1

QoS: What Went Wrong?

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23 September 2004

2

RIPQoS 2003

- Revisiting IP QoS? or *Requiescat in Pace*?
- Bruce Davie: *Deployment Experience with Differentiated Services*
- Crowcroft et. al.: *QoS's Downfall: at the bottom, or not at all!*
- Teitelbaum & Shalunov: *What QoS Research Hasn't Taught Us About Risk*

3

What is QoS, anyway?

- Depends on who you ask.
  - Set of mechanisms for traffic classification?
  - End-user service?
  - Risk mitigation technique?
- Who are the stakeholders in QoS?
  - ISPs?
  - End users (Enterprises)?
  - Consumers?

4

What QoS isn't

- It's not a way to create bandwidth
  - QoS is a zero-sum game
- It's not an end-user service
  - A platform for services (if you're an ISP)
  - An engineering tool (if you're an enterprise)

A brief* history of IP QoS

- Integrated Services (IntServ)
  - RSVP used to analyze and provision paths (signaled approach)
  - Bandwidth is reserved per flow
- Complex RSVP implementation
- Per-flow state information in routers (E2E again!)
  - Scalability issues
  - Policy enforcement issues

* In this case, brief means "paraphrased from Jim Gogan's (gogan@unc.edu) presentation "IP Quality of Service: IntServ and DiffServ"

A brief* history of IP QoS

- Differentiated Services (DiffServ)
  - Traffic is classified at the edge (IPv4 TOS field / IPv6 class field)
  - Routers allocate resources per class of traffic
  - traffic handling can change on a per-hop basis
- No per-flow state
- Policy applied to aggregate flows
- More difficult policy interface between ISPs

* Here , brief means "stolen from Cisco"

Has QoS failed?

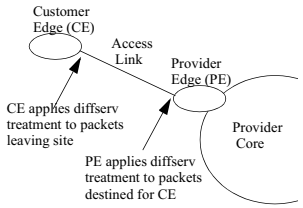
- Widely deployed support for IntServ and/or DiffServ
  - Cisco IOS
  - Juniper
  - Nortel
- Deployment is just the first step:
  - Configuration
  - management, packaging for resale, &c.

Has QoS failed? (cont.)

- Significant adoption in certain markets:
  - L3 VPNs, enterprise networks
- Typically single-provider, single administrative domain
- High-priority traffic usually between nodes within the administrative domain
- VOIP (maybe)
  - Not clear if Telcos with IP backbones are actually using QoS

Has QoS failed? (cont.)

- ISP edge deployment
  - Deployed on access link between customer and ISP
  - Difficult for ISP to categorize customer-bound traffic
  - Works well as long as only customer's outgoing traffic needs classification



Has QoS failed? (cont.)

- What about QoS at Layer 2?
  - MPLS, 802.1p, AAL1-5, FR Traffic Shaping, &c.
  - Often sophisticated, fine-grained
- Insufficient by itself - requires some Layer 3 support to be useful
  - Different transport layers = different mechanisms
- Currently not popular outside of single-domain use

Why don't ISPs offer QoS?

- Expensive
  - Possible infrastructure upgrades
  - Implementation costs: training, configuration, management
  - Consumer-end equipment
- Until recently, few clear services built on top of QoS
  - VOIP?
- No economic incentive for cooperation between ISPs
  - QoS seen as a differentiator

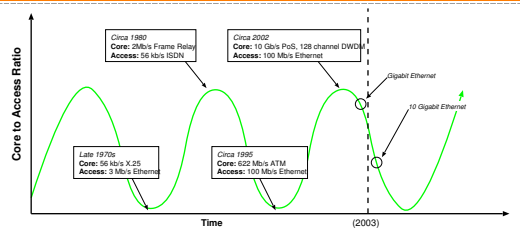
Why don't ISPs offer QoS?

- What about security?
- Theft of Resources
  - Theft of bandwidth
  - Illegal promotion of packet PHB
- Denial of Service
  - Traffic class overloading (core)
  - source penalization (edge)

The real reason: Fat Pipes

- No point implementing QoS in grossly over-provisioned networks
- Anecdotal evidence: 15% utilization = time to widen the pipe!
- A little-utilized best-effort fat pipe works well enough
- Core bandwidth far outstrips access bandwidth
  - DWDM at the core, 100Mb/s at the edge
  - Wasn't always this way, though...

A Vicious Cycle



- Warning: "bogograph"
- Core bandwidth is ahead now, but it wasn't always that way
- Why didn't QoS succeed during one of the previous troughs?

QoS R&D

- QoS interest was (is?) largely reactive
  - If there's no problem to solve, implementers focus elsewhere
  - Technical solutions have usually been too late
  - Providers historically have solved the problem by throwing bandwidth at it
- No shortage of research in the area: ~8000 papers in 10 years
- A few recent examples:

QoS in overlay networks

- A lot of recent research attention
  - QRON
  - OverQoS
- Promising results with real-world applications on the WAN
- Crowcroft et. al. : No way!
  - Not TCP-friendly
  - Adds YACS (Yet another control system)

One-bit QoS

- Proposed by Crowcroft et. al.
- Concept: Build very simple two-level QoS into the low-level internet
  - Routers signal congestion to end systems
  - End systems use higher-level algorithms to implement ‘fair share’ allocation
- Open question: which is more expensive, implementing the already extant DiffServ or deploying and implementing ‘A Bit of QoS’?

Is QoS the right solution?

- Many axes of ‘quality’: latency, bandwidth, jitter, &c.
- QoS schemes that only address one axis may be unsuitable for some applications
- What is the customer’s desired result?
  - Hint: it’s not 0 packet loss
  - An end to expensive over-provisioning
  - Protection from / mitigation of risk

Is QoS the right solution?

- Over-provisioning: “Throw bandwidth at the problem”
  - Expensive
  - Inefficient
- Doesn’t necessarily work!
  - Doesn’t prevent high-priority traffic from being dropped due to bursts of lower-priority traffic
  - The ‘backhoe’ problem (Of course, QoS doesn’t help here either)
  - How do you deal with failures?

Warranted QoS

- a.k.a. Layer 8 (Financial)
- Recognizes that customers don’t want 100% uptime
- Requires careful statistical analysis of traffic (ongoing effort)
- In the end, unlikely to succeed
  - Sets unrealistic customer expectations (”110% uptime!”)
  - DoS attacks can be engineered to exceed any assumptions based on statistical modeling

Risk management

- "Bit insurance" - also Layer 8
  - Risk assumed by a neutral third party
  - Financial compensation for network failures is usually acceptable
- Requires buy-in from ISPs to be effective
- If ISP QoS revenue is significant, could be hard to get buy-in
- Unlike QoS, insurance can be end to end without cooperation between individual ISPs

Application-layer solutions

- FEC, application-level buffering, TCP
- Impose some additional overhead
  - May or may not be reasonable, depending on application
- Same potential problem as QoS overlays - all users incented to use apps that are loss tolerant, congestion results
- Loss-tolerance techniques aren't infallible; probably unsuitable for mission-critical apps

The future of QoS?

- Demand for QoS may resume in the future
  - Access bandwidth may close the gap with core bandwidth (No more bandwidth glut)
  - Possibility of increased interest in failure-case behavior
  - Emergence of the QoS "killer app" (VOIP? Online gaming?)
- ISPs may grow more comfortable with QoS through experience in other environments
- Standardization of QoS services between providers may speed adoption

...or not.

- Core bandwidth has some headroom, still ramping at impressive rates
  - Plenty of dark fiber at this point
  - Lots of research
- Deployment issues remain thorny, unsolved
  - Need a standard way of arranging QoS between ISPs
  - Some research, but gets into Layers 8 and 9
- If throwing bandwidth at the problem will work, QoS will be left out.

Other RIPQoS papers

- Gregory Bell, LLNL: *Failure to Thrive: QoS and the Culture of Operational Networking*
- IP QoS has filed to thrive in enterprise networks due to disconnect between researchers and operations people
- Ops: complexity isn't the only potential source of failure
  - Buggy implementations hinder adoption(the deployment problem again)
  - Comparisons to IP multicast
- Lack of solid debugging tools

Other RIPQoS papers

- Carlos Macian: *Beyond Technology: The Missing Pieces For QoS Success*
- Difference of opinion between ITU and IETF on what QoS is
- QoS isn't just a network issue - apps have an impact too.
- Need a number of business environment pieces for QoS to succeed
  - Billing & accounting model
  - Trust model

Other RIPQoS papers

- Ben Teitelbaum: *Quality of Service and Denial of Service*
- QoS solutions have to be designed for worst case conditions
- Not attractive to customers if it's primarily helping the ISP stretch their bandwidth budget
- Elevated priority schemes may not provide DoS protection
  - If they don't, they're essentially undeployable
- Researchers need to think adversarially
- Open question: how do customers verify DoS protection?

Other RIPQoS papers

- Tristan Henderson: *Networked Games --- a QoS-sensitive application for QoS-insensitive users?*
- Research into the satisfaction of online gamers
  - Most games use UDP-based protocols
  - To gamers, latency is all that matters
- Turns out, gamers don't care about QoS once connected
  - Higher latency <u>will</u> keep them from joining a server, though
- How do you get price-sensitive customers to pay more for a service they're insensitive to once connected?

Other RIPQoS papers

- Panos Gevros: *Internet Service Differentiation Using Transport Options: the case for policy-aware congestion control*
- A means to control TCP congestion control dynamically in an efficient manner
- Existing QoS schemes won't survive the combinatorial explosion of application to the whole internet
- Instead, modify endpoints' congestion control parameters in response to changing network conditions
- ISPs would offer this service to end users

Additional Sources

- *Security Issues in a Differentiated Services Internet* - A. Striegel, Department of CS and E, Notre Dame
- http://www.cisco.com/en/US/tech/tk543/tk766/technologies_white_paper09186a00800a3e2f.shtml
- http://www.unc.edu/~gogan/qos/