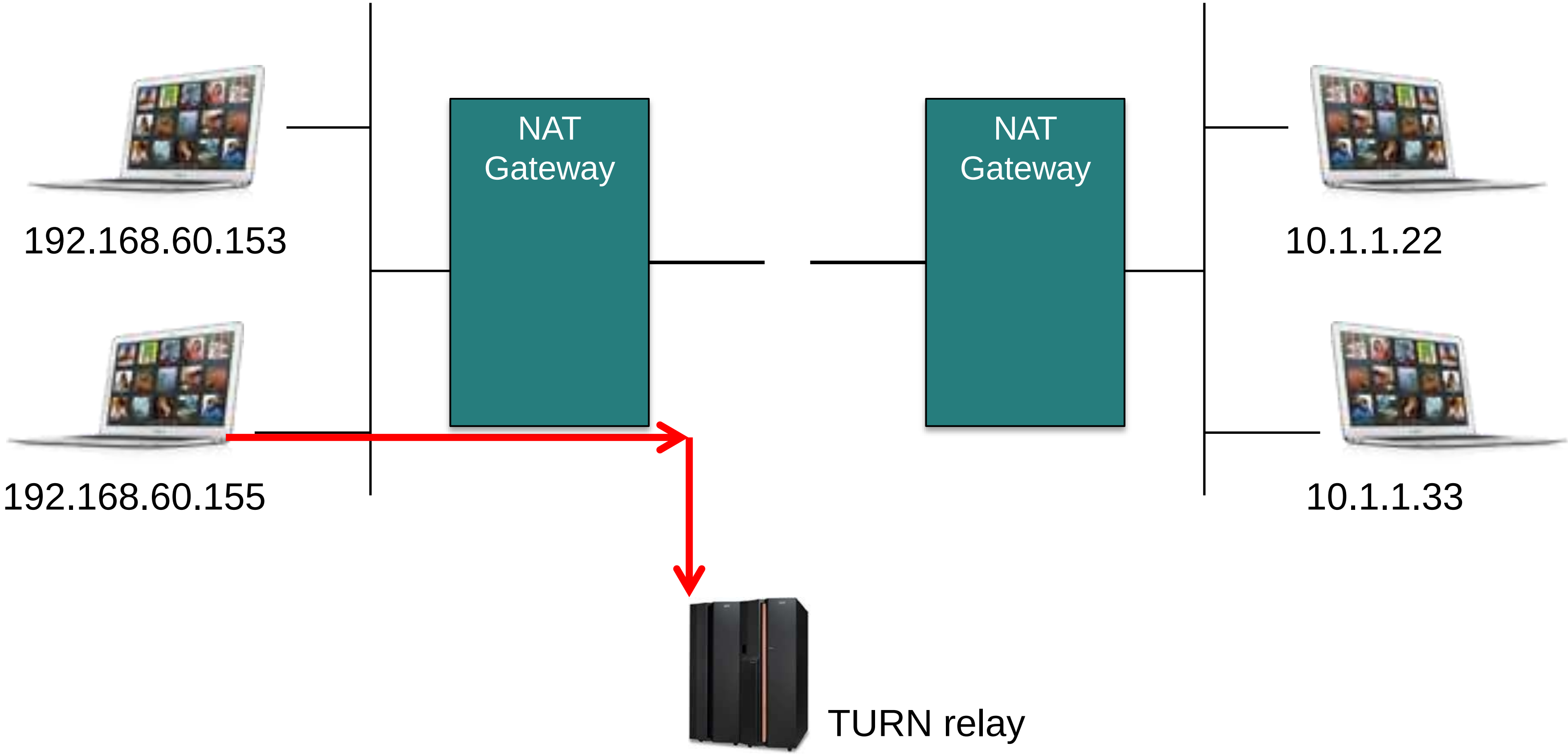
TURN

- Traversal Using Relays around NAT; RFC 5766
  - Protocol that uses a relay server

TURN

TURN server: Relay-based protocol

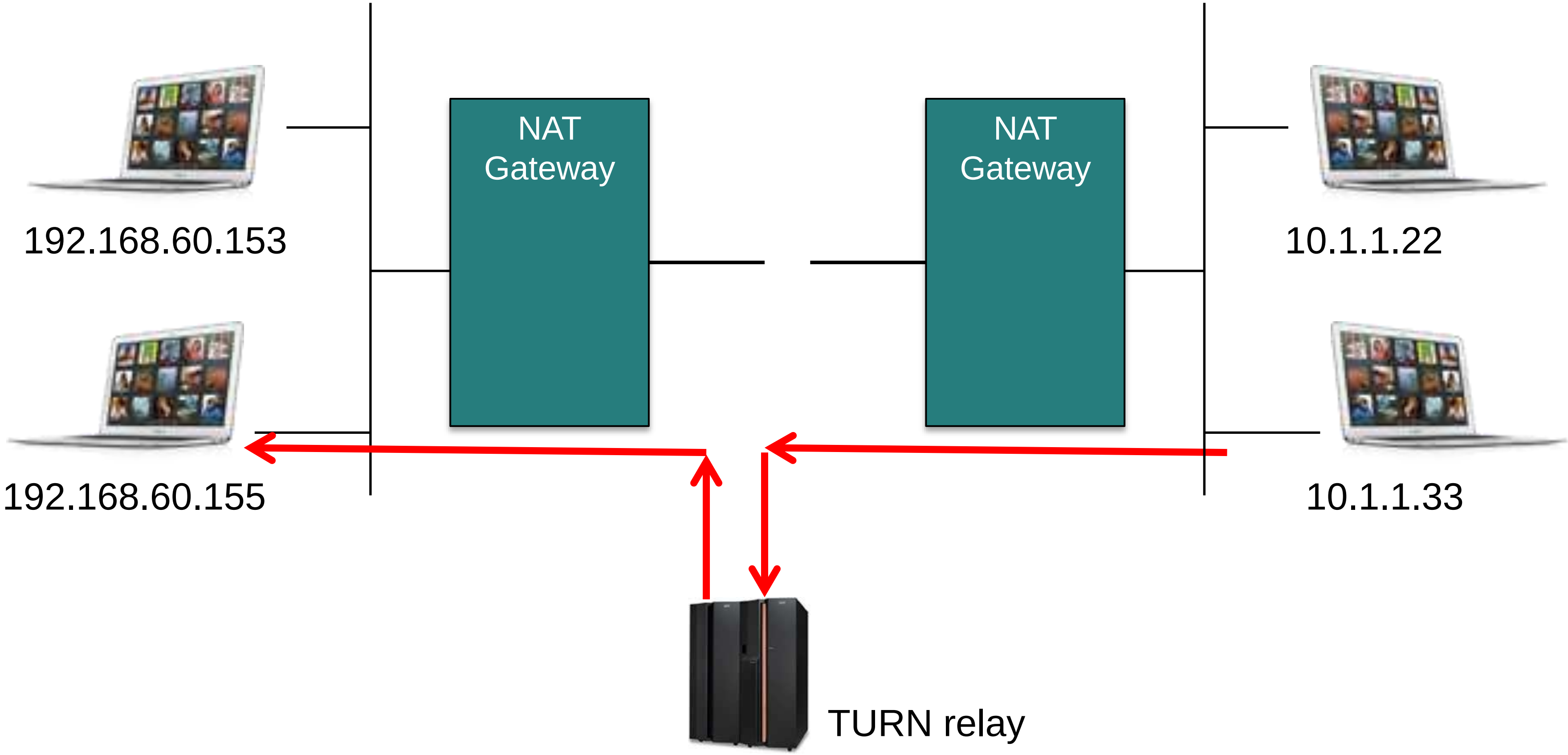
- .155 connects to a TURN server
- Informs the server which locations it should accept packets from
- Gets an IP address & port allocated by the TURN server to use as a relay



TURN

TURN server: STUN server with relay capabilities

- .33 contacts the TURN relay, which relays its external host:port to .155



ICE

- Interactive Connectivity Establishment; RFC 5245
  - Coordinates whether to use STUN or TURN
  - Protocol to negotiate NAT traversal
    - Discover presence of NAT on either side
    - Exchange information
    - Discover how to establish a connection
      - Choose STUN or TURN
  - Extension to SIP (but can be used by other protocols)

Zero Configuration Networking

Network Configuration

- Normally
  - DHCP server to get an IP address (and subnet mask, gateway)
  - DNS for looking up names
- What if we don't have these available?
  - Use IP Link-Local Addresses
  - Goal: each device gets an IP address that is unique in the LAN
  - These are non-routable (not valid on the outside Internet)

IPv4: Link-Local Addresses

- 169.254.0.0/16 block – reserved for link-local addresses
- Pick a random address in the 169.254.0.0/16 range
- Use ARP to see if someone else also has it
- If so, try again

IPv6 Stateless Address Autoconfiguration (SLAAC)

- **Link-local addresses**
  - Combination of address prefix & interface ID
    - Use fe80::/64 block as an address prefix
    - Hosts generate a unique 64-bit interface ID from the MAC address
  - Run **Duplicate Address Detection** to ensure address is unique
    - Send a *Neighbor Solicitation* request (IPv6's version of ARP)
    - If someone else has it, fail: admin intervention required.
  - Unlike IPv4, every host should have a link-local address even if they have a routable address
- **Routable addresses**
  - Routers advertise prefixes that identify the link's subnet
  - Use this prefix instead of fe80
  - SLAAC can behave like a simplified DHCP
    - Good if just getting a unique, routable address is sufficient

Multicast DNS

- RFC 6762, used by Apple Bonjour and Android ≥ 4.1
- Translate between names and IP addresses without a DNS server
  - Multicast DNS: Use IP multicast for DNS queries
    - Each computer stores its own list of resource records
    - Sort of like ARP for DNS
    - Handles queries for the .local top-level domain (by default)
  - Runs its own mini DNS server: mDNSResponder

Also see Microsoft's Link-local Multicast Name Resolution (LLMNR), RFC 4795

Multicast DNS for service discovery

- Locate or advertise services without using a directory server
- Example, Apple DNS-based Service Discovery: DNS-SD (RFC 6763)
  - Use DNS services (DNS or multicast DNS)
  - Structured Instance Names
    - SRV record: query for *Instance.Service.Domain* gives target IP, port
    - TXT record with same name: extra info provided as key/value pairs
  - PTR record: service type to see all instances of the service
  - Also
    - Simple Service Discovery Protocol (SSDP; part of UPnP)
    - Service Location Protocol (SLP)

SRV record example

- Example DNS SRV record

TTL port host

```
myprinter._printer._tcp.local.   120   IN   SRV   0 0 5432 myserver.local.
```

- DNS TXT record
  - May contain additional information
  - Example:
    - Different print queues for printer services on the same IP address
  - Information is application-specific

- PTR record

```
_printer._tcp.local.   28800 PTR myprinter._printer._tcp.local.
```

  - Allows one to query DNS for all services of type _printer.

Apple Bonjour initial steps

- New device starts up
  - **Is there a DHCP server?**
    - If yes, get IP address and routing info
    - If no, pick an address in the link-local (zeroconf) range: 169.254.0.0/16
      - Test the address and claim it if nobody responds
  - **Start up Multicast DNS responder**
    - Requests a chosen hostname
    - Multicasts query to see if it's taken
    - Claims it if not taken
  - **Start up service (get port)**
  - **Publish service** (friendly name, service name, address, port)
    - Create SRV record `friendly_name.service_name._tcp.local` that points to the hostname and port for the service
    - Create PTR record `service_name._tcp.local`

The end