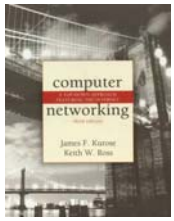
Chapter 4
Network Layer



Computer Networking: A Top Down Approach Featuring the Internet, 3rd edition.
Jim Kurose, Keith Ross
Addison-Wesley, July 2004.

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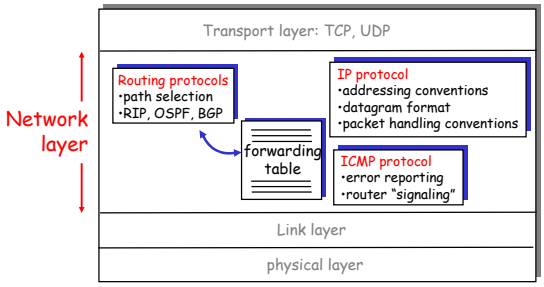
Thanks and enjoy! JFK/KWR

Chapter 4: Network Layer

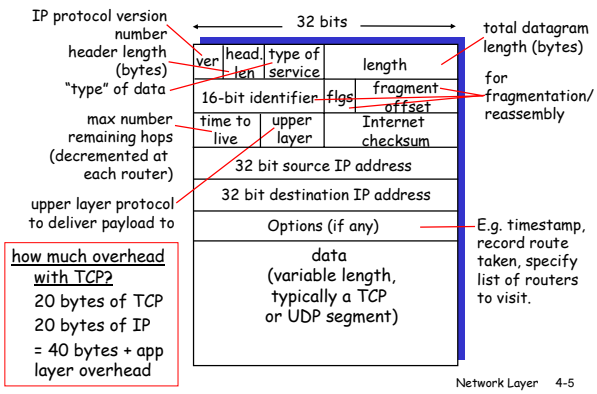
The Internet Network layer

Host, router network layer functions:



Chapter 4: Network Layer

IP datagram format

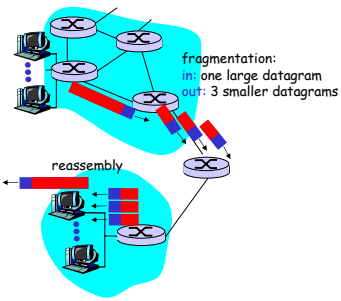


how much overhead with TCP?
- 20 bytes of TCP
- 20 bytes of IP
- = 40 bytes + app layer overhead

IP Fragmentation & Reassembly

network links have MTU (max.transfer size) - largest possible link-level frame.
- different link types, different MTUs

large IP datagram divided ("fragmented") within net
- one datagram becomes several datagrams
- "reassembled" only at final destination
- IP header bits used to identify, order related fragments

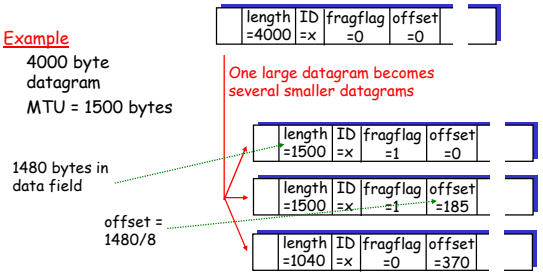


IP Fragmentation and Reassembly

Example

4000 byte datagram

MTU = 1500 bytes



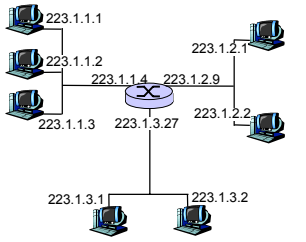
Chapter 4: Network Layer

IP Addressing: introduction

IP address: 32-bit identifier for host, router *interface*

interface: connection between host/router and physical link

- router's typically have multiple interfaces
- host may have multiple interfaces
- IP addresses associated with each interface



223.1.1.1 = 11011111 00000001 00000001 00000001

223 1 1 1

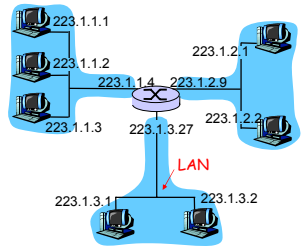
Subnets

IP address:

- subnet part (high order bits)
- host part (low order bits)

What's a subnet ?

- device interfaces with same subnet part of IP address
- can physically reach each other without intervening router

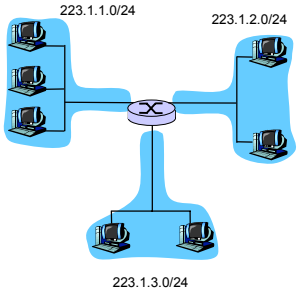


network consisting of 3 subnets

Subnets

Recipe

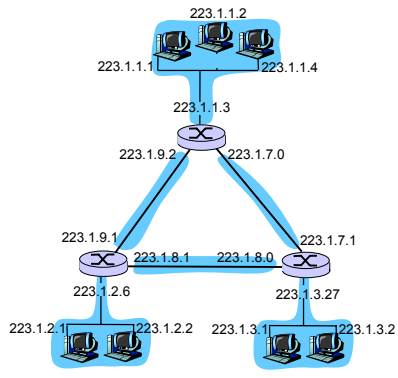
To determine the subnets, detach each interface from its host or router, creating islands of isolated networks. Each isolated network is called a subnet.



Subnet mask: /24

Subnets

How many?

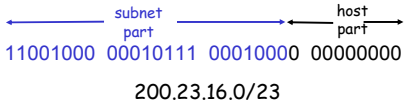


IP addressing: CIDR

CIDR: Classless InterDomain Routing

subnet portion of address of arbitrary length

address format: a.b.c.d/x, where x is # bits in subnet portion of address



200.23.16.0/23

IP addresses: how to get one?

Q: How does *host* get IP address?

hard-coded by system admin in a file

Wintel: control-panel->network->configuration->tcp/ip->properties

UNIX: /etc/rc.config

DHCP: Dynamic Host Configuration Protocol: dynamically get address from as server

"plug-and-play"

(more in next chapter)

IP addresses: how to get one?

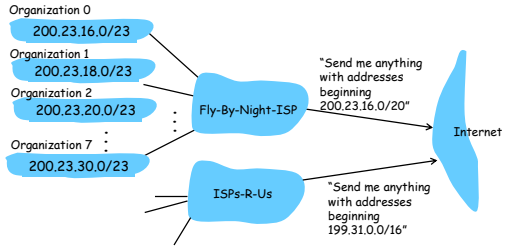
Q: How does *network* get subnet part of IP addr?

A: gets allocated portion of its provider ISP's address space

ISP's block	11001000 00010111 00010000 00000000	200.23.16.0/20
Organization 0	11001000 00010111 00010000 00000000	200.23.16.0/23
Organization 1	11001000 00010111 00010010 00000000	200.23.18.0/23
Organization 2	11001000 00010111 00010100 00000000	200.23.20.0/23
...	....	....
Organization 7	11001000 00010111 00011110 00000000	200.23.30.0/23

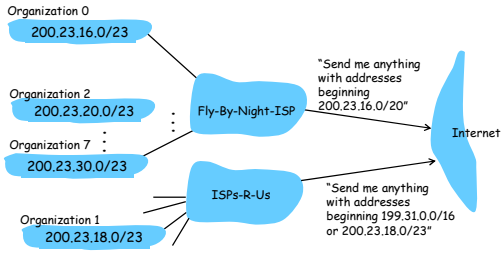
Hierarchical addressing: route aggregation

Hierarchical addressing allows efficient advertisement of routing information:



Hierarchical addressing: more specific routes

ISPs-R-Us has a more specific route to Organization 1



IP addressing: the last word...

Q: How does an ISP get block of addresses?

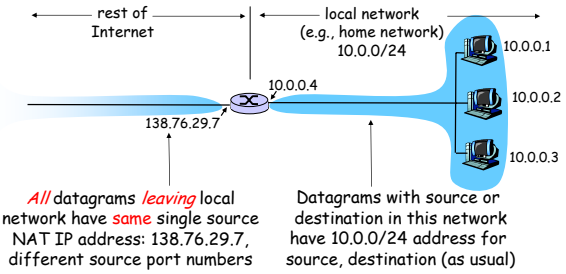
A: ICANN: Internet Corporation for Assigned Names and Numbers

allocates addresses

manages DNS

assigns domain names, resolves disputes

NAT: Network Address Translation



NAT: Network Address Translation

Motivation: local network uses just one IP address as far as outside word is concerned:

- no need to be allocated range of addresses from ISP: - just one IP address is used for all devices
- 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).

NAT: Network Address Translation

Implementation: NAT router must:

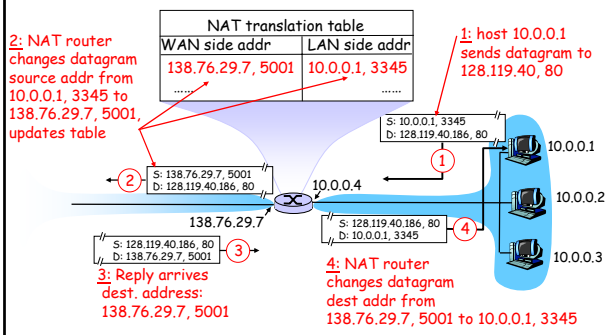
outgoing datagrams: replace (source IP address, port #) of every outgoing datagram to (NAT IP address, new port #)

. . . remote clients/servers will respond using (NAT IP address, new port #) as destination addr.

remember (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

16-bit port-number field:

- 60,000 simultaneous connections with a single LAN-side address!

NAT is controversial:

- routers should only process up to layer 3
- violates end-to-end argument
  - NAT possibility must be taken into account by app designers, eg, P2P applications
- address shortage should instead be solved by IPv6

Chapter 4: Network Layer

ICMP: Internet Control Message Protocol

used by hosts & routers to communicate network-level information
- error reporting: unreachable host, network, port, protocol
- echo request/reply (used by ping)

network-layer "above" IP:
- ICMP msgs carried in IP datagrams

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

Traceroute and ICMP

Source sends series of UDP segments to dest
- First has TTL =1
- Second has TTL=2, etc.
- Unlikely port number

When nth datagram arrives to nth router:
- Router discards datagram
- And sends to source an ICMP message (type 11, code 0)
- Message includes name of router& IP address

When ICMP message arrives, source calculates RTT

Traceroute does this 3 times

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

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

IPv6

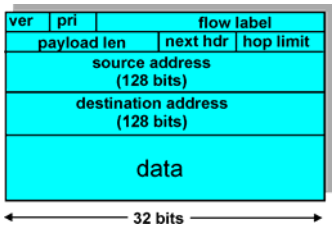
Initial motivation: 32-bit address space soon to be completely allocated.

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 Header (Cont)

Priority: identify priority among datagrams in flow
Flow Label: identify datagrams in same "flow." (concept 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

Transition From IPv4 To IPv6

Not all routers can be upgraded simultaneous
- no "flag days"
- How will the network operate with mixed IPv4 and IPv6 routers?

Tunneling: IPv6 carried as payload in IPv4 datagram among IPv4 routers

Tunneling