

# Bridging the Bandwidth Gap: Measures to Maintain Bandwidth Availability

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## ABSTRACT

With ever-increasing bandwidth requirements due to bandwidth-intensive applications such as Napster, Gnutella, Audiogalaxy, various Internet games and so forth, we were faced with determining how to bridge the gap between the amount of bandwidth we provided to our clients and the amount our clients consumed in meeting their individual needs and desires.

This paper will provide details on the issues we confronted in using a bandwidth-shaping tool and in deciding to increase our total amount of bandwidth. This paper will also discuss the factors we dealt with in developing an overarching policy for handling network usage.

## KEYWORDS

Bandwidth, bandwidth-shaping, DS-3, IP address, Packeteer, PacketShaper®, policies, priorities, Resnet, T-1, web caching.

## 1. INTRODUCTION

As with most colleges and universities, we have been faced with determining how to provide sufficient bandwidth to meet both the academic and administrative needs of faculty and staff, mainly during daytime hours, and the needs and desires, academic and otherwise, of the students in the residence halls, mainly during nighttime hours. Since Oberlin College is a private, liberal arts institution that greatly values a free and open educational environment, we sought to resolve bandwidth issues in the most positive manner. That is to say, we decided not to block access to certain applications, but merely control the amount of bandwidth being used to ensure maximum benefit and availability to all.

We've combined the procurement of additional bandwidth capability with policies and guidelines for network usage, along with the use of various network monitoring and control devices in an attempt to develop the bridge between what is available and what is desired for bandwidth.

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## 2. BACKGROUND

For some time, we had been functioning sufficiently with two T-1s for Internet access. (A T-1 is a data communications link that provides a transfer rate of 1.544 Mbps.) During the 1999-2000 academic year, we noticed rising requirements for bandwidth and, accordingly, ordered an additional T-1, bring our total bandwidth available to approximately 4.5 Mbps. The third T-1 became operational in May 2000. Since the summer months are times of decreased network activity (we have no summer classes), it wasn't until the start of the 2000-2001 academic year that we noticed a further extraordinary rise in bandwidth usage.

Figure 1 shows a graph from our Multi-Router Traffic Grapher (MRTG) data. (The MRTG is a tool to monitor the traffic load on network links. MRTG generates HTML pages containing images that provide a visual representation of this traffic. [1]) Figure 1 (left side depicts most recent month) shows the decreased activity during the summer months (June-August) after our procurement of the additional T-1 in mid-May 2000, followed by a rapid rise in bandwidth usage at the start of the Fall semester in September 2000. In November, we realized an almost maximum use of bandwidth (close to the total 4.5 Mbps). In Figure 1, the solid block represents inbound traffic; the solid line indicates outbound traffic. We attributed the rise, especially in November, with the increased number of computers acting as servers (mainly sharing music or mp3 files).

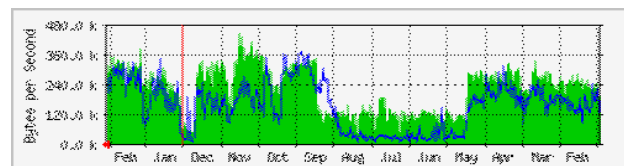


Figure 1. MRTG data

One of our initial strategies to alleviate insufficient bandwidth was to move the Residential Network, Resnet, to its own T-1 in order to keep its traffic from impacting the entire network. This allowed for greater access throughout the rest of the campus network, but proved to be greatly insufficient for Resnet users.

At this time, we urged clients to be cognizant of the issues with bandwidth availability and asked that they be diligent and proactive in helping to control bandwidth usage. We requested they:

- turn off servers in residence halls when not in use,
- close web sites that continuously updated when not in use (such as weather.com and radio stations),
- close Internet mail clients, such as yahoo and hotmail, when not in use.

Our bandwidth issues continued. Therefore, in the beginning of the 2000-01 academic year, we quickly began to discuss acquiring additional bandwidth capability. We decided upon discontinuing the three T-1s and acquiring a fractional DS-3 (Digital Signal Level 3), which equated to approximately 12 Mbps of data transmission rate. (Procurement of a DS-3 allows us the room for future expansion, up to the full DS-3, or approximately 45 Mbps. Additional cost, as well as bandwidth requirements, will be strong factors in determining future expansion.) The installation of the DS-3 took longer than anticipated, due mainly to cabling issues. This forced us to focus for a time on other measures to enhance bandwidth availability.

## 2.1 Web Caching

When we began to realize the need for bandwidth exceeded our capabilities, we also looked at the use of web caching devices as a means to alleviate problems. Web caching reduces traffic by storing frequently-used web pages locally. Since the page is stored locally at the user's site, the next user desiring access receives the cached page and thus does not have to use the bandwidth required to reach the actual server for that web page. After testing this capability with three different products, we concluded that, while they did significantly decrease the amount of traffic, other problems were generated that could not be easily resolved. Thus, after several months, we postponed further research in this arena.

## 2.2 Bandwidth-Shaping

In conjunction with our web caching research, we also began to look into the use of bandwidth-shaping tools. At this time, our clients, especially students, were clamoring for more bandwidth availability. As the students began using more bandwidth-intensive applications, such as music-sharing applications, we saw continual limits to our bandwidth availability. Daytime academic and administrative functions began to be negatively impacted. Many clients reported extreme slowness or a complete inability to access web sites throughout the day.

After initial investigations, we quickly saw the opportunities presented by use of a bandwidth-shaper and, after thorough investigation, decided to proceed with the procurement of one such tool, Packeteer, Inc.'s PacketShaper®. PacketShaper® is a bandwidth-management tool that "...discovers and classifies applications, analyzes their performance, enforces policy-based bandwidth allocation, and generates reports on the results." [2].

Thus, while still progressing towards acquiring additional bandwidth, we pursued the parallel path of exploring the capabilities of a bandwidth-shaping tool.

## 3. PACKETSHAPER®

We experimented a great deal with the Packeteer product in order to reach the best solution for Oberlin College. This product automatically detects many different types of traffic, such as http, ftp, smtp, Napster, Real Audio, Doom, Quake, AppleTalk and LPR. Traffic can be classified in many different ways, including by application, port number, and IP or MAC address.

We set up PacketShaper® in the following manner. First, we prioritized traffic based on time of day. Prior to getting the DS-3 in place, we used the following plan: From 7 A.M. to 5 P.M., we gave priority to the traffic to and from campus academic and administrative IP addresses, with Resnet receiving a maximum of 1.5 Mbps during this time; from 5 P.M. to 7 A.M., we gave priority to Resnet traffic, up to a maximum of 3 Mbps.

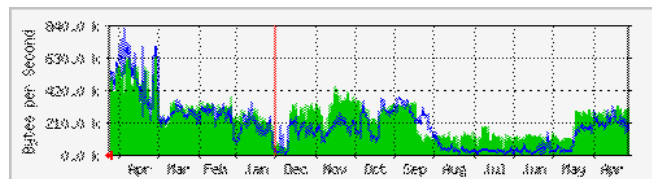
Next, we looked at how to prioritize the types of traffic. We decided to set priorities from 0 to 7, with 1 being the lowest priority we would use, meaning traffic of that type would have access to bandwidth when no other traffic type desired it. The scheme we developed is depicted in Table 1.

**Table 1. Prioritization Scheme**

PRIORITY	TYPE OF TRAFFIC
0	Unused (would receive no bandwidth)
1	Unknown ports; excessive bandwidth users; various streaming media (i.e., Napster, Gnutella) and Internet games (i.e., Quake, Doom)
2	Various streaming media (i.e., Real Audio, QuickTime); miscellaneous other types
3	Resnet ftp and http
4	Campus ftp
5	Campus http
6	SmtP
7	Reserved (only used by network administrator as required)

As shown in the table, applications that could not be automatically detected by the Packeteer product, and thus classified as unknown, were given a low priority. Additionally, clients found to be consuming an inordinate amount of bandwidth were also placed, by IP address and offending application type or port number, in the lowest priority. We found these clients to be mainly students on Resnet whose computers were functioning as servers. Since all residence halls were configured with a 10 Mbps shared capability, users whose computers acquired large amounts of available bandwidth could monopolize the entire bandwidth available to a residence hall unless we intervened. PacketShaper® allowed us to graphically view these problem areas in real-time and limit the total amount of bandwidth these clients could acquire at any given time by changing their priority.

With the use of PacketShaper®, we began to notice significant benefits almost immediately. Figure 2 shows MRTG data through April 2001 (left side of graph). In February 2001, we had much of the key constructs of the Packeteer product in place. Notice that the solid block and line are almost equivalent at this point in time, showing that we were able to better control incoming and outgoing traffic. In fact, we were able to identify and reduce the number of computers accounting for excessive bandwidth use, mainly music-sharing servers, which thereby decreased the requests for service from incoming traffic (solid block). We found that many clients who had used music-sharing applications were unaware that their computers were then acting as servers.



**Figure 2. MRTG data showing PacketShaper® in place**

Using PacketShaper®, along with our other network monitoring and control tools, such as our Smart Switch Router and our Sniffer product [3], we have been able to identify problem areas as they arise and take action quickly to restore available bandwidth to viable levels. The only clients negatively impacted are those whose

IP addresses end up with lowered prioritization. These users are contacted by our Residential Computer Coordinators (student employees who resolve computer problems in the residence halls), who assist the user in determining the reason for acquiring the unusually large amount of bandwidth, if unknown, and ensure that the issue gets resolved. Only then is a user removed from the lowest prioritization level.

We also discovered that, with PacketShaper®, we can watch for “Top Talkers”. These are depicted as the IP addresses and DNS host names for those clients whose computers acquire the highest amount of bandwidth over a given time. The data is presented via a web page. Table 2 provides a sample.

**Table 2. Top Talkers**

(Note: IPs shown are not the actual addresses)

No.	DNS Name	IP Address	Usage	Classify
1	DHCPP1070	132.162.000.07	21%	▲
2	DHCPP7971	132.162.000.10	9%	▲
3	DHCPP6728	132.162.000.05	7%	▲
4	DHCPP1059	132.162.000.03	7%	▲
5	DHCPP8289	132.162.000.01	3%	▲
6	DHCPP6993	132.162.000.08	2%	▲
7	DHCPP5357	132.162.000.09	2%	▲
8	DHCPP8866	132.162.000.04	2%	▲
9	DHCPP7782	132.162.000.06	1%	▲
10	DHCPP4545	132.162.000.02	1%	▲

The last column in the table allows us, by clicking on ▲, to see what type of traffic is causing the problem from that particular IP address. Thus, while Top Talker number 1 is using 21% of the total bandwidth, this may just be Napster traffic to/from this computer, not http or ftp. Since we expressly do not want to hinder any client’s ability to perform academic work, we therefore would use PacketShaper® in this example to set a lower priority for Napster traffic from this user, but not other types of traffic.

#### 4. CLIENT ISSUES

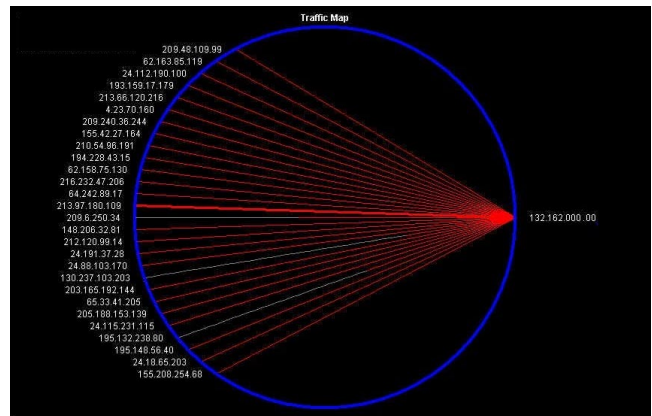
Several clients, particularly Resnet users, began to determine “work-arounds” for what they perceived to be the problem – our attempt to restrict their bandwidth usage. One client acquired IP addresses of non-Resnet computer systems and modified the IP address of his computers to use these instead. Student IP addresses normally fall within a specific range, designated by registration via DHCP (Dynamic Host Configuration Protocol). With non-Resnet IP addresses, some students determined they could work around the daytime restriction for Resnet traffic.

These IP addresses then usually showed up in the PacketShaper® reports as being excessive bandwidth users. An investigation into their use allowed us to pinpoint the actual client system and resolve the problem.

The other main issue with clients concerned the ability of any one Resnet user to acquire maximum bandwidth and retain control of that bandwidth, effectively blocking access by other users within that residence hall. Even after we procured the fractional DS-3, one Resnet client was found to be using 8 Mbps, out of a total of 9 Mbps, for several hours during one evening. This we found to be a recurring situation, which we resolved by determining the IP

address of said user’s computer and placing it at a lower prioritization level.

Figure 3 depicts an example of a Resnet client who had acquired an excessive amount of bandwidth. This client effectively had blocked other users in his residence hall from gaining access to the Internet. His computer was receiving a great deal of incoming traffic, mainly caused by functioning as a server for music files. This graphic was viewed using our Sniffer product. Pinpointing the IP address with Sniffer allowed us to then put the offending IP address in a lower priority using our PacketShaper®.

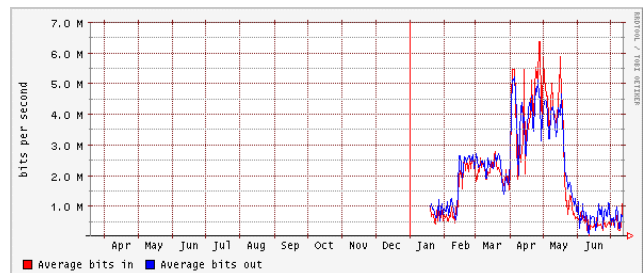


**Figure 3. Sniffer graphic showing excessive inbound traffic (Note: IP of Resnet client is not the actual address)**

#### 5. FRACTIONAL DS-3

At the same time that we investigated the possibilities with the Packeteer bandwidth-shaping tool, we proceeded with our plans to procure a fractional DS-3. As noted above, even with PacketShaper®, we experienced some users being able to establish control over large amounts of bandwidth until we intervened.

By April 2001, we had the fractional DS-3, providing 12 Mbps capability, in place. Figure 4 shows the immediate rise in bandwidth usage given this increased capability, but maximum usage still remained well below the total available capacity. The graph in Figure 4 uses Cricket, which is a program that was “...developed to help network managers visualize and understand the traffic on their networks” and which displays the data graphically via a web interface. [4]



**Figure 4. Cricket graph depicting DS-3 capacity**

Thus, with both the bandwidth-shaping tool and the fractional DS-3 in place, our ability to provide continuous sufficient bandwidth to the majority of users was realized.

At this point, it should be noted that the ability to provide sufficient bandwidth necessitates continuous monitoring and control. The combination of bandwidth capability and bandwidth-shaping has proven to be vital for our campus. Also, in order to maintain the best possible capability, we have addressed corresponding issues with policy statements and guidelines for network usage.

## 6. POLICIES

In conjunction with use of our bandwidth-shaper and procurement of additional capacity, we reviewed our acceptable use policies. As stated earlier, Oberlin College greatly values a free and open academic environment. Thus, we concluded that we did not want to rewrite our existing broad policy to include a lot of statements of what was not allowed.

We did start by thinking that perhaps we should disallow all servers in residence halls, or disallow servers that the owner did not have the express written permission of the Center for Information Technology (CIT). This led us into a discussion of how we would administer this process. We concluded that, in most cases, it was not necessary to disallow servers. In fact, we decided to allow any server (with the exception of DNS, DHCP and BOOTP servers) unless it became a problem. Instead, we would follow the constructs established within our Packeteer product to manage our bandwidth and limit the ability of any one computer (server or not) to gain an excessive amount of the total available bandwidth.

We did include a few new or modified statements in our updated "Policy for the Acceptable Use of Information Technology Resources" [5] in order to provide maximum benefit to the majority of clients. These specifically include the following:

- Users should not interfere with, interrupt, or obstruct the ability of others to use the network or other CIT resources.
- Only computers that have been registered through DHCP may be connected to Resnet, unless otherwise authorized and established by CIT. Users must not attempt to circumvent this process.
- Excessive or improper use of network resources that inhibits or interferes with use by others is prohibited and will be cause for action by CIT, which may include restricting, limiting, or disabling network access.
- Users who connect computers to the network that act as servers have the additional responsibility to respond to any use of their server that is found to be in violation of this Policy.
- In no case shall the following types of servers be connected to the network: DNS, DHCP, BOOTP, or any other server that manages network addresses.

Our policies, therefore, are intended to allow users to perform the functions they desire while ensuring that other users have the ability to use all Information Technology resources, notably access to the Internet.

## 7. CURRENT ENVIRONMENT

We have had the fractional DS-3 in place since April 2001, giving us a total of 12 Mbps bandwidth capacity. While total usage has gone up, we have not yet reached the limits.

Our configuration of PacketShaper® has remained basically as it was prior to acquisition of the DS-3. Thus, Table 1, above, remains an accurate representation of our prioritization scheme.

Additionally, the prioritization based on time of day has remained the same, except the quantities, due to the additional bandwidth capability, have changed. We now support the following: From 7 A.M. to 5 P.M., campus academic and administrative IP addresses receive priority access, with Resnet receiving a maximum of 6Mbps; from 5 P.M. to 7 A.M., Resnet IP addresses receive priority access, up to a maximum of 9 Mbps.

The Packeteer product is emplaced within our network configuration as depicted in Figure 4 below. In this way, it can best be used to monitor and control traffic between the router to the Internet and our campus Smart Switch Router.

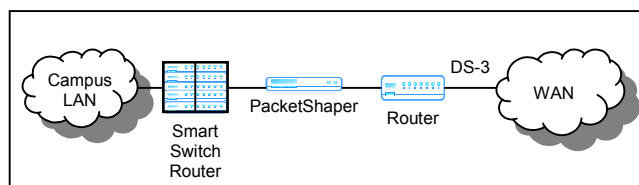


Figure 5. Campus network environment

Additionally, during the summer of 2001, all buildings that were not previously so configured, including residence halls, were upgraded from a shared 10 Mbps to a switched 10/100 Mbps capability. Thus, instead of sharing 10 Mbps per Ethernet segment, each port has up to 100 Mbps dedicated capability. Once the 2001-2002 academic year begins, we expect this capability will greatly reduce the occurrences of one client acquiring all the bandwidth available for his/her residence hall, effectively locking out all other users in that location.

We have also now removed the temptation for Resnet users to change their DHCP-registered IP addresses to non-Resnet IP addresses in an attempt to circumvent our PacketShaper® prioritization schemes. We have been able to use the capabilities of our 802.1Q switch control program to prevent any non-Resnet IP address from accessing the campus network from within Resnet. Further, we use the Smart Switch Router to prevent any non-registered Resnet user from accessing the Internet.

## 8. CONCLUSION

We remain committed to bridging any gap between the available bandwidth and the bandwidth required or desired by our clients. As we are confronted with more and more applications of the streaming-media type, including audio and video, we expect to see demand for bandwidth increase and our limits once again pushed to the maximum. We have been very pleased with, and encouraged by, the capabilities provided by our bandwidth-shaping tool, PacketShaper®. Use of this product helped put control back in the situation so that we in CIT no longer feel helpless where bandwidth usage is concerned.

PacketShaper®, combined with our more succinct policies which specifically focus on ensuring bandwidth availability for all, should help us as we try to maintain that bandwidth bridge well into the future.

## 9. REFERENCES

- [1] Multi Router Traffic Grapher.  
<http://people.ee.ethz.ch/~oetiker/webtools/mrtg>
- [2] Packeteer, Inc. "Four Steps to Application Performance Across the Network; A technical Product Overview for PacketShaper®". Packeteer, Inc., Cupertino, CA, 2001  
<http://www.packeteer.com/products/packetshaper/>
- [3] Sniffer Technologies <http://www.sniffer.com>
- [4] Cricket home page <http://cricket.sourceforge.net>
- [5] Center for Information Technology, Oberlin College, "Policy for the Acceptable Use of Information Technology Resources". <http://www.oberlin.edu/cit/policies>