Internet Multicast Routing

- group addressing
  - class D IP addresses

1110	Multicast Group ID

← 28 bits →

- link layer multicast
- two protocol functions
  - group management
    - IGMP
  - route establishment
    - DVMRP, MOSPF, CBT, PIM

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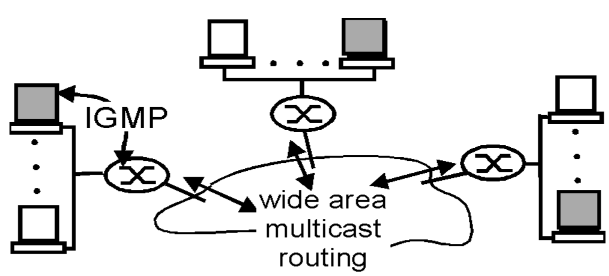
Joining a mcast group: two-step process

- ***local:*** host informs local mcast router of desire to join group: IGMP
- ***wide area:*** local router interacts with other routers to receive mcast packet flow
  - many protocols (e.g., DVMRP, MOSPF, PIM)



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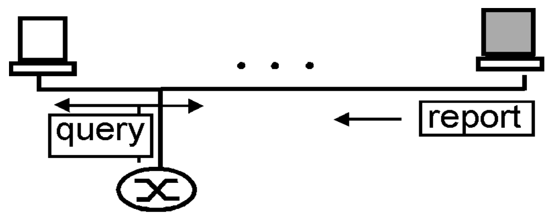
IGMP: Internet Group Management Protocol

- ***host:*** sends IGMP report when application joins mcast group
  - IP_ADD_MEMBERSHIP socket option
  - host need not explicitly "unjoin" group when leaving
- ***router:*** sends IGMP query at regular intervals
  - host belonging to a mcast group must reply to query



IGMPv1 and v2

IGMPv1

- joining host send IGMP report
- leaving host does nothing
- router periodically polls hosts on subnet using IGMP Query
- hosts respond to Query in a randomized fashion

IGMPv2

- additions:
  - Group Specific Queries
  - Leave Group Message
- host sends Leave Group message if it was the one to respond to most recent query
- router receiving Leave Group msg queries group.

IGMPv3

- unclear status??
- additions:
  - Group-Source Specific Queries, Reports and Leaves
- inclusion/exclusion of sources

Protocol Independent Multicast

Motivation:
- DVMRP good for dense group membership
- need shared/source-based tree flexibility
- independence from unicast routing

Two PIM modes:
- Dense Mode (approx. DVMRP)
- Sparse Mode

PIM- Dense Mode

- independent from underlying unicast routing
- slight efficiency cost
- contains protocol mechanisms to:
  - detect leaf routers
  - avoid packet duplicates

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PIM - Sparse Mode

- Rendezvous Point (Core):
  receivers meet sources
- reception through RP connection = Shared Tree
- establish path to source = Source-Based Tree

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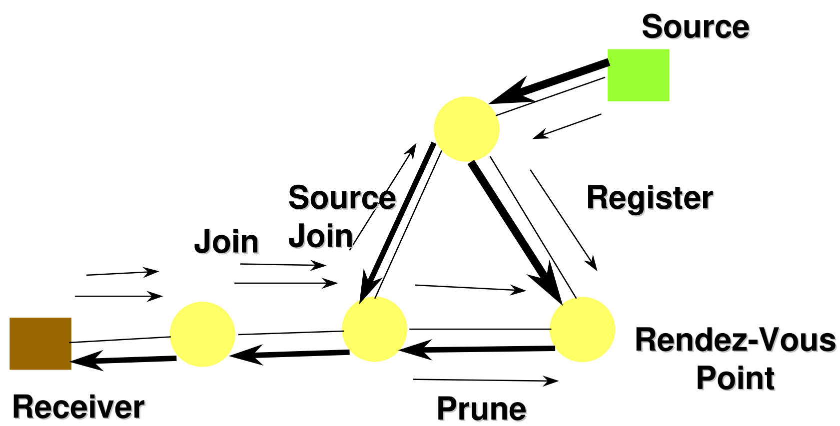
PIM - Sparse Mode



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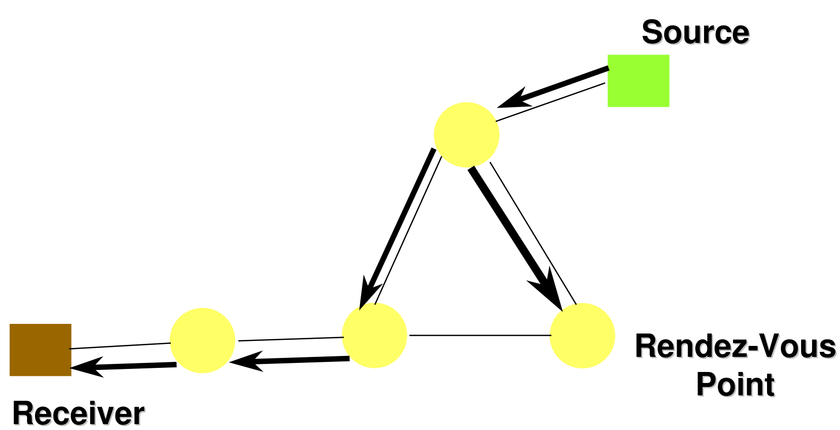
PIM - Sparse Mode



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Border Gateway Multicast Routing Protocol (BGMRP)

- a protocol for inter-domain multicast routing
- bi-directional shared tree for inter-domain routing
- cores (RPs) associated with domains
- receiver domains can utilize choice of protocol

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ICMP: Internet Message Control Protocol

- used to communicate network-level error conditions and info to IP/TCP/UDP protocols or user processes
- often considered part of IP, but
- ICMP message sent within IP datagram
- IP demultiplexes up to ICMP using IP protocol field
- ICMP message contains IP header and first 8 bytes of IP contents that causes ICMP mesage to be generated

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ICMP Packet Types

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IPv6: next generation IP

Changes to Ipv4:

- 128 bit addresses (so we don't run out of IP addresses)
- header simplification (faster processing)
- more support for type of service
  - priorities
  - flow identifier: identifiy packets in a connection
- security

Notes:

- no fragmentation in network
  - packet too big generates ICMP error to source
  - source fragmentation via extension header
- no checksum (already done at transport and data link layer)

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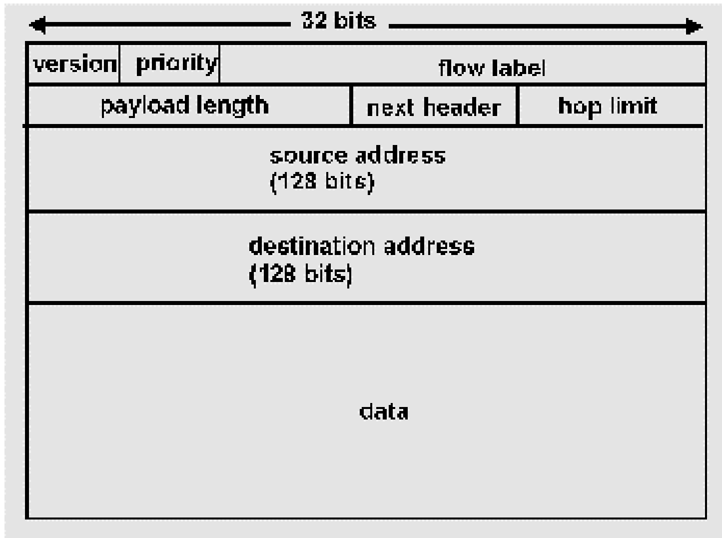

Transitioning from IPv4 to IPv6

Internet too big for "flag day":

- can't turn off all IP routers, install IPv6 and reboot
- IPv4 nodes will be legacy
- IPv6 nodes can route IPv4 packets
- IPv4 nodes cannot route IPv6 packets

Tunneling

- source and destination speak network protocol X
- physically intermediate nodes speak network protocol Y
  - source takes protocol X packet, sticks it inside (encapsulates) protocol Y packet
  - intermediate nodes route using protocol Y
  - destination receives packet using protocol Y, removes protocol X packet
- *network between source and destination looks like a single link to protocol X*

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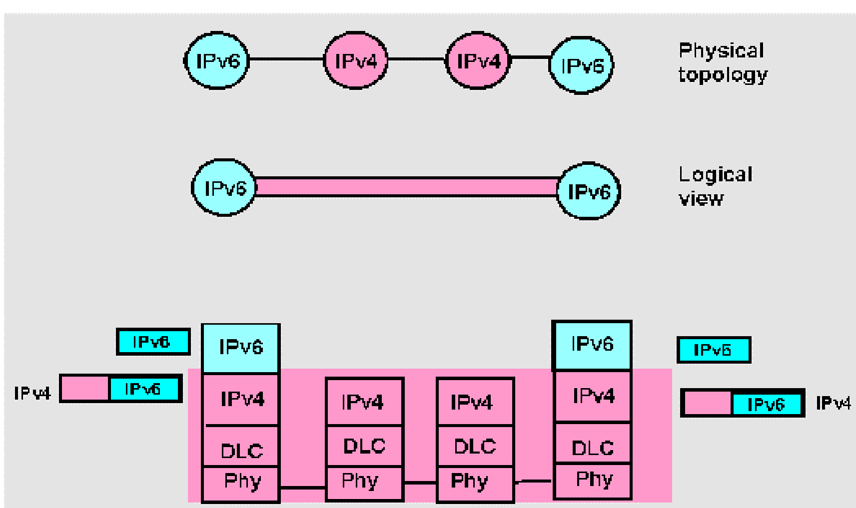
Tunneling: a pictorial view



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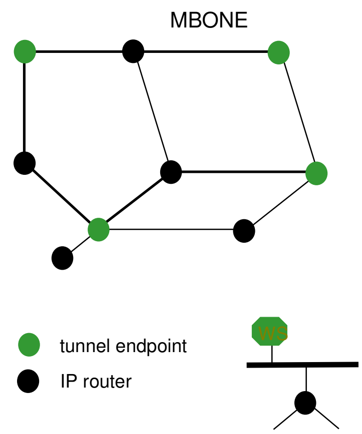
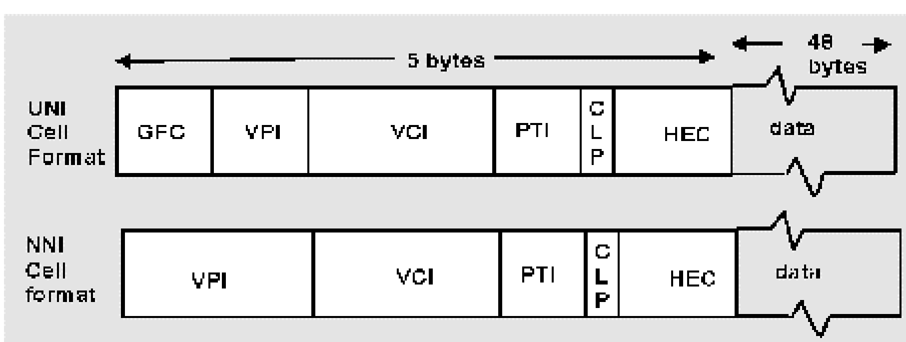
Mbone: Multicast Backbone

- virtual network overlaying Internet
- needed until multicast capable routers deployed **and turned on**
- IP in IP encapsulation
- limited capacity, resilience



Case Study: ATM Network Layer

- ATM: packet (cell) format:
- UNI: user-network interface (host-to-switch)
- NNI: network-network interface (switch-to-switch)



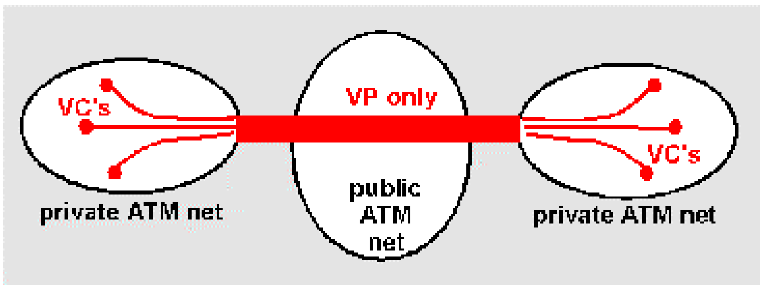
- GFC: generic flow control (unused)
- VPI: virtual path identifier
- VCI: virtual circuit identifier
  - VPI and VCI together a call/connection identifier
- PTI: payload type: 3 bits
  - 111: RM cell (recall RM congestion control)
  - 000: user cell
  - 010: user cell, congestion experienced (recall EFCI)
- CLP: cell loss priority (1 bit)
  - priority bit for discarding
- HEC: header error correction
- DATA: 48 bytes of data

Observations about ATM Cell

- very small
  - reflecting telephony origins
  - 48 bytes a compromise, halfway 64 and 32
- no explicit source/destination address
  - VCI/VPI used instead
  - faster switching (VPI/VCI can index into table)
  - 28 bit VPI/VCI for switching instead of 128 bit IP address in IPv6 (savings)
- fixed length for faster switching
- minimal priority

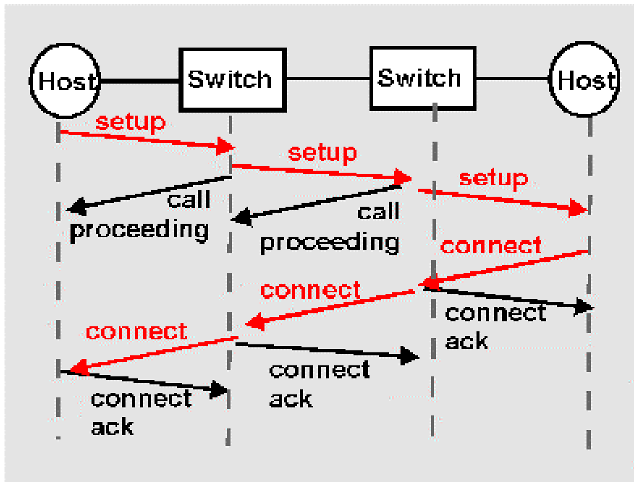
ATM networks: Virtual-circuit Oriented

- VCI/VPI together identify call
- multiple calls (VCI) bundled into same VP
  - network can switch on VP basis only
  - less state (network only sees VP's)
  - all VC's in VP follow same path



Connection Setup in ATM

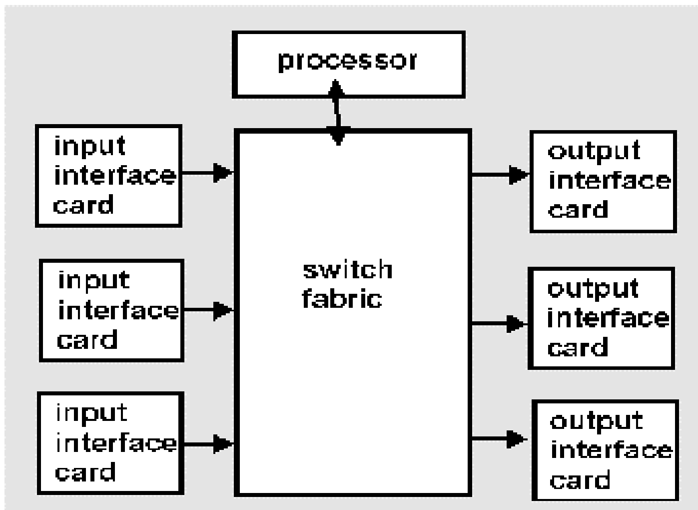
- messages ("signaling") used to setup up call through network
- state info (VP switching info - which output line to switch incoming VC) set up in switches
- meaning of call setup messages:



ATM Call Setup (cont)

Observations:

- unlike Internet, switches involved in call setup
  - state creation
  - ACKing between switches
- wait one RTT before sending data
  - unlike UDP
  - same as TCP
- what if connection breaks?
  - other switches must remove state
- ATM standard does not specify a routing protocol



Switches and Routers: What's Inside

Input interface cards:

- physical layer processing
- memory buffers to hold incoming packet

Switch fabric:

to move packets from input to output

Output interface cards:

- memory buffers to hold outgoing packets
- physical layer processing

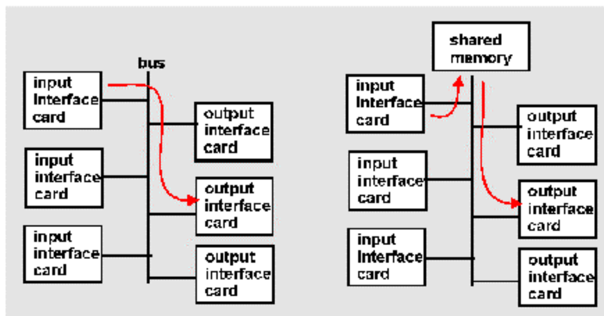
Control processor: routing table updates, supervisory (management) functions

- will typically not touch the packets being switched

Switching Fabrics

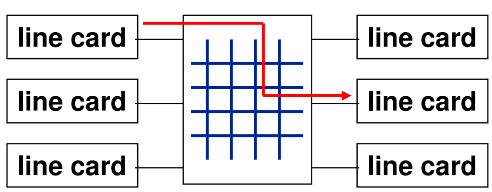
Three ways to switch:

- **switching via memory:** input line ports write to memory, output ports read from memory
- **switching via a bus:** bus (backplane) connects input and output ports
  - e.g.: Baynetworks Backbone Node has one GBps bus



Switching Fabrics

- **switching via a crossbar:** crossbar switch connects input and output ports
  - e.g.: Cisco 12000 series provide 5-60Gbs



IP Routing Table Lookup

Longest prefix matching:

- entries in routing table are prefices of IP address

Q: how to do lookup

- efficiently
- low storage requirements

Current approaches:

radix tries, Patricia tries, content addressable memories

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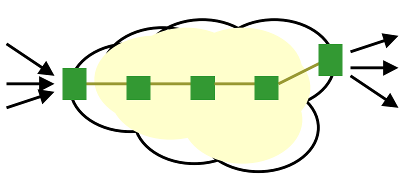
Multiprotocol Label Switching (MPLS)

- best of ATM and IP over single network



- add header with fixed length“label” to IP packet
- switch (route) based on label
- merge flows with common ingress/egress routers
- switching (routing) very fast

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Network Layer: Summary

Network service: datagram versus VC

Theory of routing protocols

- link state and distance vector
- multicast
- broadcasting

Case studies:

- Internet
  - IPv4, IPv6
  - protocols for exchanging routing information: RIP, OSPF, BGP
- ATM