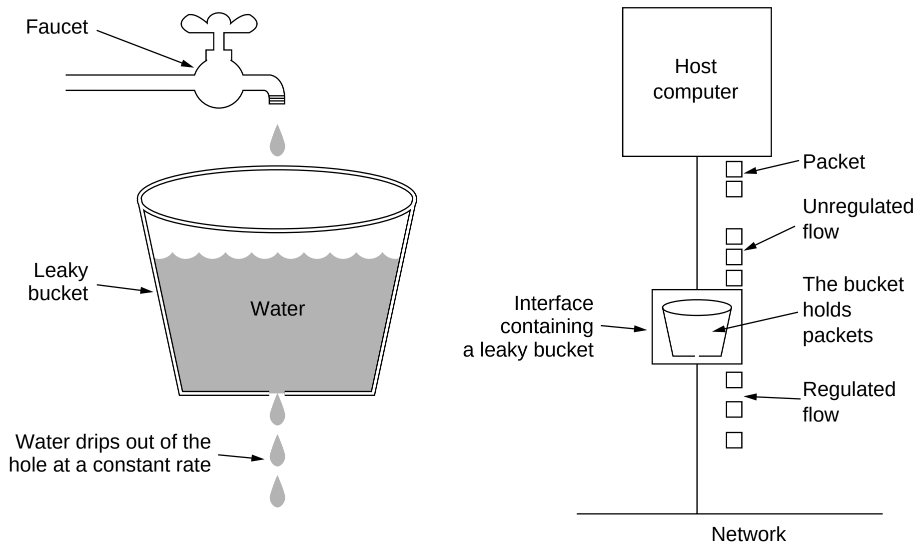
Resource Control and Reservation

Resource Control and Reservation

- policing: hold sources to committed resources
- scheduling: isolate flows, guarantees
- resource reservation: establish flows

Usage parameter control: leaky bucket algorithm

- constrain what host can inject into the network
- single server queue with fixed service time
- finite-size bucket ➠ either throttle source or loose packets
- no burstiness allowed


Faucet
Leaky
bucket
Water
Water drips out of the
hole at a constant rate
Host
computer
Packet
Unregulated
flow
Interface
containing
a leaky bucket
The bucket
holds
packets
Regulated
flow
Network

(a) (b)

Token bucket

- *tokens* allow bursts into the network
- tokens generated at constant rate up to maximum burst size
- if no token, either quench source or drop packet
- implementation: token counter, incremented periodically

Generic Cell Rate Algorithm (GCRA)

Mechanism used by UNI 3.1 to police either peak or mean cell rate.

PCR: peak cell rate

SCR: sustainable cell rate = mean cell rate

CDVT: cell delay variation tolerance

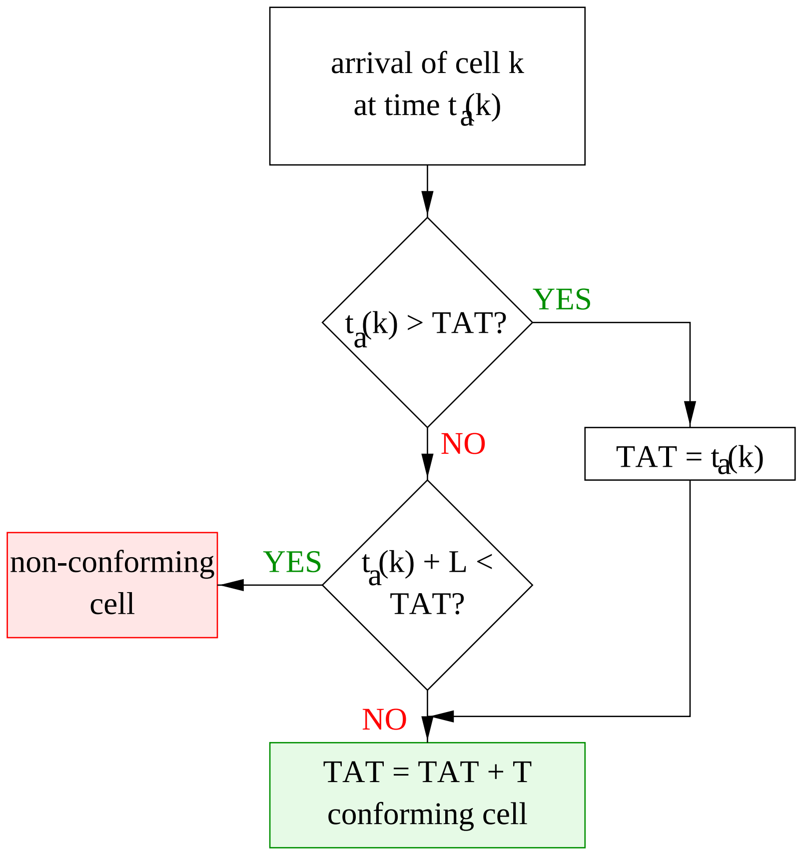
τ_s**:** burst tolerance

	peak rate	mean rate
T	1/PCR	1/SCR
L	CDVT	τ_s

GCRA

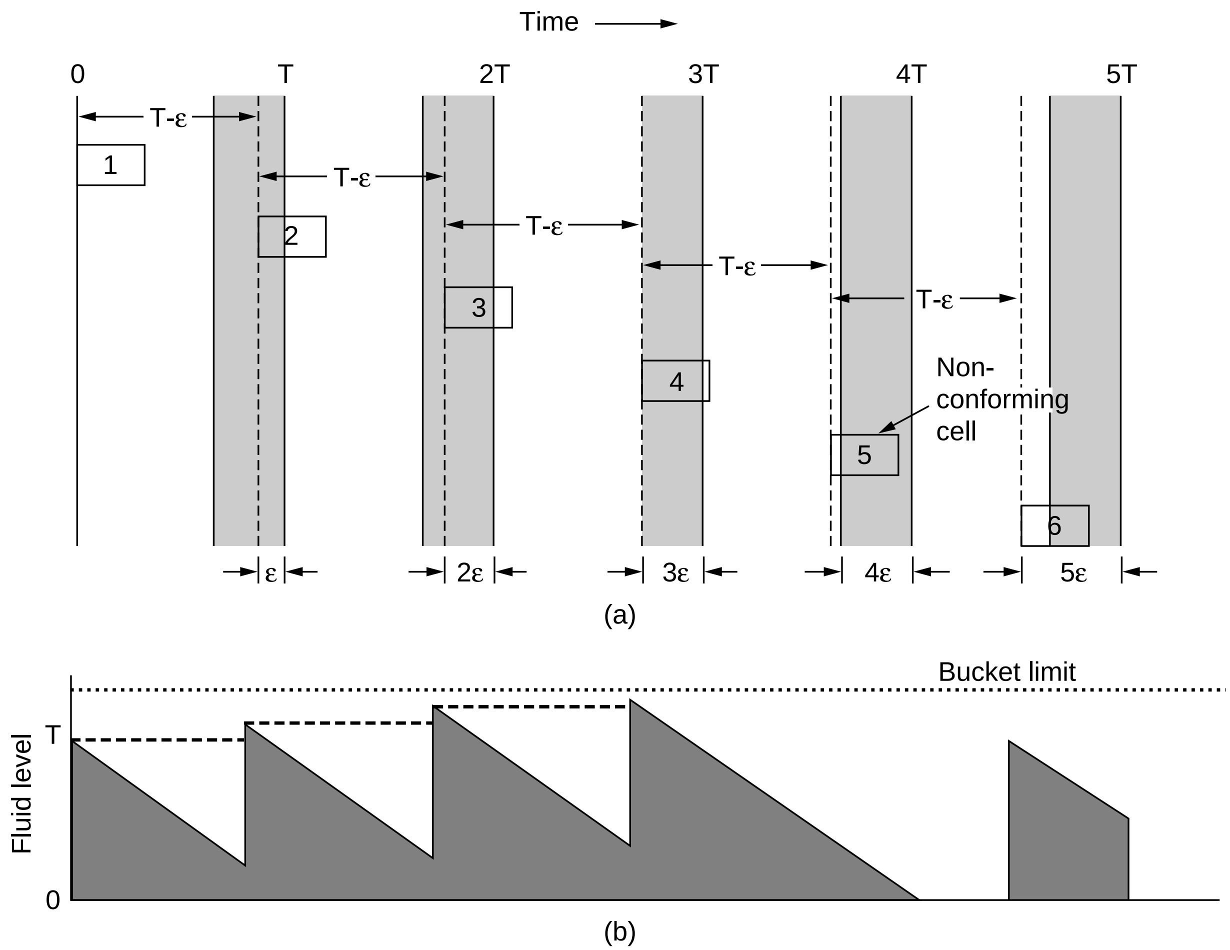
- cell i can arrive at $t_i > t_{i-1} + T - L$; but: arrival time set to $t_i = t_{i-1} + T$
- can't save up late arrivals
- can't accumulate L

GCRA flow chart



TAT = theoretical arrival time

GCRA


Time
0
T
2T
3T
4T
5T
T-ε
1
2
3
4
5
6
Non-
conforming
cell
ε
2ε
3ε
4ε
5ε
(a)
Bucket limit
Fluid level
T
0
(b)

Packet scheduling

work conserving: never delay a packet if line is idle ➠ no lower bound on jitter

non-work-conserving: minimum residency time ➠ jitter bound

Isolation: one misbehaving source can’t monopolize resources

FIFO+ and HL

For packets with real-time constraints (deadlines) ➠ give priority to those about to miss their deadline

hop-laxity: priority = $\frac{\text{hops to go}}{\text{time left}}$

drop packets that have exceeded their deadline or are too close

FIFO+: give priority to packets if travel time > average for class

- both require accumulating delays
- performance better than FIFO
- but: no guarantees, scheduling overhead

Weighted Fair Queueing (WFQ)

- fair queueing: separate queues for each input stream, round-robin ➠ favors long packets, wait for n other queues if a bit too late
- ➠ WFQ: order transmissions by when last bit would have been sent under bit-by-bit round robin
- need ordered queue of size q: $O(\log q)$ ➠ expensive
- divide bandwidth into m-bit cycles and distribute unequally

Weighted Fair Queueing

Delay D_i of flow i if token bucket at edge:

$$D_i = \frac{\beta_i}{g_i} + \frac{(h_i - 1)l_i}{g_i} + \sum_{m=1}^{h_i} \frac{l_\star}{r_m}$$

where β: bucket size; g_i: fraction; l_i: maximum packet length for i; $l_\star$: maximum packet length in network; h_i: number of hops; r_m: outbound bandwidth

Reservations

First approach: everybody is the same ➠ best effort ➠

- enough bandwidth for everybody (telephone network)
- “human backoff” if unusable
- TCP for data applications (but: also minimum usable bandwidth)
- adjust audio or video coding to best possible ➠ application control (later)
- pick least congested route: telephone system, but Internet too large

Reservations

Some are more equal than others ➠

- incumbency protection
- priorities (general over PFC)
- bulk service vs. priority delivery ➠ cost

Reservations

$/kb/s may be dynamic ➠

- reservation may change during the lifetime of an application
- networks may not be homogeneous ➠ different multicast groups for different *layers* or versions

RSVP

Receiver-oriented, out-of-band reservation protocol standardized by IETF:

- not a routing protocol, but interacts with routing
- may need *QOS routing* to pick appropriate path
- transports *opaque* QOS and policy parameters for sessions
- flow: group of packets being treated the same ➠ same multicast group or destination, IPv6 flow id, ...
- simplex ➠ setup for unidirectional data flows

RSVP, cont'd.

- does not prescribe admission or policy control
- sets up packet classifier, but does not handle packets
- independent sessions (can't tie video and audio session)
- multicast (and unicast)
- either own protocol type or UDP encapsulated

RSVP Objects

Flow descriptor =

Flowspec: • service class

- Rspec ➠ desired QoS
- Tspec ➠ describes traffic characteristics

Filterspec: which packets get this treatment ➠ sender IP address/port, protocol, other fields ➠ complex (regular expressions? IP options!) ➠ currently, sender IP address and UDP/TCP port ➠ no fragmentation

Reservation Styles

sender selection	reservations: distinct for each sender	reservations: shared
explicit	fixed filter (FF)	shared-explicit (SE)
wildcard (all)	–	wildcard filter (WF)

➠ mutually incompatible

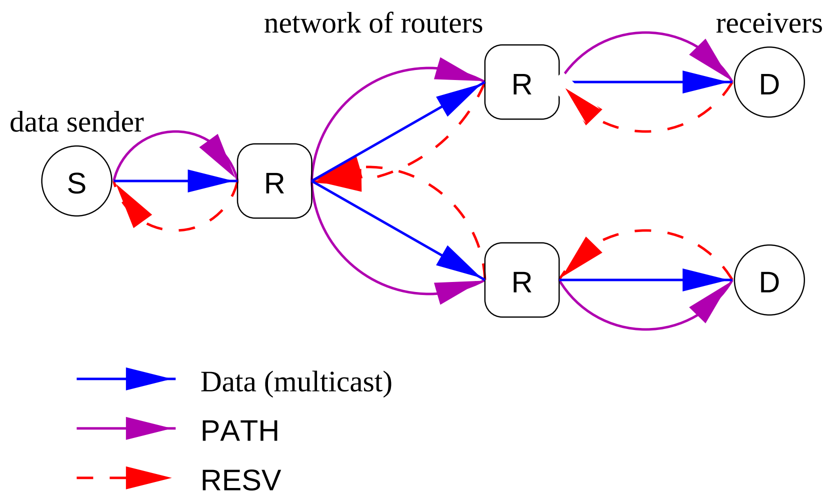
explicit: list senders by address

wildcard: any sender with a specific port (e.g.)

shared: only one active data source ➠ e.g., reserve for twice needed for audio

distinct: video

RSVP: basic operation



- receiver joins group via IGMP
- source sends PATH messages to receivers ➠ same path as data: previous hop to source, Tspec ↔ RESV one path, data another
- receivers send RESV messages back to senders

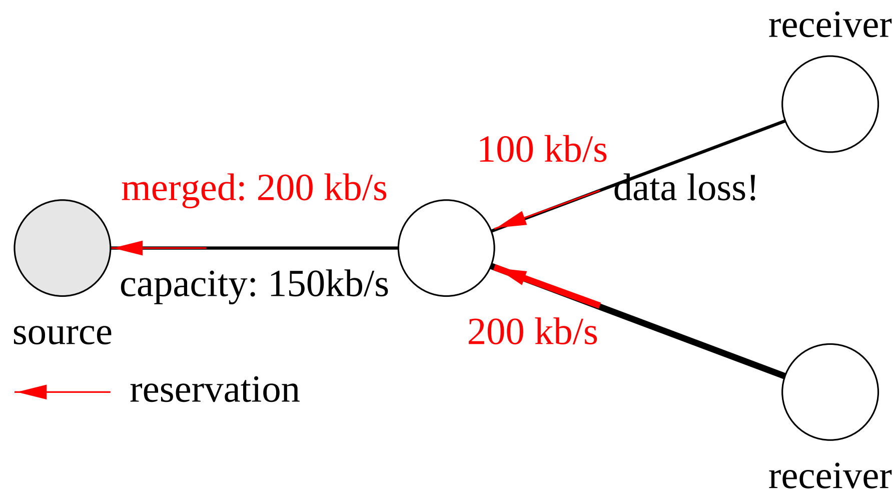
RSVP: basic operation

- reservations may be lowered
- reservations are merged at each node for same sender: max. flowspec
- merge point or data sender may send confirmation (if requested)
- reservations *may* get merged between senders (audio!)
- one-pass ➠ receiver doesn't know final QoS ➠ One Pass With Advertising
- application *should* explicitly tear down reservations

Killer Reservations

1. small reservation in place; another receiver larger reservation ➠ failure? ➠ keep old

2. large reservation fails again and again ➠ blocks new, smaller one



RSVP service classes

guaranteed: no loss, upper bound on delay

controlled load: “few” losses, “like unloaded network” ➠ delay-adaptive applications

best effort: no guarantees; current IP service model ➠ delay + bandwidth adaptive services

others: research

RSVP vs. ATM resource reservation

	IP, RSVP	ATM
multicast tree, reservation	sequential	same time
origin	receiver	sender (root) ➠ UNI4.0
change reservations	yes	no
routing changes	time-out	re-establish VC
routing	IP routing	PNNI (QOS)
flow merging (audio)	yes	no (separate VCs)
receiver diversity	not yet	no
state	soft	hard

The recurring costs of reservations

Signaling: processing and state maintenance, APIs

Routing: QoS path selection, state distribution

Policy: who gets what (and who doesn’t)

Charging, billing, accounting, service contracts: right party pays for usage, ensure QoS is delivered as promised

RSVP implementation

- scheduling: about 10% cost overhead
- low-end 68040: 0.73 ms for PATH, 0.37 ms for RESV
- ➠ approximately 1,000 flow setups/s
- processing of PATH (RESV) refresh: 0.33 ms (0.29 ms)
- ➠ approximate capacity is 1,600 flows
- about 500 bytes/flow
- refresh bandwidth ≈ 100 kb/s for 1000 flows (30 s refresh)
- PATH: 208 bytes, RESV: 148 bytes

Resource reservation: general comments

- doesn't help if network capacity $\ll$ demand
- modes:

  receiver-oriented: RSVP

  sender-oriented: YESSIR
- scaling issues: a reservation for every phone call $\leftrightarrow$ datagram idea, routing aggregation

RSVP problems

- if reservation/tear down request lost, no immediate feedback
- can increase reservation latency or “phone off hook”
- large number of refreshes ➠ scaling problems

➠ hop-by-hop confirmation ($\rightarrow$ extend refresh interval)

RSVP scaling

Scaling issues:

- number of flow states ➠ refresh, memory, time-outs
- large number of packet queues

Alternatives:

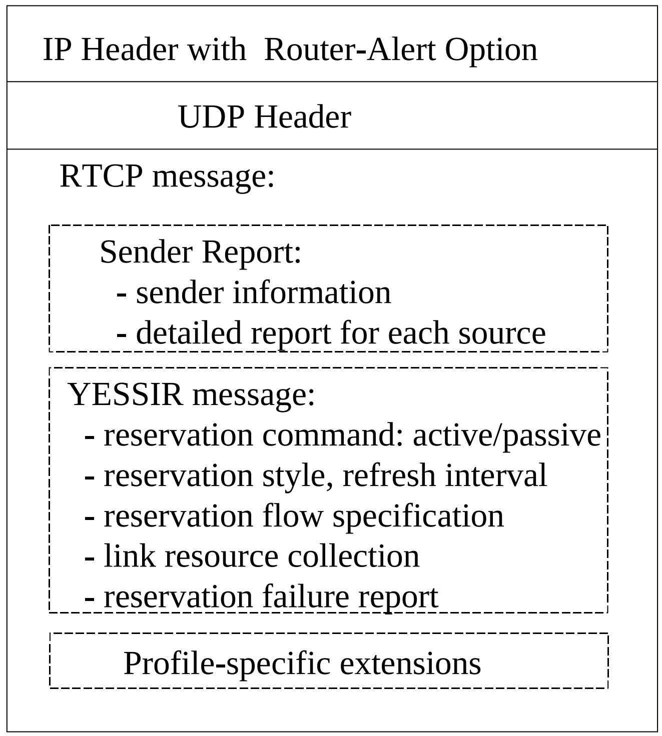
- “tunnels” = encapsulation IP-in-IP ➠ overhead
- aggregation for sender reservation ➠ flow classes
- drop and delay preferences

YESSIR: Yet another Sender Session Internet Reservation

- RSVP: separate daemon, API
- ➠ integrate into application that needs it (embedded systems!)
- in-band ➠ easier firewall
- router alert option
- soft-state + RTCP BYE
- partial reservations: add links as session ages $\leftrightarrow$ fragmentation

YESSIR

plain RTCP SRs or additional information:



end-to-end refresh (vs. hop-by-hop)

YESSIR

- measurement mode
- IntServ flow specs
- PT-based for well-known PTs
- TOS-based: value
- killer reservations ➠ SR reservation failure
- OPWA: hop count, propagation delay, aggregated bandwidth, delay bounds ➠ updated at router
- cost: 360 μs

SRP: Scalable Reservation Protocol

- sender-oriented, out-of-band
- data packets marked as REQUEST ➠ learn reservation level
- router aggregates requests, downgrades to best effort
- receiver reports rate of successful REQUESTS
- ➠ sender adjusts rate RESERVED data packets
- aggregation by estimation:
- max(observed traffic over several intervals)
- effective bandwidth $e = \sup \frac{\sum n_i}{t_j - t_i + D}$

SRP packet processing