

Network layer: “data plane” roadmap

■ Network layer: overview

- data plane
- control plane

■ What’s inside a router

- input ports, switching, output ports
- buffer management, scheduling



■ IP: the Internet Protocol

- datagram format
- addressing
- network address translation
- IPv6

■ Generalized Forwarding, SDN

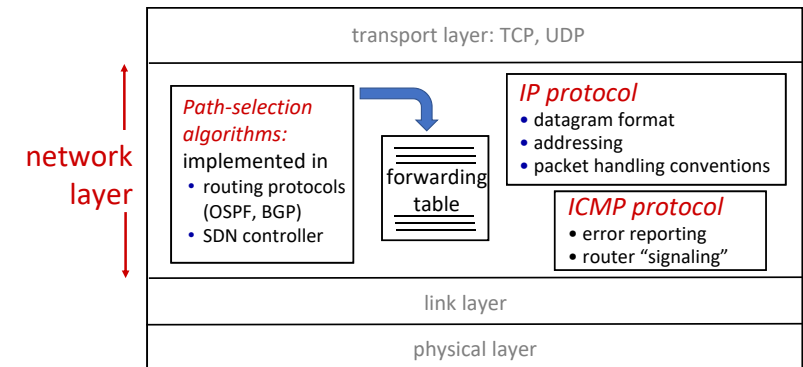
- match+action
- OpenFlow: match+action in action

■ Middleboxes

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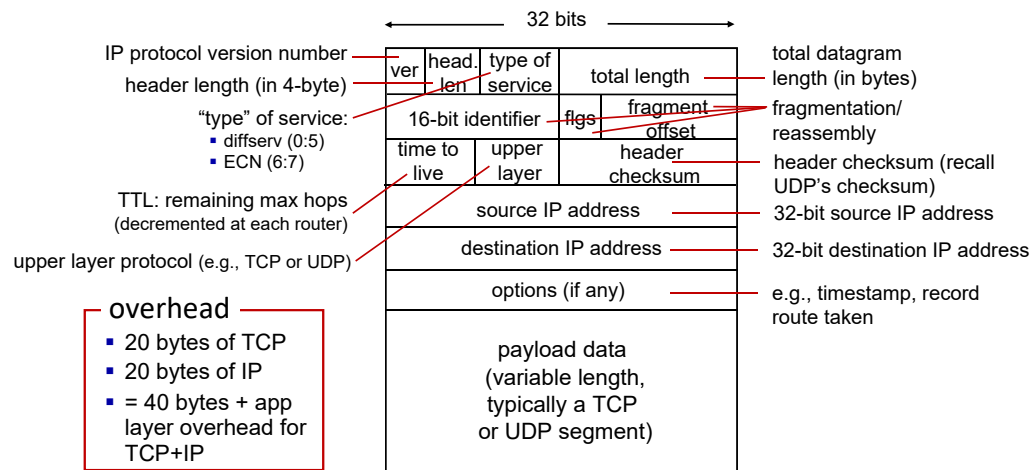
Network Layer: Internet

host, router network layer functions:



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IP Datagram format: IPv4



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IP addressing: introduction of IPv4 address

■ IP address:

- identifier in the network layer
 - is unique with some exceptions
- IP address is 32-bit (for IPv4)
 - dotted-decimal notation
- associated with each host or router *interface*

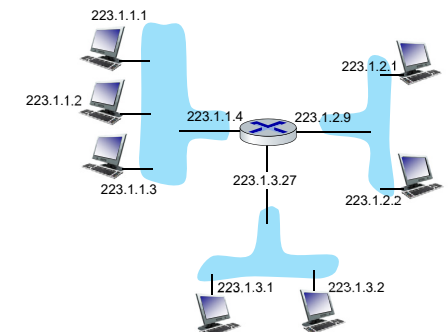
■ interface: connection between host/router and physical link

- router’s typically have multiple interfaces
- host typically has one or two interfaces (e.g., wired Ethernet, wireless 802.11)

dotted-decimal IP address notation:

223.1.1.1 = 11011111 00000001 00000001 00000001

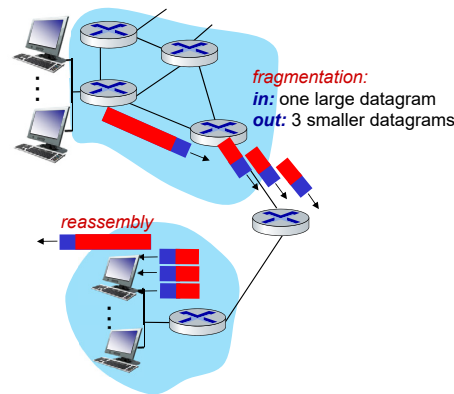
223 1 1 1



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IP fragmentation/reassembly

- link-layer frame have payload length limit, called MTU (max. transmission unit)
 - different link types have different MTUs
 - Ethernet: 1500, WiFi: 2304 (bytes)
- oversized IP datagram is divided ("fragmented") by router
 - one datagram becomes several smaller datagrams (fragments)
 - "reassembled" only at *destination*
 - IP header bits used to identify and order these fragments



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IP fragmentation/reassembly

example:

- Given a 4000-byte datagram before being fragmented
 - 20-byte IP header
 - 3980-byte data
- Given MTU = 1500 bytes
 - each fragment contains
 - 20-byte IP header
 - at most 1480-byte data
- Q: How many fragments needed?
 - $\left\lceil \frac{3980}{1480} \right\rceil = 3$
- Q: offset of each fragment?
 - For 2nd fragment: $\frac{1480}{8} = 185$

tot len	ID	fragflag	offset
=4000	=x	=0	=0

one large datagram becomes several smaller datagrams

tot len	ID	fragflag	offset
=	=x	=1	=

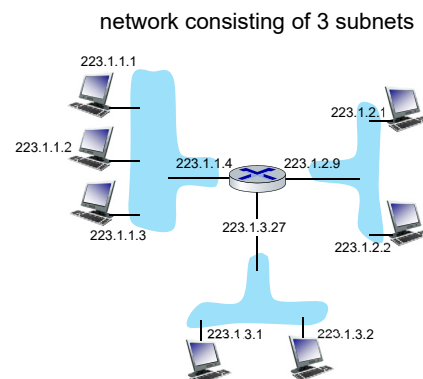
tot len	ID	fragflag	offset
=	=x	=1	=

tot len	ID	fragflag	offset
=	=x	=0	=

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Subnet

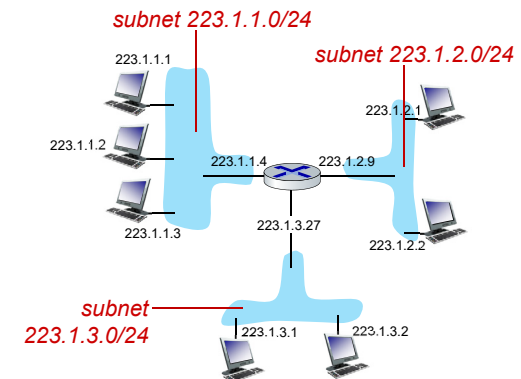
- What's a subnet ?**
 - device interfaces that can reach each other **without passing through an intervening router**
- Recipe for defining subnets:**
 - detach each interface from its host or router, creating "islands" of isolated networks
 - each isolated network is called a subnet



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Subnet

- structure of IP addresses within a subnet:
 - subnet part:** devices in same subnet have common high order bits
 - host part:** remaining low order bits
- dotted-decimal notation of subnet:



$11011111 \ 00000001 \ 00000001 \ xxxxxxxx = 223.1.1.0/24$
 $11011111 \ 00000001 \ 0000001x \ xxxxxxxx =$
 $11011111 \ 00000001 \ 00000000 \ 1xxxxxxx =$

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Subnet

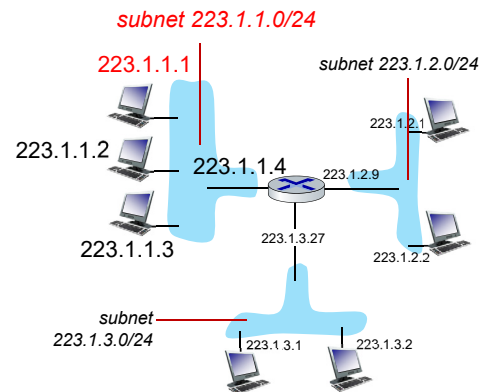
- For the host **223.1.1.1** in the subnet **223.1.1.0/24**, its setting is as follows

- IP address: **223.1.1.1**
- subnet mask: /24 or 255.255.255.0

223.1.1.0/24 =
11011111 00000001 00000001 xxxxxxxx

11111111 11111111 11111111 00000000

- gateway:



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IP address (assignment and routing): CIDR

CIDR: Classless InterDomain Routing (pronounced “cider”)

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

← subnet part → ← host part →
11001000 00010111 00010000 00000000
200.23.16.0/23

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