

More on IP and the Network Layer

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The Internet Protocol

- hierarchical addressing
- packet format
- hierarchical routing:
 - intra-AS (RIP, OSPF)
 - inter-AS (BGP)

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IPv6

- **A key motivation:** address depletion \Rightarrow 32-bit address space soon to be used up.
 - 128-bit addresses
- **Additional motivation:**
 - simplification help speed processing/forwarding
 - fixed-length 40 byte header
 - no fragmentation allowed in intermediate routers
 - header changes to facilitate QoS
 - flow label
 - new "anycast" address: route to one of a set of several servers

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Transition From IPv4 To IPv6

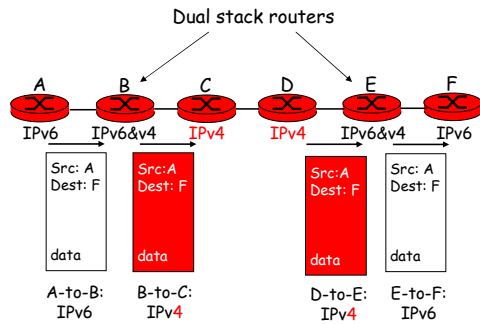
- It is difficult to change the network layer protocol
 - The large number of routers and administrative autonomy makes simultaneous change impossible.
 - Routers speaking different protocols do not naturally work together.
 - What should we do?
- Two proposed approaches:
 - **Dual Stack:** some routers with dual stack (v6, v4) can "translate" between formats
 - **Tunneling:** IPv6 carried as payload in IPv4 packet among IPv4 routers

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Dual Stack Approach



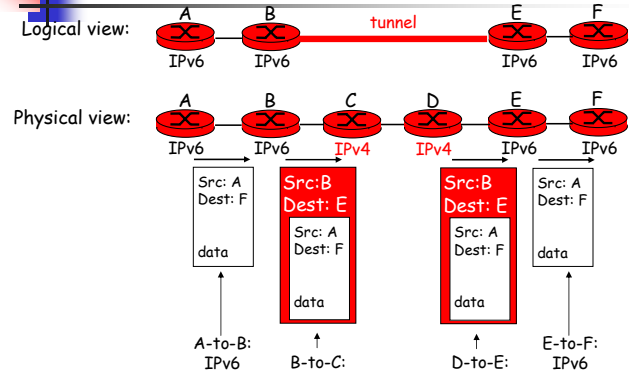
Are there any problems?

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Tunneling Approach



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IPv6 Deployment

IPv6 deployment is slow:

- resistance to change ⇔ lack of critical mass
- immature technology: anycast

how about address depletion?

- DHCP (dynamic host configuration protocol)
- NAT (network address translation)

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IPsec: Network Layer Security

- security services needed at the network layer:
 - source authentication
 - data integrity
 - data confidentiality
- source authentication & data integrity
 - signed message digests
- data confidentiality
 - encryption using a symmetric session key



- IPsec deployment?

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Outline

- IPv6
- IPsec
- Multicast routing
 - basic concept
 - Principle: basic approaches
 - Practice: protocols

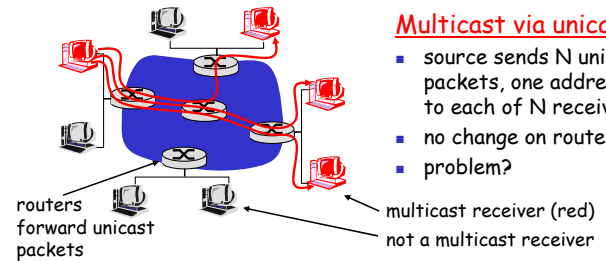
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Multicast

- Multicast: act of sending packet to multiple receivers with single "transmit" operation
- Applications??



Multicast via unicast

- source sends N unicast packets, one addressed to each of N receivers
- no change on routers
- problem?

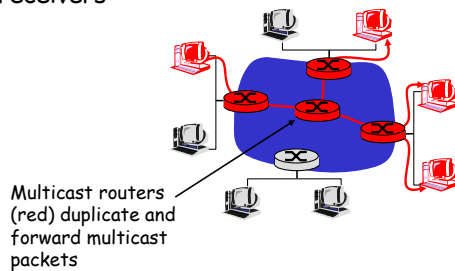
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Ideal Network Multicast

Routers actively participate in multicast, making copies of packets as needed and forwarding towards multicast receivers

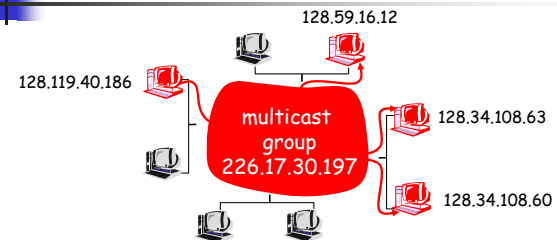


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Internet Multicast Service Model



Multicast group concept: use of indirection

- hosts "join" multicast group
- hosts send IP packets with the multicast group address
- routers forward multicast packets to hosts that have "joined" that multicast group

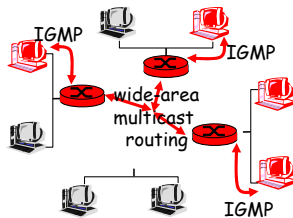
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Local and Wide-Area Multicast Management

- **local:** host informs local mcast router of desire to join group
 - IGMP (Internet Group Management Protocol)
- **wide area:** local router interacts with other routers to receive mcast packet flow



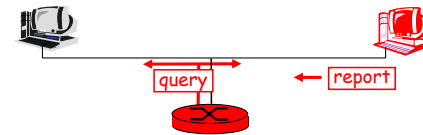
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IGMP: Internet Group Management Protocol

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



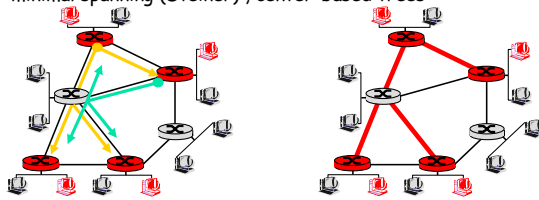
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Wide-area Multicast Routing

- **Goal:** find path/paths (tree) connecting routers having local mcast group members
- **source-based tree:** one tree per source
 - shortest path trees, reverse path forwarding
- **group-shared tree:** group uses one tree
 - minimal spanning (Steiner), center-based trees



Source-based trees

Shared tree

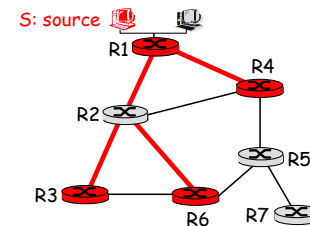
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Shortest Path Tree

- **mcast forwarding tree:** tree of shortest path routes from source to all receivers
 - Dijkstra's algorithm



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Reverse Path Forwarding

What if we don't have global network information?

- rely on router's knowledge of unicast routing table
- each router has simple forwarding behavior:

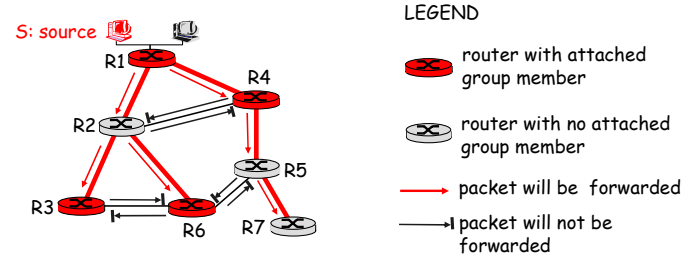
if (mcast packet received on incoming link on shortest path back to source)
then flood packet onto all outgoing links
else ignore packet

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Reverse Path Forwarding: Example



- result is a source-specific *reverse SPT*
- problem: reaching routers that are not in the group

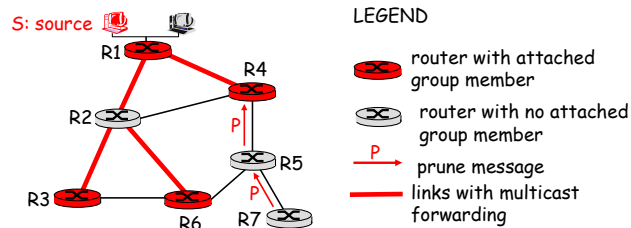
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Reverse Path Forwarding: Pruning

- forwarding tree contains subtrees with no mcast group members
 - "prune" msgs sent upstream by router with no downstream group members



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Shared-Tree

- Single delivery tree shared by all
- Assume complete global network information is available, derive minimum cost tree connecting all routers with attached group members
 - problem is NP-complete
 - heuristic approximation exists

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A distributed solution: Center-based Tree

- One router identified as "*center*" of tree
- To join:
 - edge router sends unicast *join-msg* addressed to center router
 - *join-msg* "processed" by intermediate routers and forwarded towards center
 - *join-msg* either hits existing tree branch for this center, or arrives at center
 - path taken by *join-msg* becomes new branch of tree for this router

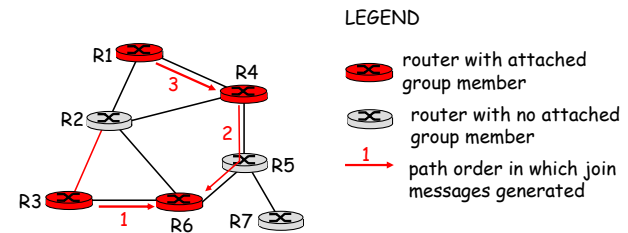
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Center-based Trees: An Example

Suppose R6 chosen as center:



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Internet Multicasting Routing

- **DVMRP**: distance vector multicast routing protocol, based on RPF (reverse path forwarding) and pruning
 - first and the most commonly supported
- **PIM**: protocol independent multicast
 - in a *sparse* mode where DVMRP doesn't do well, it uses Center-based Trees
- IP multicast deployment?

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