

## Campus Bandwidth Management: Approaches and Tradeoffs

*This is a work in progress. Oct 31, 2003*

Approach	Advantages	Disadvantages	Examples
Do Nothing	<ul style="list-style-type: none"> <li>• Simple</li> </ul>	<ul style="list-style-type: none"> <li>• Unfair</li> <li>• Expensive</li> <li>• Mis-match between usage and cost recovery, especially severe if university is charged per-bit, but performs cost recovery by charging flat fees</li> <li>• Mission of university may be impeded by inappropriate use</li> </ul>	<i>Many</i>
Per-IP Quotas (Rate-Based)	<ul style="list-style-type: none"> <li>• Arguably "fair"</li> <li>• Can tune quotas so that conforming traffic rarely experiences congestion</li> <li>• No need for application-level classification</li> <li>• End-system portability is supported (since all ResHall IP addresses are policed identically)</li> </ul>	<ul style="list-style-type: none"> <li>• IP addresses become an artificially rare commodity (consider impact on IPv6)</li> <li>• Additional router complexity</li> <li>• May impede deployment of meritorious high-bandwidth applications (especially if limits apply to Internet2 traffic)</li> <li>• Inability to burst once in a while</li> </ul>	<i>U. Penn</i> An overall rate limit is applied to outbound ResHall traffic. Additionally, rate-limiters (one per IP address) are installed on the edge router and applied only to outbound traffic. <a href="#">[talk]</a> <a href="#">[updated talk]</a>

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Per-IP Quotas (Volume-Based)	<ul style="list-style-type: none"> <li>• Top talkers can be isolated by placing them in a penalty box</li> <li>• Negative feedback loop encourages users to modify their own behavior</li> <li>• No need for application-level classification</li> <li>• Ability to burst once in a while</li> </ul>	<ul style="list-style-type: none"> <li>• IP addresses become an artificially rare commodity (consider impact on IPv6)</li> <li>• May impede deployment of meritorious high-bandwidth applications (especially if limits apply to Internet2 traffic)</li> <li>• Additional router complexity</li> <li>• Additional accounting complexity</li> <li>• Usage and penalty status need to be communicated quickly to average users</li> </ul>	<p><i>North Dakota State University</i> Quotas apply only to ResHall users. Quota is 300 MB per day per user. Users who exceed their quota are placed in a shared pool rate-limited to 256kbps. <a href="#">[talk]</a> <a href="#">[ResNet]</a></p> <p><i>University of Waterloo</i> Residence hall users subjected to per-user quotas of the form "x MB in last y days". In addition the residence hall traffic aggregate is given a guaranteed minimum share of external bandwidth through CB-WFQ. <a href="#">[more info]</a></p> <p><i>Iowa State</i> Residence hall users who exceed a specific level (currently 200 MB), are transferred to a "slower Internet connection". As abuse continues, offending users are shifted to ever more restricted traffic classes. User quotas are reset at the end of each day,</p>

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			<p>except for those in the rate-limited classes, for whom a 24-hour moving average is applied to determine when they are returned to a less restrictive traffic class.  <a href="#">[more info]</a></p> <p><i>Virginia Tech</i>  <a href="#">see below</a></p>
Per-Class Quotas (Rate-Based)	<ul style="list-style-type: none"> <li>• Can balance use among different user communities</li> <li>• Can tune so that conforming or exempt classes rarely experience congestion</li> <li>• Easy to implement (if not discriminating between commodity and Internet2 traffic)</li> <li>• No need for application-level classification</li> </ul>	<ul style="list-style-type: none"> <li>• No fairness within classes</li> <li>• May impede deployment of meritorious high-bandwidth applications (especially if limits apply to Internet2 traffic)</li> </ul>	<p><i>UC Berkeley</i>  Packeteers in front of a campus edge router separately rate-limit commodity traffic to/from residence halls and to/from the rest of campus (ROC) traffic. Two PacketShapers are required because the total bandwidth exceeds the 100 Mbps. Routing has been engineered to keep ResHall and ROC traffic separate.  <a href="#">[talk]</a><sup>1</sup></p> <p><i>Virginia Tech</i>  Complex hybrid approach that primarily employs class-based policing, but also makes use of application-based policing and a penalty box scheme. Off-</p>

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			<p>campus traffic from residence hall subnets is policed to 60 Mbps aggregate and off-campus traffic from the campus news server is policed to 5 Mbps. "Nuisance applications" are policed to 10 Mbps in aggregate (profiles are generated manually). Finally, individual users are placed in one of three classes: Class 0 (unpoliced), Class 1 (policed to 1.5 Mbps), and Class 3 (policed to 250 Kbps). When users exceed a certain threshold (currently 650 MB) in a 24hr period, their class is incremented; if they stay under threshold, their class is decremented. (The CB-WFQ scheme described in the talk below is not currently in use.)</p> <p><a href="#">[talk]</a></p> <p><i>University of Washington</i> Total network bandwidth from the residence halls to off-campus commodity destinations is limited to 100 Mbps. Off-campus access to</p>

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			<p>common server ports (Web, FTP, IRC, etc) in the residence halls is blocked. Inbound peer-to-peer traffic is rate-limited to 20 Mbps; outbound peer-to-peer traffic is limited to 2 Mbps.</p> <p><a href="#">[residence hall computing policy]</a></p> <p><i>UC Santa Cruz</i> <a href="#">see below</a></p>
Per-Class Proportional Sharing	<ul style="list-style-type: none"> <li>Restricted traffic classes can use unused capacity</li> </ul>	<ul style="list-style-type: none"> <li>No fairness within classes</li> <li>May impede deployment of meritorious high-bandwidth applications (especially if limits apply to Internet2 traffic)</li> </ul>	<p><i>University of Waterloo</i> Residence hall traffic is given a guaranteed minimum share of external bandwidth through CB-WFQ. (<a href="#">see above</a>)</p> <p><i>Texas A&amp;M</i> Planning to support four application classes. Per-session admission to classes. Diff-serv edge marking, policing, and stateless core queueing. (Currently using per-application rate-limits.) <a href="#">[talk]</a></p>

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Per-IP Proportional Sharing	<ul style="list-style-type: none"> <li>• Arguably "fair"</li> <li>• No surprises (users get the service they pay for)</li> <li>• <a href="#">[additional praise]</a></li> </ul>	<ul style="list-style-type: none"> <li>• IP addresses become an artificially rare commodity (consider impact on IPv6)</li> <li>• May impede deployment of meritorious high-bandwidth applications (especially if limits apply to Internet2 traffic)</li> <li>• Additional router complexity</li> <li>• Many queues required</li> <li>• Care must be taken not to restrict Internet2 performance</li> </ul>	<p><i>No known deployment examples</i></p>
Usage-based Charges After Threshold	<ul style="list-style-type: none"> <li>• Economically rational (users who get the most value from a scarce resource pay the most for it)</li> <li>• Fair</li> <li>• Negative feedback loop for heavy users</li> <li>• Can be tuned so that most users pay flat monthly rate; similar to pricing of department printers for students, of cell phones, etc.</li> <li>• <a href="#">[additional praise]</a></li> </ul>	<ul style="list-style-type: none"> <li>• Additional accounting and billing complexity</li> <li>• Need system to collect usage stats (<i>e.g.</i> NetFlow)</li> </ul>	<p><i>Cornell</i>  Planning to charge each department a monthly fee that includes a WAN usage component. Rate structure to include a mix of port fees, infrastructure tax, and usage fees. Per-megabit usage fees will only kick in for use above a certain threshold (adjusted so that 80% of IP addresses will avoid usage fees). Monthly bills to the departments will include enough detail to support recursive usage-based charges to individual users or</p>

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			<p>research groups. NetFlow-based billing system using Apogee software and home-brewed scripts.  <a href="#">[white paper]</a> <a href="#">[web site]</a></p> <p><i>University of Kansas</i>  Applying artificially low usage based charge to ResHall users. Only heavy users will feel the usage based fees; ordinary users will be charged a flat rate.</p>
Per-Application Quotas (Rate-Based)	<ul style="list-style-type: none"> <li>• Majority of problems often caused by small number of applications</li> <li>• Tool to reduce illegal use of network (<i>e.g.</i> illegal distribution of copyrighted materials)</li> <li>• "Magic bullet" middlebox</li> <li>• Automatic maintenance through "bad apps du jour" subscriptions</li> <li>• <a href="#">[additional praise]</a></li> </ul>	<ul style="list-style-type: none"> <li>• Must pass judgment on which applications are "good" and which are "bad"</li> <li>• Performance impact (QoS appliances are designed to handle a scarce resource and therefore generally lag routers in their ability to handle high speeds or maintain very low loss rates for "good" traffic)</li> <li>• Loss of transparency (<i>e.g.</i> rewriting of TCP window size)</li> <li>• Complex and dynamic configurations complicate performance debugging</li> </ul>	<p><i>UC Santa Cruz</i>  Allot NetEnforcer deployed between ResNet and commodity/Internet2 access link. Traffic is classified into four priority levels: High (web, ssh), Medium (everything except peer-to-peer), Low (peer-to-peer), Blocked (worms).  <a href="#">[talk]</a><sup>2</sup></p> <p><i>Virginia Tech</i>  <a href="#">see above</a></p> <p><i>University of Washington</i>  <a href="#">see above</a></p>

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		<ul style="list-style-type: none"> <li>• Application profiling creates a cat and mouse game that the mouse will win (e.g. http, https, proxies, random port numbers, ssh, etc.)</li> <li>• <a href="#">[additional criticism]</a></li> </ul>	
Outsource Residential Networking			<i>University of New Mexico</i>
Block Servers (with NAT or firewall)	<ul style="list-style-type: none"> <li>• Can apply only in "bad neighborhoods" (e.g. residence halls)</li> </ul>	<ul style="list-style-type: none"> <li>• Destroying end-to-end transparency can restrict deployment of numerous advanced applications (e.g. VoIP, research-oriented peer-to-peer)</li> <li>• Potentially sever performance impacts</li> <li>• Motivated users will learn to punch through</li> </ul>	<i>We know you are out there!</i>

## Footnotes

1. Talk addenda (10/25/2002): ResHall rate limit is 60 Mbps in each direction and ROC rate limit is 100 Mbps in each direction; SETI@Home has purchased its own ISP service and is no longer in Berkeley's IP address space
2. Talk addendum (10/25/2002): UCSC has acquired a faster Allot box with more memory; they are still experiencing some problems with interactive performance.