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City of Worcester Telecommunications Analysis

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City of Worcester Telecommunications Analysis

An Interdisciplinary Qualifying Project
Submitted to the faculty of
Worcester Polytechnic Institute
In partial fulfillment of the requirements for the
Degree of Bachelor of Science

Submitted by:

Danato Borelli | Seth Desmarais | Matthew Piette

Submitted to
Project Advisor
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Project Liaison
Mr. David Moore

Date: March 1, 2004
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Executive Summary

The City of Worcester requested an evaluation of its current telecommunications (telecom) infrastructure, and its delegation of responsibilities in the telecom system. These were the main objectives of this Interactive Qualifying Project (IQP).

A telecom system is defined as any process that enables one or more users (people or machines) to pass to information from point to point. The current telecommunications system of the City is fragmented. The data system is comprised of the I-net provided by Charter Communications. This system is rapidly becoming obsolete, as it only provides a 4 Mbps (.5 Megabytes per second) backbone between city buildings. Internally, most government buildings are wired with Cat 3 cable, which is only rated for 10 Mbps of data transmission. The school department is slightly better off, as it has moved some of its schools to individual T1 lines. In terms of internal wiring, most of the schools were recently rewired with Cat5 cable, allowing 100 Mbps speeds. The network cabling and maintenance is provided by Charter as a stipulation of their cable contract, while the city provides the routers and other network distribution equipment. The entire network lacks the bandwidth necessary for newer applications and streaming video and voice applications.

The phone system has recently been unified into one large Centrex phone contract with Lightship Communications. This contract was signed in January of 2005, and will run for three to five years. This system costs approximately 400,000 dollars per year. Cell phones are still handled on a department-by-department basis, with multiple service providers providing wireless service to the city.

Video is handled by Charter. They provide the City with three channels of public access, one for school programming, one for government, and one for general public access television. They have not responded to requests for a second public access channel. The newer schools are set up for distributed video, with the incoming cable signal modulated to remove objectionable channels and to reassign numbers into a continuous band.

The main issue facing the delegation of responsibilities as it relates to the telecom system is the fragmentation of the departments. Currently, the Law Office is responsible for negotiating and maintaining the cable contract, while Parks and Recreation is charged with maintaining the phone contract. Outside of this, the Information Services department is charged with internal software development and network maintenance. The Law Office has no desire to maintain a cable contract, as that falls outside its normal realm of responsibility.

Through our research, we have concluded that the city needs to expand its network. An optimal system would consist of a backbone comprised of fiber optic cabling capable of supporting multiplexing, which allows multiple signals to be sent over the same fiber. This cabling would be arranged in multiple rings throughout the city, with two strands on each run to provide for backup redundancy. The City's routers can currently support this configuration with inexpensive add on cards. This system is hardware expandable, meaning that the cable can support even higher speeds with different hardware at the ends. With the proper hardware, systems like this can support speeds of over 1 Tbps, which is equivalent to 1,000,000 Mbps. A new generation of optical routers allows bandwidth to be allocated on the fly via software, allowing for extra bandwidth to be allocated on demand for special events or emergencies. Building cabling should also be upgraded to Cat6e, which supports 1 Gbps of data transfer.

With the extra bandwidth provided by a system like this, Voice over Internet Protocol (VoIP) becomes a viable technology. This system changes analog voice signals into digital pulses that can be transmitted over a data network. This means that internal calls would be free, as the data never leaves the City's network. VoIP allows you to add additional features via software as well, such as new voicemail systems. This can significantly reduce costs. Video can also benefit from higher bandwidth, as streaming video becomes an option. This could allow training to be conducted at an employee's desk, with one video feed being sent to tens or hundreds of desktop computers at the same time. Schools could also utilize content on demand for educational programming, so that shows are available when they are needed.

We recommend that the city utilize a private network provider to meet its need. Municipally built networks are coming under legal pressure from telecommunications providers, who claim that taxpayer subsidized telecommunications networks limit their ability to compete. Many states have passed bills blocking municipality supported networks.

Finally, for Worcester to stay current on telecommunications technologies, a department consolidation is necessary. Consolidating the phone system, the data system, and the cable contract will allow all of these systems to work together far more efficiently. As technology advances, these three technologies are being tied together more and more, so this is a necessity for an advanced telecommunications system.

This project is a valuable one because it provides the City with a consolidated overview of its current telecommunications. From this overview and the accompanying technology outlines, the City can make intelligent choices about the future of its telecommunications network. The project is also an IQP because it allows the group to interact with society to help improve the operation of the City government. This in turn will hopefully impact the quality of services offered to the residents of Worcester, allowing our work to impact society.

Abstract

The City of Worcester realizes that an efficient and capable telecommunications system is essential for proper operation of the city government. Our team will assess options that Worcester can utilize in updating their city-wide network. We will also analyze the telephone system and the responsibilities surrounding the entire telecommunications system. Interviews will be utilized to assess the needs of various departments, and ideas presented in these interviews will be further researched. Finally, a report will be prepared consisting of recommendations for the City.

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1.0 Introduction

Telecommunications is a large and fast-growing field. In 2002, 104 million households had telephone service, and almost fifty million homes and businesses had high speed data lines in place (United States Telecom Association [USTA], 2004). Cities are finding that if they want to keep and attract businesses, they must have infrastructure in place to provide companies with high speed telecommunications services (telecom). Services and applications that residents desire operate 'on-top' of telecom systems and allow the user to interact with the system to accomplish various tasks. For this system to function, a strong underlying network must be maintained and expanded/upgraded as the needs of the city around it grow (Harte et al, 2002, 2).

Like any technology, telecommunications has evolved with the passing of time. When Worcester's network was established in the early 1990's, it was the pinnacle of high-speed telecommunications equipment. Now ten years older, it is barely adequate in meeting the City of Worcester's needs (P. Covello, personal communication, December 2, 2004). The government of the city is also being restructured, giving city officials an opportunity to revamp their aging network (Kotsopoulos, 2004). In order to meet the increasing demands of government and business, Worcester wishes to upgrade its telecommunications infrastructure.

A well formulated plan is crucial to the success of implementing any telecommunications system, and is a common first step in a telecommunications upgrade. Jacksonville, FL, has invested in a telecommunications master plan to assist with this planning stage (Black & Veatch, 2003). While Jacksonville is larger and possesses greater finances than Worcester, it will still be helpful to review this information, as the general principles can still be applied. We have studied several master plans from different cities for comparison for a proposed plan for Worcester. Texts that describe and study the various compositions of telecommunications systems have also been acquired to aid in evaluating the different technical aspects of the system (Dravida et al, 2002). Since any changes in the existing telecom system will influence the majority of businesses in the city, we have also researched texts analyzing telecom systems and their effect on commerce (Peterson, 2000).

The main purpose of this IQP is to analyze the current telecommunications system, determine the City's needs, and recommend a set of solutions. While our sponsor possesses a great deal of knowledge about the technology that comprises the current system, they lack information about the newest technologies and telecommunication practices. This gap will be filled by both technical journals (Savage, 2002) and through the telecom plans developed by other cities (Vernez, 1998). A previous IQP has examined the inner workings of the Worcester city government (Marcus, 2000). While this is very informative, due to the reorganization of the city government, it has become outdated. More information will have to be gathered in this field in order to make sure the latest data is used.

The City of Worcester needs a detailed analysis of its current communication network's capabilities, along with a list of its needs, both current and future. In order to accomplish this, both the current and planned local government structures have been examined. Benchmarks have been established to make an informed and balanced decision about possible improvements. Finally, efficient means of networking have been researched in order to provide the city government with viable options. The city of

Worcester will be presented with a report containing this information. This document will conclude with recommendations from the project team for where Worcester should seek to improve its telecommunications system. A multimedia presentation will also be delivered to the sponsor, so that they will be able to make the best decision for the city of Worcester.

This project is a valuable one because it provides the City with a consolidated overview of its current telecommunications. From this overview and the accompanying technology outlines, the City can make intelligent choices about the future of its telecommunications network. The project is also an IQP because it allows the group to interact with society to help improve the operation of the City government. This in turn will hopefully impact the quality of services offered to the residents of Worcester, allowing our work to impact society.

2.0 Background

This chapter will provide the reader with a greater sense of the nature of this Interactive Qualifying Project (IQP). This IQP primarily dealt with the assessment of the current telecommunications network already in place. The city-wide internet, including both commercial and residential consumers, was analyzed. In order to accomplish this, the very nature of what a telecommunications (telecom) system is was determined, along with what makes a telecom system "good" or "bad."

Worcester's current telecom contract was first analyzed in order to weigh the pros and cons of the current system versus potential alternatives. In order to find the best solution, the telecommunications networks of other mid-sized cities were also reviewed and analyzed. Additionally, the structure of the City's government will be undergoing reorganization in the near future. The current telecommunications system was designed with the old arrangement in place, so the planned reformation must take into consideration the newly reorganized structure. Finally, the financial state of the City of Worcester was given sufficient consideration throughout the course of this project.

2.1 What is a Telecommunications System

Telecommunications is any process "that enables one or more users (people or machines) to pass to one or more other users information of any nature delivered in any usable form (Pecar & Garbin, 2000, p. 29)." Telecommunications systems include user equipment, access lines, interconnection equipment, and a coordinating (controlling) structure. Examples of user equipment are telephones, computer terminals, or pagers. These devices communicate with the telecommunication network through access lines and/or access points. Access systems can be interconnected with each other to form large networks. Control systems are responsible for authorizing access to the system, managing network resources, and measuring usage for billing and accounting purposes (Harte et al, 2002).

2.1.1 Available Telecommunications Options

The connecting of computers within a single building is known as a Local Area Network (LAN). The most common types of connections are Ethernet and Wireless (Wei et al, 2004). Each type of network has sub-types of various speeds, costs, and reliabilities, as illustrated in Table A.

Table A: A Comparison of Networking Technologies

Technology	Speed	Wireless	Range	Support	Cost
Ethernet 10/100	10/100Mbps	N	A	A	A
Gigabit Ethernet	1000Mbps	N	A	D	D
802.11b	11Mbps	Y	B	A	B
802.11g	22/54Mbps	Y	C	NA	NA
802.11a	52/72 Mbps	Y	C	B	C

Sources: (Memsen Corp, 2004) and (Flexwork, 2002)

In Table A, the name of the LAN type is listed in the leftmost column, with its maximum network speed(s) in Megabits per second listed one column over. The "Wireless" column simply denotes if a given technology uses wires, or high-frequency radio waves to connect computers together. The remaining columns all provide their ratings on an alphabetical scale, with "A" being the highest possible score and "D" being the lowest. Range is a measure of how far a network of the given type can extend, from state-wide WANs, down to private residences. A score is given in Support, based on how well the technology is supported by the industry. Older, more proven technologies generally have higher ratings, as opposed to new and relatively untried ones. Finally, "Cost" is a relative measure of the price to implement a given technology over a standard sized area.

The 802 series of networks are wireless, meaning that they can link computers without them being physically connected to each other. This is very useful in older buildings and in structures where running wire through multiple floors and rooms is too costly and difficult. 802.11b is the current standard in wireless networking, possessing the best range out of other, newer wireless technologies. While it is the slowest LAN technology listed, it is more than adequate for most business purposes. The other wireless technologies are much faster, but they are newer and less reliable. Their costs are also generally prohibitive, and their ranges sub par (Memsen Corp, 2004).

Ethernet technologies use special cabling to physically connect computers to the local network. While this is the most secure and reliable form of networking, it poses certain difficulties when running this wire throughout buildings that were built before this technology was available. Ethernet 10/100 has a network speed of 100 Megabits per second (Mbps), and is the most cost effective networking solution currently on the market. The range of these networks is only limited by the amount of Ethernet cable available (Wei et al, 2004).

2.2 Current City Government and Telecom System

This section analyzes the way that the City government is currently laid out. It also explains how the City's current telecommunications system currently functions, and the responsibilities for the various parts.

2.2.1 Current Government Layout

Currently, the City is laid out with the City Manager at the top of a unilevel structure of city departments. All information that must be transferred from department to department goes through the City Manager first. Figure 1 below shows this layout.

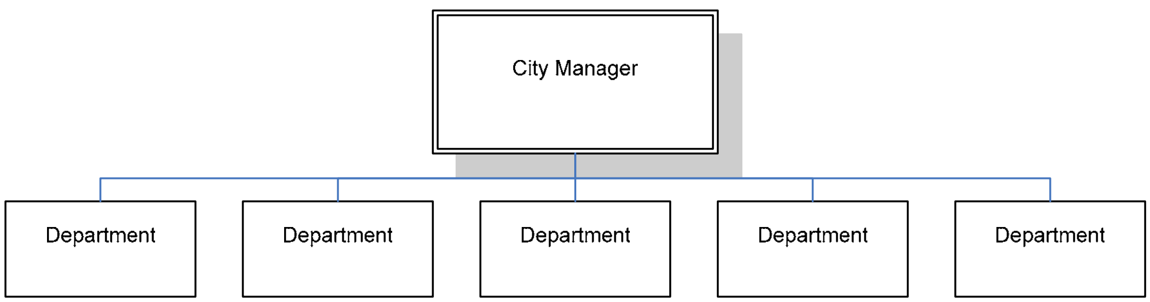

Figure 1 – Current Government Layout

The current City Manager has expressed his displeasure with this system, and is currently reorganizing the structure of the Worcester government offices.

2.2.2 Current Telecommunication Network

The City currently has a cable contract with Charter Communications. This contract is valuable in that it allows the City to use Charter's infrastructure for its own networking purposes. This network is referred to as the "I-net". This saves the City from having to build and maintain its own network. The residents are indirectly paying for the city network infrastructure through their cable bills, much like a gas tax pays for road construction and repair (Moore, 1998).

The City of Worcester currently possesses a Wide Area Network (WAN) connecting 94 buildings using old copper coaxial cabling that was installed prior to 1993 (P. Covello, personal communication, December 2, 2004). This once state-of-the-art technology is now obsolete because of advances in networking systems. More modern fiber optics systems are being used in an increasing number of networks each year (Savage, 2002).

Coaxial cable networks are the standard in high-speed internet and video access, having been in use for well over a decade. While reliable, they currently only have the capacity to transmit data or video over their lines (Dravida et al, 2002). While this may change in the future, right now it is necessary to have a separate provider of telephone communication. If the network is interrupted for an unforeseeable reason, the telephone system still functions, as it is not an integrated part of the cable system.

2.2.3 Telecom System Organizational Problems

Currently, responsibilities for the telecommunication system of the City are spread out among various departments. The Law Office is currently responsible for maintaining and enforcing the cable contract with Charter Telecommunications. Generally, the Law Office writes and reviews contracts. They are not usually responsible for enforcing the terms of them, and would like this responsibility moved elsewhere. The City telephone system is currently under the control of the Parks and Cemeteries office.

This is due to budget cuts in the mid-1990's that eliminated the Office of the City Messenger, which was created in the early 1900's to transfer documents between city offices via messenger. The Information Services Department (IS) is responsible for purchasing and maintaining the computer system and the internal networks not maintained by Charter, as well as printers (City of Worcester, 2004). The current distributed system causes a lack of communication between departments when considering telecom system maintenance and purchases (D. Moore, personal communication, 2004).

2.3 Proposed City Government and Telecom Solutions

This is an overview of the new government structure of Worcester, as well as ways to change the responsibilities inherent in the telecommunications system.

2.3.1 Proposed Government Structure

The new government organization will be more of a hierarchy. The City Manager will remain on top. However directly beneath him will be a number of "super-departments." Figure 2 below shows the new layout. These departments will be organized so that each department will contain offices that often need to share information with each other. This way, information is not being channeled through the City Manager's office when it is unnecessary.

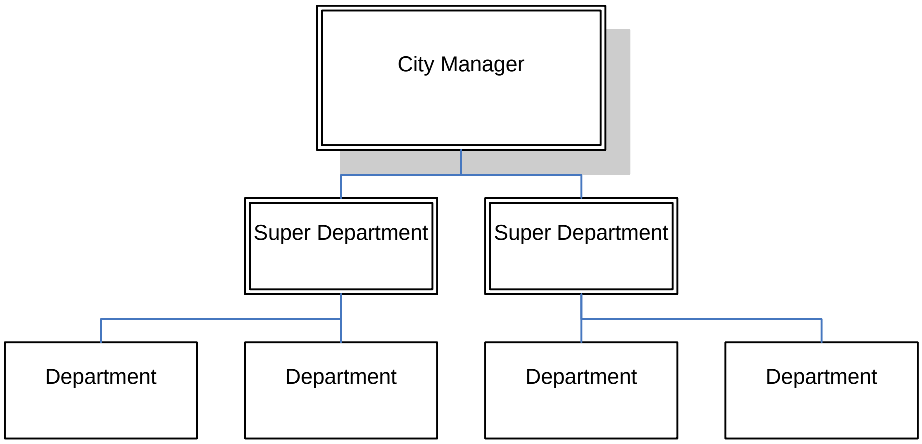

Figure 2 – New Government Layout

With the upcoming reorganization, the City government feels that now would be an excellent time to study the telecommunication system and see if it can be modified to work more efficiently with the new governmental layout. For example, the City's current telecom analysis suggests creating the position of the Telecommunications Coordinator. This person would be responsible for overseeing Worcester's telecom development and planning. This position is no longer funded under the current IS budget, but could be re-instated during the reorganization.

2.4 Evaluating Proposed Telecommunications Systems

We examined criteria that can be used specifically for evaluating a telecommunications system. Through background research comprised of master plans from other cities (City of Richmond, 1996; City of San Francisco, 2001; Vernez, 1998), a list of important criteria has been established that was used to weigh various options. These standards are:

- Cost – This item incorporates both startup costs, as well as maintenance and operations costs. All of the other master plans list this as a main priority, due to the tight budget process of any city.

- Amount of proprietary equipment – Worcester's Chief Information Officer stressed that his office is very hesitant to purchase anything that does not work with industry standards. This is logical because buying a proprietary solution shackles the buyer to that company for the life of the product, and usually means that you will end up paying more for improvements and replacement parts/consumables (P. Covello, personal communication, December 2, 2004).
- Future expandability – Telecommunications hardware is a large investment. We need to evaluate each system to see which systems can be kept up to date by adding new hardware as needed, instead of replacing everything every time an update is necessary.
- Meets users' needs – The plan must consider the needs of its user base. In the master plans researched by the group, the standard practice was to ensure that these requirements were met fully or even exceeded in the interest of insuring that the system remains viable in the future.
- Security of data/Disaster recovery – The Deputy Chief Information Officer compared the function of the City's computer system to that of a bank. The bank must have funds available at the beginning of the day, disburse and take in funds during the workday, and then close with all the money transactions working out evenly. The City must do the same with its data, by making sure that everything is secure during non-business hours, then moving it around during the day as needed. At the end of the day, the City must make sure that nothing was lost, and that backups are made so that

it can carry out it's job the next day. Data is money to the City, and any network solution must be as secure as possible. Cases also need to be considered where a portion of the network is rendered unusable. The City needs contingency plans in the case of a network outage (E. Cazaropoul, informal communication, December 2, 2004).

2.4.1 Creating a Telecommunications Master Plan

Before deciding which is best for Worcester, a Telecommunications Master Plan must be developed, based on a set of standards, outlined by Bonnett, and put into use by the firm Black & Veatch. It is best to start by conducting extensive research and gathering information regarding the City's telecommunications use, needs, and current infrastructure. This includes interviews, a formal market analysis, and a review of carrier offerings and facilities owned and operated by agencies of the government. Then, telecommunications strategies from other communities across the country should be examined for both ideas and solid approaches. Next, multiple designs for consolidating and extending telecommunications facilities owned and operated by agencies of the consolidated government should be developed. Each of these designs should then have cost/benefit analyses performed on them, looking at both direct cost savings to the consolidated government, and at overall benefits to the entire city.

Using these standards, the city of Jacksonville recommended a Gigabit Ethernet network which is one thousand times that of a normal DLS or T1 line (Black & Veatch, 2003). The estimated cost in the Telecommunications Action Plan for the Jacksonville Master Plan was a little over $700 million and that cost does not include maintenance and many other operational costs. The population of Jacksonville is significantly higher than that of Worcester. Using similar data gathered from the Jacksonville Master Plan and applying that situation to Worcester, it would cost the City approximately $165 million to construct (Moore, 1998).

2.5 Public versus Private Networks

The Worcester Telecommunications Action Plan (WTAP), written on August 12, 1998, outlines several paths through which the City could decide on a private sector as their primary source for a telecom provider. Companies such as RCN, NEESCom and Bell Atlantic were mentioned throughout the document as potential sources for a telecom system. These companies already have a telecommunications infrastructure embedded throughout the City. This would decrease the start up time and initial cost of utilizing their private networks in the short term.

Orange County, Iowa has a telecommunications system supplied by a telephone company to provide their residents with high-speed internet (Bonnett, 2001). Similarly, both Massachusetts and Colorado have outsourced to telecom companies abiding by the FCC (2000) regulation that each potential bidder must offer each municipality the same price regardless of location (Bonnett, 2001).

Many other cities that have found outsourcing to be too risky opt to create their own public telecommunications system. As Tom Bonnett states in his article from the Rural Research Report:

> "More than 200 publicly owned utilities in this country currently provide telecommunications services. Included are 109 municipal utilities which provide

> cable television services; 61 which offer Internet access; 58 which lease fiber to private sector companies; 32 which provide high-speed data services; 18 which provide local telephone services; and 10 which provide long-distance voice service. Iowa has 30 municipalities that provide facilities-based telecommunications. (Bonnett, 2001, p.5)"

There are ways to circumvent this risk, however. The government of Richmond, VA Master Plan was interested in creating a fiber network. Taking into consideration the networks, both public and private, that were already in place, they decided to integrate the disparate systems into one whole. In the end, Richmond contracted a company in the private sector to handle the unification of the telecom system. By outsourcing the work, but using networks that were already in place, Richmond was able to construct a telecommunications network at a lower risk than if they had hired a third-party to construct their telecom system (City of Richmond's Telecom Task Force, 1996).

2.6 Emerging Telecommunications Technologies

Research has been conducted into some of the newest telecommunications technologies. These technologies may be helpful in providing the city of Worcester with the telecommunications functionality that it desires, while reducing costs.

2.6.1 Data

The data network is the backbone of Worcester's telecommunication system. A high-bandwidth system is necessary to allow the city to transmit the increasing amounts of data that it needs to conduct business. Telecommunications companies are moving to fiber optic cable as a replacement for the more limited copper cabling.

2.6.1.1 Fiber Optic Cabling

The main need of the city is obviously more bandwidth both within its buildings and better connections between buildings as well. Copper cabling technology is starting to peak, as it is very bandwidth limited and cannot handle multiple frequencies on the same line (multiplexing) very well. The emerging technology is fiber optic cabling. Fiber optic cabling has already begun to make inroads in the city, as Charter, Neescom, and several other communications companies all have fiber under the Worcester streets. Neescom is the only company operating in Worcester that has chosen to reveal the locations of some of its fiber rings (NEESCom, 2005), as the other companies consider their locations secret and do not reveal them to the public and competitors.

There are two different categories of fiber optic cable: single-mode and multimode. Multimode fiber passes multiple wavelengths of light through the core of the cable. These light signals bounce back and forth off the cladding layer until they reach the other end of the cable.

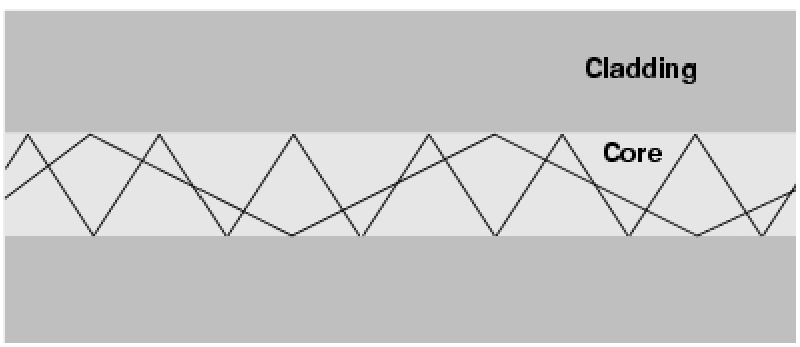

Figure 3: Multimode Cable (Cisco, 2004a, 2-7)

The problem with this transport method is that all light travels at the same speed, so different wavelengths arrive at the end of the cable at different times, which is referred to as “modal dispersion”. Generally, the accepted longest cable distance for multimode fiber is under a mile and a half, which keeps the modal dispersion down to negligible levels. This kind of cable is usually used in office runs, from a server room to a desktop or other machine.

Single mode fiber is a slightly different system. Single mode fiber utilizes a narrower core that only allows one light signal to pass through it at a time. This eliminates modal dispersion, allowing single mode fiber to be used for very long runs.

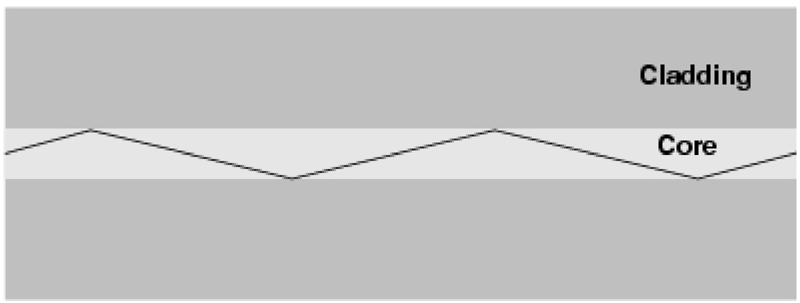

Figure 4: Single mode fiber. (Cisco, 2004a, 2-7)

Single mode cable is usually used by telecommunications companies for long-haul cable runs, and for Wide Area Networks (WANs) in cities (Cisco, 2004a, 2-6). Either type of fiber cable is capable of supporting over 1000 Mbps of connection speed, with the main controlling factor being the hardware hooked up to the end of the fiber.

2.6.1.2 Fiber Optic Technology

Fiber optic networks can be arranged in a few different ways. The simplest method is point-to-point topology. This connects two nodes directly together, and is used for direct connections from a provider to a business.

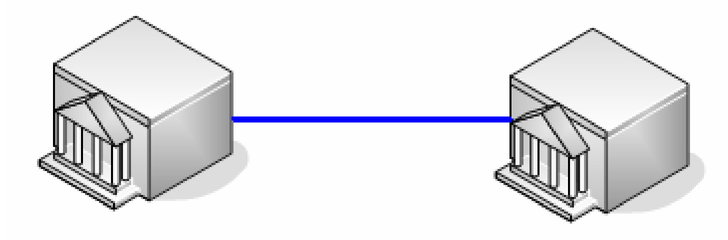

Figure 5: Point-to-Point Topology

A more common method of connecting sites to a fiber network is the ring topology. This setup has the advantage of allowing multiple rings to be used to provide redundancy. This allows it to be much more reliable than one or two point to point connections due to the ability to send data over the second ring if the first one experiences a service interruption. It is also more efficient, as it allows for each building to connect with each other building on the network, without the need for point-to-point connections to each building. A Unidirectional Path Switched Ring (UPSR) is shown below. This system allows for data to flow in both directions for better disaster recovery.

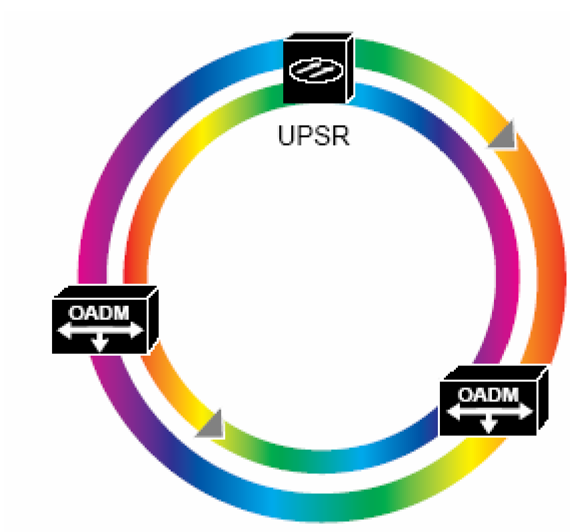

Figure 6: USPR topology (Cisco, 2004b, 3-11)

The newest topology concept is a mesh topology. It is a system where each node has connections to its nearest neighbors, allowing data multiple pathways to each building. This is the ultimate in path redundancy, as the data can be rerouted in the case of a network outage with minimal data loss. Protocols are still being developed to address the larger issues with this technology, namely the need for very intelligent switching mechanisms to choose the best path for data, and a comprehensive software package to support the routing of information. Mesh topologies can use point-to-point interfaces to interconnect with existing rings, allowing new mesh systems to remain compatible with existing infrastructure. A mesh topology is shown below, along with connectivity to a rin layout.

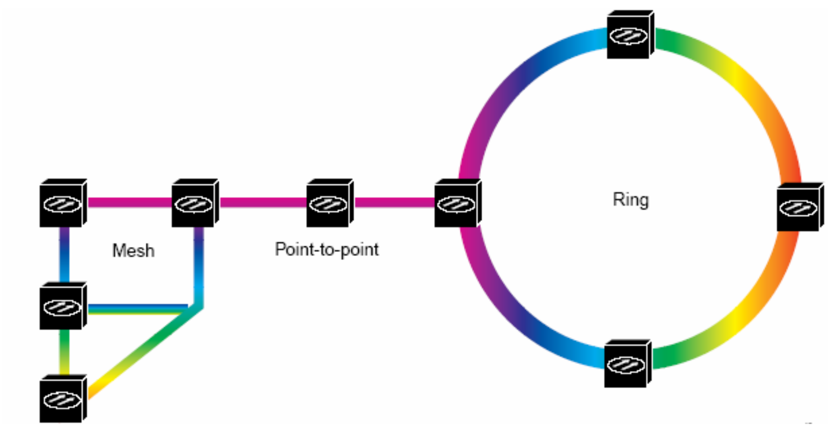

Figure 7: Mesh topology integrated into a ring system (Cisco, 2004b, 3-12)

2.6.1.3 Dense Wave Division Multiplexing

To increase bandwidth, a technology called dense wave division multiplexing (DWDM) is often used in conjunction with single mode fiber. DWDM allows multiple signals to be combined into one beam of light, and passed through a single mode fiber. A modulator at the receiving end splits the signal back down into its component parts. The newest technologies can multiplex 160 or more different signals into one single mode fiber. (Avion, 2004, 1-2) This allows DWDM capable strands of existing fiber to effectively be used over and over again.

The largest issue with the DWDM system is that it is fairly rigid and inflexible. This is due to the hardware that is presently in use in most systems. A fiber loop utilizing DWDM uses one hub that provides signal, and multiple Optical Add/Drop Multiplexers (OADMs) that filter the signal so that the necessary portion goes down their branch of the network. This configuration is shown below

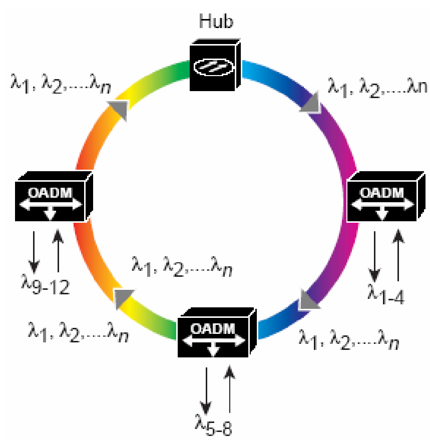

Figure 8: A DWDM ring. Each lambda represents one data channel. (Cisco, 2005, 3-10)

The largest problem with these systems is their rigid nature. The allocation of data channels needs to be laid out in advance of actual network installation, and no provisions are made for easy bandwidth allocation. For example, if the far right node in the above diagram needed more bandwidth for a day due to a special event, technicians would have to go to the OADM, and change filters and retune the entire unit to function with more or fewer channel inputs. This is a time intensive process, and disrupts network services to the other points on the network (Barry, 2004, 75-76)

The telecommunications industry has overcome these limitations and has begun producing next generation OADMs, called Reconfigurable Optical Add/Drop Multiplexers (ROADMs). These new units allow network administrators to change the channel settings for the network via remote administration, so that on-the-fly provisioning of bandwidth is possible for city disasters, large conferences, or even a remote training session. Using this technology, the network administrators could turn up the bandwidth between the IS training room and City Hall for a few hours, to allow a streaming video workshop to be played in higher quality to the employees receiving remote training (Lambert, 2004).

2.6.2 Voice

In preliminary interviews before the official start of the project, the interview with the IS department indicated that they were interested in Voice over Internet Protocol technology. This is a newer technology, and research was conducted to establish its merits.

2.6.2.1 Voice Over Internet Protocol

Voice over Internet Protocol (VoIP) is a voice communication technology that has emerged in the past few years. This technology works by utilizing existing broadband data lines and using a special phone to convert analog audio into a digital medium. This signal is then sent via the pre-existing broadband connection to its destination, where it is converted back to analog audio (InfoTech, 2003). These phones are most widely available in the desk phone variety, however VoIP enabled cell phones are beginning to be distributed to large businesses, and should be available in the residential market within a few years (ShoreTel, 2004).

Since VoIP utilizes the existing high-speed data lines, there are no additional costs outside of the actual phones when used to call from city building to city building. This allows for a massive reduction in the capital needed to operate a large phone system, outside of the initial equipment. A large wide area network (WAN), such as the one in use by the City of Worcester, could be easily linked by a series of VoIP enabled phones via the existing telecommunications infrastructure. Since the numerous analog phone lines would be condensed into a few fiber optic strands, maintenance would be a much smaller problem.

By running voice signals over an existing local network, the overhead is greatly reduced (AT&T, 2004). However, the telephone system is now only as reliable as the telecommunications network that it is a part of. This means that if the network were to fail for any length of time, the entire phone system would be crippled as well (B. Borski, personal communications, January 18, 2005). This necessitates keeping a reduced number of analog phone lines to be used as redundant backups in case of an emergency or a critical network failure. This hybrid system would still be less costly to maintain, as only a fraction of the original analog lines would need to be kept.

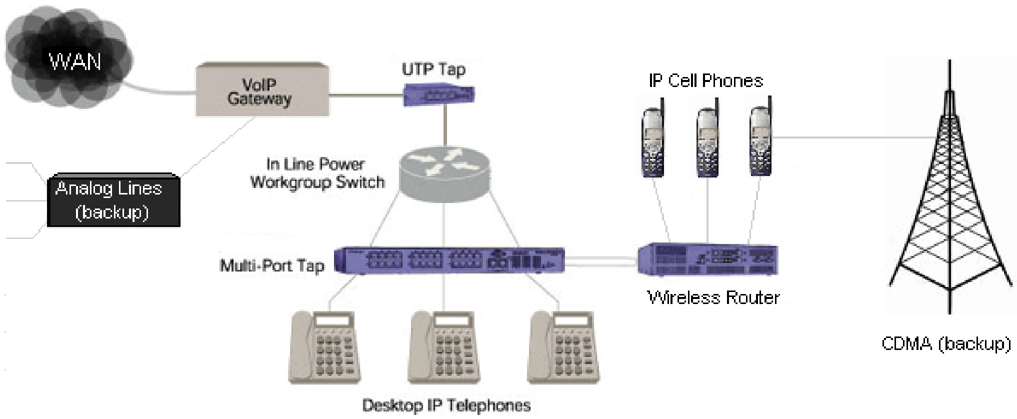

Figure 9 : A VoIP system

With an IP-based communications network system enhancements are done with software downloads and require minimal new hardware. For example, a business with a VoIP network can easily add an IP-based voice mail system within its main data center for storage of all voice messages, lowering costs and transport fees. With centralized storage, it becomes easy for employees to receive voicemail and email through almost any IP enabled device, whether it be a computer, PDA, Blackberry, or multiple other devices. (Ostrowski, 2004)

2.6.2.2 Private Branch Exchange

A Private Branch Exchange (PBX) is a telephone system within a network that switches calls between users on interoffice lines while allowing all users to share a certain number of external phone lines. The main purpose of a PBX is to save the cost of requiring a line for each user to the telephone company's central office. The PBX is owned and operated by the business rather than the telephone company, which may be a supplier or service provider, however. Private branch exchanges used analog technology originally. Today, PBXs use digital technology. These digital signals are converted to analog for outside calls on the local loop using standard telephone service (Angus, 2001).

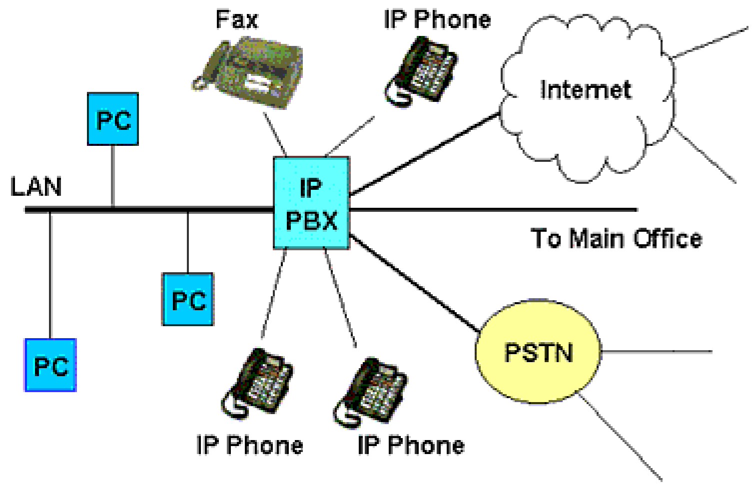

Figure 10: A PBX system
Source: www.silicon-press.com

As illustrated in the above picture, a PBX network can be hooked into an existing LAN. This allows for a situation similar to VoIP, where the voice signal can be sent over an existing data network. While an older and more studied method than strict VoIP, this method lacks the flexibility of VoIP, while requiring the City to maintain its own phone equipment as in a standard PBX system.

2.6.3 Video

Telecommunications companies, Charter included, are heading toward the use of fiber networks and fiber to the home to transfer data to and from their customers (IEC, 2005). This allows the usage of next-generation video ordering and distribution systems. Streaming Video or Media is defined as just-in-time delivery of multimedia information. It is typically applied to compressed multimedia formats delivered over the Internet. Streaming Media allows downloads to start playing almost instantly, with only a very small portion of the video downloaded. While the beginning of the video is playing, more of the video is being downloaded. This eliminates waiting for an entire file to download before viewing. The implementation of a fiber network would allow the City to run not only the cable television signal, but also stream live video for teleconferencing and online classrooms. Utilizing streaming video technology over a fiber optic network would allow for remote instruction of city workers. Instead of teaching in classrooms built to house ten to twenty people, city employees could log into a live teaching session from their own computer. This decreases training time, as travel is not an issue, and can increase numerical penetration of training lessons. With speeds of up to 1 Gb possible through a fiber network and it only restricted through the wiring on the building and the devices on the computer, streaming video would compress and decompress showing the video with clarity and a transmission delay that is nearly unnoticeable (Feder, 2000).

3.0 Methodology

The goal of our project was to analyze the city of Worcester's telecommunication system. We considered the structure of the current physical network as well as the decision making and responsibilities associated with the telecommunications system. From this analysis, we determined possible new options for the city to improve its telecommunication abilities. The specific questions that we attempted to answer were the following:

- What are the possible options for the operation of Worcester's Telecommunication system, and how will they impact the city?
- Is the current telephone system sufficient, and if not what are possible options for improvement?
- What are some options for the organization of telecommunications responsibilities within the city of Worcester?

This chapter will discuss the information that we collected, as well as methods that we used to collect information which will allow us to answer these questions.

3.1 What are the possible options for Worcester's Telecommunication system?

Evaluating the current and possible telecommunications system required us to use several different data collection methods. The first of these was field research. This involved our sponsor, David Moore, as well as Eileen Cazaropoul. Eileen is the Deputy Chief Information Officer for the City, and our contact at Information Services. From her we obtained knowledge of the workings of the current network, and areas that it could potentially be improved in. We were also put in contact with Bob Borski of Information

Services, and Rob Antonelli of Parks and Cemeteries, as well as Charles Campbell, Tim Williams, and Bill May from the Worcester Public School Department. We sought their input on the following questions:

- What other departments do you work with the closest?
- What data do you transmit, receive, and use on a regular basis?
- Do you have difficulties with the way data is currently transmitted?
- What is your current telephone system, and does it fit your needs as a department?
- What do you use your network capabilities for, and to what extent are they utilized?
- What would your department like to see added in terms of telecommunications to enhance the capabilities and productivity of the department?

Our goal in asking these questions was to gauge the satisfaction of the city departments with their current capabilities, as well as to what extent they use the network. This allowed us to establish a summary of the current network utilization, as well as a list of possible future needs that can be considered when making recommendations for city planning. We scheduled follow up interviews with Mr. Borski, to discuss the feasibility of our proposed solutions, and deputy City Solicitor Michael Traynor, to ensure that our project was still in line with his goals.

The summary and list was used to formulate recommendations for the City. The group then conducted research with reference materials to find a solution that balances the wants of the departments, general best practices for telecommunications, and feasibility. It is simply not possible to give every department everything that they desire. Similarly, it is not possible to follow every best practice. The City would face budget issues, and be left with a system that may not meet the needs of its departments very well. Our team focused on solutions that take into account desires of the departments, standard best practices, and implementation feasibility.

3.2 Evaluating the Telephone System

The ability to simplify the network by integrating the phone system with the other telecommunications functions of the city network is an option that the City can consider. Information provided to us by the Information Services (IS) department of Worcester gave us a broader understanding of how upgrading the telecommunications system would allow for not only the transfer of data to increase, but also the transfer of voice and video through the same lines.

The phone network of the city buildings was analyzed to see if it is feasible to tie it into the data portion of the network with new technologies. Currently, the phone network falls under the jurisdiction of the Parks and Cemeteries Department. Under the current department structure, there is little to no interdepartmental communication. Because of this, Parks and Cemeteries makes the vast majority of its phone network-based decisions without consulting any of the other departments concerned with the telecommunications network. This is a highly inefficient manner of business and this problem was addressed with the departmental reorganization.

The first step in deciding whether to implement a new phone system was to examine viable options for the city choose from. The current copper network infrastructure is a very outdated instrument and the IS department explained their desire to implement a fiber network. Fiber would enable the city to take advantage of new voice over IP technologies, which are not currently feasible due to the low bandwidth of the current system. Fiber also allows for a combination of signals over one high-bandwith line, including data, voice-over IP, and video. We studied a complete combination of all these information types, as well as separate implementations and different combinations. Using the data from the questions asked earlier, we compiled answers to the following questions:

- How much bandwidth is required for each department?
- Can the departments utilize data, VoIP, and/or video services?
- What is the department's current phone system?
- What is the operating cost of the phone system per year?
- How secure are the different portions of the telecommunications system used by the department?

The data compilation enabled the group to make a decision about the possibility of improving the city phone system with new technology. We used similar criteria to the first portion of the project. The criteria for the decision was the feasibility (both budget and technical), desires of the departments, and best practices for phone systems. We have multiple sources dealing with phone system implementation and best practices that were referenced for the final analysis.

3.3 Assessing Telecommunications Responsibilites

This portion of the project required more interviews with the heads of departments that are currently responsible for different parts of city telecommunications. The purpose of these interviews was to determine the feasibility of adding a new city position with the purpose of managing the city's telecommunications. This position would consolidate the phone system, cable contract management, and the maintenance of the network in city buildings. Currently, the cable contract is handled by the city solicitor, which is an unsatisfactory arrangement to that office. Parks and Cemeteries is currently in charge of the city's phone system. The physical network in the city buildings is managed by the IS department. We studied the feasibility of consolidating these positions into one.

We scheduled individual interviews with the heads of the Law Office, Parks and Cemeteries, and IS. Our objective was to learn each department's stance on creating a new office to manage the City's long term telecommunications planning. These questions were asked to gather the appropriate facts:

- What does your department do for the city's telecommunication system? (To ensure that the group understands the responsibilities of the department).
- Would you characterize the current telecommunications responsibility layout as efficient or inefficient, and why?
- Do you feel that your department has the funding and personnel to fully evaluate situations and make the appropriate decisions for the city's networks?
- What would you propose as a way to simplify the responsibilities associated with the city's telecom system?

From these questions, we devised a plausible plan that we can recommend to the city to make sure that the telecommunication decisions of the city are being made by informed and cooperating parties, instead of the disjointed unit that is operating currently.

3.4 Conclusion

From the data accumulated from interviews and additional research into specific networking products and technologies, we formulated a plan for the telecommunications system of Worcester. We also reported on the feasibility of reorganizing the telecommunications decision making structure, taking into account the politics inherent in the city system.

4.0) Findings

Using interviews and background research, the current state of the City's network has been determined. Also, further research into new technologies which could possibly be implemented by the City has been conducted. The findings are broken into data, voice, and video categories, with an additional section on public versus private infrastructure networks.

4.1) Data

The current data transport system used by the City is Charter Communications' I-Net. This is a copper cable network that is mainly used to deliver cable television content to the City and its residents. The City has the rights to put data onto the network, whereas normal cable subscribers do not have this ability. Two data channels are allocated for general government usage, and four are reserved for the school department. Each channel is limited to 4 Mbps (.5 megabytes per second). The largest problem that the city has is network congestion, due to the low bandwidth of the network. For a quick comparison, every student in a WPI dormitory receives a 10 Mbps connection to the network.

Since the original installation, the city has requested and has received access to a fiber optic strand running along Main Street. The strand runs past City Hall, the Police Station/IS building, and the courthouses. This has helped to alleviate much of the congestion for the government buildings, but the system is still running at close to full capacity. Off of the fiber strand and I-net connections are the building connections, which are 10 Mb connections to each building. Cisco routing equipment divides the connections to individual computers.

Most of the government buildings in Worcester are wired internally (from the routers directly to computers) using CAT3 cable, which is only rated for 10 Mb/s data transfer rate. The IS department is currently running these cables over their rating to achieve higher speeds, usually in the 75-90 Mb/s range. The connections are throttled back when unacceptable levels of data loss occur. This requires monitoring to ensure that packet loss stay at acceptable levels, taking up the time of IS employees. The data cables also degrade with time, lessening the ability of the IS department to push larger data amounts through them. (Borski, Personal Communication, January 19, 2005)

4.1.1 School Data Network

The school network is currently divided into four subnets, with each subnet utilizing one channel of the I-net. Each channel is divided between multiple schools. This arrangement does not meet the bandwidth needs of the schools, especially the high schools, as the older students are more actively using the internet and by extension the network. The city has decided recently to purchase individual T-1 lines for the schools with the most network traffic, which has slightly helped to ease the congestion. The T-1 lines operate at a full-duplex 1.5 Mb, meaning that a full 1.5 Mb is reserved for uploads and an equivalent size pipe is always available for downloads. A chart showing the network layout is below.

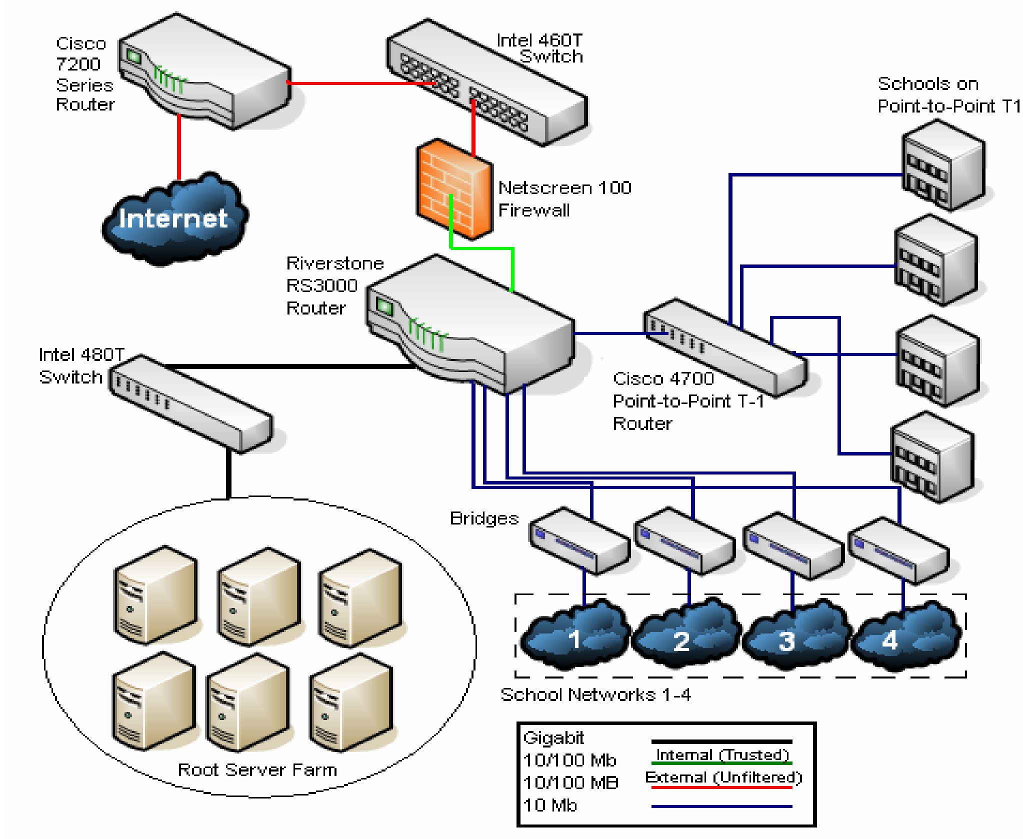

Figure 11: School Network Layout

Table B: Listing of Schools on each channel

School Network 1	School Network 2	School Network 3	School Network 4	T-1 Connections
All School	911 Llincoln St.	Forest Grove Middle	Belmont Elem.	Admin. Building
Burncoat Middle	Alternative	Quinsigamond Elem.	Burncoat Elem.	North High
Chandler Mag. Elem.	Cantebury Elem.	Voc-Tech A	Burncoat High	South High
M.I. Dartmouth	City View Elem.	Voc-Tech C	Chandler Elem.	Sullivan Middle
Goddard Elem.	Clark Street Elem.	Voc-Tech D	Chandler Mag. Elem.	Doherty High
Quinsigamond Elem.	Colombus Park	Worc. East Middle	Elm Park Elem.	Burncoat High
Union Hill Elem.	Comprehensive Skills		Flagg Street Elem.	School Shop
University Park	DAB		Harlow Elem.	Adult Learn. Center
Vernon Hill	Fanning Building		Heard Street Elem.	
	Gates Lane School		Jacob Hiatt Magnet	
	Grafton St. Elem.		Lincoln Street Elem.	
	Lakeview Elem.		May Street Elem.	
	Nelson Place Elem.		McGrath Elementary	
	Norrback Elem.		Midland Elem.	
	Parent Info Center		Mill Swan Elem.	
	Quinsigamond Elem.		New Ludlow Elem.	
	Rice Square Elem.		Quinsigamond Elem.	

Roosevelt Elem. Tatnuck Elem. Throndyke Elem. West Tatnuck Elem. Worc. Arts Magnet		Wawecus Elem.

The school network administrators have reported problems with the system that are directly related to the very limited bandwidth. The first is severe network congestion when rolling out updates and patches for software, the most prominent example being Microsoft Windows. Windows needs updates on average weekly, and each of these updates can range from half a megabyte to upwards of 250 megabytes for the last service pack. The school department starts the patching process after the business day, and due to the slow network, the patching process can extend into the next business day. This results in a nearly unusable network for the schools during that day. Due to this slowdown, the network administrators often wait to deploy patches until weekends or other off times, which can have an impact on network security as it leaves known system exploits available to worms and viruses for a longer period of time. (Tim Williams, Personal Communication, February 9th, 2005)

The low bandwidth also hinders the ability of administrators to log into computers remotely over the network and diagnose problems due to network congestion which causes unacceptable lag in the connection between the administrator and the client computer to the point that remote assistance becomes impossible. It becomes more efficient to actually have the computer physically brought in, which in itself is very time consuming.

The last issue with the school network is problems supporting newer software. More and more educational applications are being designed to be run in a client/server environment. This is where most of the data for the program is stored on a server, and distributed to individual computers over the network as the computers request it. The already overloaded network cannot handle applications like this, so they are forced to rely on only client-side applications, which require installation of all the program data on every computer that wants to run the computer. This takes more time in initial setup of the machines, and also consumes more hard drive space, which is a very limited resource on older machines (Bill May, Personal Communication, February 9th, 2005).

The school network also has to be built around considerations for a program called E-rate. This program, officially called the Universal Service Program is administered by the Schools and Libraries Division of the Universal Service Administrative Company. This not-for-profit corporation was appointed by the Federal Communications Commission to ensure that the benefits of telecommunications services reach students and communities across the country (Universal, 2002). Currently, E-rate uses a funding formula that counts the number of students in a district, and uses the percentage of those eligible for school lunch assistance to determine poverty levels. The poverty level is plugged into a matrix, and a discount percentage is calculated.

Worcester Public Schools qualified for a 75% discount in internet and telecommunications services in the 2004 year. The E-rate program provided the Worcester School Department with $61,102.08 in funding for internet access, which includes needed hardware and other miscellaneous costs associated with network administration, as well as funding the point-to-point T1 lines. The School Department also received $193,500 for telecommunications services, which pays for most of the School Department’s portion of the Centrex phone system bill (Universal, 2005).

4.2) Voice

Prior to Parks and Cemeteries acquiring the responsibility of managing the citywide phone system in the early 1990s, the network was in disarray. Disparate companies comprised the city phone network, and many of them utilized proprietary systems. This made repair and maintenance a hassle, and also decreased the useful life of the telephone network, as the hardware could not be used with other providers. Much of the time since this acquisition has been spent in “damage control,” eliminating the holdover proprietary systems and bringing the entire network of city buildings under a single phone contract (R. Antonelli, personal communication, February 1, 2005).

The City of Worcester currently has a contract with Lightship Telecom to provide centralized, non-proprietary phone services. This agreement, which was signed in January 2005, has a binding duration of three years, with the option to extend to a maximum of five years, pending the approval of the City Council. As stated in the City of Worcester’s Request For Proposal (RFP), Lightship must “provide Centrex or Centrex-like services for the City of Worcester” in accordance with specific requirements (Orrell, 2004).

Central office exchange service (Centrex) is a system in which up-to-date phone facilities at a phone company's central office are offered to business users so that they don't need to purchase their own facilities. The Centrex service effectively partitions part of its own centralized capabilities among its business customers. The customer is spared the expense of having to keep up with fast-moving technology changes and the phone company has a new set of services to sell (Abrahams, 2003).

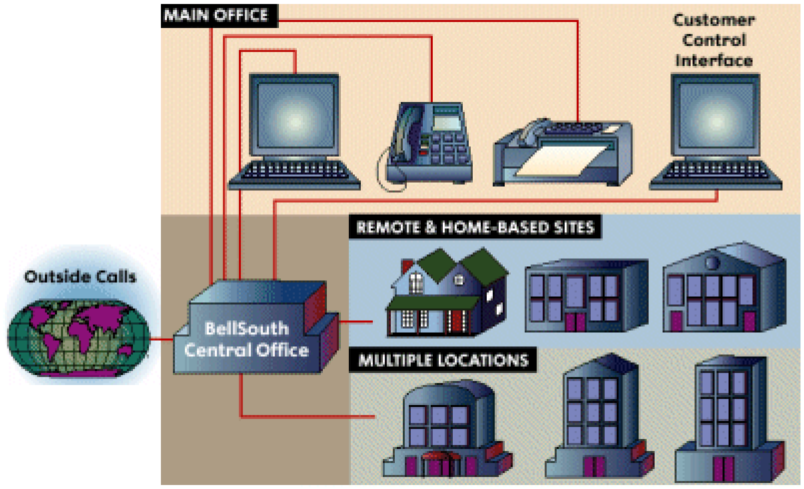

Figure 12: A Centrex system
Source: www.bellsouth.com

Under the terms of the agreement, Lightship is providing 1,884 phone lines to the City, 1770 analog and 114 digital phone lines. Of these analog lines, 882 (49.8%) are used by the school system alone (Orrell, 2004). Last fiscal year, a similar system cost the city approximately 400,000 dollars (R. Antonelli, personal communication, February 1, 2005). While this Centrex system is far more efficient and cost-effective than the fractured system that was in place before the early nineties, there is still room for improvement.

4.2.1 Cellular Telephones

Currently, every department is responsible to procure their own cell phones for employee use. As a result, nearly every company from Cingular to Nextel does business with the various departments of the City. This lack of a unified business front allows these cell phone providers to charge each department individually, costing the city increasing amounts of money each year (R. Antonelli, personal communication, February 1, 2005). With the advent of VoIP enabled cell phones, it will become much easier for the city to centralize cell phone usage (WITSA, 2004). The government could potentially eliminate the need for each department to seek individual cell phone contracts by issuing Worcester city network enabled VoIP cell phones to each department.

4.3) Video

The City of Worcester is currently in a contract with Charter Communications to provide the city with cable service. As the cable carrier in the area, Charter also provides the City with station bandwidth for public access television. Three channels are currently provided: a government channel, a school channel, and a public access channel (Cable Advisory Committee Meeting, 2005). Many of the government buildings are wired for cable connectivity, as are the newer schools. In the school environment, the incoming Charter cable signal is modulated by network administrators to only show certain channels, and to allow the school to broadcast its own content over the in-building cable.

4.4) Legal Issues

Research was done into current legal struggles of multiple telecommunications providers that were seen as possible alternatives to charter. During the course of this research, it became apparent that telecom providers are currently involved in lawsuits against municipalities that have started their own telecommunication systems. The legal landscape of telecommunications is an unsure environment at this point in time.

4.4.1 Lawsuits Against Telecommunications Companies

Research into the current legal status of several major telecommunications carriers was conducted. The research originally included three telecommunication providers: Verizon, Comcast, and RCN. Upon further investigation, RCN was found to have gone bankrupt (Strahinich, 2005), and is obviously not a viable choice.

Comcast had two major lawsuits filed against them in 2004. In May of 2004, a dispute between the city of Palo Alto and Comcast moved to the courts after Comcast failed to create the fiber network that it promised in 2000 (Palo Alto, 2004). The two parties had agreed that Comcast would upgrade the city's coaxial copper cabling to a complete fiber network. This lawsuit is very pertinent to Worcester, as the current network is in the same condition as Palo Alto's used to be, and the City is looking to upgrade from copper coaxial to a fiber network. Also, in San Jose a judge dismissed a suit filed by Comcast against the city for allegedly forcing the company to build an expensive network in return for the right to operate in the city (Gonzales, 2004). Research of Verizon did not uncover any similar legal suits.

4.4.2 Telecommunications Lawsuits Against Cities

Many cities have begun building their own telecommunications infrastructure. This investment is seen as essential to staying competitive with other cities and to pleasing new and existing businesses, as well as streamlining city government functions.

However, telecommunications providers are fighting municipally sponsored networks. For instance, in Tallahassee there is a bill being proposed that would limit the network services offered by governments (Scott, 2005). The current bill would stop governments that are in the communications business from gaining new customers until a solution is found. There are already bills in 14 other states that have the potential to restrict municipalities from creating their own networks (Free Press, 2005). The core issue is that the telecommunication companies do not like the idea of competing with the government, since the government uses public funds to build their infrastructure and can offer lower prices. These legal struggles have been occurring since 2001, when Bristol, Virginia had a suit overturned that restricted them from creating a public network (Wigfield, 2001). Since then, Virginia has turned into a state that has legal barriers against community internet (Free Press, 2005). The turbulent legal state of municipal networks makes us hesitant to recommend a city-owned network due to possible legal challenges.

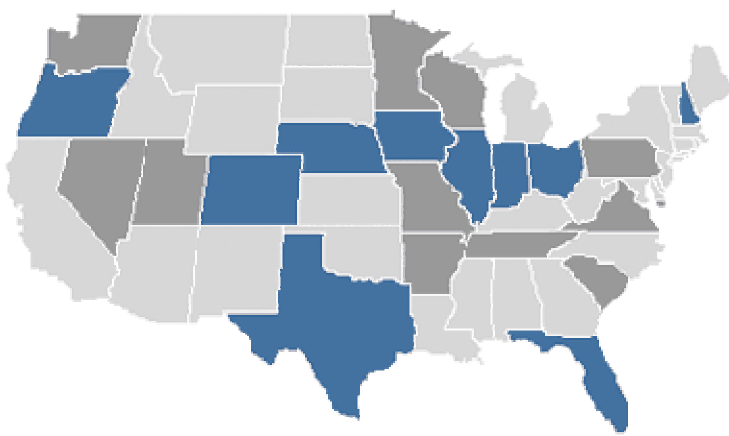

Figure 13: Public Network Regulation
Dark Gray = States with legal barriers to Community Internet
Blue = States with pending anti-municipal broadband legislation
Source: (Free Press, 2005)

5.0) Conclusions

With the wealth of available telecommunications technologies available, careful consideration must go into any decision. As with planning any type of large-scale solution, thought must be given to the financial and political environment of the target community. While a high-end solution allows for maximum future expandability, it is extremely expensive and its current usability is often limited by present technologies. On the other extreme, a low-end solution that requires little in the way of initial capital expenditure will impede business, as this type of telecommunications network is often insufficient to the task of supporting the day-to-day operations of a modern city.

5.1) Data Solutions

A network backbone, composed of multiple fiber rings for redundancy, is the current standard in large-scale network operations (Rosamond, 2004). Such an infrastructure provides the basis for running large-scale business applications, as well as streaming video teleconferencing. Voice Over Internet Protocol is also made possible due to the increased bandwidth of a fiber backbone. Multiplexing technology would allow for multiple channels of voice, video, and data to exist on a single strand of fiber, allowing a city or business to expand their network in the future without having to physically add additional wiring (Song, 2000). Also, remote technical support becomes possible, with the higher bandwidth allowing a lesser number to support staff to administer to a large number of computers without having to travel to each site separately (W. May, personal communication, February 9, 2005). However, a fiber backbone such as the one described will either have to be leased from a third party provider such as

Charter, Verizon, or Neescom, or outright purchased by the City of Worcester. Additionally, such a system dictates that a dedicated maintenance and support staff be recruited to handle the day-to-day operations of this fiber infrastructure.

Another option is to run a single strand of fiber through the geographic area where the majority of network traffic exists. The remainder of the area outside of the strands coverage can be reached through coaxial cabling. However, such a system is inadequate to the City of Worcester's current needs, and offers no room for future expansion. In fact, this system is so inadequate, that additional T1 lines need to be purchased to supplement the existing bandwidth (C. Campbell, personal communication, February 9, 2005). The only benefit of this system is that it is already in place, thus nullifying initial equipment costs.

Once some form of fiber backbone is in place, each individual building must access this infrastructure. This can be accomplished in a number of ways. For the fastest possible connection, fiber strands can be run directly to the buildings. This will enable gigabit access to the backbone itself, and work to minimize network congestion. Fiber would have to connected to each building on the network, however, and with ninety-four buildings on the Worcester network, the costs for doing so will be high (Metallo, 2003).

A less expensive alternative would be to run copper cable to each building rather than fiber, or only run fiber to the buildings that utilize the most bandwidth. This solution, while lower in cost, would greatly restrict the network speeds to copper wired buildings. Large business applications would consume the supply of bandwidth to the copper wired buildings, and create more network congestion by limiting the flow of data from the fiber backbone (B. Borski, personal communication, January 19, 2005).

Each computer within a networked building must access the building's internal network before being routed out to the larger network. Running fiber directly to each computer is the fastest way to connect to the fiber network. Such a setup allows an unfettered pipeline directly to the fiber backbone, allowing for network access speeds in the 10 Gbps range (Intel Corp et al, 2002). This solution makes full use of fiber run to the buildings, and the fiber infrastructure as a whole. Future expansion is also made easy, due to the enormous amount of bandwidth available to individual personal computers (PCs). This solution is the most expensive one, however, as none of the networked buildings are currently wired to support this. Due to the age of some city buildings, this type of fiber optic wiring might not be easily achieved, increasing costs and making maintenance more troublesome (B. Borski, personal communication, January 19, 2005). This technology is not fully tested for or utilized by desktop computer at this point, but it is a possible solution for the future.

A more cost effective alternative is to run Category 6 (Cat6) wiring within each building. Most city buildings are currently wired with Category 3 (Cat3) Ethernet cable. It would be easier to simply re-run Cat6 through the existing paths left by the Cat3 cable than wire the building with fiber optics. Cat6 wiring itself is also far cheaper than fiber optic cabling. Current Cat6 Ethernet is rated for speeds of up to 1000 Mbps, which is fast enough for any current business application, with room to grow in the future (Baddar, 2000). Cabling would still need to be run though the majority of the city buildings, but since most public school buildings are running fairly modern Category 5 wiring (100 Mbps), they would not need to be rewired to fit in a new Cat6 based infrastructure (T. Williams, personal communication, February 9, 2005).

A low cost option is to simply keep the current Cat3 wiring. While it is only rated for 10 Mbps, it can be pushed to nearly 100 Mbps with the right equipment. However, this creates instabilities within the system and can lead to data loss, so it must be monitored closely (B. Borski, personal communication, January 19, 2005). Since all city buildings are currently wired with Cat3 wiring or better, no additional funds would need to be spent. The upkeep and repair fees would still remain substantial.

5.2) Voice Solutions

Broadband networks, while mainly used for transmitting data, can also be used to carry voice as well. Voice over Internet Protocol (VoIP) is an emerging technology that allows a network to be used as a phone system (WITSA, 2004). This would allow the City to make greater use of its WAN, and cut costs by using a network that they are already paying for to complement their analog phone systems. By gradually phasing VoIP into their communications network, the number of digital and analog lines Worcester subscribes to can be reduced, decreasing the amount spent on their upkeep each year. While switching to VoIP would save money on a yearly phone contract, it would require an initial investment to purchase new phones and other necessary equipment. The City of Worcester would also be responsible for maintaining and upgrading its own equipment.

Using a combination of analog and digital phone lines is another potential solution. While a more tried and tested technology than the relatively new VoIP, the sheer amount of phone lines that the City needs to purchase quickly adds up in costs (Orrell, 2004). Since the current analog phone contract, signed January 2005 does not expire for a minimum of three years, this will give the City of Worcester time to gradually phase in a VoIP system, should they choose to do so.

Over the past decade, cell phones have become an integral part of the business world. Nowadays, not all business is conducted from the desk. The ability to be out in the field and conducting commerce as normal is crucial to any successful endeavor. Currently, several major cell phone service providers are testing VoIP cell phones, with plans to deploy them on a large-scale within the next few years. Much like standard Voice over IP phones, these cell phones will utilize existing wireless broadband networks to send and receive calls, with a standard cell phone network providing back-up in the case of network outages (ShoreTel, 2004). This will allow Worcester to centralize cell phone distribution, and cut costs drastically.

The City could also continue to use standard cell phones, either the way they currently do, or by bringing the entire city under a single contract. As with any other fast growing technology, cell phone business plan costs have risen steadily over the past few years (R. Antonelli, personal communication, February 1, 2005). Combined with the costs of distributing cell phones to a large number of employees within the city, this is a very expensive alternative.

5.3 Video Solutions

With a fiber backbone in place, streaming video becomes a viable option due to the excess of bandwidth available. With the physical network structure already in place, costs for delivering streaming video would be kept to a minimum. This opens the door to remote teleconferencing, a form of business that has become increasingly popular over the past years (B. Borski, personal communication, January 19, 2005).

The current coaxial cable system does not have the bandwidth to support streaming video. To stream good quality video media over a network, you need a minimum of 100 Kbps (Kyas et al, 2002). The current network is already congested from standard traffic, and does not possess enough bandwidth for video. The public school system currently pipes in cable television over separate lines, so as to bring the “school channel” to the classrooms (C. Campbell, February 6, 2005). If a fiber network were to be installed, multiplexing could be used to run the video over the network directly to the schools, generating further savings in cable costs.

5.4) Public versus Private Networks

While there has been talk of the City creating its own network, this would not be a cost-effective option. Fiber would either have to be purchased from an existing company, or laid by Worcester. This would require an enormous expenditure of initial capital, funds that are not currently available. Running a public network would also necessitate the creation of a department whose job it is to perform maintenance on the network itself. This department would also be responsible for monitoring the network 24-hours a day, to maintain network stability and deal with any problems that arise. In essence, the City of Worcester would have to create its own cable company (B. Borski, personal communication, January 19, 2005).

The City of Worcester is currently running on a private network, in this case, one owned and operated by Charter Communications (Moore, 1998). By leasing, Worcester sidesteps the responsibility of having to maintain the majority of the physical structure of the network. It allows the City to focus on running its own offices, rather than have to worry about the functionality of their network. By using a private network, Worcester also sidesteps the many tricky legal issues that surround municipalities that attempt to create public networks.

5.5) Delegation of Responsibilities

Currently, Information Services (IS) is in charge of the data portion of the city-wide network, while the Parks and Cemeteries department maintains the phone contract. The current telecommunications network does not possesses the capability to stream video on the scale to be useful in business applications, so there is technically no department in currently charge of this.

The current department structure could be left “as is,” maintaining the status quo. However, this system simply can not support a larger, faster and more efficient network. In order to bring the City of Worcester’s telecommunication system into the future, changes must be made to the supporting departments.

An optimal solution would be to have one department in charge of all aspects of telecommunications, with sub-departments for each specific branch (data, voice, and video). Within that department, Information Services would oversee data and the network, and possibly be granted more manpower to meet the needs the additional services that a fiber network could support. The phone system would have a sub-department created to manage it. The video department would be responsible for maintaining the cable contract, as well as pushing advances in streaming video. This would create a department superstructure that would work together to effectively deal with any problems that might arise.   Multiple cities already use a similar structure, including Tulsa, Oklahoma (City of Tulsa, 2000) and Yakima, Washington (City of Yakima, 2005).

5.6) Final Recommendations

It is recommended that the City of Worcester secure access to multiple fiber rings through a private third-party. These fiber rings should be capable of supporting DWDM functions, and have multiple rings per route for network reliability. Each building should be connected to this backbone via fiber strands to each building All city buildings utilizing internal wiring of Category 3 or less should be reconfigured to accept Category 6e Ethernet, or the wireless equivalent where wires are not possible or cost-efficient. The three year contract with Lightship provides a perfect opportunity to spread the cost of VoIP technology over multiple years, so that when he lightship contract expires, Voice over IP services can be implemented. The City should also monitor the status of the VoIP cell phone technology so that it can be implemented when ready for widespread use. Making do with anything less than these technologies is just a “stop-gap” measure, and will necessitate yet another upgrade in the near future.

5.7) Project Extension

While many hours of research went into this report, there were several areas that fell outside of the scope of this project. In order to effectively phase Voice over IP in over the three to five year life of the current Centrex phone contract, a detailed Voice Technology Plan is needed. This group does not have the professional knowledge to supply one. Additionally, no members of this group are considered professionals in the field of network technologies. Therefore, it is advisable for the City of Worcester to acquire the services of a professional knowledgeable in new network technologies, and consult with them on the feasibility of the recommended network technologies.

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<u>**Appendix A: Task Chart**</u>