University of Toronto
ECE361
Computer Networks

Dynamic Host Configuration Protocol (DHCP)

IP addresses: how to get one?

Q: How does a *host* get IP address?

- Option 1: hard-coded by system admin in a file
  - Windows: control-panel->network->configuration
  - UNIX: /rc.config
- Option 2: DHCP: Dynamic Host Configuration Protocol: Dynamically get an IP address from as server.
  - "plug-and-play"

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DHCP: Overview

- When a new computer is attached to a LAN, the computer broadcasts a message asking a server "give me a network address."
- Server maintains a pool of free IPs and assigns one to this computer with a specified time-to-live (e.g. one hour).
- The computer can then start using the standard Internet applications.
- As the time-to-live becomes close to zero, computer asks the server for an extension (which is normally granted).
- If connection is terminated then the IP is returned to the pool of free IPs.

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DHCP: Dynamic Host Configuration Protocol

- Dynamic assignment of IP addresses is desirable for several reasons:
  - Avoid manual IP configuration.
  - IP addresses are assigned on-demand.
  - Support mobility of laptops.
  - Allows reusing of the IP Addresses
  - Supports temporary allocation ("leases") of IP addresses.
  - Is the preferred mechanism for dynamic assignment of IP addresses.

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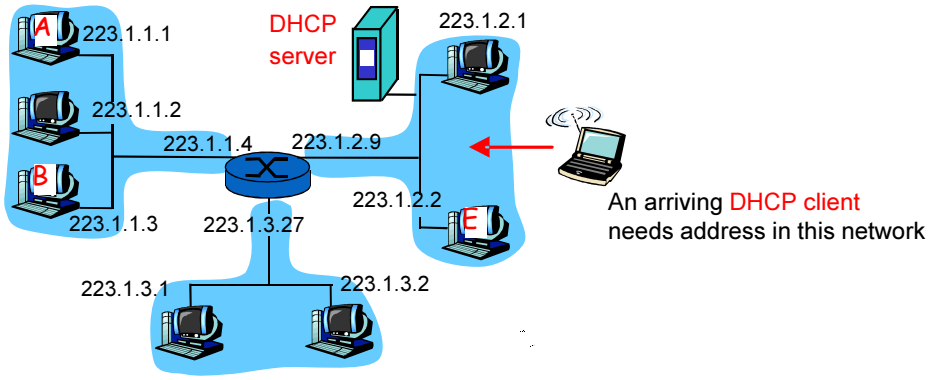
DHCP client-server scenario



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DHCP overview:

- DHCP discover: Client broadcasts in order to find out available DHCP servers.
- DHCP offer: Response from a server to a DHCPDISCOVER and offering IP address and other parameters.
- DHCP request: Message from a client to servers that does one of the following:
  - Requests the parameters offered by one of the servers and declines all other offers.
  - Verifies a previously allocated address after a system or network change (a reboot for example).
  - Requests the extension of a lease on a particular address.
- DHCP ack: Acknowledgement from server to client with parameters, including IP address.

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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 server
  - network mask (indicating network versus host portion of address)

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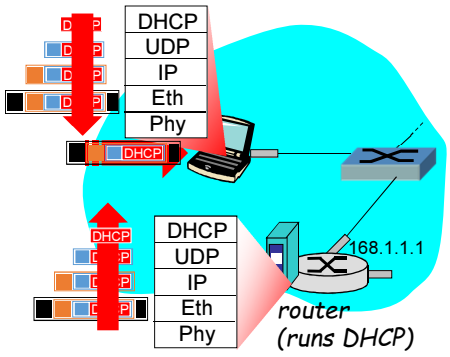
DHCP: Example



- Connecting laptop needs its IP address, addr of first-hop router, addr of DNS server: use DHCP
- DHCP request encapsulated in UDP, encapsulated in IP, encapsulated in 802.1 Ethernet
- Ethernet frame broadcast (dest: FFFFFFFFFFFF) on LAN, received at router running DHCP server
- Message is demultiplexed.

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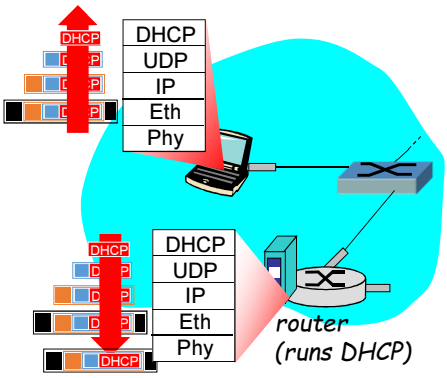
DHCP: Example



- DHCP server formulates ACK containing client's IP address, IP address of first-hop router for client, name & IP address of DNS server
- Encapsulation of DHCP server, frame forwarded to client
- Client now knows its IP address, name and IP address of DNS server, IP address of its first-hop router

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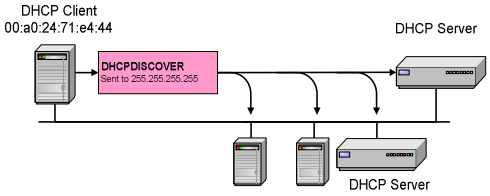
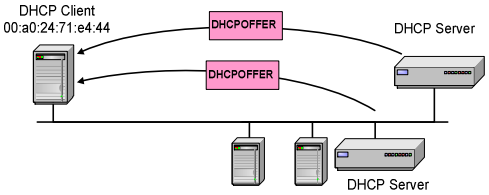
DHCP Operation

DCHP DISCOVER



DCHP OFFER



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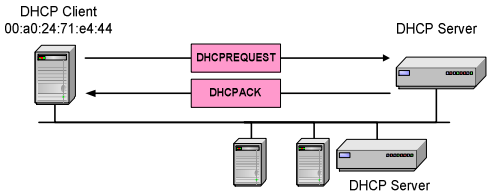
DHCP Operation

DCHP Request / DHCP ACK

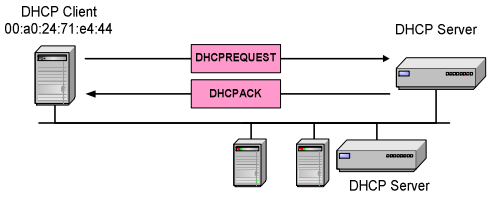
After receiving ACK, the DHCP client can start to use the IP address



Renewing a Lease

(sent when 50% of lease has expired)

If DHCP server sends DHCPNACK, then address is released.



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Broadcast or Unicast

- It is possible to use broadcast for the complete assignment process (DISCOVERY, OFFER, REQUEST, ACK), but unicast is frequently used:
  - When DHCP client knows address of DHCP server, it may use unicast in all its messages.

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Notes

- An issue that arises with automatic assignment of IP addresses from a pool is for how long an IP address should be allocated. If a host leaves the network and does not return its IP address to the DHCP server, that address will be permanently lost.
  - After a period of time, many addresses may be lost.
  - To prevent that from happening, IP address may be assigned for a fixed period of time, this technique is called leasing.
  - Then before the lease expires, the host must ask for a DHCP renewal.
  - If client does not receive an ACK message after its lease has expired, then client is automatically forced to stop its current TCP configuration.
  - Client may then return to the initial state, issuing a DISCOVER broadcast to try and obtain any valid address.

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Network Address Translation

(NAT)

Private Network

- A *Private IP* network is an IP network that is not directly connected to the Internet.
- IP addresses in a private network can be assigned arbitrarily.
  - Not registered and not guaranteed to be globally unique.
- Private networks can use addresses from the following experimental address ranges:
  - 10.0.0.0 – 10.255.255.255
  - 172.16.0.0 – 172.31.255.255
  - 192.168.0.0 – 192.168.255.255

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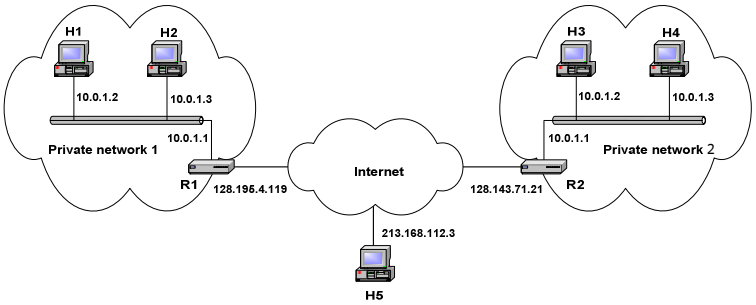
Private Addresses



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Network Address Translation (NAT)

- Is a method that enables hosts on private networks to communicate with hosts on the Internet.
- Runs on routers that connect private networks to the public Internet, to replace the IP address-port pair of an IP packet with another IP address-port pair.

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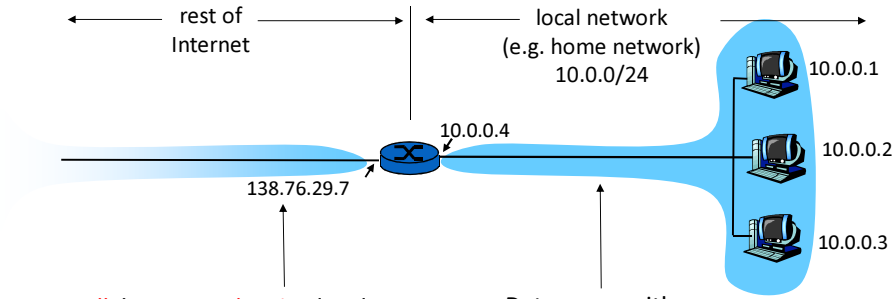
NAT: Network Address Translation



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 10.0.0.0/24 address

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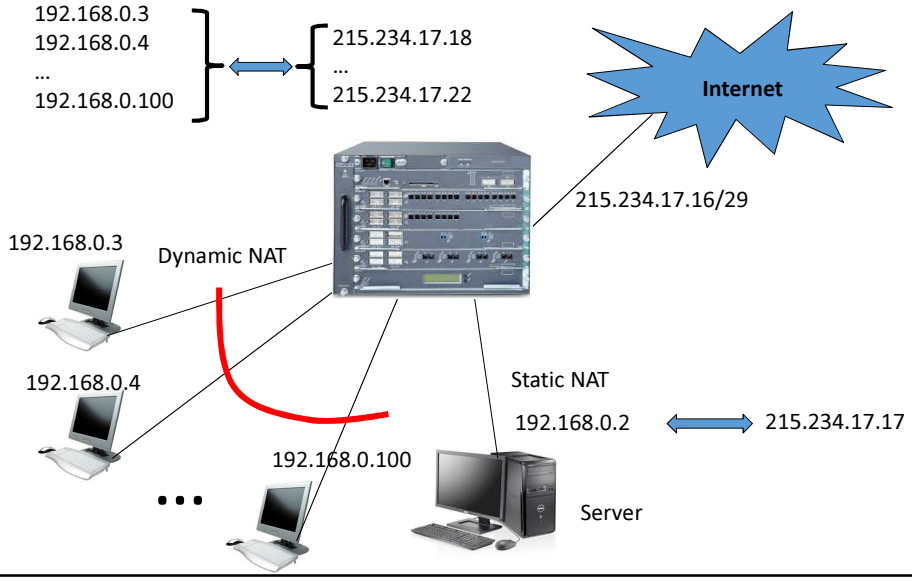
Address Translation



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Static/Dynamic NAT

Static NAT – Mapping an unregistered IP address to a registered IP address on a one-to-one basis. Particularly useful when a device needs to be accessible from outside the network.
Example: In previous example, the computer with the IP address of 192.168.0.2 will always translate to 215.234.17.17

Dynamic NAT – Maps an unregistered IP address to a registered IP address from a group of registered IP addresses.
Example: In previous example, the computer with the IP address of 192.168.0.3 will translate to the first available address in the range from 215.234.17.17 to 215.234.17.22

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IP Overloading

- NAT maps single public IP address to multiple unregistered IP addresses (private network addresses) by using different port numbers.
  - Called PAT (Port Address Translation), single address NAT, port-level multiplexed NAT, or NAPT (Network Address and Port Translation).
  - NAPT operates at the Transport Layer.
  - NAPT translation Table contains 4-tuples of source and destination protocol port numbers and IP addresses.
- **Example:** Each computer on the private network is translated to the same IP address (215.234.17.17) but with a different port number assignment**.**

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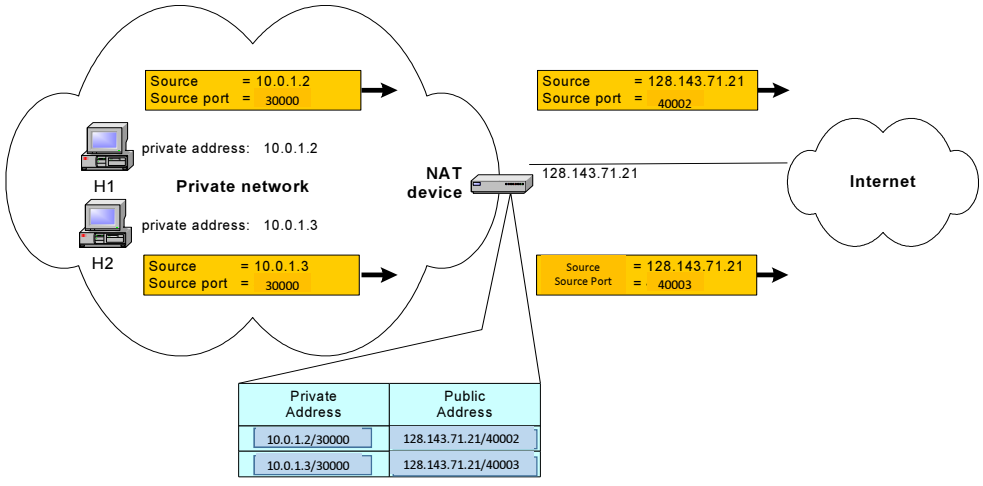
IP Overloading



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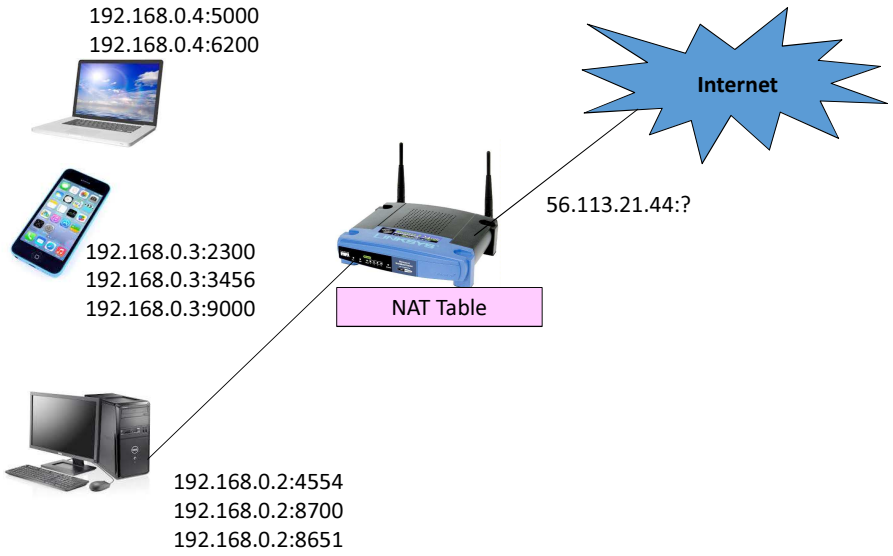
Port Translation



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Supporting migration between ISPs

- **Scenario:** IP addresses in a corporate network are obtained from the service provider. Changing the service provider requires changing all IP addresses in the network.
- **NAT solution:**
  - The corporate network is assigned private addresses to its hosts.
  - NAT device has static address translation entries that can bind the private addresses of hosts to the public addresses.
  - Migration to a new network service provider merely requires an update of the NAT device. The migration is not noticeable to the hosts on the network.

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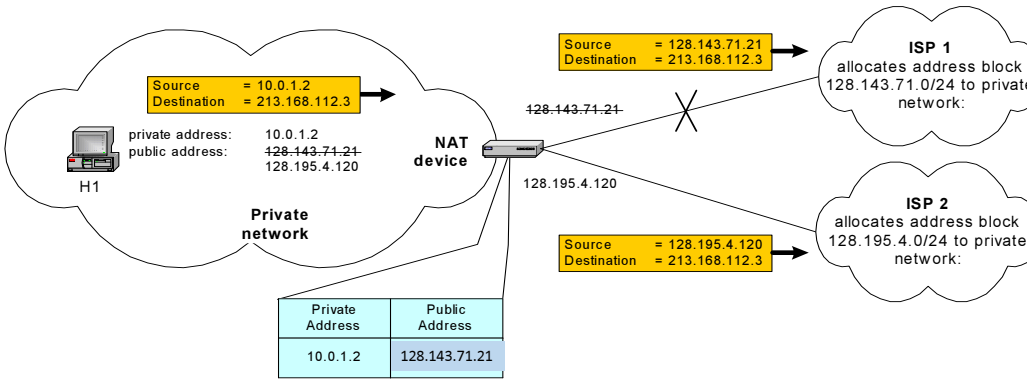
Supporting migration between network ISPs



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Load balancing of servers

- **Scenario:** Balance the load on a set of identical servers, which are accessible from a single IP address.

- **NAT solution:**
  - Servers are assigned private addresses.
  - NAT device acts as a proxy for requests to the server from the public network.
  - NAT device changes the destination IP address of arriving packets to one of the private addresses for a server.
  - Then can evenly distribute the load.

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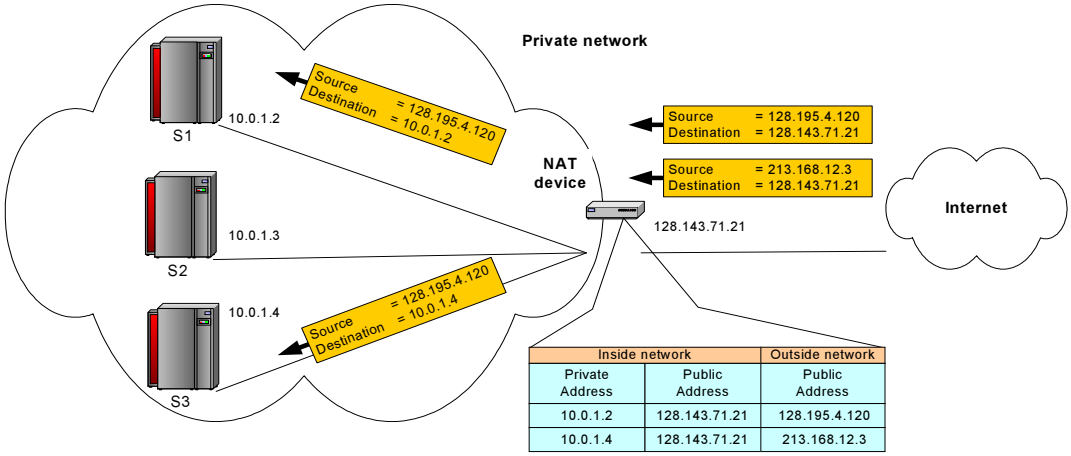
Load balancing of servers



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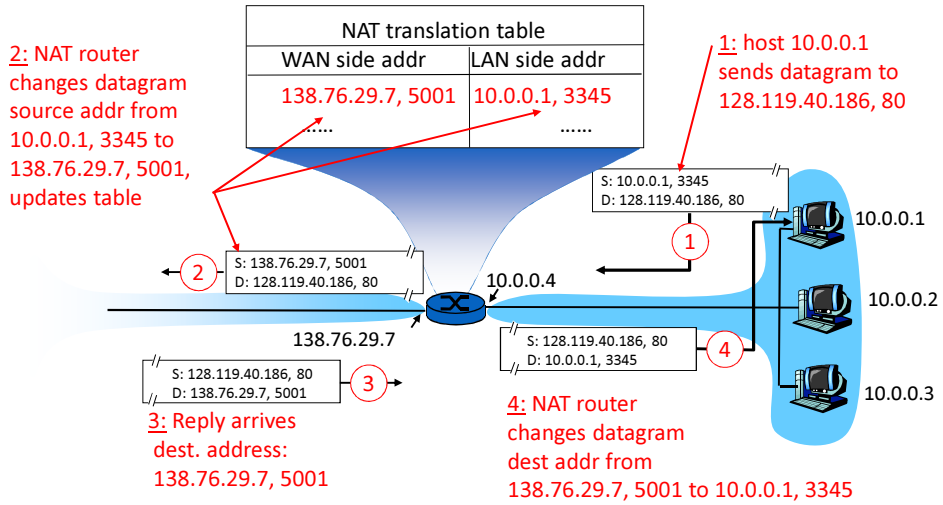
NAT: Network Address Translation



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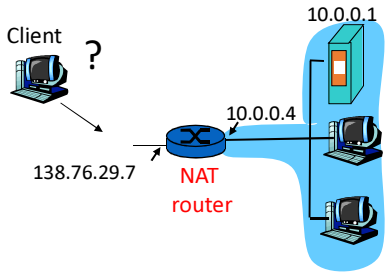
NAT traversal problem

- client wants to connect to server with address 10.0.0.1
  - server address 10.0.0.1 local to LAN (client cannot use it as destination address)
  - only one externally visible NATted address: 138.76.29.7
- solution: statically configure NAT to forward incoming connection requests at a given port to server
  - e.g. (123.76.29.7, port 2500) always forwarded to 10.0.0.1 port 25000



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NAT Advantages

- Can use only one IP address (could be more) for all the devices in the network.
- Can change addresses of devices in local network without notifying outside world.
- Devices inside local net not explicitly addressable, visible by outside world (a security plus).
- Can perform load balancing of servers.
- Reduces the cost associated with purchasing host numbers.
- Makes transition from one ISP to another easy.

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NAT Disadvantages

- **Intensive computation:**
  - NAT requires intensive computation such to modify IP addresses, port numbers, and recalculate checksums.
- **End-to-end connectivity:**
  - NAT destroys universal end-to-end reachability of hosts on the Internet.
  - If any end-to-end security protocol is implemented then NAT may not work since NAT changes the IP header and this is considered as a security violation.
  - A host in the public Internet often cannot initiate communication to a host in a private network.
  - Routers should only process up to layer 3
- **Better approach:** IP address shortage should instead be solved by IPv6.

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Internet Control Message Protocol

(ICMP)

Chapter 4: Network Layer

- 4. 1 Introduction
- 4.2 Virtual circuit and datagram networks
- 4.3 What's inside a router
- 4.4 IP: Internet Protocol
  - Datagram format
  - IPv4 addressing
  - ICMP
  - IPv6
- 4.5 Routing algorithms
  - Link state
  - Distance Vector
  - Hierarchical routing
- 4.6 Routing in the Internet
  - RIP
  - OSPF
  - BGP
- 4.7 Broadcast and multicast routing

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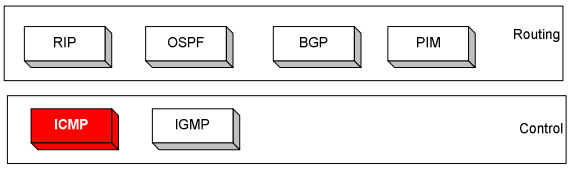
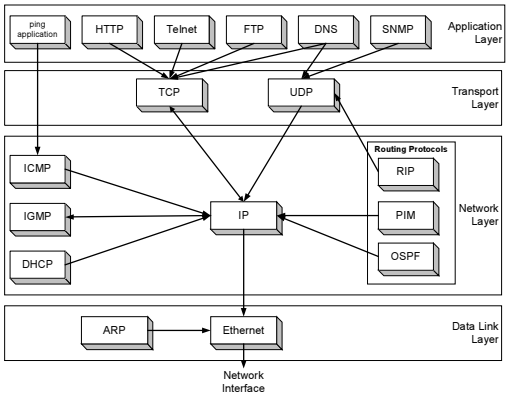
Overview

- The IP (Internet Protocol) relies on several other protocols to perform necessary control and routing functions:
  - Control functions (ICMP)
  - Multicast signaling (IGMP)
  - Setting up routing tables
    (RIP, OSPF, BGP, PIM, …)





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ICMP: Internet Control Message Protocol

- Used by hosts and routers to communicate network-level information
  - Error reporting: unreachable host, network, port, protocol
  - Echo request/reply (used by ping)
  - Simple queries
- Resides at the Network-layer "above" IP:
  - ICMP messages are carried in IP datagrams
- ICMP messages are encapsulated as IP datagrams:
  - Protocol field in the IP header is set to: 0x01

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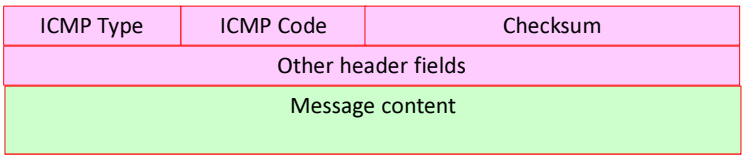
ICMP Header

- All ICMP packets will have an 8-byte header and variable-sized data section:
  - The first byte is for the ICMP type.
  - The second byte is for the ICMP code.
  - The third and fourth bytes are a checksum of the entire ICMP message.
  - The contents of the remaining 4 bytes of the header will vary based on the ICMP type and code. If there is no additional data, then these 4 bytes are set to zero.



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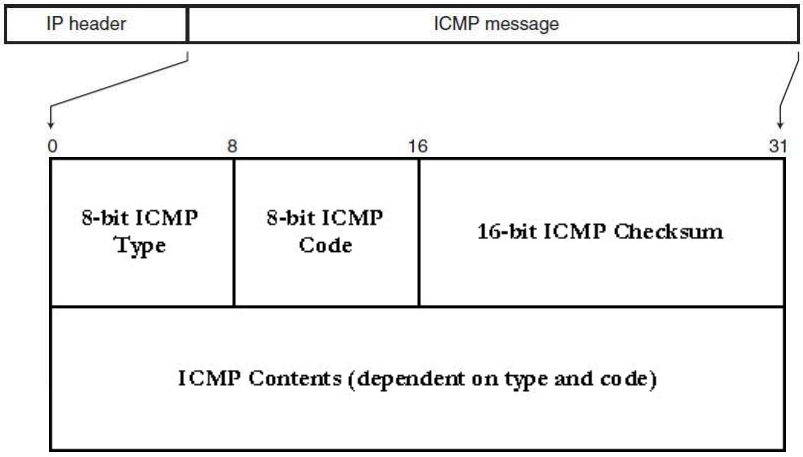
ICMP Message



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ICMP: Internet Control Message Protocol

- ICMP message: type, code plus first 8 bytes of IP datagram causing error

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

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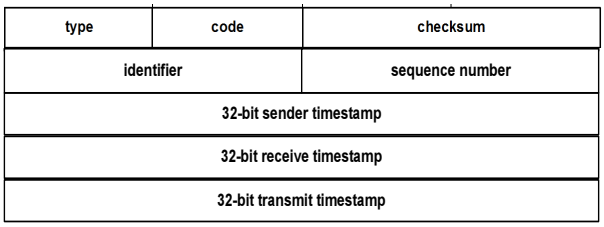
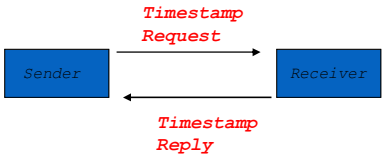
Example of a Query: ICMP Timestamp

- A system (host or router) asks another system for the current time.
- Time is measured in milliseconds after midnight UTC (Universal Coordinated Time) of the current day
- Sender sends a request, receiver responds with reply





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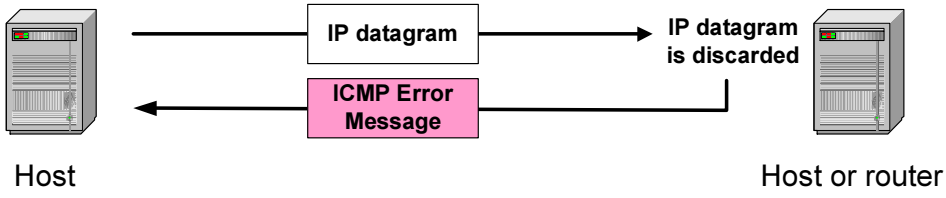
ICMP Error message



- ICMP error messages report error conditions
- Typically sent when a datagram is discarded
- Error message is often passed from ICMP to the application program

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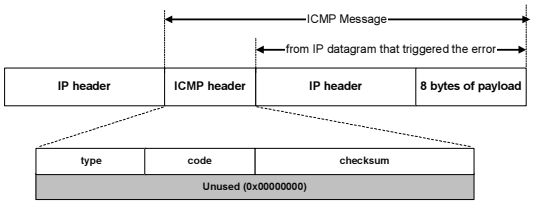
ICMP Error message



20-byte IP header (protocol = 1—ICMP)		
Type = 11	Code	Checksum
unused		
IP header + first 8 payload bytes of packet that caused ICMP to be generated		

- ICMP error messages include the complete IP header and the first 8 bytes of the payload (typically: UDP, TCP) of the packet that triggered the error condition

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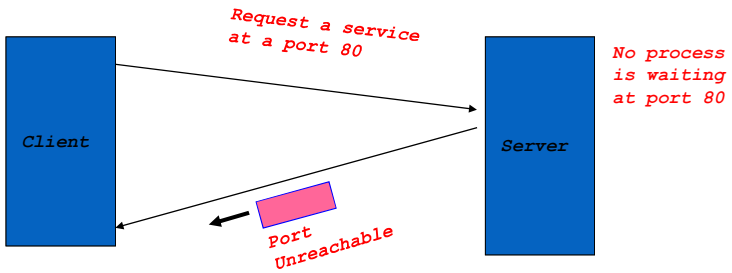
Example: ICMP Port Unreachable

- RFC 792:
  - If, in the destination host, the IP module cannot deliver the datagram because the indicated protocol module or process port is not active, the destination host may send a destination unreachable message to the source host.
- Scenario:
  - We request to non-existing web server



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Traceroute

- Is implemented by ICMP
- Allows to determine the names and addresses of the routers from source to destination.
- Sends a series of UDP datagrams with TTL 1, 2, 3, …, n
  - Potentially with no Port Number.
- Starts a timer for each datagram.
- As a datagram arrives at a router and eventually the TTL expires:
  - Router sends back an unreachable ICMP message (type 11, code 0)
  - Router drops the datagram.
  - The ICMP message has both name and the IP address of the router.

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Traceroute

- When ICMP message arrives at the source then source calculates RTT.
- Traceroute sends sets of 3 packets with the same TTL.

Stopping criterion

- UDP segment eventually arrives at the destination host
- Destination returns ICMP "host unreachable" packet (type 3, code 3)
- When source gets this ICMP, stops.

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