Networking Technologies and Applications

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IP Multicast

- Joining a multicast tree done in two steps
  - On the local area network (LAN)
    - A user announces its local multicast routers about the groups he would like to join
    - IGMP (IPv4), MLD (IPv6)
  - Over the large Internet (WAN)
    - The local router cooperates with the other multicast routers of the network to build the tree and forward the packets along that tree
    - DVMRP, MOSPF, CBT, PIM-DM, PIM-SM, PIM-SSM

IGMP

- **Internet Group Management Protocol**
- An IPv4 protocol, running between the final users and the local multicast routers on the local network
  - Handles multicast group membership
  - Asymmetric protocol
    - User side
    - Router side
- The router learns which groups the end-users on his local network listen to
  - Not interested in how many receivers, important thing is to have at least on receiver
  - Not interested in exactly who are the receivers

IGMPv1

- S. Deering, "Host Extensions for IP Multicasting", RFC 1112, 1989.
- A multicast router sends regular **Query** messages to the multicast address of all the users (224.0.0.1)
- A user answers with a **Report** message, in which specifies the groups he listens to
  - The Report is sent to the multicast addresses of those groups
- To decrease the number of Report messages:
  - Using timers
    - A user does not answer immediately to the Query
  - Host Suppression
    - If someone else answers faster, it deletes its own Report message
- **Unsolicited Report**
  - If a user wants to listen immediately to a new group

IGMPv1 Router

- An IGMPv1 router maintains a multicast membership table
  - Which multicast groups have members on its network
  - When was the last Report message received about those groups
- **Soft-state** protocol
  - If in a given time nobody refreshes its interest in a given groups, the group will be deleted from the multicast membership table
- It forwards to the local network all packets that are sent to a multicast destination address that is contained in its membership table

IGMPv2

- W. Fenner, "Internet Group Management Protocol, Version 2", RFC 2236, November 1997.
  http://www.ietf.org/rfc/rfc2236.txt

- IPv6 version: MLD (Multicast Listener Discovery)
  - S. Deering, W. Fenner, B. Haberman, "Multicast Listener Discovery (MLD) for IPv6", RFC 2710, November 1999.
    http://www.ietf.org/rfc/rfc2710.txt

- Introduces a **Fast Leave** mechanism
  - Do not have to wait until a timer expires to cut off a group

IGMPv2 messages

- Membership Query
  - General Query
  - Group Specific Query
- Membership Report
- **Leave Group Message**

- If a host wants to leave a group, it sends a Leave message to the multicast address of all the multicast routers (224.0.0.2)
- Before cutting off the group, the router has to ask if anybody else is still interested in that group or not
  - Group Specific Query
  - If no answer in a given limited time, the router cuts off the group from its table

- IGMPv3 – later...

Multicast Routing

- A source sends its packets to the group's multicast address
- The multicast routers in the network build and maintain a multicast tree
  - Packets are forwarded along that tree
- The local multicast router, based on its IGMP membership table, joins or leaves this tree
- A multicast routing protocol runs among the routers of the network
  - MOSPF, DVMRP, CBT, PIM

MOSPF

- **Multicast Open Shortest Path First**
  - J. Moy, „Multicast Extensions to OSPF”, RFC 1584, March 1994 http://www.ietf.org/rfc/rfc1584.txt
- Link State protocol
- Extends the OSPF unicast routing protocol
  - Multicast group membership information is also distributed among the routers
  - Each MOSPF router learns which multicast groups have listeners on which local network
  - Based on this information they build a shortest path tree for each source and each group
- Large signaling overhead
- Difficult to handle topology changes
  - All the trees have to be recalculated

DVMRP

- **Distance Vector Multicast Routing Protocol**
  - D. Waitzman, C. Partridge, S. Deering, "Distance Vector Multicast Routing Protocol", RFC 1075, November 1988

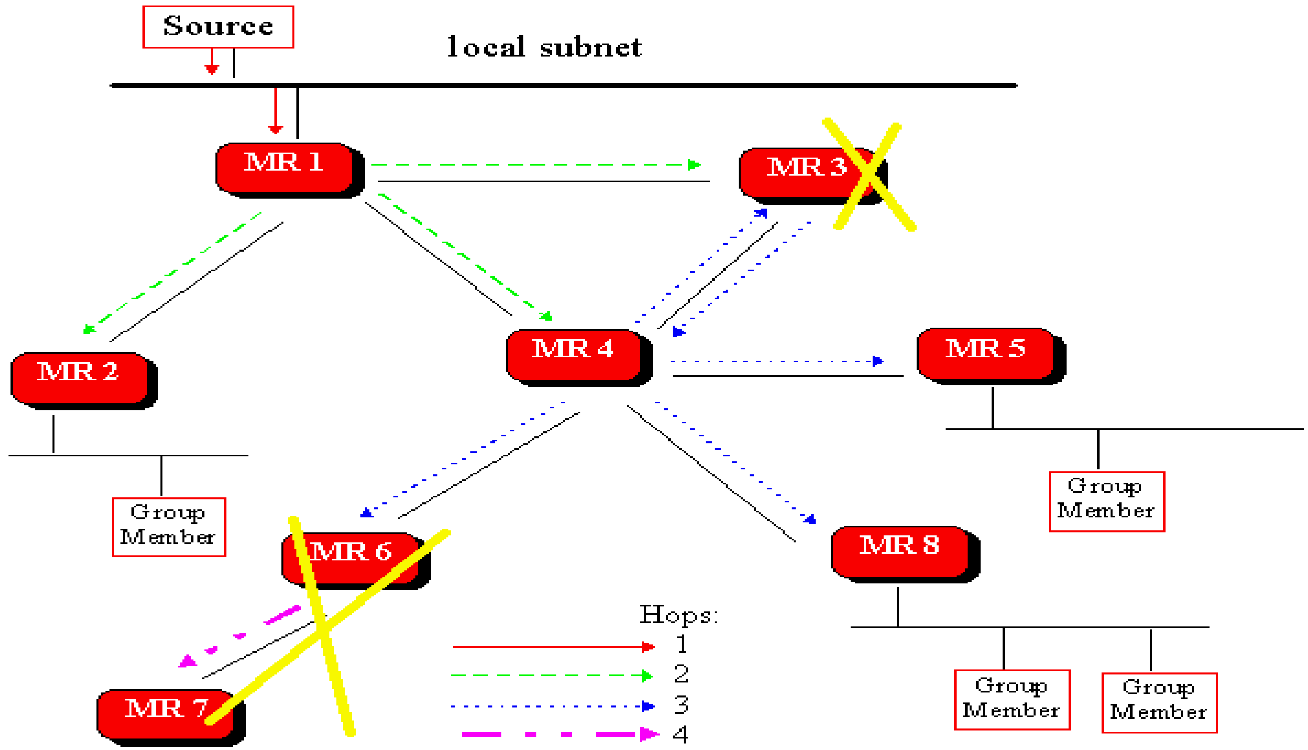
    http://www.ietf.org/rfc/rfc1075.txt

- Distance vector protocol
  - Uses the RIP unicast routing protocol

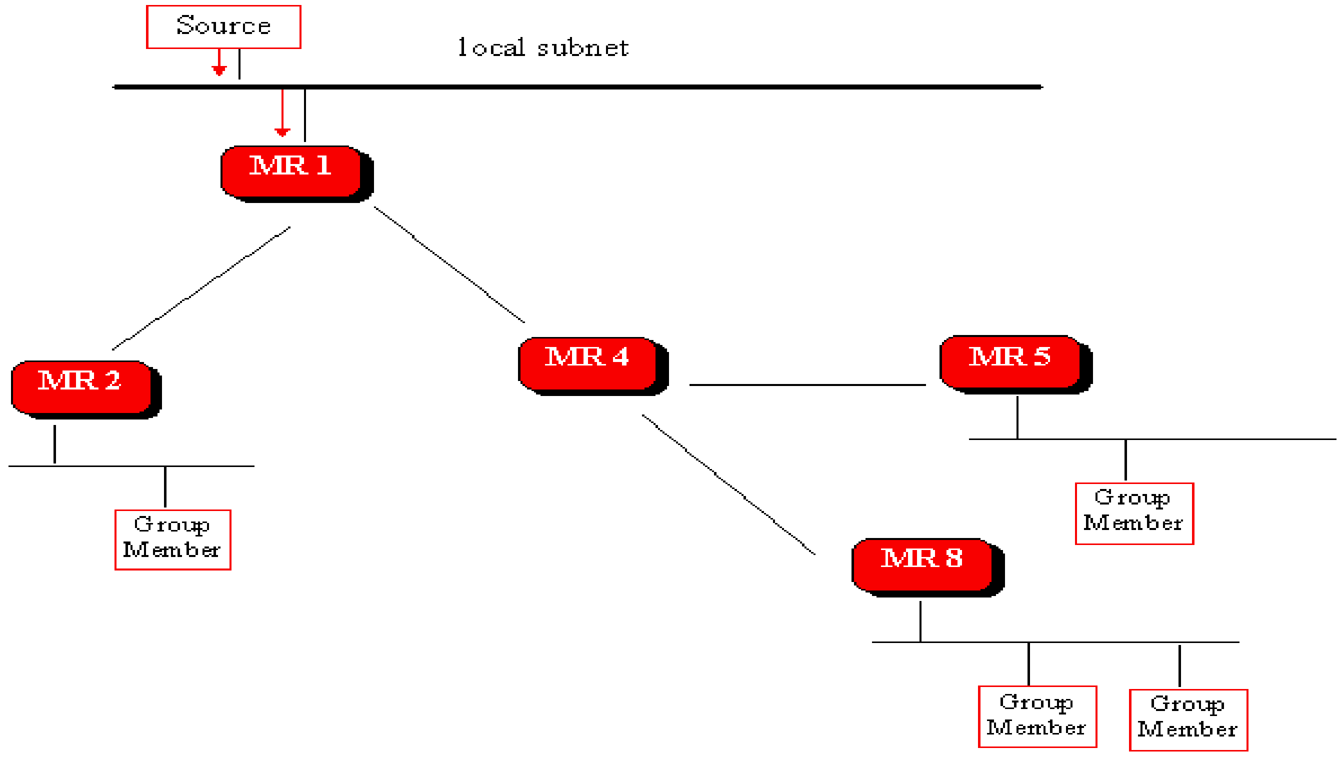
DVMRP

- Flood and prune
  - Flooding
    - Checks the incoming interfaces of the packets
    - If not over the shortest path towards the source, the packets are dropped
    - If yes, packets are flooded over all the interfaces
  - Pruning
    - If no interested receiver on the local network
    - If packet not received over the shortest path
  - An internal router learns its interfaces over which it recieved a Prune message
    - The upcoming packets are not forwarded over those interfaces anymore
    - Prune messages become obsole after a while (one minute by default)

DVMRP flooding



DVMRP prune


Source
local subnet
MR 1
MR 2
MR 4
MR 5
MR 8
Group Member
Group Member
Group Member
Group Member

PIM

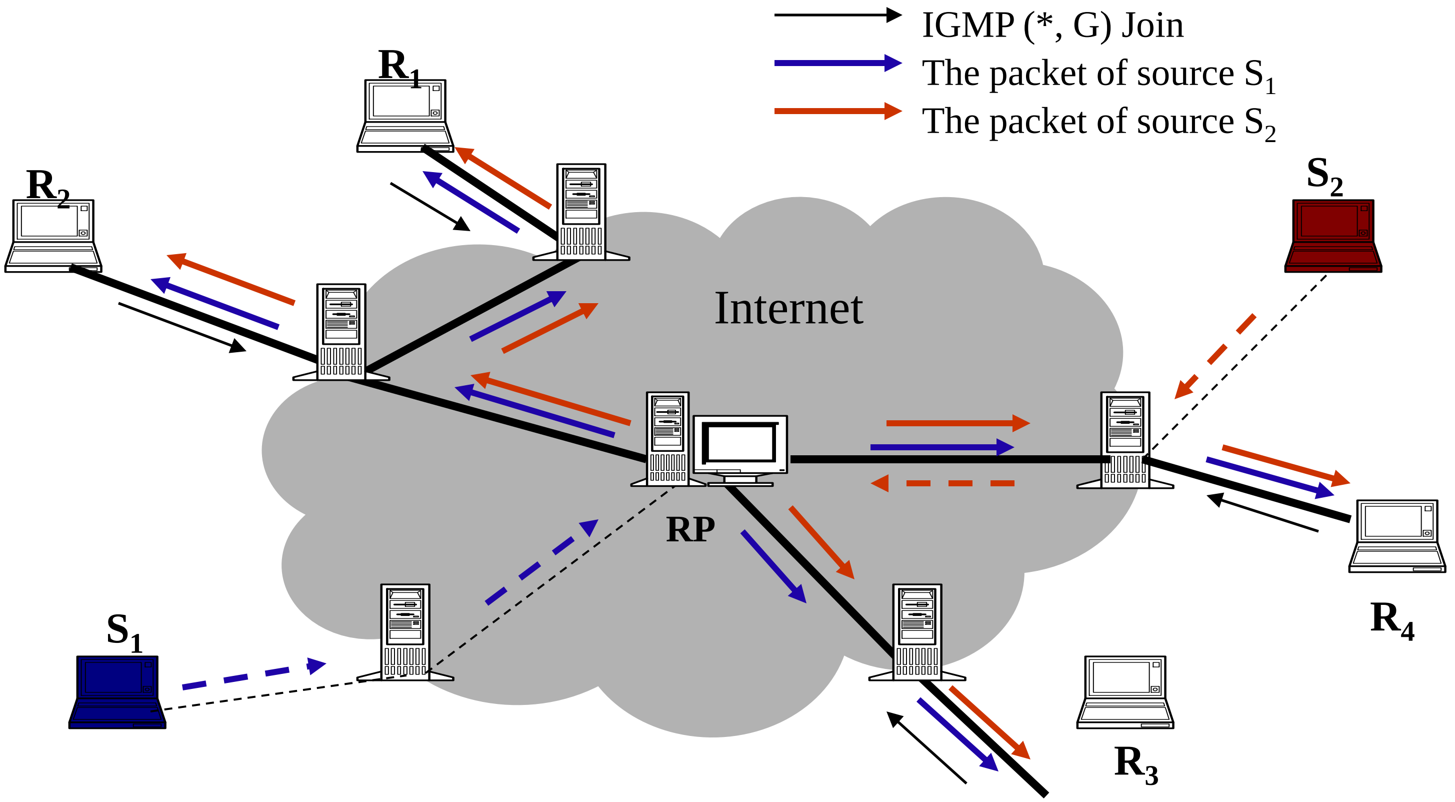
- Protocol Independent Multicast
  - PIM Dense Mode (PIM-DM)
  - PIM Sparse Mode (PIM-SM)

- PIM-SM
  - W. Fenner et al., „Protocol Independent Multicast - Sparse Mode (PIM-SM): Protocol Specification (Revised)” , RFC 4601, August 2006
  - The most used multicast routing protocol today

PIM-SM

- Builds a **shared multicast tree**
- Chooses a rendez-vous point (RP)
  - The RP is the root of the shared tree
    - „Explicit join” – not everybody wants to listen to it
  - Each source sends its message to the RP
    - The RP forwards the messages along the shared tree
  - Optimization to switch after a while from the shared tree to a source-specific tree

PIM-SM operation



Drawbacks of the ASM model

- Several economic and technical issues delayed the large scale deployment of the ASM model
  - Complicated address allocation
    - Dynamic IP address allocation to the source
    - Complex address allocation solutions
      - GLOP (RFC 3180) – static assignment of multicast addresses to ASes
        - » Autonomous System – e.g., the network of an ISP
      - MALLOC - Multicast Address Allocation Architecture (RFC 2908)
        - » MADCAP – Multicast Address Dynamic Client Allocation Protocol
        - » AAP – Multicast Address Allocation Protocol
        - » MASC – Multicast Address Set Claim

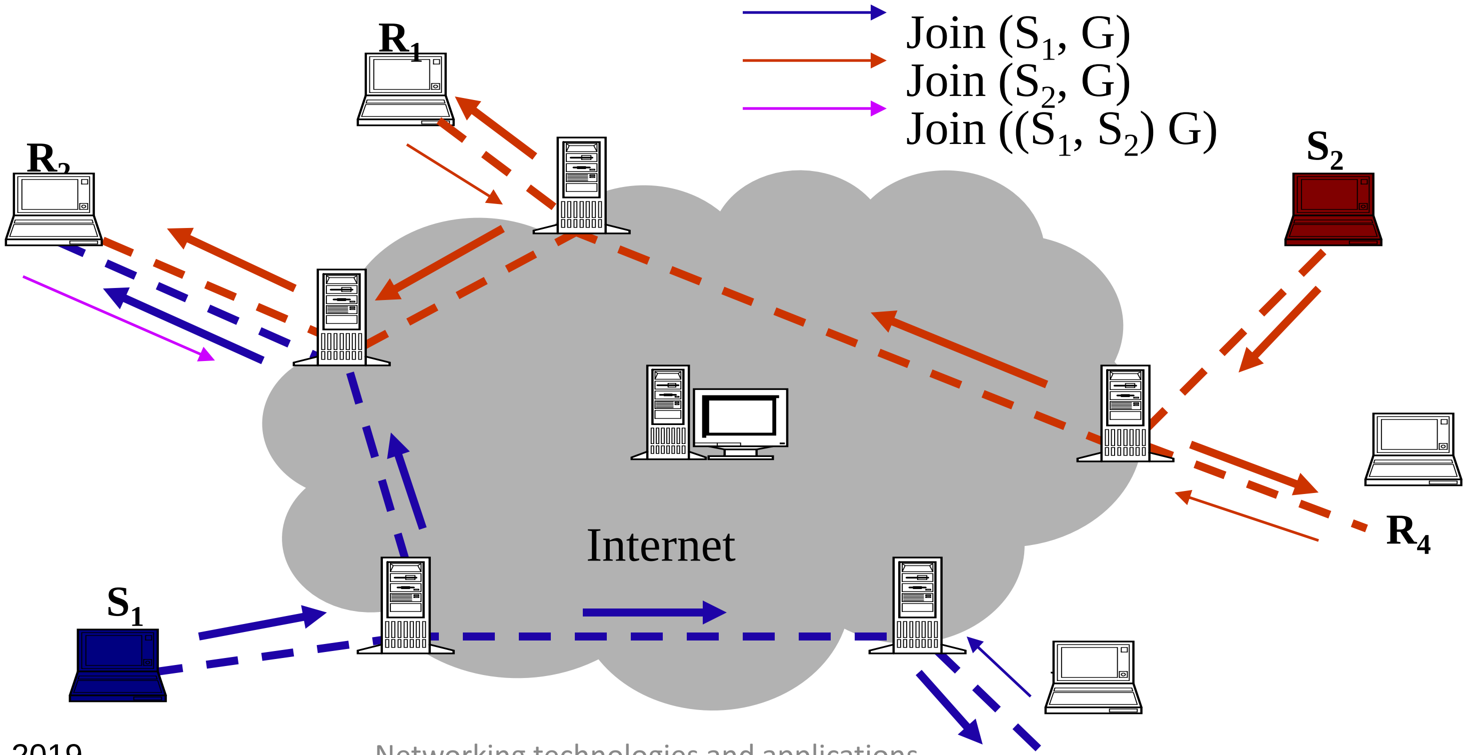
Drawbacks of the ASM model

- Too open model for service providers
  - No control over the sources and receivers
  - Difficult charging
- Not sclabale for inter-domain routing
  - PIM-SM only inside a domain
  - An ISP does not like if its traffic is controlled by an RP located in the network of another ISP
  - Other protocols for inter-domain routing
    - MSDP – Multicast Source Discovery Protocol
    - MBGP – Multicast Border Gateway Protocol

The SSM model

- Need for a simpler model
- **SSM - Source Specific Multicast**
  - Based on the Express model
  - H. Holbrook, D. Cheriton, "IP Multicast Channels: Express Support for Large-Scale Single-Source Application", in *Proceedings of ACM SIGCOMM'99*, Cambridge, MA, USA, Sept. 1999.
- The (*,G) multicast group is replaced by the (S,G) multicast channel
  - S the unicast address of the source
  - G the multicast address of the group
  - Only source S can send packets to the receivers of channel (S,G)
  - Traffic is forwarded along a source-specific tree

SSM model



Source filtering

- The SSM model needs source filtering
  - The host specifies not only which group it wants to listen to, but also which source that sends to that group
- IPv4 – IGMPv3
  - B. Cain, et. Al, "Internet Group Management Protocol, Version 3", RFC 3376, October 2002.
    http://www.ietf.org/rfc/rfc3376.txt
- IPv6 – MLDv2
  - R. Vida, L. Costa, „Multicast Listener Discovery Version 2 (MLDv2) for IPv6", RFC 3810, June 2004.
    http://www.ietf.org/rfc/rfc3810.txt

Message types

- IGMP/MLD Query
  - General Query
    - Who listens what?
  - Group Specific Query
    - Does anybody listen this specific group?
  - Group and Source Specific Query
    - Does anyone listen to this specific source that sends to this specific group?
- IGMP/MLD Report
  - Current State Record
    - What do I listen to – e.g. Include (A) or Exclude (B)
      - A and B are source address sets
  - Filter Mode Change Record
    - Changing the filter mode (Include or Exclude)
  - Source List Change Record
    - Allow (A) or Block (B)

IP Multicast

- Considered for several years the „revolutionary technology of the future”
- Advantages
  - Efficient data transfer
    - Usually over the shortest path (DVMRP, MOSPF, PIM-SSM)
    - Taking into accoun the physical topology
  - Efficient use of resources
    - One packet is sent just once over a specific link
  - Scalable for handling the communication of large groups
    - The group is identified by a virtual group address
      - One routing table entry for a very large group
    - Nobody tracks who is part of the group, and how large is the group

IP Multicast

- Still not deployed at large scale
  - Technical and economic reasons
- Technical reasons
  - Complicated addressing
  - No sclabale inter-domain multicast routing
  - Does not scale to a large number of groups
    - The router has to keep one entry per multicast group
    - Multicast addresses are hard to aggregate
  - Lack of support for higher layer services
    - IP multicast is a *best-effort (multi)point-to-multipoint* data transfer service
    - End users are responsible for handling higher layer services
    - Difficult congestion control and reliablility handling

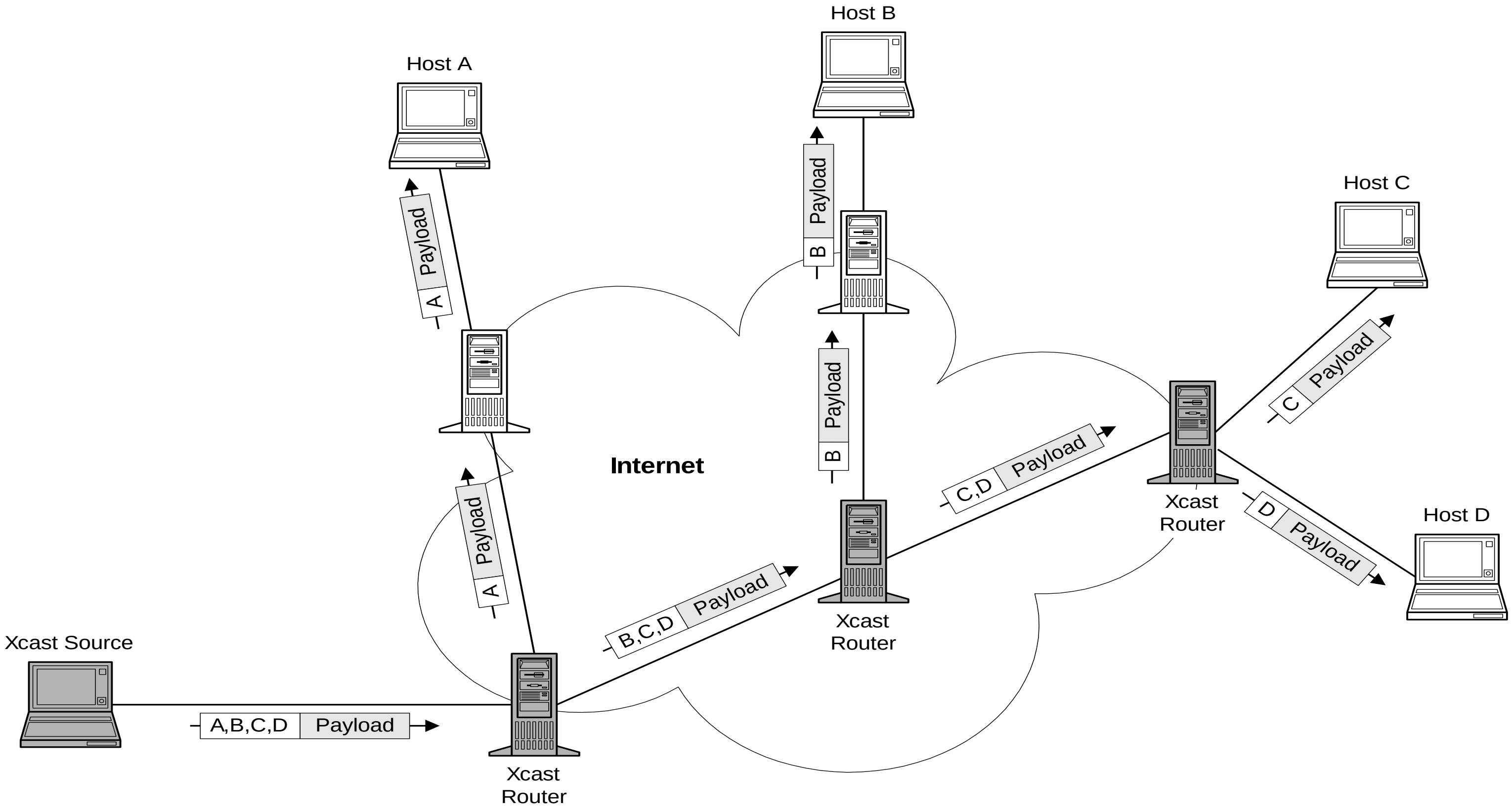
IP Multicast

- Economic reasons
  - Slow and difficult deployment in the network
    - Even though all the routers „speak” today the most important multicast protocols, the ISPs sometimes do not activate them on their networks
    - Really efficient only if used in the entire network
    - Otherwise tunneling is needed
  - „Chicken-egg” problem
    - ISPs do not support it, not enough multicast applications, no need for it
    - A szoftware cégek nem fejlesztenek multicast alkalmazásokat, mert nincs hálózati támogatás, nem lehet majd őket eladni
  - No convenient economic model behind it
    - ISPs have difficulties in controlling the use of networking resources
    - The content provider has difficulties in controlling who uses the service
    - No convenient charging solution behind it

Explicit Multicast (Xcast)

- Network layer multicast solution
- Does not use multicast addresses
  - The source puts in the paket header the unicast IP address of all the group members
- Intermediate Xcast routers duplicate the packets if needed, based on their own internal unicast routing tables
  - The router checks which are the outgoing interfaces for each of the group members, based on its routing table
  - Duplicates the packets if needed, and prepares the corresponding headers

Explicit Multicast (Xcast)



Explicit Multicast (Xcast)

- Not scalable for large groups
  - If many group members, the header becomes too large

- Scales very well for many small groups (for which IP multicast is not good)
  - Routers do not need multicast routing tables

- R. Boivie, N. Feldman, C. Metz, "Small Group Multicast: A New Solution for Multicasting on the Internet", *Internet Computing*, vol. 4, no. 3, May/June 2000, pp. 75-79.

Alternative multicast solutions

C. Diot et al, "Deployment Issues for the IP Multicast Service and Architecture", *IEEE Network Magazine*, *Special Issue on Multicasting*, vol. 14, no. 1, January/February 2000, pp. 78-88.

Can we imagine a group communication service where we do not need network layer support from ISPs?

ALM – Application Layer Multicast

or...

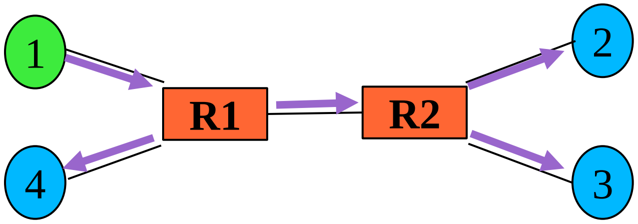
ESM – End System Multicast

or..

HBM – Host-based Multicast

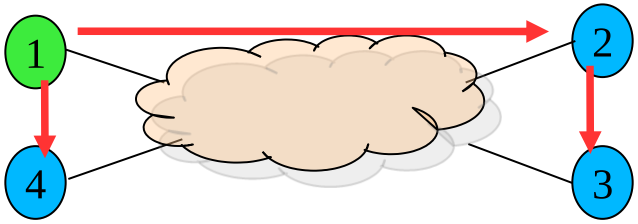
IP multicast - ALM

- IP multicast



- Duplication in the routers
  - Network support
- The topology depends on...
  - The routing tables
  - The physical topology

- ALM
-



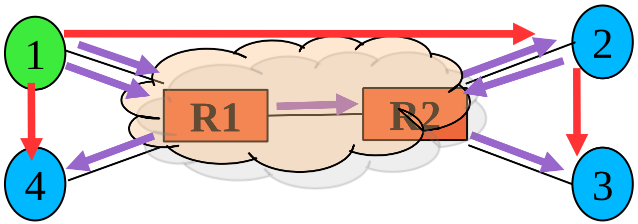
- Duplication at the end hosts
  - No network support needed
- Virtual topology
  - The physical topology is a „black box"

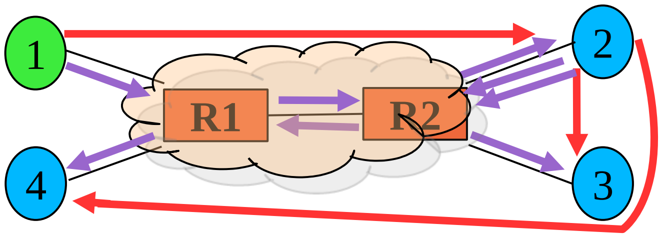
ALM: motivation

- Data transfer
  - No IP multicast support needed
    - Uses only unicast communications
  - Small groups
    - IP multicast is not always the best solution
  - Actively using the data
    - Data can be modified/analyzed during transmission
    - Topology can be modified on the fly, based on the content
- Control
  - Aggregation of control data (reliable multicast)

ALM: drawbacks

- Efficiency
  - End-to-end “branches”
    - Delay might be very large
    - Inefficient use of resources





- Scalability
  - Continuous evaluation of the connections between peers
    - Complete graph: n*(n-1) virtual connections in a group with n members

ALM: drawbacks (2)

- Stability
  - Stability of the nodes
    - In the overlay network the participants („routers”) are end hosts
      - Not as reliable as a real router
      - **High churn** - Hosts might join and leave the group quite often
  - Stability of the measurements
    - The efficiency of the overlay depends also on the stability of the chosen metric
      - RTT, bandwidth, etc.
    - Trade-off between the efficient data transfer and the signalling overhead