L73 - IP QoS Integrated Services Model

IP QoS IntServ

Integrated Services Model
Resource Reservation Protocol (RSVP)

Agenda

- Integrated Services Principles
- Resource Reservation Protocol
- RSVP Message Formats
- RSVP in a IP Multicasting Environment

Design Intentions

- **The Internet was based on a best effort packet delivery service, but nowadays the Internet carries many more different applications**
- **Some applications require special bandwidth and delay; real time transmissions also became important**
- **The Integrated Services Model**
  - was introduced to guarantee predictable network behavior for these applications (RFC 1633)
- **The underlying Internet architecture should not be modified to support QoS**

Design Intentions

- **Resources (e.g., bandwidth) must be explicitly managed**
  - in order to meet application requirements for packet delay and throughput
- **This implies that resource reservation and admission control are key building blocks of IntServ**

Design Intentions

- **Basic idea: Client reserves network resources on every router "upstream" to the server**
  - using a signaling protocol
  - Resource ReSerVation Protocol (RSVP), RFC 2205
  - resource reservation is initiated by the receiver
- **Flow-based concept**
  - "Flow" = packets of the same session, identified by socket parameters
- **Using RSVP a client requests specific QoS parameters**
  - at each router along the upstream path
  - if possible, routers reserve resources for this flow
  - each flow then uses a single, designated path

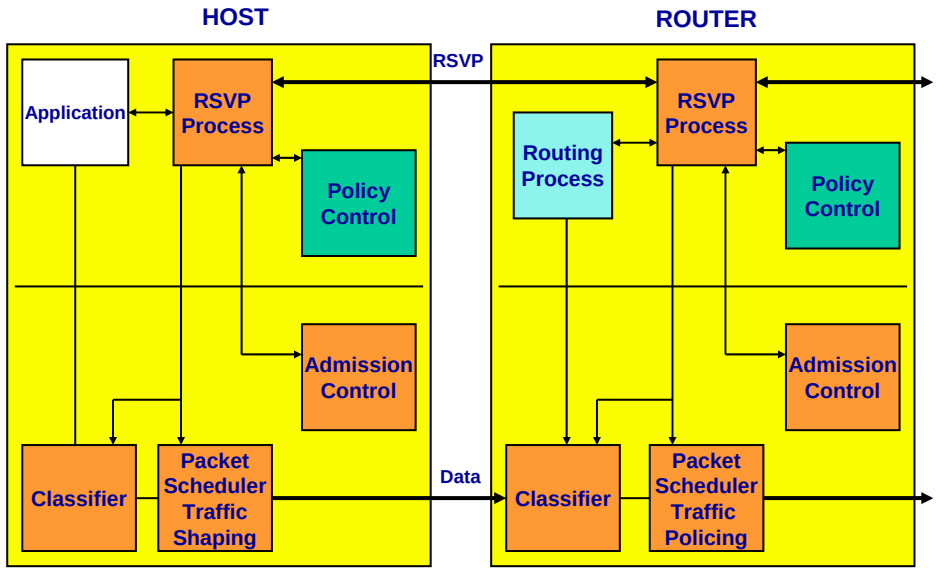
IntServ Components

- **Generally IntServ consists of three traffic-control and one reservation mechanisms:**
  - Packet scheduler:
    - actually manages the forwarding of different packet streams additionally metering and traffic policing is done at each router
    - additionally traffic shaping is done at the sender
  - Packet classifier:
    - each incoming packet must be mapped into some class to allow traffic control; all packets in the same class get the same treatment from the packet scheduler
    - a class might correspond to a broad category of flows, e.g., all video flows or all flows attributable to a particular organization
    - on the other hand, a class might hold only a single flow

IntServ Components

- **Generally IntServ consists of three traffic-control and one reservation mechanisms (cont.):**
  - Admission control:
    - determines whether the node has sufficient available resources to supply the requested QoS
    - that means whether a new flow can be granted the requested QoS without impacting earlier guarantees
  - Reservation setup protocol,
    - which is necessary to create and maintain flow-specific state in the endpoint hosts and in router along the path of a flow
    - protocol called RSVP (for "ReSerVation Protocol")
- **Policy Control**
  - additionally needed but outside the scope of IntServ
    - determines whether the user has the administrative permission to make a reservation including authentication of request

IntServ Components



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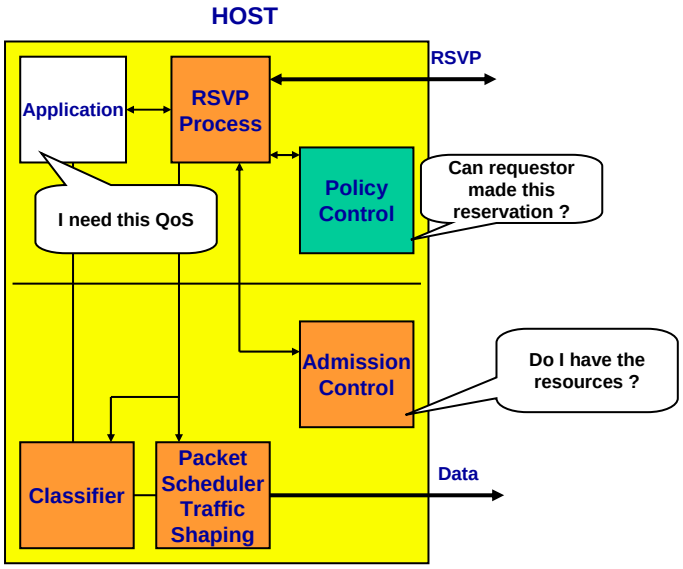
IntServ Components



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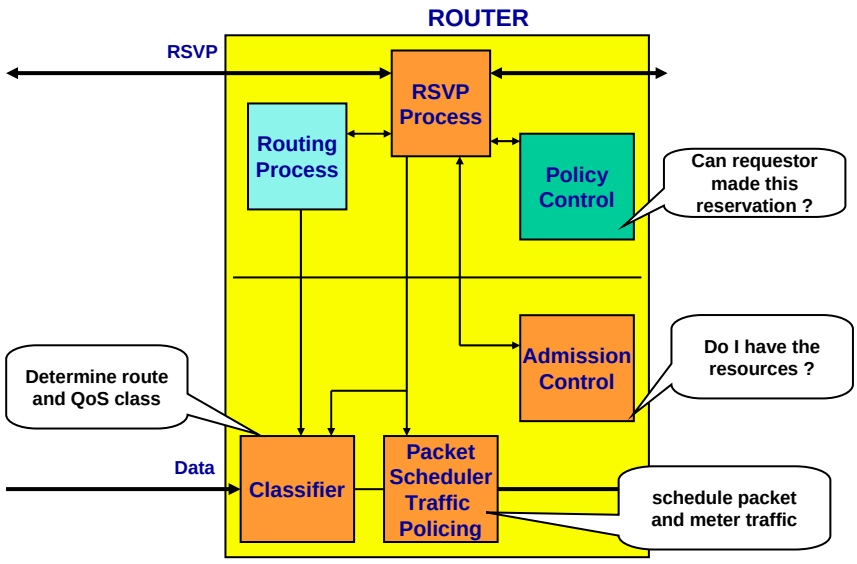
IntServ Components



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IntServ Components

- **Output queue can be controlled by a token bucket model**
  - token bucket parameters can be reserved via RSVP, the Resource Reservation Protocol
    - token rate, bucket depth
    - maximum packet size, peak rate, minimum policed size
- **RSVP uses these token bucket parameters in its flow descriptor field**

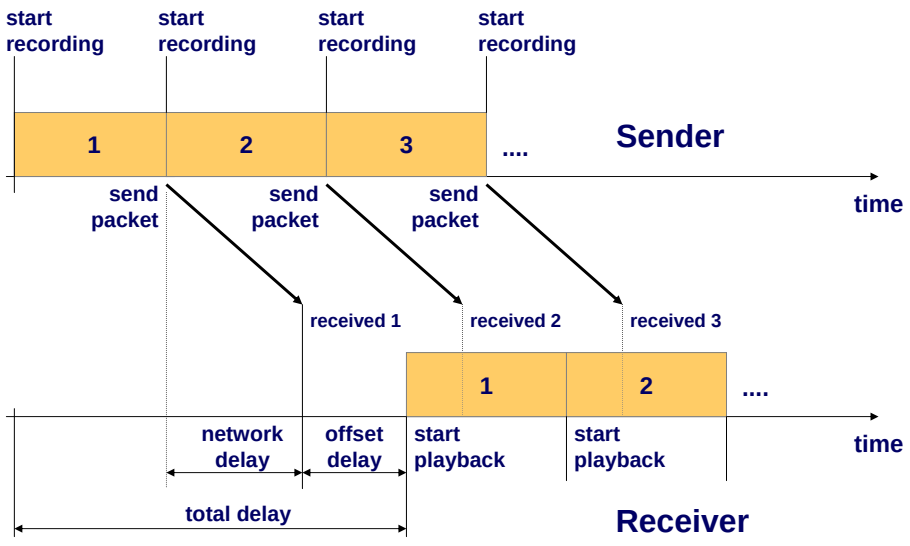
Two IntServ Classes

- **"Guaranteed QoS" (RFC 2212)**
  - guarantees a maximum queuing delay, minimum of interference from best-effort traffic, isolation between reserved flows;
    - Assuming no failure of network components or changes in routing during the life of the flow
  - the datagram delivery time is bounded
- **"Controlled Load"(RFC 2211)**
  - simulates unloaded conditions only
  - better than best effort
  - network guarantees that the reserved flow will reach its destination with a minimum of interference from the best-effort traffic

The Problem with Real-Time Traffic

- The sender packetizes some data stream and sends it to the receiver
- The receiver de-packetizes this packets into the original data stream and playbacks it
- Receiver must smooth transmission jitter by buffering the data
  - introducing an offset delay

Real-Time Traffic



Types of Real-Time Applications

- **Intolerant Real-Time Applications**
  - are very sensitive to jitter — require Guaranteed QoS
  - e.g. conference applications, telephony
- **Tolerant Real-Time Applications**
  - agree with nominal amount of jitter — require Controlled Load Service only
  - e.g. audio and video streaming

Guaranteed QoS Class

- **Applications that have hard real time requirements, will require guaranteed service**
  - real-time multimedia applications, such as video and audio broadcasting systems that use streaming technologies, cannot use datagram's that arrive after theirs proper play-back time

Guaranteed QoS Class

- **Let the application control the network's queuing delay**
  - by specifying token bucket parameters and bandwidth for requested reservation
  - token bucket depth and data rate are part of the flow descriptor
- **If possible (available resources, permission) the router reserves the requested resources for this flow**
  - using the flow descriptor´s parameters

Controlled Load Service Class

- **Is intended to support the class of applications that are highly sensitive to overloaded conditions in the Internet**
- **"Best effort service under unloaded conditions"**
- **Application may announce an estimation of the traffic it will generate to the network**
  - using a traffic specification (TSpec) as part of the flow descriptor
- **A small amount of packet loss is still possible**
  - service degrades quickly under overloaded conditions
    - if an application uses the Controlled Load service, the performance of a specific data flow does not degrade if the network load increases

Agenda

- Integrated Services Principles
- Resource Reservation Protocol
- RSVP Message Formats
- RSVP in a IP Multicasting Environment

RSVP 1

- RSVP is an Internet control protocol
  - RSVP depends on an underlying routing mechanism and IP (multicast)
  - RFC 2205
- RSVP messages are encapsulated within raw IP or UDP
- For any particular flow the receiver can reserve resources along its path to the sender
- Note: RSVP does not
  - QoS routing like ATM (PNNI routing and QoS signaling)
  - admission control and packet scheduling
  - forwarding/routing of data packets

RSVP 2

- **RSVP makes resource reservations for both unicast and multicast applications**
  - adapting dynamically to changing group membership as well as to changing routes
- **RSVP is simplex**
  - it makes reservations for unidirectional data flows.
- **RSVP is receiver-oriented**
  - the receiver of a data flow initiates and maintains the resource reservation used for that flow

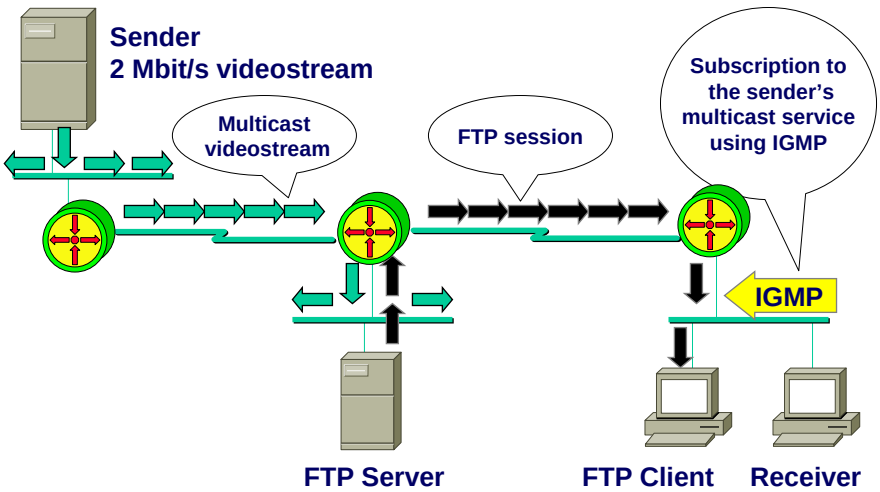
RSVP 3

- **RSVP maintains "soft" state in routers and hosts**
- **RSVP is not a routing protocol but depends upon present and future routing protocols**
- **RSVP transports and maintains traffic control and policy control parameters that are opaque to RSVP**
- **RSVP provides several reservation models or "styles" to fit a variety of applications**
- **RSVP provides transparent operation through routers that do not support it**
- **RSVP supports both IPv4 and IPv6**

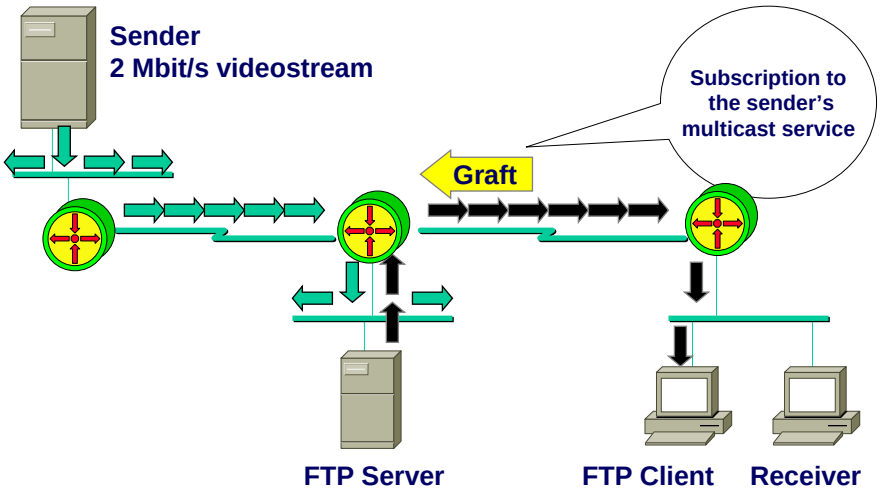
RSVP Messages

- **RSVP uses seven message types**
  - two required message types
    - PATH
    - RESV
  - five optional message types
    - PATH ERROR
      - Sent by the receiver or router notifying the sender when errors in PATH are found (fundamental format or integrity check fault)
    - PATH TEARDOWN
      - Are sent to multicast group with sender's source address when the PATH must be flushed from the database (e.g. link failure) or because the sender is exiting the multicast group
    - RESV ERROR
      - When errors in RESV message are found, RESV ERROR sent by sender or router informing the receiver
    - RESV CONFIRM
    - RESV TEARDOWN

RSVP Example



Normal Subscription to Multicast Service



RSVP in Action

- **Sender sends RSVP PATH messages periodically**
  - PATH messages include the IP address of the interface through which it is sent
  - these messages describe the data they intend to send
- **Each RSVP router catches the PATH messages**
  - it saves the previous hop address, writes its own address as the previous hop, and sends the updated PATH along the same way the application data is using
- **Routers which do not implement RSVP simply forward the PATH message to the next-hop router**
  - in a network which uses the IntServ model it is not a requirement that all routers implement RSVP

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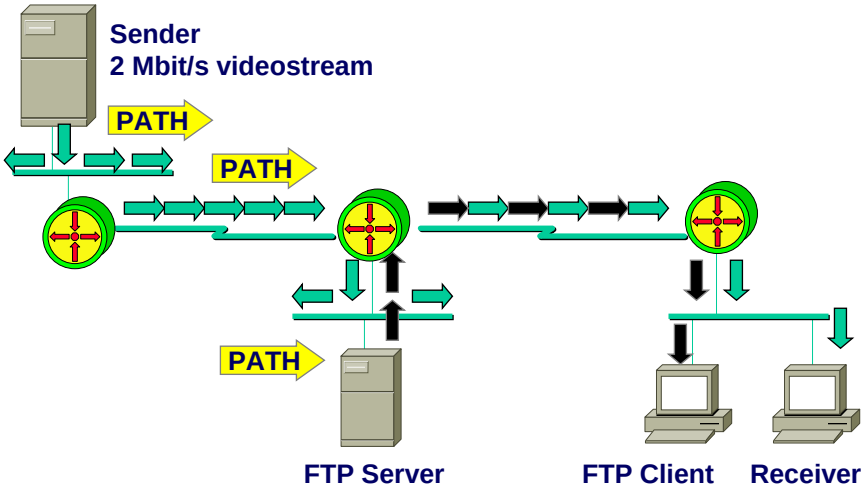
Demand for More Network Resources



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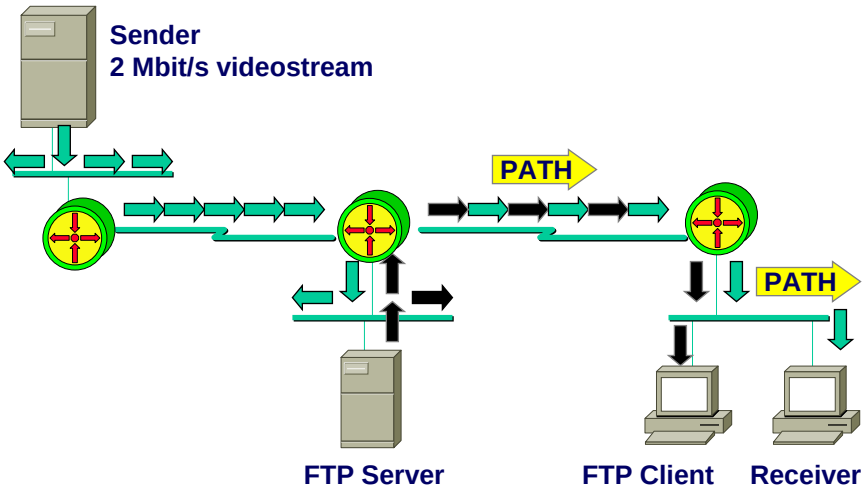
RSVP Functionality Announcement via PATH



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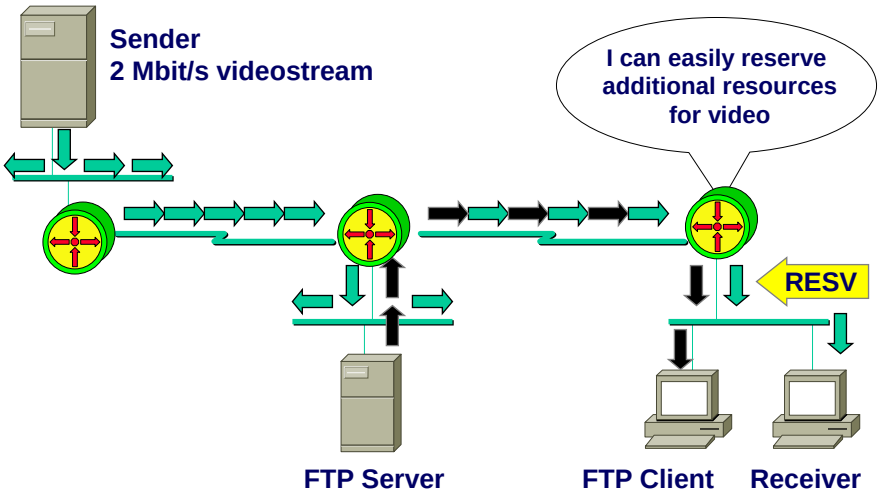
RSVP in Action

- **Receivers identify interesting flows by the TCP/UDP port number**
- **Receivers initiate a resource reservation by sending periodically a RESV message to the next-hop upstream to the sender**
  - containing a flow descriptor for traffic description and reservation identification
- **The RESV messages take a the reverse way of PATH messages, means they go from receiver to sender**

Resource Reservation Upstream 1



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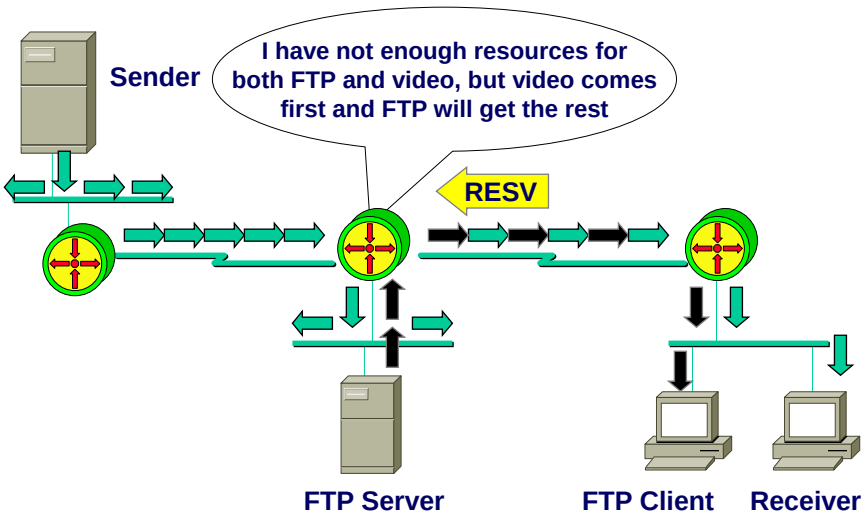
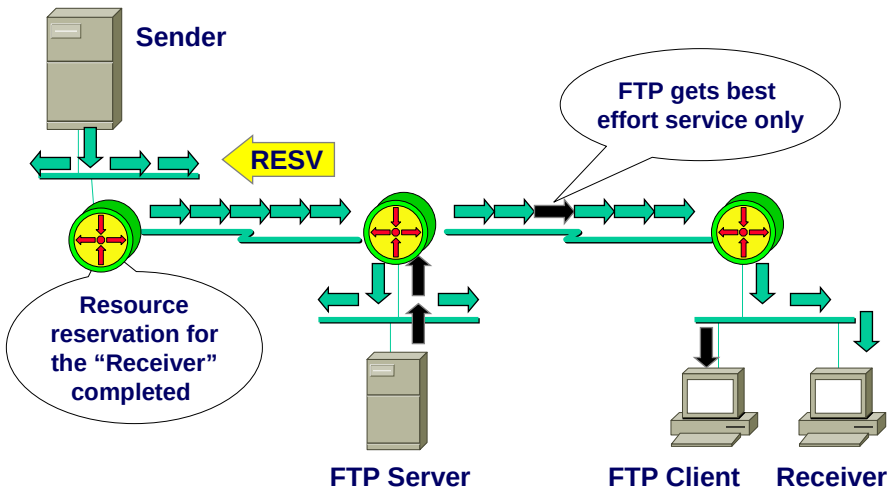
Resource Reservation Upstream 2



Resource Reservation Upstream 3



RSVP in Action

- **When a router receives a RESV:**
  - it passes the request to its admission control function
    - to find out whether there are sufficient resources to implement the reservation request
  - it passes the request to its policy control function
    - to determine whether policy rules allow the user to make the reservation request
  - if both checks succeed,
    - it sets parameters in the packet classifier and scheduler functions to implement the requested reservation
  - it forwards the RESV message to its upstream neighbor
- **The last router sends a confirmation message back to the receiver (optional RESV CONFIRM)**
  - if routers cannot adjust some resources according to RESV, they will refuse the reservations and inform the receiver
    - if they can, they merge reservation requests being received and request a reservation from the previous hop router

RSVP in Action

- **RSVP is often used in IP multicast environments**
  - several RESV messages for the same sender can be merged together
    - for example applications carrying voice or video over IP
  - when the current reservation is equal or greater than that being requested, that RESV message need not be forwarded upstream any longer
- **Non-RSVP routers within the path are weak links; service degrades to “best effort”**

Removing Reservations

- **Reservations can be removed by RSVP TEARDOWN messages:**
  - Sender initiated: Using PATH-TEAR to eliminate all downstream path states and associated reservation tables
  - Receiver initiated: Using RESV-TEAR messages to eliminate all upstream reservation states

RSVP Soft States

- **RSVP is a state protocol, which means that each router in the reservation process has to maintain a resource state for each RSVP session and update it regularly**
- **But IP/UDP is an insecure protocol, so it can easily be that a message, which requests to tear down the QoS connection, gets lost**

RSVP Soft States (cont.)

- **As a consequence the connection will stay in the net until the router memory for storing states is full**
- **To avoid this situation a so called SOFT state is introduced**
  - in a Soft state both sender and receiver repeat their PATH/RESV messages periodically
  - if a message does not arrive several times one after another, the states along the route will be deleted
  - if the loss of a data packet is the reason of the packet's non-appearance then the reservation will be initialized again with the following RESV message

RSVP Terminology

- **RSVP session is identified**
  - by the session specification (session ID)
    - receiver address (destination address of a flow), protocol type, destination port (UDP,TCP)
  - by a unique flow descriptor
    - defining the required QoS and traffic characteristics
- **A flow descriptor consist of**
  - filter specification (filterspec)
  - flow specification (flowspec)

Flow Descriptor Components

- **Filter specification**
  - identifies packets belonging to a specific flow; using sender IP address and source port
  - used by the packet classifier
- **Flow specification contains**
  - Traffic specification (TSpec)
    - describes the traffic characteristics of the requested service using a token bucket filter
  - Service request specification (RSpec)
    - specifies the requested QoS (bandwidth, max delay, max packet loss rate)

RSVP Reservation Styles

- **A reservation request (RESV) contains**
  - a set of options called the “Reservation Style”
- **Reservation styles describe**
  - how the receiver wants to get the data from different senders in one session
  - the receiver can establish
    - Distinct reservation for each upstream sender or
    - Shared reservation for all packets of selected senders in one session
  - senders for a reservation request are selected through
    - Explicit server list
      - explicit list of all selected senders
      - filterspec must identify exactly one sender
    - Wildcard
      - implicitly selects all the senders to the session
      - filterspec is not needed

RSVP Reservation Styles

Distinct versus Shared

Sender Selection	Distinct Reservation	Shared Reservation
Explicit	Fixed-Filter (FF) Style	Shared-Explicit (SE) Style
Wildcard	(Not Defined)	Wildcard-Filter (WF) Style

Reservation Styles

- **Fixed-filter style (FF)**
  - one reservation for data packets from a particular sender; for applications that need one pipe per source (e.g. video)
  - packets from different senders that are in the same session do not share reservations
- **Shared-explicit style (SE)**
  - a single reservation shared by selected upstream senders
  - receiver controls explicitly who can use the shared pipe
    - a sender list must be included into the reservation request from the receiver

Reservation Styles (cont.)

- **Wildcard-filter style (WF)**
  - a single reservation for all sources sending to the same RSVP session
    - reservations from different senders are merged together along the path so only the biggest reservation request reaches the senders
    - supports self-limiting applications (e.g. audio conference)
  - if new senders appear in the session the reservation is extended to these new senders

Agenda

- **Integrated Services Principles**
- **Resource Reservation Protocol**
- **RSVP Message Formats**
- **RSVP in a IP Multicasting Environment**

RSVP Types

- Native RSVP
  - encapsulated within IP only
  - using protocol number 46
- **UDP-encapsulated RSVP**
  - exceptionally, for some end-systems not able to use raw IP network I/O service
  - ports 1698 and 1699

Native RSVP

- **All RSVP messages consist of the same header format and a body**
- **The body consists of several objects**
  - containing necessary information for the resource reservation
  - e.g. flow descriptor and reservation style

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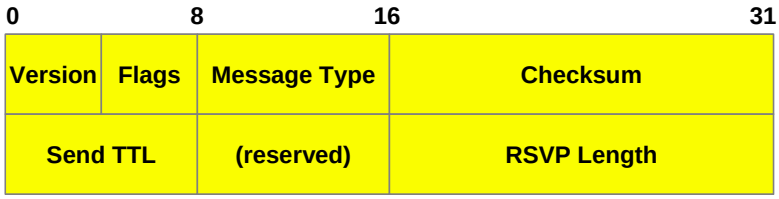
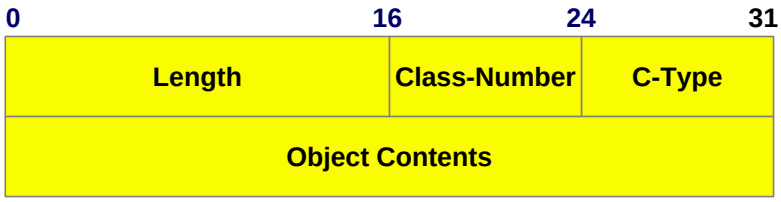
Header Format



Version	RSVP protocol number; current version is 1
Flags	No flags defined yet
Message Type	PATH, RESV, PATH_ERR, RESV_ERR, PATH_TEAR, RESV_TEAR, RESV_CONF.
Checksum	Used by receivers to detect RSVP message errors
Send TTL	Contains the IP TTL value the message was sent with
RSVP Length	Total length of message including header and body

Object Format

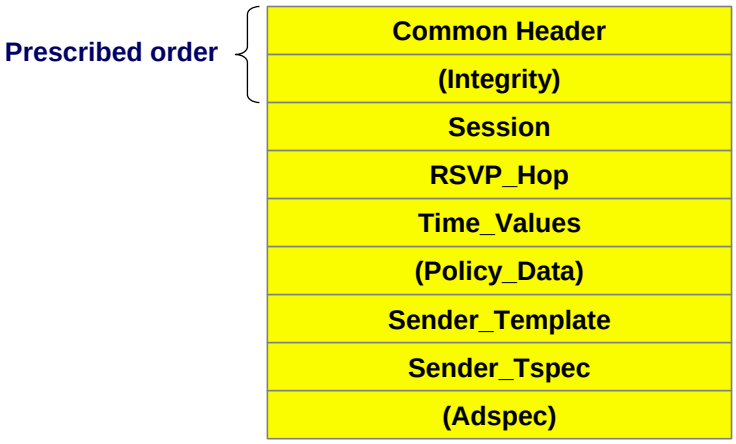


Length	Object length in bytes; must be a multiple of four
Class-Number	Identifies the object class (see below)
C-Type	Specifies the object type within the class number; IPv4 and IPv6 uses different object types
Object Contents	Up to 65528 bytes long

RSVP Class-Numbers

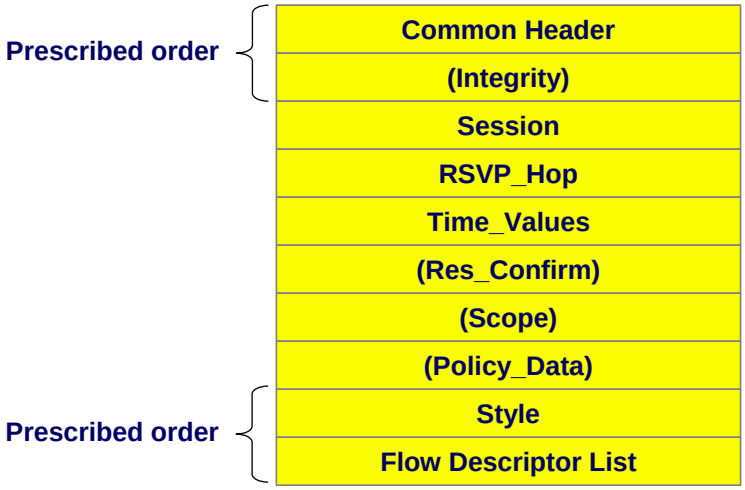
Object-class	Description
Null	object content ignored by receiver
Session	destination's IP address, port number and IP protocol ID
RSVP_Hop	IP address of node that sent this message
Time_Values	refresh period for PATH and RESV messages
Style	reservation style
Flowspec	specifies required QoS in RESV messages
Filterspec	which data-packets take advantage of QoS
Sender_Template	sender's IP address and additional ID-information
Sender_Tspec	defines traffic characteristics of the sender's data flow
Adspec	advertising information for the traffic-control modules
Error_Spec	specifies error (PathErr or ResvErr message) or confirmation (ResvConf)
Policy_Data	to support decisions of policy-modules
Integrity	cryptographic data to authenticate the origin node and message-contents
Scope	explicit list of server hosts (this object appears in RESV* messages)
Resv_Confirm	IP address of client who requests confirmation for its reservation

Object-Order of PATH Messages



Recommended object order in PATH messages following RFC 2205

Object-Order of RESV Messages



Recommended object order in RESV messages following RFC 2205

RSVP Usage

- **RSVP provides the highest level of IP QoS but is the most complex solution**
  - only suitable for private and corporate networks
- **Each additional data flow requires an additional RSVP session**
  - to be handled by the RSVP process inside the router; routing performance decreases!

RSVP Benefits and Drawbacks

- **Benefits**
  - + Explicit resource admission control (end to end)
  - + Per-request policy admission control (authorization object, policy object)
  - + Signaling of dynamic port numbers
- **Drawbacks**
  - - Continuous signaling due to stateless architecture
  - - Not scalable

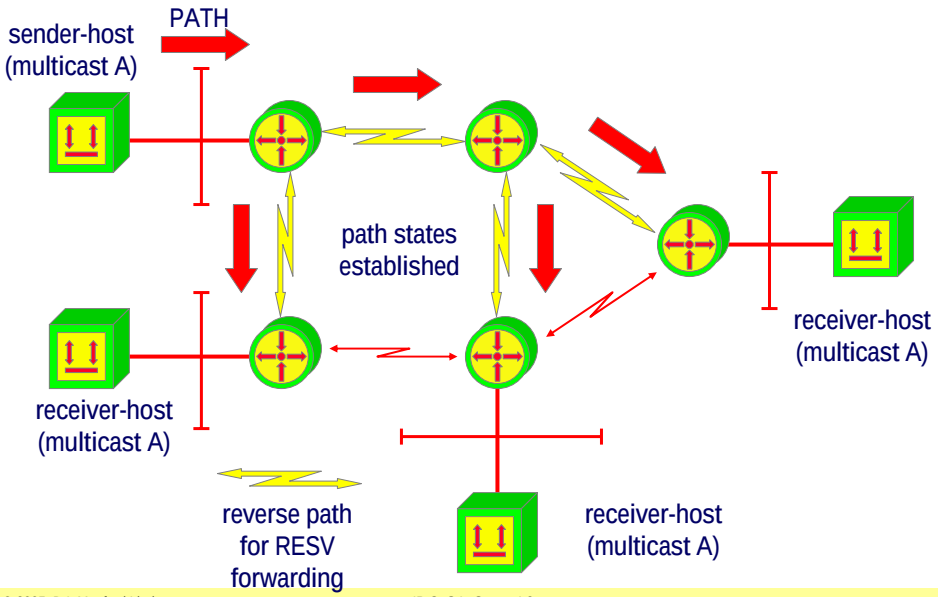
Agenda

- **Integrated Services Principles**
- **Resource Reservation Protocol**
- **RSVP Message Formats**
- **RSVP in a IP Multicasting Environment**

RSVP Procedure 1

- **RSVP sender-host**
  - transmits PATH downstream along the unicast / multicast routes provided by the routing protocol
    - PATH contains
      - RSVP sender IP address, UDP/TCP sender port
      - traffic specification (Tspec)
    - PATH is sent with same source and destination IP addresses as the data
- **PATH stores path state in each node along the way**
  - state includes unicast IP address of previous hop node
  - router learns upstream RSVP neighbor for each sender
  - states are used later to carry RESV hop-by-hop in the reverse direction

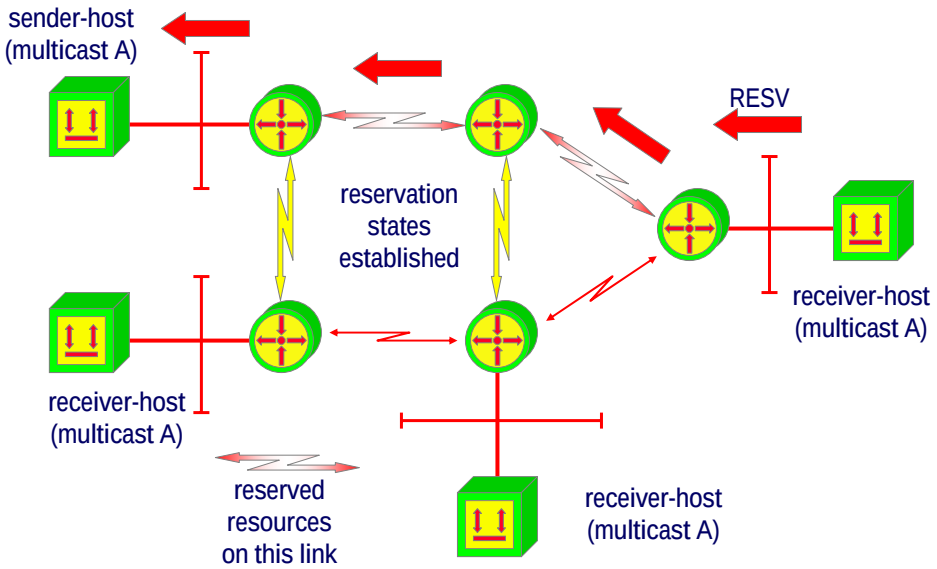
PATH Message Downstream



RSVP Procedure 2

- **RSVP receiver-host**
  - sends RESV upstream towards the sender following the reverse of the path the data packet will use
- **if reservation is rejected by a node**
  - RESV_ERR is sent to the receiver-host by the corresponding node
- **if reservation can be accepted**
  - RESV is forwarded upstream
  - a reservation state is stored in the node
- **RESV is finally delivered to the sender-host itself**

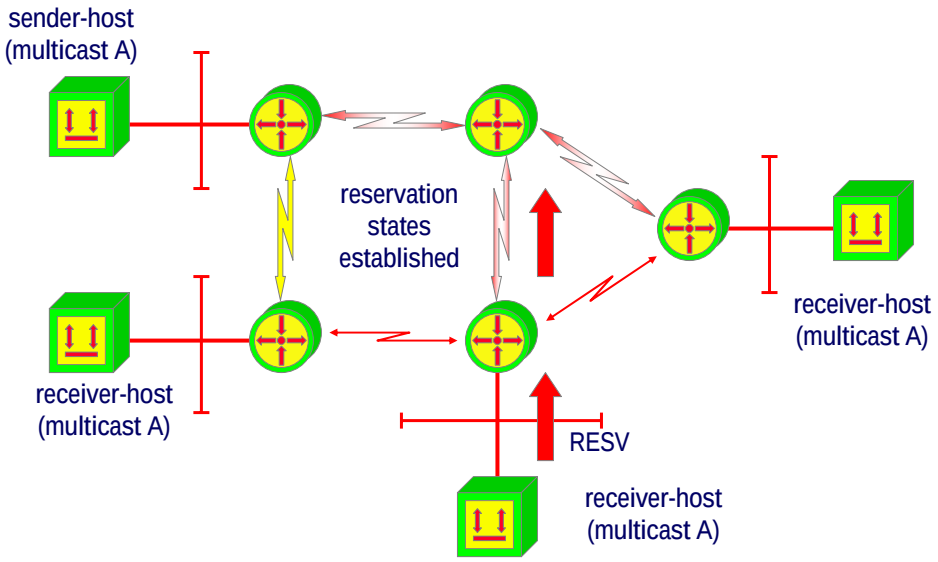
RESV Message Upstream



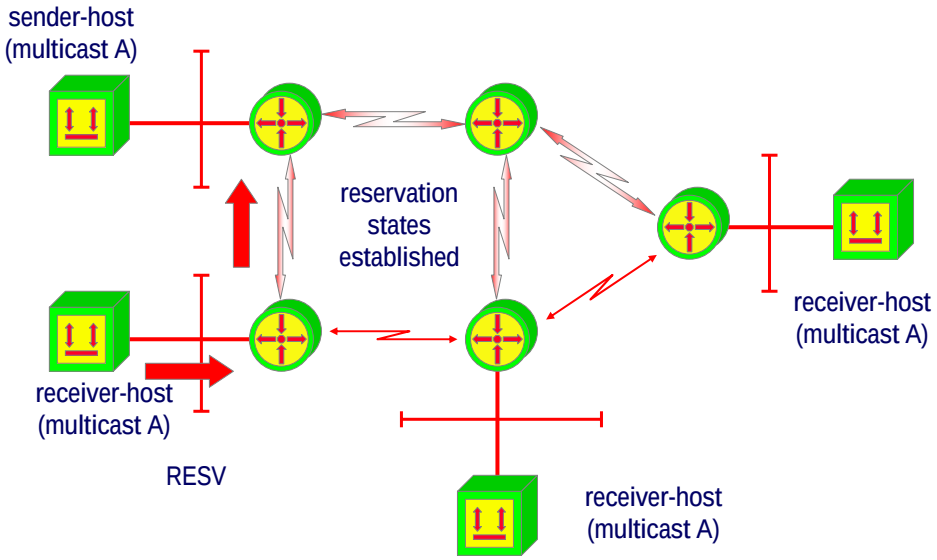
RSVP Procedure 3

- **In case of multicasting**
  - RESV messages are carried along the reverse path to the data source but only as far as the node where the receivers data path joins the current multicast reservation tree
    - Merge procedure
- **QoS is implemented by traffic control**
  - Packet classifier
    - E.g. based on session ID, filter specification
  - Admission control
    - E.g. based on available resources
  - Packet scheduler
    - E.g. based on weighted fair queuing

RESV Message Upstream - Merge



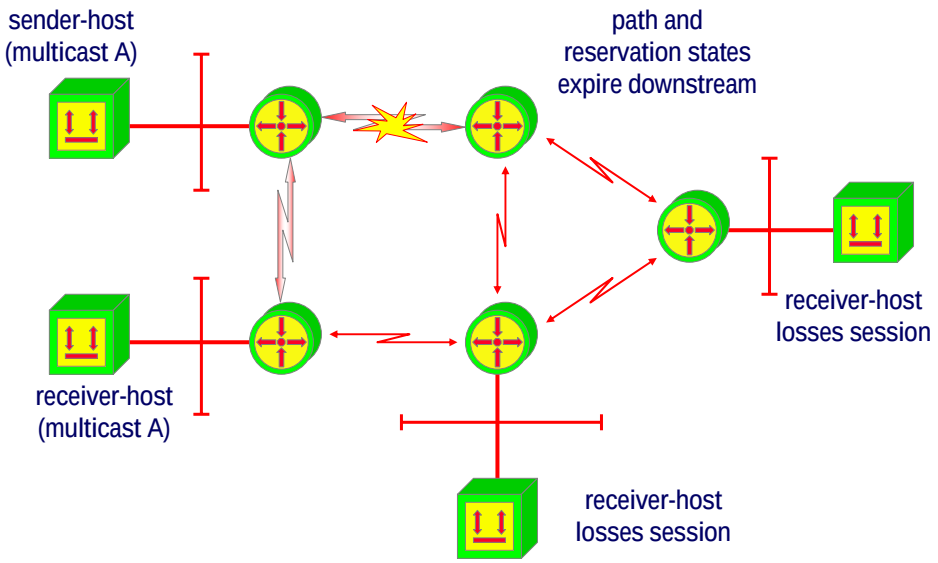
RESV Message Upstream - Merge



RSVP Procedure 4

- **Path states and reservation states**
  - are refreshed periodically by corresponding PATH and RESV messages
  - are deleted if no matching refresh messages arrive before expiration of a cleanup timeout (soft state)
- **When a route changes**
  - next PATH will initialize path state on the new route
  - next RESV messages will establish reservation state on the new route
  - its possible that a receiver-host - which was granted QoS for a session before - will be refused on the new route caused by lack of network resources
  - rerouting will offer at least best effort service

Topology Change



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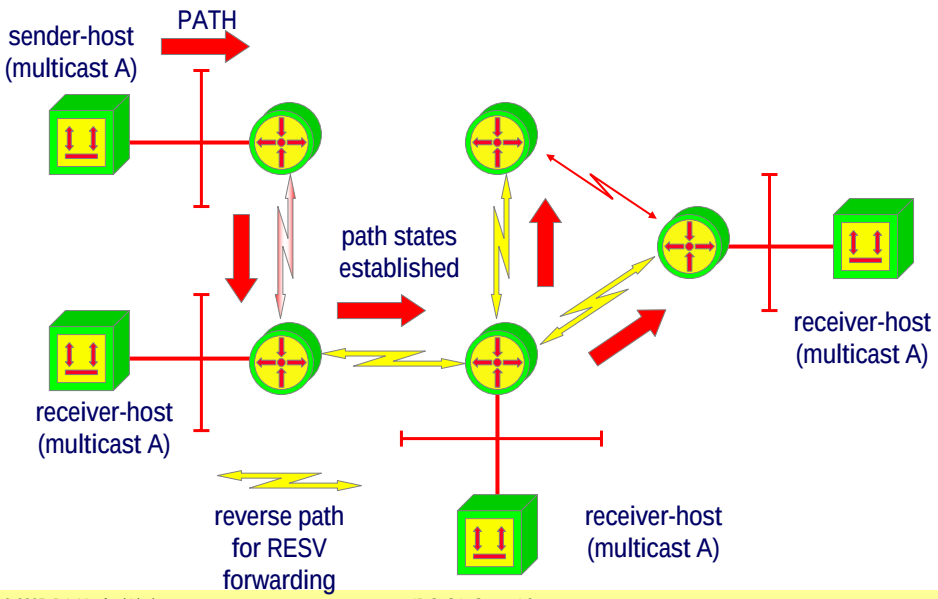
New PATH Message Downstream



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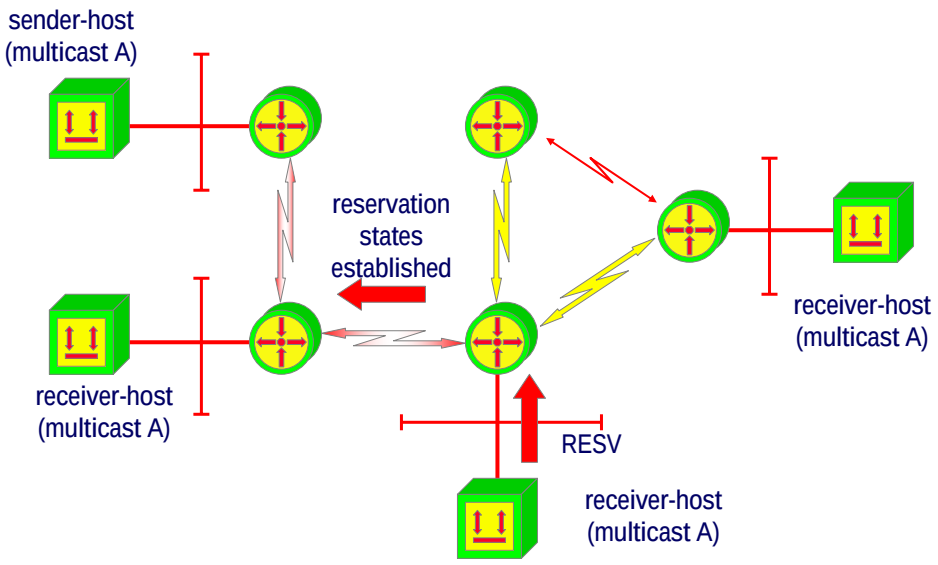
New RESV Message Upstream



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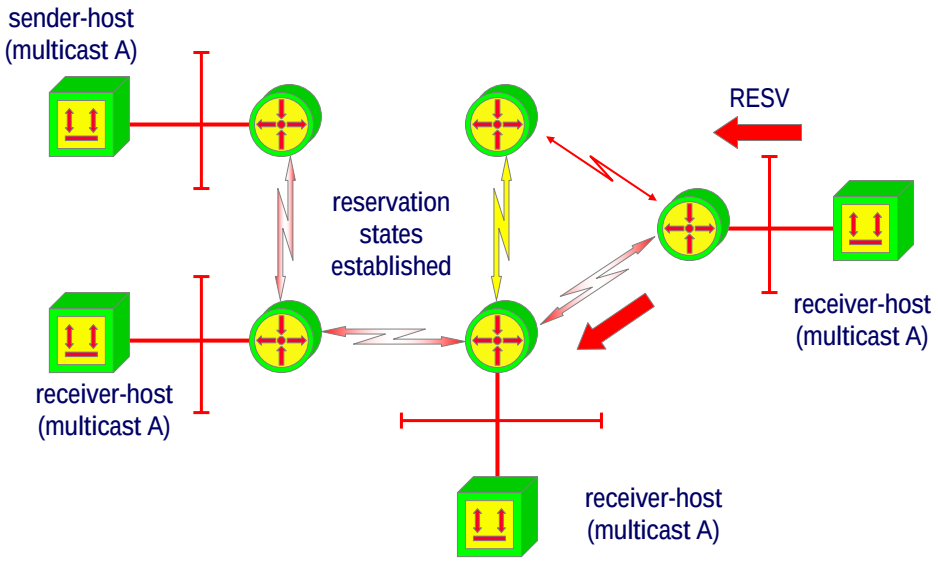
New RESV Message Upstream - Merge



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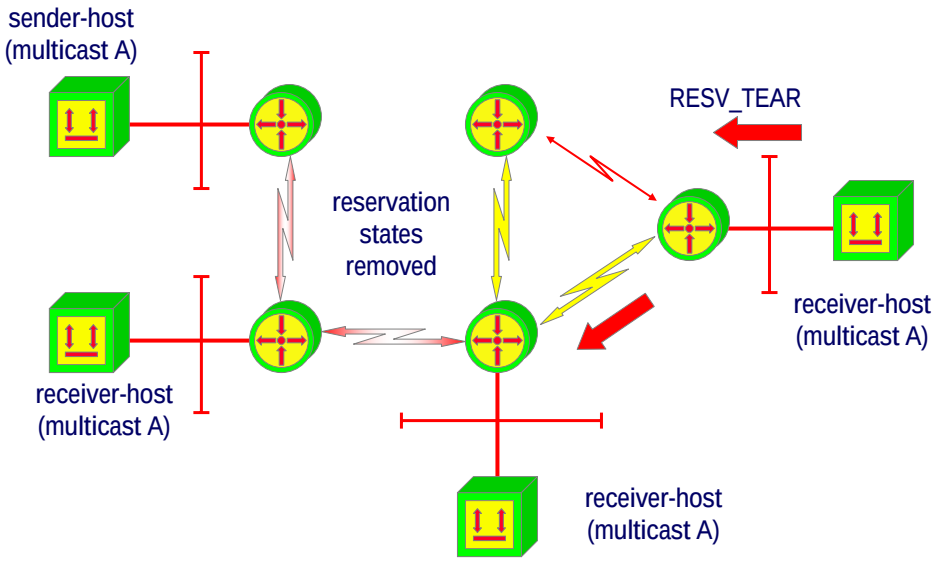
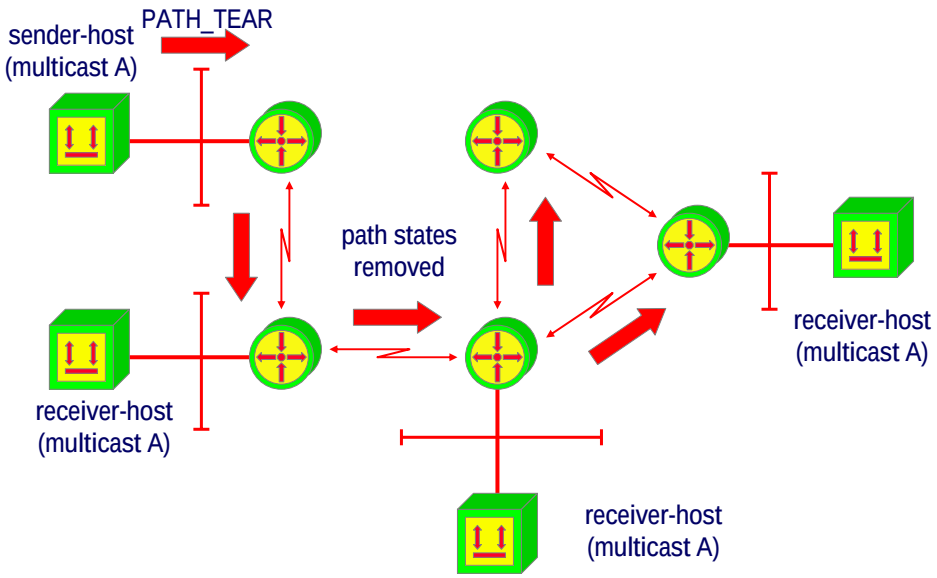
RSVP Procedure 5

- **RSVP sender host**
  - Can tear down a session by PATH_TEAR
    - PATH_TEAR travels downstream towards all receivers
    - All corresponding path states as well as reservation states are cleared
- **RSVP receiver host**
  - Can tear down a session by RESV_TEAR
    - RESV_TEAR travels upstream towards the sender
    - All corresponding reservation states are cleared

RESV_TEAR Message



Path_TEAR Message



RSVP Problems

- **Routing difficulties**
  - path reserved over a long route, but data follow a shorter route
    - self healing by refreshing, but there could be problems with stability
- **QoS based routing**
  - no resources on shortest path but available resources on longer path
- **Transition through areas not supporting RSVP**
  - hopefully: over-provisioning of network resources
- **Scalability**
  - number of soft-states (remedy: flow aggregation)