MSC ISP Bandwidth

Evaluation and Proposal to Increase Morrisville State College's Internet Connection Speed

Prepared for
Dr. Raymond W. Cross – President
Jean Boland – Vice President for Administrative Services and Information Technology
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December 4th, 2010

Letter of Transmittal

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Dr. Raymond Cross, President, Morrisville State College
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Dear Dr. Cross:

This is my comprehensive report concerning the state of Morrisville State College's Internet connection bandwidth. While researching this report, I confirmed my belief that Morrisville is in need of a faster Internet connection. I believe that my report will serve as a solid reference when considering an upgrade to the amount of bandwidth available to campus from our Internet service provider.

I plan to graduate from Morrisville State College in May of 2012 with a Bachelor's degree in Network Administration. My curriculum covers the topic at hand and allowed me to provide an accurate analysis. In the future, my professional duties will include sizing up situations such as our own bandwidth dilemma and propose solutions.

From experience here as a student, I can tell you that the amount of available bandwidth has affected me directly. CITA majors are often required to download material from the Internet whose files are of considerable size. Because of the nature of CITA courses, a CITA student may download a few DVD images over the course of a single day. These images are usually around four gigabytes in size and normally take a few hours to download. When little bandwidth is available, *the time required can increase to days***.** For this reason, it is imperative that an appropriate level of bandwidth be available to campus inhabitants, specifically our resident students who rely on our Internet connection not only for research, but for entertainment as well.

I must applaud Matt Barber, MSC network administrator for doing a wonderful job in ensuring the best possible service to faculty, staff and students. While researching this report, it was obvious that Mr. Barber is quite aware of the situation at hand and seems to have a solid grasp on it. As the usage of the Internet and technology in our daily lives increases, his role will prove even more important to technical operations on campus.

Morrisville prides itself in its claim to having the fastest wireless network in the world. Without a fast WAN uplink, that ultrafast wireless network sometimes seems crippled. Let's ensure that our reputation as being a "*campus at the forefront of a technological revolution*" holds strong.

Sincerely,
Brian Dwyer

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Informative Abstract

This is an evaluation of Morrisville's current-standing wide area network (WAN) uplink. The WAN uplink serves to connect the Morrisville campus to the rest of the Internet. This identifies current issues with available bandwidth on this link. It also identifies how future Internet and technology trends may affect the suitability of our current level of service.

Our current WAN uplink has the following problems:

- Limited bandwidth availability and network congestion during hours of peak usage
- Limited ability to support and deliver media-rich content during hours of peak usage
- Long download times for large files during hours of peak usage

In the future, Morrisville's WAN uplink may encounter the following issues:

- Further increased levels of network congestion
- Inability to support widespread use of new Internet technologies such as streaming media applications
- Limited user satisfaction and possibly end-user frustration
- Inability to support future Internet usage trends

The above stated problems are and/or will be the result of one thing:

- A 200mbps WAN uplink is not suitable for the number of users on campus

The situation can/will be amplified by:

- Increased number of students/faculty on campus
- Increased usage of Internet technologies and services
- Widespread adoption of bandwidth consuming technologies on campus
- Rapid proliferation of ubiquitous computing

The bandwidth situation can be remediated by:

- Upgrading to a higher bandwidth WAN uplink
- Purchasing burstable bandwidth from our current ISP
- Filtering traffic and creating limitations on a per-user basis

Suggested Solutions

Based on my research, I feel only two solutions are viable options.

1. I believe that upgrading to a higher bandwidth WAN uplink is the best solution. This would provide a real fix for the issues experienced. This would provide user satisfaction, future sustainability and most importantly it would eliminate network congestion. Although more bandwidth usually costs more money, my research has found that this is not always the case. A re-evaluation of the current contract with our Internet service provider may reveal that we are paying more for the bandwidth we have now than we would be for an increased amount of bandwidth. Bandwidth pricing decreases as the

deliverable capacity increases over time. For this reason, long-term contracts are not in the best interest of the campus. Short, flexible contracts should be signed that allow for service to be changed without breaking the agreement.

2. If purchasing additional fixed bandwidth is out of the question, our Internet service provider should be contacted to determine the availability of burstable bandwidth. Burstable bandwidth would provide extra bandwidth only during periods of peak usage when it is needed most. Results show that our network can adequately handle traffic for most of the day, therefore at the present time burstable bandwidth would prove an acceptable temporary solution. I must stress that this solution is only a temporary fix that will not prevent future problems. As we further incorporate the use of technology into our daily lives, the amount of traffic traversing our WAN uplink will increase proportionately. During future hours of peak usage, available bandwidth will become increasingly scarce and available bandwidth throughout the day will decrease. This situation can be remediated only by the purchase of more bandwidth.

Introduction

The purpose of this report is to determine the benefits of upgrading Morrisville's Internet connection. It will provide an estimated cost of upgrade as well as an overall bandwidth availability comparison of our current WAN implementation versus the proposed solution. This report also explains how bandwidth plays a role in network performance and how it can both positively and negatively affect the end-user experience. This report is meant to bring the issue of bandwidth availability to light and describe how it affects not only students, but faculty as well. It also offers possible solutions to these issues as well as an analysis of Morrisville's current WAN connection's suitability for future usage.

I conducted this report for the Administrative faculty located in the Whipple Administration building. It was conducted specifically for Dr. Raymond W. Cross, MSC President and Jean Boland, MSC Vice President for Administrative Services and Information Technology. The price of commercial-grade Internet service is very high therefore the purchasing decision must be made by high ranking college officials. Jean Boland's technical expertise allows for interpretation of the advanced information in this report while the included descriptions and definitions serve to educate Dr. Cross. It is imperative that Dr. Cross is aware of this situation because future technologies will rely upon a fast Internet connection.

The campus Internet connection serves to connect Morrisville's Local Area Network to the World Wide Web. This link is otherwise referred to as a WAN uplink, or Wide Area Network uplink. This link can become saturated during hours of peak usage causing connection errors, pages failing to load and overall poor performance. This is due to lack of available bandwidth, with bandwidth being the measurement of the network link's capacity. As a network administration student, I have a general understanding of how to measure bandwidth needs on a per-user basis as well as how to apply this theory to a logical campus network such as Morrisville's. Bandwidth is distributed equally amongst network users. Bandwidth can be compared to a pie; in order to provide many people with a similarly sized slice, a large pie is needed. As more consumers of this pie request a slice, the slices become smaller. Bandwidth works the same way. Morrisville possesses a 200Mbps connection. If 200 users are downloading from the Internet, they each receive 1Mbps because 200 divided by 200 equals 1.

Bandwidth is obtained from an Internet Service Provider. Morrisville currently obtains its Internet service through Cogent. Cogent has a high-speed worldwide network which it sells access to. When we connect to the Internet, we are connecting through Cogent's network. Bandwidth is sold on a per-unit basis and is usually measured in megabits per second. Different types of connections offer different levels of bandwidth. Changing the connection type usually involves the purchasing of new hardware which can handle the extra bandwidth. Our current WAN equipment allows for up to 1000Mbps of throughput before requiring replacement.

Ubiquitous computing is the concept that technology will be embedded in almost every aspect of our daily lives. Computing becomes almost invisible to the end user and they may not even realize they are doing it. For example, modern cellular phone technology allows us to perform

tasks which previously were only possible with a computer. In our pocket, we now have access to the Internet, e-mail and other services which previously required a standalone laptop or desktop computer. Their functionality has gone above and beyond its initial, simple purpose. Ubiquitous computing entails that other technologies will take a similar path and this can already be seen today. We now have alarm clocks and refrigerators which can access local weather and other information via the Internet. These technologies all use the Internet and in doing so consume bandwidth. As these technologies become more commonplace in our society, we will ultimately move closer to a concept of ubiquitous computing.

To research the current condition of Morrisville's network, I contacted Matt Barber who is Morrisville's Network Administrator. Matt oversees the day to day operation of our network and maintains its operational functionality. It is important to distinguish the role of Mr. Barber from his peers. His primary concern is Morrisville's actual network, not the services it delivers. Services such as Outlook e-mail, Web for Students and Blackboard are maintained by Kyle Campanaro, Morrisville's System Administrator. It is important to distinguish between the two because this document focuses on the schools network which is only a delivery mechanism for these services. The solutions proposed in this document would not have any effect on said intranet services as this network traffic usually does not require traversal of the WAN uplink.

To gather historical information about Morrisville's network, I contacted CITA professor Patrick Cronn. In addition to teaching here at Morrisville, Professor Cronn worked in Network Operations and helped deploy Morrisville's current wireless network in 2007. He was also a student here from 1999 to 2001. Professor Cronn has much experience with Morrisville's network infrastructure including special knowledge of how it was designed and constructed. He previously provided support for all desktop machines on campus. He also provided support to all faculty members with any technological problems. In addition to providing support in these areas, he helped establish many network services including printing, antivirus, Microsoft Active Directory, group policy, PC imaging, software rollouts, and network upgrades. Professor Cronn possesses a robust knowledgebase of Morrisville's network due to his longstanding presence in the campus technology community.

To gather information about Internet Service Provider availability and pricing, I contacted a few agencies who specialize in this field, Global Communications Group and T1Agent.com. These agencies were able to provide information about what services are available in the vicinity of Morrisville's location. In addition, they were able to provide information concerning Internet service provider bandwidth pricing. This information was used to determine what services are physically available to Morrisville as well as an estimate of what they cost.

By contacting Matt Barber, I solidified my understanding of our current WAN connection. In addition, Matt Barber provided specifications for a few pieces of equipment which are closely associated with the delivery of Internet service to campus. I also discovered how our campus core networks communicate with satellite buildings not located on the premises of the main campus. This allowed me to determine which available services are compatible with our current network infrastructure. This is important because some solutions would require the

purchase of additional equipment for successful implementation. The cost of these purchases may offset the benefit of the proposed solutions therefore equipment compatibility is crucial.

This report identifies the major problems with the campus WAN uplink, their causes, consequences and possible solutions. The report concludes with a suggested course of action to remediate said issues.

Findings and Conclusions

My initial findings were not surprising; Morrisville possesses a robust network infrastructure. According to Matt Barber, all equipment in our network is rated for gigabit speeds. Gigabit throughput ratings allow traffic to traverse our side of the network at an extremely high rate of speed. Morrisville's distribution network is composed mainly of multi-mode fiber optic cabling which can be upgraded to beyond gigabit speeds relatively easily. The cabling infrastructure serves to carry light pulses from one end to the other. To upgrade speeds, only the transmitter and receiver need to be replaced; the physical cable plant does not need replacement. Transmission mediums other than fiber require new cable plant infrastructure to be installed which is extremely costly.

Another aspect which must be looked at is how Morrisville interacts with buildings which are logically attached to the campus core network. For example, buildings which are not on main campus property are still attached to the campus core network. The network engineer made a smart decision; they attached these buildings to campus by stringing single-mode fiber optic cable from the remote location and terminating it in at the campus core switch in the basement of Charleton hall. This allows ingress and egress traffic from remote facilities to utilize our standing network infrastructure. This concerns the bandwidth situation because traffic to and from buildings outside Morrisville's main perimeter does not have to traverse the WAN uplink. If this remote cabling infrastructure was not in place, traffic for services such as e-mail and Blackboard would traverse the WAN uplink, further saturating the campus' available bandwidth. This aspect of network design must have been accounted for by the Network Engineer when designing Morrisville's distribution network.

While interviewing Professor Cronn, I discovered that an initiative exists on campus to attempt delivery of television over our current network infrastructure to our on campus population. This is important to consider because streaming video delivery requires a very high amount of bandwidth. This would also bring the extra load of television delivery to bear on our existing network infrastructure.

Main Problem

One primary issue with the campus WAN connection was identified. The main issue is *limited bandwidth availability causing network congestion during hours of peak usage*. This results in a limited ability to support and deliver media-rich content and long download times for large files during hours of peak usage. Currently, if a user attempts to access streaming services, they may not be able to do so without interruption.

Limited Bandwidth Availability & Network Congestion

During hours of peak usage, a limited amount of bandwidth is available and network congestion is present. As seen in **Figure 1**, a download from a high-speed public FTP server only received 138Kbps of bandwidth. This translates to about 1Mbit of bandwidth available to each user during this time period. Out of the available 200Mbps, here only one was received. This is a common occurrence on campus during the evening. According to the 2010 Global Internet Phenomena Report, the average user spends three hours per day on the Internet, and peak usage hours are from 4P.M. to 1A.M (Sandvine Intelligent Broadband Networks, October, 2010). This trend is apparent on campus and will only worsen as we approach the concept of ubiquitous computing.

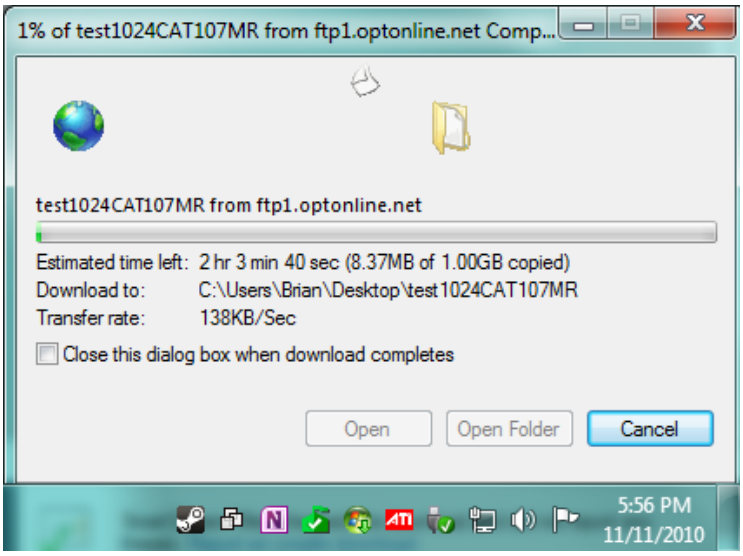

Figure 1 – File transfer during hours of peak usage.

Cause of Limited Bandwidth & Congestion

The issue of limited bandwidth availability and network congestion is directly related to the ratio of users to available bandwidth. To investigate this, we must first define how much bandwidth is required to provide an acceptable usage experience to a single user. For the purposes of this report, we will assume that the end-user is attempting to view high definition content on a service such as Netflix. According to Netflix, the minimum required bandwidth to view high definition content is 2600kbps (Netflix, 2008). This equates to roughly 3.6Mbps, with megabit per second (Mbps) being the common unit of bandwidth used in this report. This means that in order to deliver high definition content, each user requires 3.6Mbps of bandwidth. From this, we can determine that the current connection speed of 200Mbps can only support 50 users simultaneously streaming high-definition content. In all reality, this only holds true when no other users are consuming bandwidth. Also, 20Mbps of bandwidth is reserved for network management so realistically only 180Mbps is available to campus. Assuming Morrisville's average network load is 50%, this means that only 24 users can simultaneously stream high definition content at any given time. On a campus such as our own where almost 1,800 students reside, 24 is an unacceptable number.

The bandwidth consumed by modern mobile web enabled devices such as cellular phones must also be taken into account. Because Morrisville has wireless access available almost everywhere near campus facilities, students and faculty are able to use the Internet wherever they are on campus. This results in a large number of users being logged into the network at all times. For example, the Morrisville wireless network *MSCdevices* is design specifically for

devices such as cellular phones which are compatible with the 802.11 Wi-Fi standards. Cellular phones are usually powered on at all times meaning that if it has a Wi-Fi radio it is connected to the Morrisville wireless network any time it is within range of an *MSCdevices* wireless access point. Mobile device traffic is usually optimized and designed specifically to consume a small amount of bandwidth due to the limited available processing power. Web pages for mobile devices are optimized with minimal graphics and limited multimedia content to be more bandwidth and processor friendly. Individually, mobile devices consume less bandwidth then their laptop counterparts. However, because of the widespread popularity of Wi-Fi enabled mobile devices, their overall bandwidth footprint is rather large and must be accounted for. According to a study conducted by ABI research, among those who have Wi-Fi on their phones, 74 percent use the feature, and 77 percent say they will also seek Wi-Fi connectivity in their next phone. (Wi-Fi Alliance, 2009) **Figure 2** demonstrates that mobile devices are used almost as much as their PC counterparts for activities such as real-time communications and social networking. Overall, mobile devices are used nearly as much as their PC counterparts to access the web.

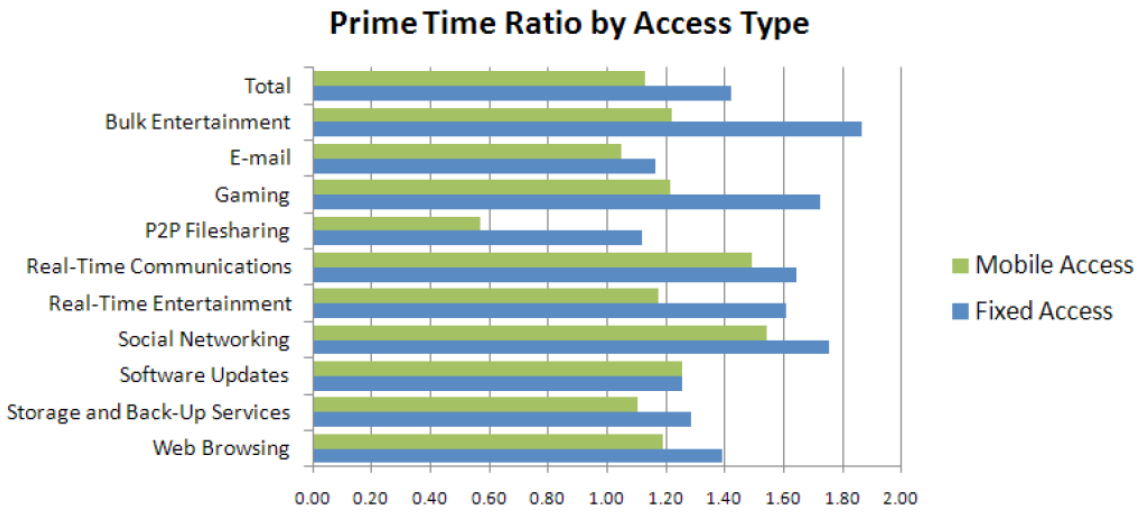

Figure 2 – Prime Time Ratios (Mobile vs. Fixed – Fall 2010)

The modern usage of the Internet has a direct effect on the overall amount of bandwidth consumed on campus. Modern uses such as real-time communications and real-time entertainment consume much more bandwidth than tasks such as web browsing and email. **Figure 2** also demonstrates that on average, Internet users during peak hours use 42 percent more bandwidth than users during off peak hours. This means that Morrisville's network is placed under a higher load per user during peak hours. Currently, Morrisville's network is just barely able to keep up during peak hours. According to Matt Barber, the Morrisville WAN uplink peaks at 180Mbps throughput once a day. Bandwidth to campus is limited to 90 percent of our available 200Mbps. This means that we are reaching peak throughput if the limiter has to kick in, which it does at 180Mbps. If the bandwidth limiter kicks in and more users attempt to utilize the Internet connection, the amount of bandwidth available to each user is reduced proportionately so that the new user gets some bandwidth as well. A good way to understand

this concept is to think of bandwidth as a water pipe. If many faucets are attached to this pipe, it must be large enough to support the extra water which must flow through the pipe. If you have four faucets hooked to one pipe and only turn on one, the pressure will be high. If you turn on the rest of the faucets, the pressure is equalized amongst them and the pressure from each will decrease. We can relate this concept to bandwidth by imagining it as a pipe. High bandwidth Internet applications require high pressure while low bandwidth applications such as web browsing do not require as much. Delivery of these high-bandwidth applications requires a bigger pipe, aka more bandwidth.

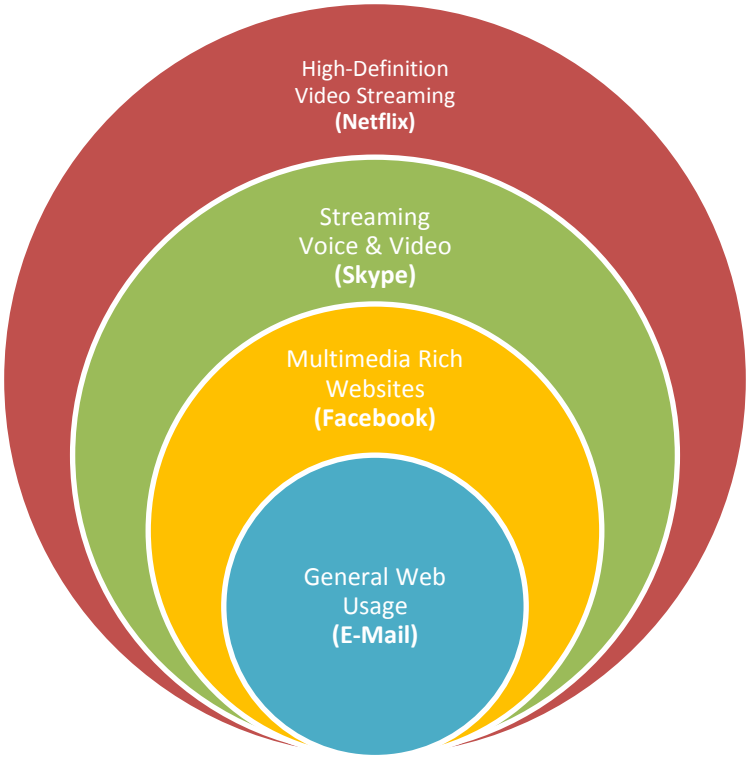

Figure 3 – Cylindrical "Pipe" Representation of Bandwidth Requirements

From **Figure 3**, it can be seen that applications such as Netflix or Skype consume a large amount of bandwidth. These high bandwidth services are pictured as the largest pipes. General web usage such as web browsing and e-mail do not consume nearly as much bandwidth.

Because Morrisville is a college and the majority of our users are young and technologically savvy, the campus population integrates these high bandwidth services into their digital lifestyle. With a resident population of 1725, more than 24 people attempting to stream high-definition content from Netflix simultaneously must be expected. The WAN uplink's current state cannot support this. Internet trends shown in **Figure 4** demonstrate that the majority of Internet bandwidth is consumed by real-time entertainment. This has changed from previous years where the majority of bandwidth was consumed by web browsing followed by peer-to-peer traffic. Matt Barber indicated that this graph provides an accurate description of the bandwidth consumption on campus. It is important to note that the P2P traffic depicted in **Figure 4** does not apply to Morrisville State College because our Network Administrator has put

policies in place that prevent P2P technologies, specifically Torrent traffic. (Barber, 2010) This is because most P2P traffic is illegal file-sharing. Network equipment automatically filters and blocks this type of traffic.

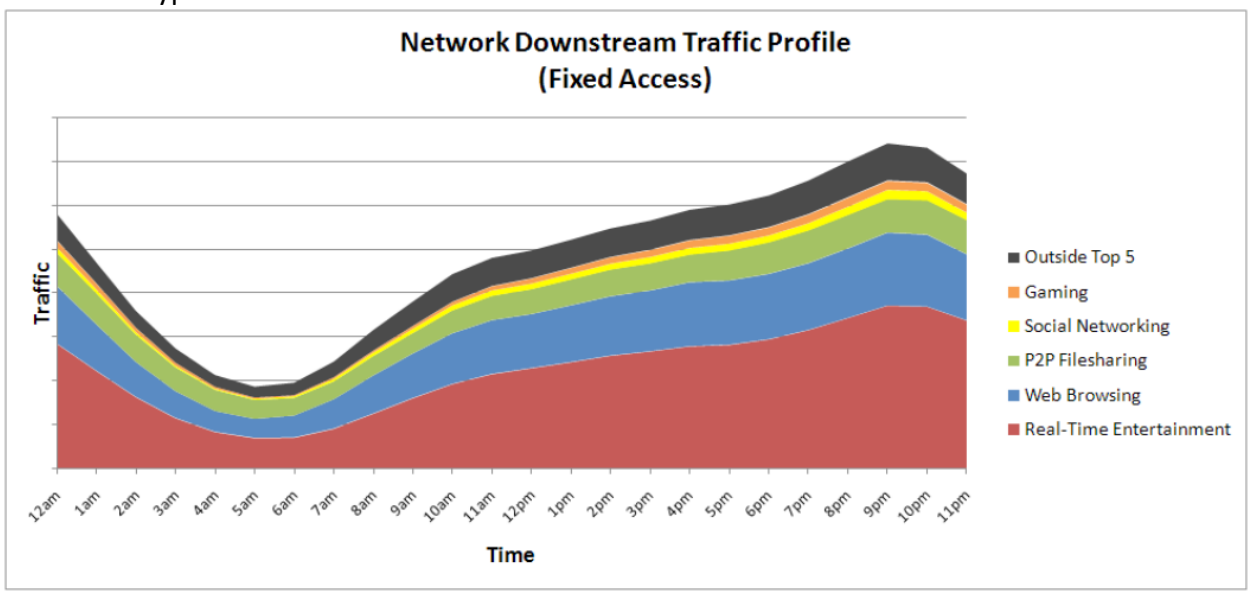

Figure 4 – North American Downstream Traffic Profile Trends - Fall 2010

It must be kept in mind that college students are typically technologically-savvy. We must also weigh in the fact that Morrisville advertises its state of the art 802.11N wireless network. We attract technologically-savvy students who utilize state-of-the-art technology. High-definition content streaming and other real-time entertainment traffic represent a new front of a technological revolution. Delivery of this content consumes a large amount of bandwidth. Currently when students attempt to access these services, the load placed on our WAN uplink causes a high level of saturation to be reached resulting in the amount of bandwidth delivered to each individual student to drop. **At any given time, our current WAN uplink is not able to deliver these services to more than 24 of our 1,725 resident student population simultaneously**. It is important that Morrisville be able to provide these services to a *more* reasonable amount of our resident population.

The secondary issue is not so much a problem, but a trend. Modern technologies such as video streaming and the advent of on-demand high-definition content are delivered via a network connection. Because these technologies increase an individual's bandwidth consumption footprint, collectively these users saturate our available WAN uplink bandwidth. *Our cultures integration of these technologies will only increase in the future so this issue will only worsen if no action is taken.* Companies such as Blockbuster are being put out of business by companies like Netflix who deliver on-demand content. Today, a Netflix subscription includes having DVD's mailed to your residence. Netflix's library of on-demand content is getting larger by the day and the focus of their business model now revolves around streaming content. As these technologies become even more popular, they will place an increasing load on our WAN uplink. It is better to *prepare* for this extra load than to *react* to it.

Recommendations

I feel that Morrisville State College's network represents that of an Internet Service Provider; With 1,725 resident students on campus, our network serves a formidable amount of users. I do not think that anyone could deny the cultural diversity we possess here on campus. Given the large amount of resident students and their undeniable cultural diversity, I think it's safe to say that Morrisville's network represents a miniature Internet. I feel that the resident students are the people who rely upon our WAN uplink to the Internet the most. Given the resemblance of our network to the Internet, I feel that the Internet trend statistics provided in Sandvine's Fall 2010 Internet Phenomena study can serve the basis of my recommendations in this report.

Morrisville Bandwidth Requirements

According to Sandvine's Internet Phenomena study, 40 percent of downstream traffic is consumed by only two percent of subscribers. Given our resemblance to an ISP, we can consider the total amount of subscribers equal to the number of resident students on campus, 1725. Given these two statistics, we can state that 35 students will represent 40 percent of our bandwidth consumption. Now, we will say that these 35 students should have access to a minimum of 5Mbps at all times. This means that these 35 users will represent a 40% portion of the pie of bandwidth. According to **Figure 5**, 90% of traffic is represented by 25% of the population. This means that 90% of the bandwidth on campus is consumed by 432 resident students on campus. It is safe to say then that the median is 216 users which are consuming roughly fifty percent of the bandwidth on campus during peak hours. Peak hours, 4P.M. to 1A.M are times when resident students represent 90% of traffic on the network.

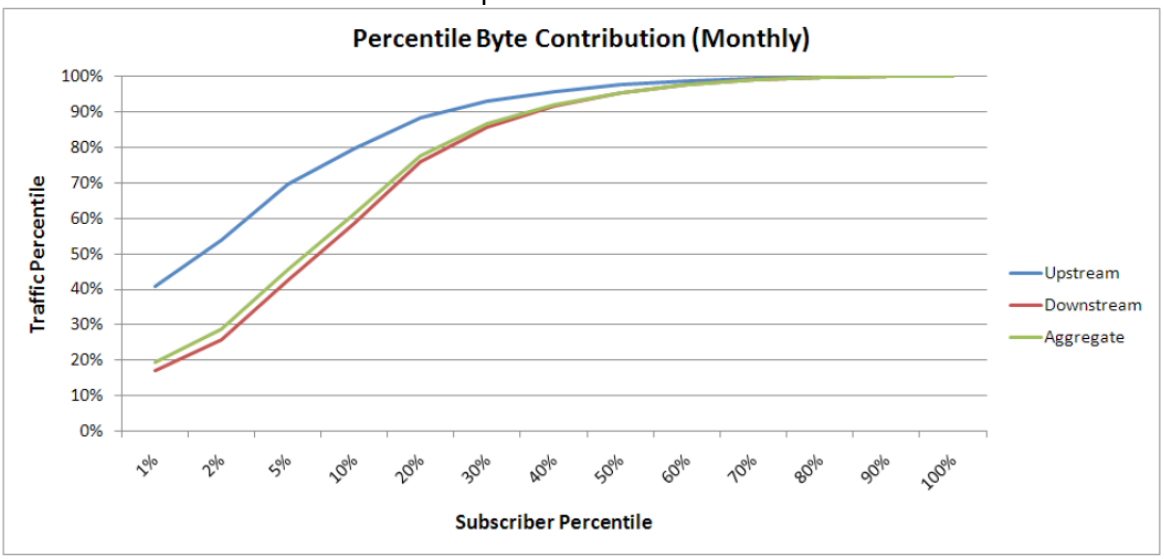

Figure 5 - Percentile (Traffic vs. Population) of Bandwidth Consumption

Figure 4 shows that 50% of throughput is composed of streaming video traffic. We can reasonably say then that only 50% of the previously stated 432 students will be streaming video at any given time. Because of this, I estimate that only 216 users will require 3Mbps at any given time.

Given the facts, I can reasonably estimate then that given 3Mbps each, this population should represent 648Mbps of throughput on the WAN. At 700Mbps, Morrisville's WAN uplink would have a roughly 10% buffer for bandwidth which could accommodate the aggregate traffic consumption of the previously stated 35 users who represent the heaviest users of our Internet connection.

Figure 5 also demonstrates that users tend to use 20% more downstream bandwidth than they do upstream. Given the previously recommended allocation of 700Mbps, this means that the resident campus population would only represent 80% of the WAN upstream throughput, measuring in at 560Mbps total of upstream bandwidth consumed. This leaves 140Mbps of upstream throughput as a buffer and also for our Internet accessible campus services.

Because we host the Morrisville.edu website which must be accessible from the Internet and serve off-campus VPN users, this projected spread allows for a minimum throughput of 140Mbps to be guaranteed to the website and VPN users at any given time. The current bandwidth limiter being used on our 200Mbps connection can set aside 20% of our allocated bandwidth, guaranteeing egress WAN traffic 140Mbps throughput at any given time. Given the state of our current website, VPN infrastructure and other Internet accessible campus services, this allocation would allow for plenty of overhead.

Television over IP

The aforementioned discovery of an initiative to deliver television via our school network brings about another interesting consideration. If the television over IP initiative is deployed on campus, this brings an extra load to our existing network infrastructure. Given its current ability to deliver 1Gbps (1000Mbps) of throughput, our internal LAN infrastructure would support a smooth transition. Our 802.11n access points deployed around campus allow for any given computer to achieve up to 300Mbps of throughput. This is more than enough given the Netflix estimate of 3.6Mbps required to deliver high definition content to each customer. With respect to television delivery, this should be considered differently being that the amount of bandwidth consumed does not vary from user to user. If someone is watching television, it will consume the same amount of bandwidth for each user. Given that Morrisville models an ISP and an ISP should guarantee delivery of its service to each of its customers, this means that we would require a minimum of 5692Mbps of throughput in our core network infrastructure to deliver a high definition stream to each of our resident students.

Morrisville's network is composed of network equipment manufactured mainly by Enterasys Networks and Meru Networks. Our network infrastructure only contains a single, core router located in Charleton Hall. **Figure 6** shows our hub & spoke topology with an Enterasys X8 router serving as a hub to the spoke links. This router's chassis retails for roughly $33,500 and supports backplane throughput of up to 320Gbps. This core

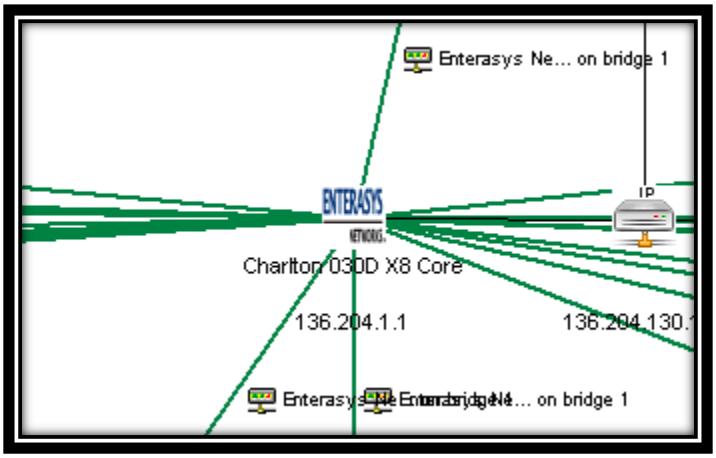

Figure 6 – "Hub & Spoke" MSC Core Network Topology Diagram

router is connected to over twenty satellite switches via multi-mode and single-mode fiber optic cables, each supporting throughput of 10Gbps. Each building which contains Morrisville network infrastructure possesses at least one switch which distributes network access to clients. In **Figure 6**, each of these links is represented by a green line. Since these links support 10Gbps, our current network infrastructure can provide adequate throughput for television delivery in addition to other network traffic.

Although our network infrastructure can handle the added delivery of streaming television, it would only be successful if served from our current television equipment located in the Whipple building. The service must originate from inside our network; it cannot traverse the WAN uplink. WAN bandwidth is expensive and encoding the television into video streams would be cost effective only if performed on campus. If we streamed from an outside source, 5692Mbps of WAN bandwidth would need to be purchased. This number makes the large 700Mbps look meek in comparison. This encoding must originate from inside our network to be cost effective.

Cost

With regard to pricing, our current Internet service provider Cogent's website claims to be the *home of the $4 Megabit*, indicating that a 700Mbit connection would run a measly $2800 per month. According to my source at T1Agent.com, "a rough quote from Time Warner came back at 8-10 thousand (*per month*) for 250Mbps." (Conner, 2010) This demonstrates that the $4 dollar megabit does not exist and is only marketing hype. Gerald Romano of Global Communications Corporation said that bandwidth goes for around $20 per megabit in the vicinity of Morrisville. From this, I would estimate the price of a 700Mbit connection to be roughly $14,000 per month.

Current WAN Throughput vs. Recommended

A 700Mbit connection would yield Morrisville a 350% increase in WAN throughput. **Figure 7** depicts our current 200Mbps connection in relation to the amount of bandwidth available to campus with the recommended 700Mbps connection.

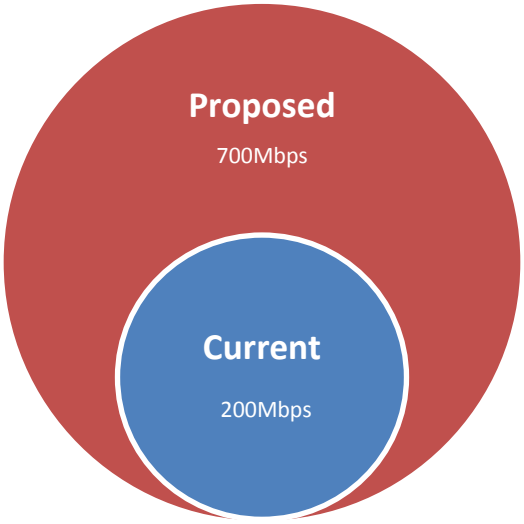

Figure 7 - Bandwidth "Pipe" Comparison

Future Trends

It is important to consider the future when considering technology purchases. In the future, student reliance on the WAN uplink will only increase. We step closer to the concept of ubiquitous computing each day and this utilizes network technology. As computing becomes increasingly transparent to the end user, so should the network. These technologies will be hindered by a congested WAN uplink; they require a lot of bandwidth to reach their full potential.

It can be hard to forecast technology usage since it changes at such a rapid pace. For this reason, I suggest that Morrisville purchase a burstable contract regardless of the bandwidth level purchased. Burstable contracts allow for the WAN to exceed its maximum rated speed during hours of peak usage. It does not allow for an infinite increase, but usually an extra 10%. Adding a burstable option to our current contract could prove a temporary solution if the campus cannot allocate adequate funds for additional fixed bandwidth.

Conclusion

Being that technology advances at such a fast pace, it is important that any contract signed with an ISP not bind us for more than two years. In my opinion, new technologies take about two years to reach mainstream usage. A contract length of less than two years will allow us to adjust to new technologies accordingly. According to both Matt Barber and Patrick Cronn, the price of bandwidth changes quickly and frequent shopping can lead to finding better deals. Matt Barber stated that our recent increase in bandwidth costs less than what we were previously paying for less bandwidth. This situation must be avoided especially as the State of New York clamps down on its SUNY budgeting. Any excess costs must be avoided and obtaining the best price per unit of bandwidth is critical in present times.

Earlier I demonstrated how our WAN uplink is similar to a pipe and water pressure. As seen in **Figure 7**, the proposed WAN throughput is 350% greater, allowing 250% more pressure to flow through this pipe. With regard to high-definition video streaming, we can compare pressure to picture quality. As available bandwidth (pressure) decreases, picture quality decreases. This is similar to how as more faucets are turned on, the available water pressure decreases after each one is opened. A good plumber knows how large a building's water pipe must be to ensure adequate pressure at each faucet. Here, each faucet is a user and the network architect must ensure that each user receives an adequate amount of bandwidth.

In this case, *you* the purchasing officials of Morrisville State College are the architects in that *you* control the amount of bandwidth our campus has access to. A 350% increase may seem large but it must be kept in mind how fast technology evolves. Our campus website claims our campus possesses one of the fastest networks in the world and we are *"at the forefront of a technological revolution"*. In order to maintain this status, our WAN uplink capacity must be increased. This bragging right is something that some prospective students look for when selecting a college. This claim lured me to Morrisville and I would like to see to it that it attracts students with similar mindsets in the future. Our existing network infrastructure is ready for an increase in bandwidth and current technology demands it, therefore I see no reason not to upgrade.

Appendix A: Interview with Patrick Cronn – CITA Professor

Dwyer: What is your background with Morrisville State College?

Cronn: "I was a Technical Support Specialist for Technology Services for several years and then changed roles to an Assistant Professor in the Computer Information Technology department."

Dwyer: What is your history of involvement with MSC Information Technology services?

Cronn: "My involvement with Technology services was substantial in many areas. My primary position was the support of all desktop machines on campus as well as supporting all staff with any technological problems. There are a number of areas that I helped deal with including printing, antivirus, active directory, group policy, imaging, software rollouts, and network upgrades."

Dwyer: Do you feel that the Internet is playing an increasing role in our daily lives?

Cronn: "Of course. We are getting closer to the concept of ubiquitous computing every day."

Dwyer: Are professors becoming increasingly reliant upon the availability of Internet technologies?

Cronn: "I would say that for the most part yes. Technology professors, such as myself, rely on Blackboard, Exchange as well as MyITLab. For a professor, they can use Internet technologies as much or as little as they want. I am sure that there are many who use a computer as little as possible for their classes. It really depends on that individuals teaching style."

Dwyer: How could a congested network affect students?

Cronn: "A congested network affects us all. Technology Services has guidelines in place to protect faculty, staff and students in that they should be able to do what they want, when they want on the network. They support a free and open philosophy that is not hindered by rules and regulations (as much as possible). This would be the exact opposite of a bank. Because of this it is very difficult with the technology guidelines that we have to ban or block certain websites. We do use a bandwidth limiter but I am not sure of the rules that are in place anymore."

Dwyer: Do you feel the campus network in its current state is able to adequately handle traffic during hours of peak usage?

Cronn: "Yes in its current state I believe it is adequate. During our wireless presentation, Matt (Barber) showed us graphs of traffic and bandwidth utilization on campus. During the highest traffic hours the output was only around 160-180 out of 200Mbps. However, as Morrisville gets new students and many more devices begin to relay on the campus network, additional changes will have to be made."

Dwyer: How would you feel about increasing our WAN capacity? How long until you feel it will be necessary?

Cronn: "My guess would be relatively soon if it hasn't been done already for places like Norwich and EOC in Syracuse."

Dwyer: Can you think of any new, emerging technologies that require or will require a large amount of bandwidth?

Cronn: "Streaming television on campus —although I do not think there are any plans to do this anytime soon."

Dwyer: In the past, the Internet was seen as a luxury. With regard to budgeting, do you feel that this should be seen in this way?

Cronn: "With the evolvement towards ubiquitous computing and the heavy reliance on the campus network, it should not be seen as a luxury anymore. It should be looked at as an important tool for the campus and one that should be given priority when it comes to a budget.

Dwyer: Do you feel that our ISP service is a good target for budget cuts or would you oppose this?

Cronn: "There are always good deals out there for ISPs. Depending upon the current contract and how long we have, it never hurts to shop around for better deals. In many cases, by the time the contract is up, you can get more bandwidth for cheaper than what you were currently paying."

Appendix B: Interview with Matt Barber – MSC Network Administrator

Dwyer: Could you shed some light onto the status of our ISP connection speed?

Barber: "We used to have 90Mbps, dual T3's as you guessed, and we now have 200Mbps of a gigabit link. The hardware and our link all supports up to 1 gigabit, so upgrading in the future will be relatively easy."

Dwyer: Which Internet Service Providers are available at our location?

Barber: "The only providers that own fiber in the area are Frontier and Time Warner, but other providers, like our ISP Cogent use Time Warner as a local loop provider."

Dwyer: How do the new roles and increased usage of the Internet affect a Network Administrator or Engineer?

Barber: "We've had to upgrade some equipment in line to support gigabit speeds, since we were going above 100Mbps on that link for the first time."

Dwyer: Do you feel the campus network in its current state is able to adequately handle traffic during hours of peak usage?

Barber: "Previously, we completely saturated our 90Mbps connection during peak hours and overall congestion was high. We now peak around 160Mbps of throughput, but only for a little while every day."

Dwyer: How would you feel about increasing our WAN capacity? How long until you feel it will be necessary?

Barber: "We now peak around 160Mbps of throughput out of our available 200Mbps. Equipment is in place to limit speeds when our WAN link reaches 80% capacity which is 160Mbps."

Dwyer: Can you think of any new, emerging technologies that require or will require a large amount of bandwidth?

Barber: "The recent growth of online streaming video services like Netflix has generated a large amount of traffic. As the popularity of these services increase, more bandwidth will be required."

Dwyer: Do you feel that the Sandvine Global Internet Phenomena report gives an accurate representation of the bandwidth consumption on campus?

Barber: "Overall, yes. The majority of these trends can be seen on campus. Because of the young, tech-savvy campus population, some of these trends are even more prevalent. The only statistic which is not accurate is the P2P traffic. We have policies in place that prevent P2P technologies, specifically Torrent traffic."

Dwyer: Do you feel that our ISP service is a good target for budget cuts or would you oppose this?

Barber: "It depends. I can't give you specifics on pricing, but we are paying less for our 200Mbps link than we were for our 90Mbps because the price drops very quickly over time and we went out for competing quotes. It shouldn't be a target for budget cuts, but we should ensure we are getting the best price per unit (of bandwidth) possible."

Appendix C: Phone Interview with John Conner – T1Agent.com

Internet Service Provider Availability and Pricing

Dwyer: Which providers have fiber-optic infrastructure in the vicinity of Morrisville?

Conner: "As far as I know, Time Warner and Frontier are the only two providers who physically possess fiber-optic infrastructure in your area. As far as I know, they are the only local-loop providers in your area."

Dwyer: John, what do you mean by local-loop provider?

Conner: "A local-loop provider is a provider who leases out their infrastructure for use by other providers. For example, you currently have service through Cogent even though they do not possess physical infrastructure in the area. They purchase the rights to use Time Warner's infrastructure to deliver their service. Basically, they provide service over another company's infrastructure."

Dwyer: Roughly how much would a 250Mbps GigE connection cost?

Conner: "A rough quote from Time Warner came back at 8-10 thousand (*per month*) for 250Mbps. I should have accurate quotes in a couple weeks."

Appendix D: E-Mail Response from Gerald Romano - Global Communications Group

Bandwidth Pricing

Dwyer: I'm currently conducting a research project and attempting to gather some information concerning bandwidth pricing. With respect to my location in Morrisville, NY, could you provide a ballpark estimate of bandwidth pricing?

Romano: "Hey Brian, a rough estimate for a full GIGE circuit would be about $15-20/per mb depending on the carrier. This is for budget purposes only."

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