Integrated Services in the Internet

Lecture for QoS in the Internet –course

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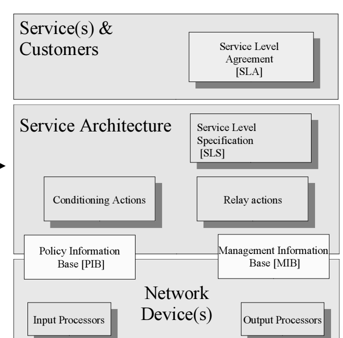
The QoS story so far...

- Where are we in this lecture:
  - Low level mechanisms (building blocks of the QoS) have been dealt with
    - Schedulers, queuing, routing
  - Time to advance to building service architectures using the building blocks
  - Time to apply engineering visions



Knowledge gained in this lecture

- After this lecture you should be able to
  - Explain the constraints and objectives for the development of Integrated Services –architecture
  - Explain the service classes of IntServ and use the flow model to estimate traffic behavior in an IntServ router
  - Explain, in a detailed level, the architecture of an IntServ router
  - Understand the weaknesses of the per-flow approach

Outline

- History and preliminary concepts
  - types of Internet applications
  - general QoS concepts
- *Concepts of IntServ*
  - flow model
  - service classes
- *Building the IntServ-router*
  - routing, scheduling
- Notes on future

History

- It was 1991...
  - and there was not (that much) traffic in the internet
  - No WWW until 1993
  - no other multimedia... yet
    - multicast was already designed, but it was just starting with IETF audio- and videocasts in MBone
- Some people observed some, and anticipated more, problems due to multimedia-applications

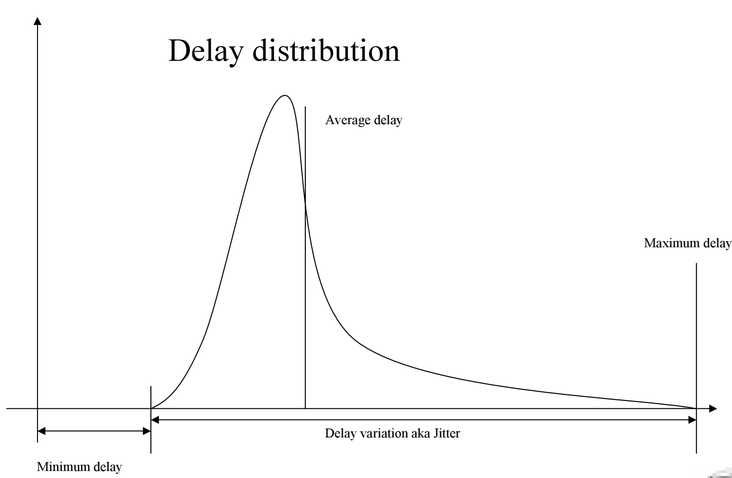
Application types

- Elastic
  - All tolerant ”old-fashioned” Internet applications
    - FTP, Usenet News, E-mail,
- Tolerant playback applications
  - One-way video feed, oneway broadcast
    - Some tolerance achieved with play-out buffers
- Intolerant playback applications
  - Applications that need data to be delivered in real-time
    - low delay, no jitters, enough bandwidth
  - Two way conversations (IP phone)

Quantitative QoS-parameters

- *Available bit rate/ bandwidth*
  - How fast you are allowed to send packets to the network?
- *Packet discard / Data loss*
  - What packets are dropped in case of congestion?
- *Delay*
  - Time for the packet to reach its destination
  - How long is your data relevant?
- *Variation of delay / Jitter*
  - effectively kills the usability of Voice over IP –applications

Delay and delay variation



Original design objectives for IntServ

- Build a multicast network with videoconferencing ability
  - Only a few senders at a time
    - real-time
    - low packet loss
    - no congestion control (UDP)
  - VoIP not expected!!
- Protect multimedia traffic from TCP effects and vice cersa
- Objective: Preserve the datagram model of IP networks AND provide support for resource reservations and end-to-end performance guarantees to individual or groups of traffic flows

Integrated Services

- Provide Best Effort as before
  - no reservations for TCP traffic
  - possibility to use adaptive applications
  - sometimes BandWidth is enough
- Provide resources for multimedia traffic
  - multicast streams are long lasting, therefore state setups are ok
    - Caveat!!: VoIP is not OK !!
- Provide services for individual users and their applications!!
  - aka per-flow approach
- Capability requirements (to build IntServ-networks):
  - functions in individual network elements (router enhancements)
  - way(s) to communicate the requests between elements (protocol: RSVP)

Integrated as in Integrating real-time services to best-effort network

Tools of IntServ

- Signalling to convey the traffic contract
  - RSVP, separate lecture
- Admission control to determine whether new flow fits into the network
- Policing & Shaping to keep the existing flows within the negotiated parameters
- Network design & engineering to keep blocking probability low

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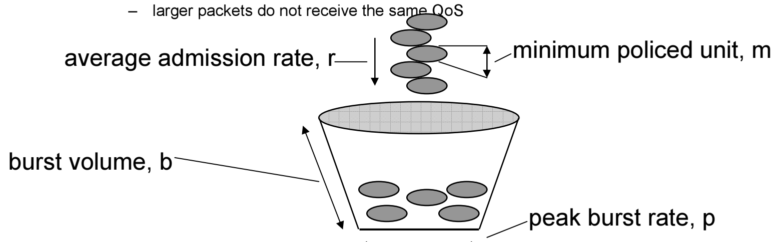
Flow model of IntServ

- A flow (in IntServ) is a distinguishable stream of related datagrams that results from a single user activity and requires the same QoS
  - the finest granularity of packet stream that can be identified
- Flow model described by a leaky bucket
  - token rate, rate of leaky bucket (r): 1 byte/s - 40 Terabytes/s
  - token-bucket depth (b): 1 byte - 250 Gbytes
  - peak traffic rate (p): 1 byte - 40 Terabytes/s
  - minimum policed unit (m): amount of data in the IP packet (other protocols, user data)
  - maximum packet size (M): maximum size of the packet within this flow (bytes)
    - larger packets do not receive the same QoS



Controlled load service (RFC 2211)

- provides unloaded network conditions
  - for applications requiring reliable and enhanced best-effort service
  - aims to provide service that closely approximates traditional best-effort in a lightly loaded or unloaded network environment -> better than best effort
- intended for adaptive applications
  - applications provide network an estimation of the traffic it is about to send
  - acceptance (by the network) of a controlled load request implies a commitment to provide better than best-effort
- priority service with admission control
- no fragmentation, packets must comply to MTU

Guaranteed service (RFC 2212)

- for non-adaptive applications requiring fixed delay bound and a bandwidth guarantee
- WFQ service (refer to lecture on queuing mechanisms)
- **computes and controls the maximum queuing delay**
  - guarantees that packets will arrive within a certain delivery time and will not be discarded because of queue overflows, provided that flow's traffic stays within the bounds of its specified traffic parameters
- does not control minimal or average delay of traffic, nor is there control or minimization for jitter
- no packet fragmentation is allowed, packets larger than M are nonconforming.
- traffic policing with simple policing and reshaping

Delay calculation for Guaranteed Service

End-to-end queuing delay:

$$Q_{delay} = \frac{(b-M)(p-R)}{R(p-r)} + \frac{(M+C_{tot})}{R} + D_{tot}, \text{ if } p > R \geq r \quad \text{or} \quad Q_{delay} = \frac{(M+C_{tot})}{R} + D_{tot}, \text{ if } R \geq p \geq r$$

- p=peak rate of flow (bytes/s) (***Tspec***)
- b=bucket depth (bytes) (***Tspec***)
- r=token bucket rate (bytes/s) (***Tspec***)
- R=bandwidth (service link rate) (***Rspec***)
- m=minimum policed unit (bytes) (***Tspec***)
- M=maximum datagram size (bytes) (***Tspec***)
- C=packet delay caused by flow parameters (bytes) (***Rspec***)
- D=rate independent delay caused by network nodes (μs)

- The delay estimates are based on a so called fluid model
  - C and D indicate the deviation of the node from the ideal fluid model
- There is no control (in GS) for
  - minimal or average delay
  - propagation delay
- No estimate for jitter
- Only thing promised is the maximum delay.

Estimate on required buffer space:

$$B_{size} = M + \frac{(b-M)(p-X)}{(p-r)} + X\left(\frac{C_{sum}}{R} + D_{sum}\right), \text{ where}$$

$$X = \begin{cases} r, \text{ if } \frac{b-M}{p-r} < \frac{C_{sum}}{R} + D_{sum} \\ R, \text{ if } \frac{b-M}{p-r} \geq \frac{C_{sum}}{R} + D_{sum} \wedge \text{p} > \text{r} \\ \text{p, otherwise} \end{cases}$$

TOKEN_BUCKET_TSPEC

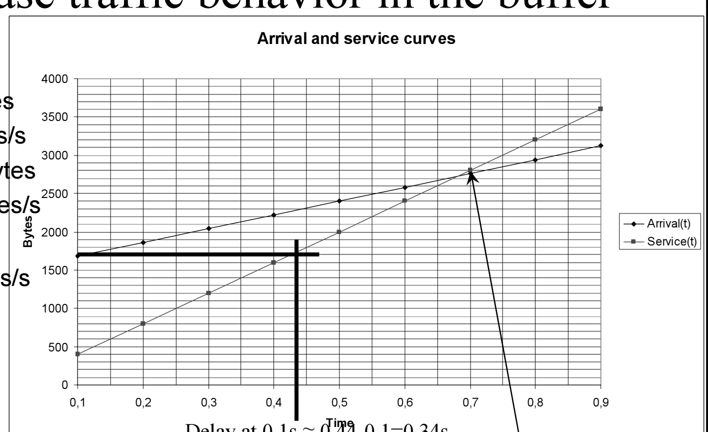
- Guaranteed service is invoked by a sender specifying the flow parameters in the Tspec
- Controlled-load service is described in Tspec
- Describes traffic with
  - bucket rate (r)
  - peak rate (p)
  - bucket depth (b)
  - minimum policed unit (m) and maximum packet size (M)

Rspec

- Receiver determines/requests a desired network service level with Rspec
- Used only in Guaranteed Service
  - Question: How does ”Controlled load” work?
- Describes the service requirements with
  - Service rate (R), R>=r, may be higher than requested (taking into account the p (peak rate)
  - Slack Term (S), microseconds, describing the difference between the desired delay and the delay obtained by using a reservation level of R.

Worst case traffic behavior in the buffer

- Tspec
  - M=1500 bytes
  - p=3500 bytes/s
  - Tbd=1500 bytes
  - tbr=1800 bytes/s
- Rspec
  - R=4000 bytes/s
- Max. Delay
  - M/R=0,375s



Buffer empty!

Note and exercise for final exam: Type in the equations couple of slides back and play with different parameter combinations. Final exam is likely to have a question where you have to explain a figure like the above.

QoS in the Internet-routers

- New router functionality
  - Traffic shaping
  - Admission control
    - To control resources
  - Differential congestion management
    - advanced queue management algorithms
    - CBQ, WFQ, etc.
  - Consistent handling of packets
    - State, 'global' knowledge of policy and QoS/CoS decisions

"There is an inescapable requirement for routers to be able to reserve resources in order to provide special QoS for specific user packet streams."

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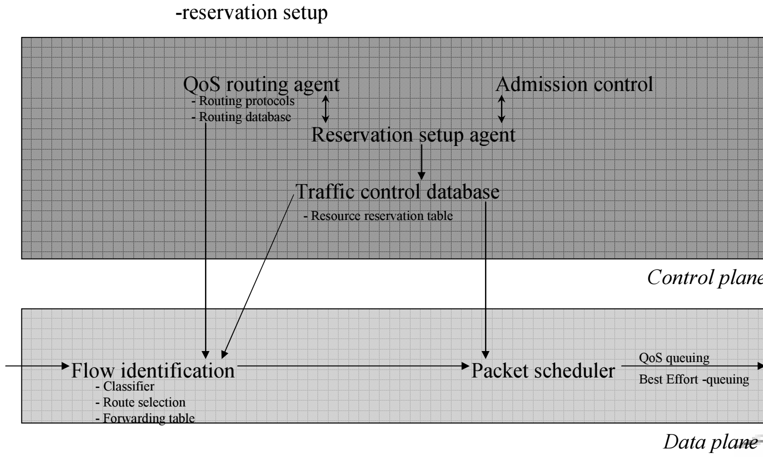
IntServ router implementation reference model

In IntServ the resources are explicitly managed with

-packet scheduler
-classifiers
-admission control
-reservation setup



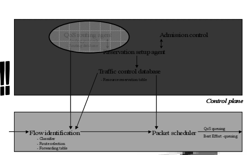
IntServ node characterization

- General descriptive parameters used to characterize the QoS capabilities of nodes in the path of a packet flow (RFC 2215)
  - NON_IS_HOP
    - the break bit indicating a break in the QoS chain
    - set by the device that is not IntServ compliant or knows such devices to exist in the path
  - NUMBER_OF_IS HOPS
  - AVAILABLE_BANDWIDTH
    - 1 byte/s ... 40 Terabytes/s
  - MINIMUM_PATH_LATENCY
    - speed-of-light + packet processing limitations
  - PATH_MTU
  - TOKEN_BUCKET_TSPEC
    - only used by the sender and the edge node

Router blocks: QoS routing

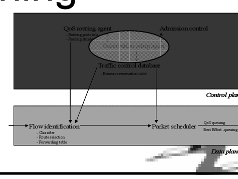
- Current Internet uses distributed route calculation
  - Every router decides for itself what is the best route to a given destination.
- In the future Internet route calculation has to be more centralized
  - Ability to compute the path at the source
  - Ability to distribute information about network topology and link attributes
  - Ability to do explicit routing
  - Resource reservations and link attrribute updates

QoS routing is not specified in any manner within the IntServ!!



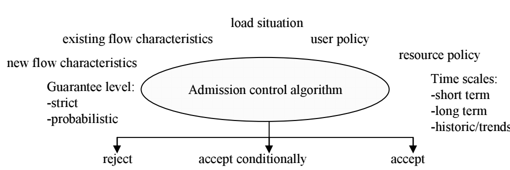
Router blocks: Reservation setup

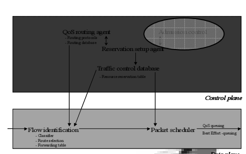
- Need for a protocol
  - RSVP
- Hop by hop state establishment
  - traffic characteristics
- Billing/accounting setup
- More on RSVP in the provisioning lecture



Router blocks: Admission control

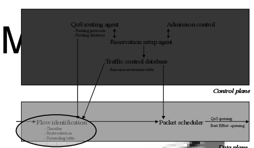
- Before a flow is accepted it has to pass the admission control test
- Parameter based
  - precise characterization of a traffic flow
  - difficulty of accurately modeling traffic
- Measurement based
  - probabilistic traffic characterization
  - good level of guarantee to resource utilization ratio





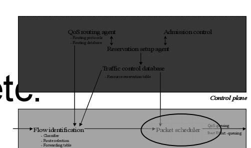
Router blocks: Flow identification

- Identify to what flows (if any) packets belong to
  - must be performed to every incoming packet
    - Multifield classification decides the appropriate queue
  - requires fast hardware if (and when) performed at wire speed
  - 64 byte packets arrive in 622 M back to back in less than 1μs



Router blocks: Packet scheduling

- Refer to the previous lecture on scheduling algorithms
  - WFQ (primary choice)
    - explained with the fluid model
  - GPS
  - PGPS
  - WF^{2}Q
  - Hierarchical WFQ
  - SCFQ, WRR, DRR, CRR etc. etc.



IntServ problems

- Resources
  - OK in small networks
    - provides for end-to-end exact QoS
  - What about large networks?
    - router capacity for resource reservation cannot be scaled on per-flow basis (in the Internet core)
- For IntServ to function, especially for Guaranteed Service, every node on the path must implement the IntServ functionality
- Router requirements are high
  - RSVP, admission control, MF classification and packet scheduling

Integrated Services will be deployed first in intranets and other local environments where scaling and policy control are much less challenging.
-Bob Braden-

Future of IntServ

- In the core there might be a large amount of reservations to be updated, so you have to:
  - not isolate individual flows
  - map flows into fixed number of service classes
  - don’t bother reservation messages
  - keep state on the edges
  - > DiffServ (next week’s lecture)

The problems of per-flow approach

- Scalability
  - If the amount of information grows faster or at the same pace in the core as it does at the edge the solution in question DOES NOT SCALE well.
- Millions of users are hard to manage one by one according to their individual wishes.
  - qualitative QoS -> not IntServ
- It is easier to decide *which* packet is forwarded and which dropped or delayed than to determine *when* a packet should be forwarded.
  - qualitative QoS -> not IntServ
- Qualitative is easier to <u>implement</u> than quantitative
  - IntServ is not likely to be the <u>widely</u> implemented QoS solution!!