

TELEMENTAL HEALTH: IMPACT OF NETWORK IMPAIRMENTS ON INTERNET-BASED DEPRESSION
COUNSELING

A Major Qualifying Project

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Justin Odom

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Approved:

Professor Eleanor Loiacono, Advisor

Professor Bengisu Tulu, Advisor

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Abstract

The purpose of this study is to investigate the technical feasibility of deploying a telemental health depression evaluation over the Internet. The paper presents a series of network scenarios that might commonly be encountered on the Internet and describes exactly how telemental health consultations and most importantly the users may be affected by these scenarios. Finally this study presents experimental results on the user's evaluation of audio and video quality under different levels of network impairments and provides recommendations based off those results.

Authorship

This document and research was conducted and written solely by Justin Odom. The contents was reviewed and edited by Professor Eleanor Loiacono and Professor Bengisu Tulu, but all substantive work was that of Justin Odom.

Executive Summary

Providing reliable healthcare to remote locations has always been a difficult task. While there are some conditions that require travel to a major hospital in order to remediate, there are a large number of cases that go unanswered simply due to the fact that it is not feasible to travel hundreds of miles away to these major hospitals. An excellent example of this is an issue with mental health. In a situation where there is a patient seeing a counselor in the same room, why can't that room be brought into the virtual world? Telemental health aims to address this problem by providing a Voice/Video over IP call via the Internet.

The problem addressed by this report is a simple but common one. Is it technically feasible to deploy a telemental health solution over a commodity Internet link that is available to a small business? If so, what are the factors that can impact it? It is crucial to know the limitations of this technology as well as to know what correlations exist between audio and video quality and specific network factors. This information is imperative when deploying a solution that involves a person's health.

The issue that this research aims to identify is the effect of various network impairments on a Voice/Video over IP call. For a set of network impairment scenarios, subjective quality evaluations were performed by the test volunteers who were mocking a depression consultation session.

First to gather the information I needed to accurately design a telemental health solution, I had to first gain a better understanding of telemental health. I found several articles on the topic that provided a great number of answers. I had to define, what exactly I was going to be testing, what the common problems were, and what the absolute requirements of the solution were.

In order to provide accurate testing and evaluation, A testbed designed and built simulated two endpoints. One of these endpoints was a major hospital; the other endpoint was a rural clinic. This testbed allowed me to fully manipulate the traffic in between these two points in such a way that I could mimic conditions that might be seen on the Public Internet. As the rural clinic would be connected to the Public Internet and not a leased line, knowing how these impairments would impact the solution was critical.

Five counselors for the hospital side and 10 patients for the rural clinic side were recruited. I then performed a series of experiments where the counselors would ask the patients a series of questions. For each question that was asked, I simulated a different scenario of network impairment on the "Internet" between the two sites. The volunteers were then asked to fill out an evaluation sheet for each question rating their opinions of the audio and video quality.

I chose to gather and use subjective data for a couple of reasons. First, I feel that subjective data provided a more realistic view of the quality. Quality is not an objective measure, we can't simply just say a 3 on a scale of 5 will appease everyone, some people might see that as excellent, others might see it as not so good. In order to gain the most realistic usage data possible, I chose to utilize subjective collection methods. The second reason was that there is no accurate way to measure both audio and video quality on the solution I was using as a separate state. Due to this, the choice to use subjective data was unavoidable.

First, there was a significant positive correlation between audio quality and video quality. This means that as the audio quality moved in one direction, as did the video quality in the same direction. Even though there was a negative correlation between audio quality and jitter, drop, delay values, only the correlation between audio quality and jitter was consistently significant. On the other hand, there was a consistently significant negative correlation between video quality and all three impairment factors. This illustrates that for audio quality, drop and delay did not have a drastic effect on the quality.

Jitter, which is the variation of delay, had the most visible quality, most likely due to the irregularity of quality that was produced in the call. Video quality was consistently significantly affected by drop, delay, and jitter. This is most likely due to the test subjects comparing the video showing on the screen to the audio they are hearing. If a person is speaking on video but the audio is greatly out of sync, that is obviously a major quality issue. The same logic can be applied to drop and jitter in video, if large portions of the video stream are missing or incorrectly represented, subjects are more likely to judge at a lower quality.

There was also a noticeable variation on the location of the Call Manager and audio quality. Subjects at the hospital site had a much higher rating of audio quality than subjects at the clinic site. This is most likely due to the fact that the hospital site had no delay in reaching the Call Manager, and the clinic site had the network impairments implemented by the NISTNet affecting it.

I would argue that designing and implementing a telemental health solution between a hospital and rural clinic over the internet is a technically feasible option. However, there are several factors that must be taken into consideration before an effective deployment can be accomplished.

First, there should an analysis done between the network path between the hospital and clinic sites. The levels of network impairments (drop, jitter, and delay) should be measured along the path and worked to be minimized, with jitter minimization having the highest priority. This is one of the advantages of having the same ISP (Internet Service Provider) at both sites, commonly the network the data will be traveling over will be 100% owned by that ISP, making it easier to troubleshoot problems and reduce issues as they can all be accomplished through a single entity. In addition to minimizing network impairments, it is also crucial deploy QoS (Quality of Service) wherever possible in the network. This will ensure that Voice/Video data gets a higher priority than other data. This will help to prevent other network traffic from creating issues with the telemental health solution.

User Training is also a crucial component of deploying an effective Telemental health solution. Users should be trained on the equipment so they are accustomed to its operation and limitations and also so that realistic expectations are set. Connections over the public Internet are not 100% perfect; therefore users should be aware of this to be able to respond accordingly.

Providing that network impairments can be minimized, a telemental healthcare solution will make an excellent alternative to physical, in person healthcare to those who are comfortable, or not able to travel.

1. Introduction

The population of the world is diverse and spread out. Some people choose to live in major cities, others in the suburbs, and some choose to live far away from major developments in rural areas. This presents several important issues that must be addressed in the provisioning and delivery of services. One of these services is the delivery of healthcare.

The stream of revenue for the healthcare industry (hospitals and doctor's offices) is greater in urban areas than in suburban and rural areas.ⁱⁱ For this reason, usually hospitals located in major cities are able to attract the best doctors and other employees as well as have the most up to date and modern equipment. While this may suffice for people in suburban areas that can easily travel to a city, it provides a show stopping issue for people who choose to live in rural areas. Sometimes there may not be a facility or doctor capable of diagnosing a patients issue for hundreds of miles. A solution is required for clinics and facilities in these rural areas to have easy access to experts that for the most part, work in a major hospital. The answer to that problem is telemedicine.

Telemedicine is a method of providing healthcare to remote sites without having to travel and waste time and resources. It is defined by the American Telemedicine Association as "the use of medical information exchanged from one site to another via electronic communications to improve patients' health status."ⁱⁱⁱ A telemedicine session can take place over the Internet. It can be between any group of parties, such as an expert doctor at a major hospital communicating with the staff and a patient of a rural clinic hundreds or thousands of miles away. It allows the patient at the rural clinic to receive the same care that they would if they were physically present at the hospital in the major city. Telemedicine is not only useful for connecting hospitals with remote sites, but also providing a better quality of care to patients. There are several mental conditions which can make a patient very uncomfortable with leaving their homes. One example of this condition is agoraphobia. This condition causes people to fear public places or any place they might have a panic attack.^{iv} Telemedicine allows a doctor to make a house call to a patient's home, set up communications equipment and provide remote healthcare support via a hospital. The ability to provide healthcare in any place at any time is a revolutionary advancement in patient care.

As with all technologies, there are issues surrounding its use. With telemedicine, one big issue is network connections. The audio/video stream must be on a stable network connection with levels of drop, delay, and jitter within acceptable levels. If any one of these anomalies in network traffic is above an acceptable amount, there will be effects in the audio video stream. These effects can range from a few distorted pieces of the image, image delay, audio stutter, or complete loss of either stream or both. For these reasons it is imperative to know the levels that are tolerable by the application and insure that that the ceiling is not reached.^v

The intended goal of this project is to determine the technical feasibility of deploying a telemental healthcare solution of common network links available to consumers and small businesses. Within this project, a series of tests will be run utilizing several different types of network anomalies; such as delay, jitter, and drop. Within each of the anomalies, the upper boundaries will be discovered at which point the telemental health solution becomes ineffective.

For example, a major hospital might have several experts residing on their main campus. These experts are available to patients within the hospital and surrounding areas. However, there may be several rural clinics which may not be able to send patients to the major hospital and travel is out of the question. These clinics may connect to the Internet via standard small business connections such as a business grade cable modem or DSL. These rural clinics would then connect into the major hospital for a telemental health session. Utilizing Voice/Video over IP technologies, the patient residing at the rural

clinic will be able to have a face-to-face interaction with the expert at the hospital. This will provide an experience for the patient and doctor that would have in most situations not been possible due to cost and travel restrictions. For this type of situation, it is imperative to know the boundaries in which a telemental health solution can remain effective.

The goal of this paper is to provide an effective guide to any person interested in telemental health solutions and the feasibility of deploying them over the Internet. This will be accomplished by first providing some background information on the topic; which includes some literature on telemental health, voice and video over IP, network emulation, and signaling protocols. I will then detail information on the equipment that makes up the testbed. The final part of the report will be the methodology and conclusion section. In these sections will be all the required steps and information to reliably reproduce this test as well as the ideal conditions in which a telemental health solution can be effectively deployed.

2. Project Objectives

The purpose of this project is twofold. The first objective is to discover the technical feasibility of which a telemental health solution can be deployed over the public Internet. The second objective of this project is to analyze which network variables impact the quality of the telemental health solution the most and provide recommendations on what can be done to limit the impact of these variables.

3. Background

3.1 Telemental Health

3.1.1 Introduction

One of the greatest challenges in providing quality healthcare is ensuring that all people near and far have reliable, consistent access to medical care. One of the areas in which this has proved to be exceedingly difficult is mental healthcare. Unlike other areas of healthcare where a doctor can be sent a medical chart, x-ray, or other information for review either by e-mail, fax, or regular mail; a mental health expert must have a personal connection with their patient.^{vi} It is often the case that a successful diagnosis of a condition affecting a mental health patient cannot be made unless the doctor and patient share this connection, for this reason an audio only connection will not work. In order for the diagnostic process to be truly effective, an acceptable audio/video stream must be used. This is where telemental healthcare utilizing Voice/Video over IP technologies over the Internet comes into play.

3.1.2 Advantages

There are many different instances in which telemental healthcare diagnostic tools prove to be useful. One of the main reasons is distance. People live all over the place, some in major cities, others in rural areas, for the most part; people in these rural areas do not have easy access to healthcare experts as the local clinic near them may have limited resources. Another common situation where the technology proves itself useful is when diagnostics need to be made in non-standard locations, such as a patient's home, nursing homes, schools, ships at sea, and prisons.^{vii}

These technologies are not only beneficial to patients but also to people who are practicing their mental health diagnostic techniques, such as a medical student. This technology allows students to be supervised by people who are more experienced in the field, in a virtual classroom setup. This practice allows the students to be trained by the very best available doctors in the field. Standard distance learning was almost always deployed via a one-way video stream; the instructor would record a lecture into a video camera, which would then be transmitted to students. The students would then be able to either submit questions through some type of chat interface, or through e-mail. Through the use two-way telecommunications technology, the students are able to ask questions of their instructor and receive the answer and feedback in real-time.^{viii}

3.1.3 Disadvantages

One of the major bottle necks to deploying a successful implementation of a telemental health solution was the sheer cost of it. The equipment required to implement a system like this until recently, has been priced extremely high. Over the past several years, there has been a drastic reduction in the cost of equipment and many different competitors coming to market with competing Voice/Video over IP products.^{ix} This has helped to drive down the costs of deployment of a solution. This allows rural clinics to be able to afford the equipment for these solutions that might have otherwise been cost prohibitive.

Another issue that arises with making video calls over the Internet is network bandwidth. Video calls are extremely resource intensive; they require a large amount of network bandwidth to insure that an appropriate amount of data is sent in the video stream to produce detailed enough images on the other end. While the costs of large amounts of network bandwidth have dropped over the past few

years, the technology is still not available universally. Within major cities and suburbs, there is usually not an issue with locating appropriate Internet connections that will provide adequate bandwidth. In and around cities, healthcare organizations are usually able to obtain a leased private line, consumer broadband (cable or DSL) or any other readily available access method. In rural areas, the options are much more limited. There are many instances where there is simply not a high speed solution readily available far away from a major metropolitan area. Sometimes the only solutions available in these locations are dial up or satellite. Dial up connections are virtually unusable for a video call solution as they only provide up to 56kbps. It is recommended that video calls have at least 460kbps of bandwidth (including overhead).^x There is simply not enough bandwidth in these lines to be able to maintain a consistence voice and data stream. Satellite, although it has a somewhat higher latency than cable or DSL, has the bandwidth necessary to maintain a video call. This makes video calls over a satellite internet connection feasible; there just may be a slight delay between the users.

Finding an appropriate connection to the Internet that will provide an appropriate level of bandwidth and latency is crucial to deploying a successful telemental health solution utilizing Voice and Video over the Internet.

3.2 Voice/Video over IP

3.2.1 Introduction

The ability to transmit voice and video over the Internet has completely revolutionized the communications industry. Before the invention of Voice/Video over IP (VVoIP) all calls were forced to travel over the PSTN (Public Switched Telephone Network). Healthcare organizations typically had a PBX (Public Branch Exchange) within their buildings. This allowed them to have a large amount of phones (often one in each room) without having a large number of extensions. The PBX allows someone to dial into it and then dial the extension of the room or location they are trying to reach. The PBX would be connected to the outside world via a land line connected to the PSTN. VVoIP changed the requirements of this setup; the connections were no longer limited to locations with land lines, but any place with an Internet connection. The inner workings are virtually transparent to the end user, as they pick up the phone, hear a dial tone, and make a call just as they always would have, but there is a great deal of activity going on behind the scenes.

3.2.2 Advantages

A main advantage of using a VVoIP solution versus a traditional land line is cost savings. For example, take a company that has offices in Boston, Massachusetts and San Jose, California. If employee A in the Boston office wished to make a call to employee B in the San Jose office using the traditional method, they would do the following:

1. Pick up the phone and dial the employees number
2. Call would then be connected to the company's PBX
3. Call would then be transferred from PBX to the Public Switched Telephone Network (PSTN)
4. Call would then connect to Telephone Branch Office
5. Call travels across the PSTN via long distance carrier (incurring charges)
6. Call would then connect to Remote Branch Office
7. Call would leave the PSTN and enter company's PBX
8. Call is delivered to employee's phone.

* Please see Figure 2.1

While this process works, it is not very flexible, requires the presence of a land line, and also incurs long distance charges via the carrier. While this may not be a huge deal for one or two calls, when there are hundreds or thousands of calls a day, the charges can greatly add up.

With VVoIP however, the call would take a different path. To the end user, the process would be almost exactly the same, the real technology lies behind the scenes. This is how the scenario would look in a VVoIP call:

1. Pick up the phone and dial the employees number
2. Call is connected to the Call Manager, this analyzes whether to route the call to the PSTN or over an IP Network
3. Call Manager directs call over the Internet to San Jose site
4. Call enters San Jose Call Manager from the Internet
5. Call Manager delivers the call to the employee's phone

*Please see Figure 2.2

This allows the company to save on long distance charges that may accrue if they were using the PSTN method of transmission. VVoIP also allows the company to perform a better level of tuning on their calls with a much finer grain of control.

Figure 2.1: Traditional Telephony Call

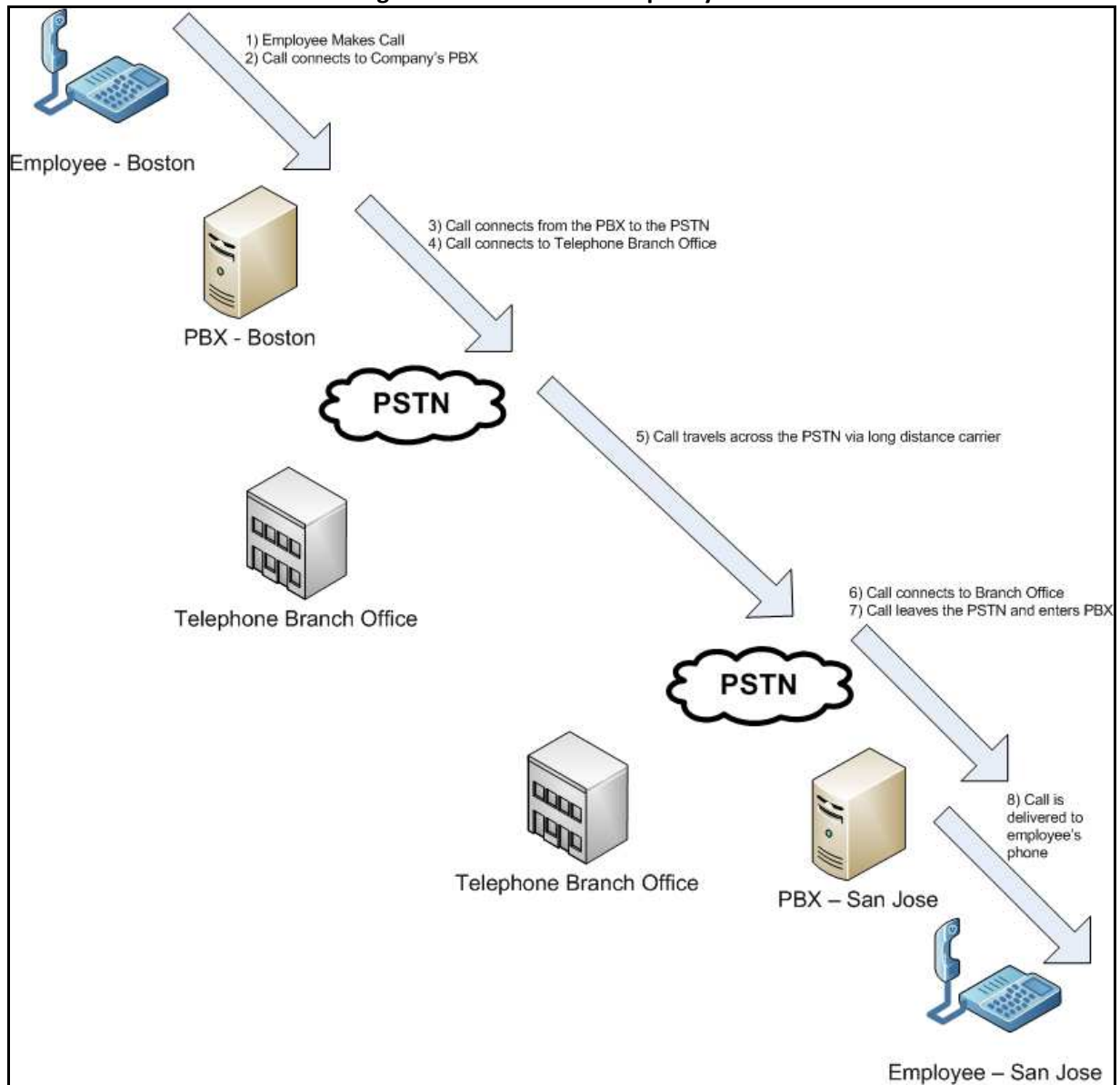
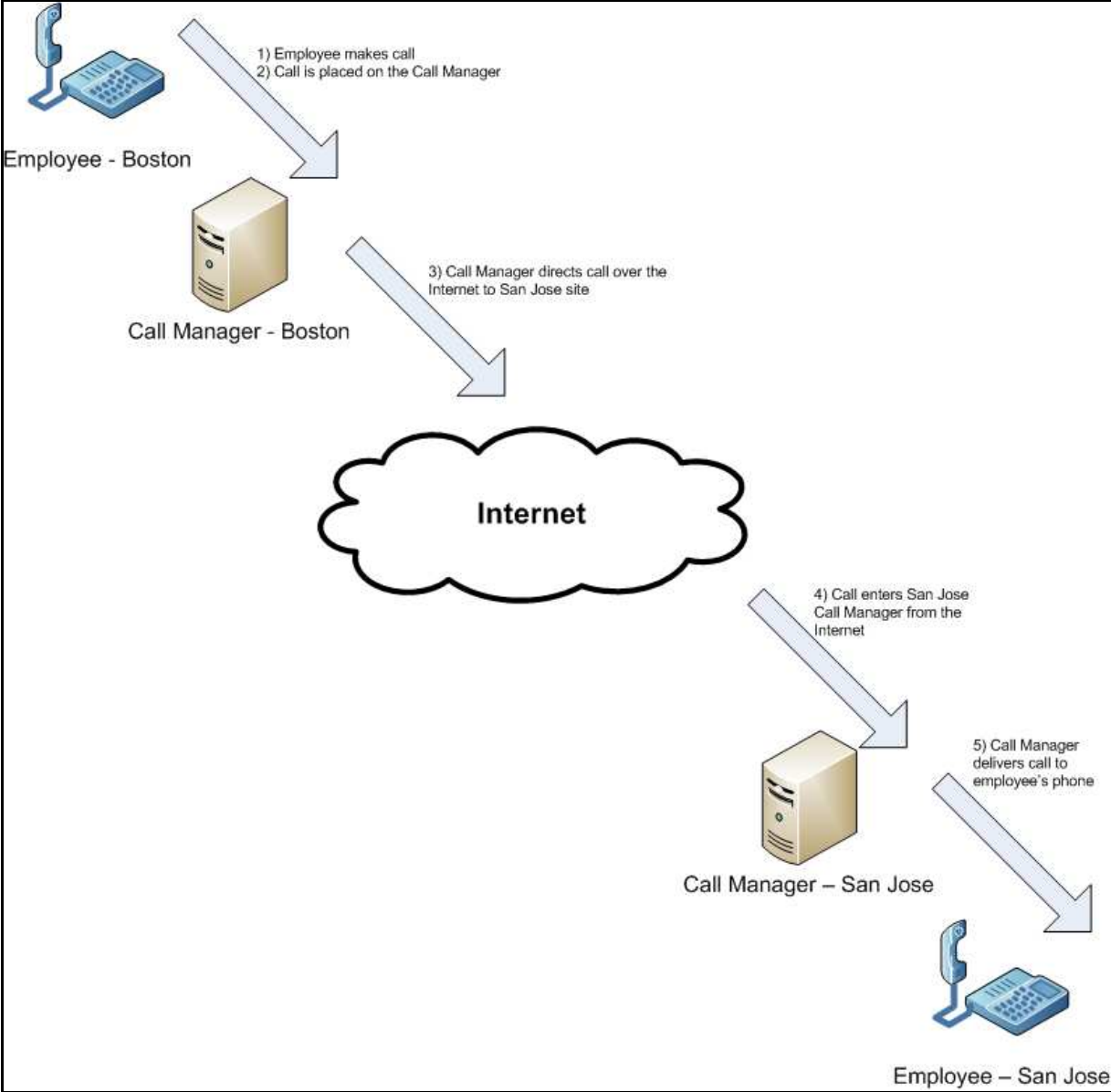


Figure 2.2: IP Telephony Call



3.2.3 Disadvantages

While there are many positives to implementing VVoIP, there are also several issues that must be taken into account. One of the main issues is presence, with a standard telephone line, the location is fixed, the local telecommunications company knows where this is and if someone dials 911 from that location, they know where to direct emergency support to. VVoIP makes this situation somewhat difficult. One of the benefits of VVoIP is that it allows a user to connect from anywhere in the world, transparently, as if they were in their standard location. While this provides a great level of working flexibility for users, it can prove to be a nightmare for administrators. There have been several different services to try and mitigate this problem, but none of them have come up with a concrete answer as of yet. The most reliable way is to update the phone profile on the server to the location of where the phone is going to be used; this will allow dynamic routing of 911 calls to the local support organizations.

Another possible disadvantage of a VVoIP solution is that it requires a larger amount of power to function than a traditional analog line connected to the PSTN. Traditional phones that utilize the PSTN receive a small amount of voltage over the line; this allows simple phones to be powered using the phone connection instead of a separate power source. This can prove extremely useful within power outages, snow storms, or other issues where power may be affected. Enterprise grade VVoIP deployments however depend on a large amount of network equipment and in some cases Power over Ethernet (the phones are powered directly from the network switches, eliminating the need for a separate power source). If any of the equipment drops offline due to power issues, communications will not be functional within the site.^{xi}

As stated, the quality of VVoIP solutions is closely related to the quality of the network link and the network infrastructure as a whole. If at any point in the path a problem is encountered, this can impact the entire stream. Therefore, it is important to know the limitations of the protocol you are using and exactly what the boundaries are. Network Emulation is an excellent tool to discover these limitations.

3.3 Network Emulation

Network emulation is the practice of affecting network in such a way to create non-ideal scenarios in order to simulate possible conditions that one might run into on a public network. Network emulators are capable of running on a variety of platforms, including PC's and routers. They are capable of affecting network bandwidth, packet loss, delay, jitter, packet rearrangement, as well as many other types of anomalies. Using these many different types of traffic impairments, network engineers are able to simulate various scenarios that they may run into on public networks. This allows them to see how each type of situation will impact the operation of network based software and to try to figure out ways to work around situations that are created. A network emulator sits in line between two network points and modifies traffic as it passes through. It acts in bridge mode, so the two endpoints are unaware that there is anything in between them.^{xii}

One of the most popular pieces of network emulation software is NIST Net. This software loads onto a Linux server and integrates directly with the Linux Kernel. It is capable of turning a standard PC into a router to emulate almost any type of network traffic conditions such as congestion, loss, and bandwidth limitation.^{xiii}

Another piece of common network emulation software is Pagent. This software is capable of almost all types of network emulation that you may find in other emulation products (such as drop, jitter, delay, and bandwidth limitation). The feature that sets this software apart from all the others is its ability to be loaded onto almost any Cisco router. This allows an extremely easy deployment into an existing infrastructure instead of having to setup a PC and run additional network cables between the

equipment. The Pagent software is deployed as an IOS (Internetwork Operating System) image, the standard Operating System that is in place on nearly all Cisco equipment. There is also a version of Pagent that can be installed on a POSIX compatible system in lieu of a hardware router.

3.4 Protocols

3.4.1 Skinny Client Control Protocol (SCCP)

SCCP is a proprietary protocol of Cisco Systems. There are several 3rd party companies that are licensed to use the technology, but generally its use is limited to Cisco only systems. SCCP enables communication between two endpoints via the use of a Call Manager. When an endpoint comes online, it will register itself with a Call Manager, typically on port 2000. This connection will remain active for as long as the endpoint is on the network and as long as the Call Manager stays active. While the two skinny endpoints will be able to communicate with each other (if configured in this manner) all call signaling passes through the Call Manager, such as initiating the call, terminating the call and so on.^{xiv}

3.4.2 Session Initiated Protocol (SIP)

While SCCP is a protocol that is mainly restricted to Cisco equipment, SIP is an open protocol. SIP has been implemented by many different vendors of Voice over IP solutions. Like SCCP, SIP is responsible for call signaling between two endpoints. SIP however allows different endpoints to communicate and interoperate transparently. Also, SIP allows for direct communication between endpoints. A user is able to specify an endpoint by its IP address and communicate with that station directly without the requirement of a Call Manager in between. This allows SIP to be extremely flexible on where and how it is deployed.^{xv}

4. Methodology

4.1 Introduction

The purpose of this experimental setup is to provide a reliable means for testing the impact of various anomalies one might encounter when performing a Voice/Video over IP call on the Internet to conduct telemedicine. A test bed is designed to replicate the basic setup of two telemedicine sites, in this case, a major hospital and a rural clinic. As can be seen in Figure 4.1, for the most part, there is an identical setup at each site. Each site has a PC with a webcam attached to it. This PC is running the CUVA (Cisco Unified Video Advantage) software, as shown in figure 4.2; this allows tagging of the video stream to the same Voice VLAN that IP telephony traffic travels over. The PC is connected into the PC port on the Cisco 7970 IP Phone; this allows for the appropriate VLAN tagging to take place and is required for the video stream to work properly. The hospital site, in addition to all the equipment the clinic has, also hosts a Cisco Unified Call Manager installed on its network. The Call Manager is responsible for coordinating the calls between the two sites. The Call Manager reports information on what features are available to the users as well as what features are available by phone model. The Call Manager also keeps voice call statistics so one can easily see the audio quality of calls and see if there are network issues. The most important piece of the test bed however is the server in between both sites running NISTNet network emulation software. This server acts as a router between the Hospital and Rural sites. This router is capable of accurately reproducing many common network anomalies one might see on a computer network. Pictures of the testbed can be seen in Figures 4.3 – 4.5.

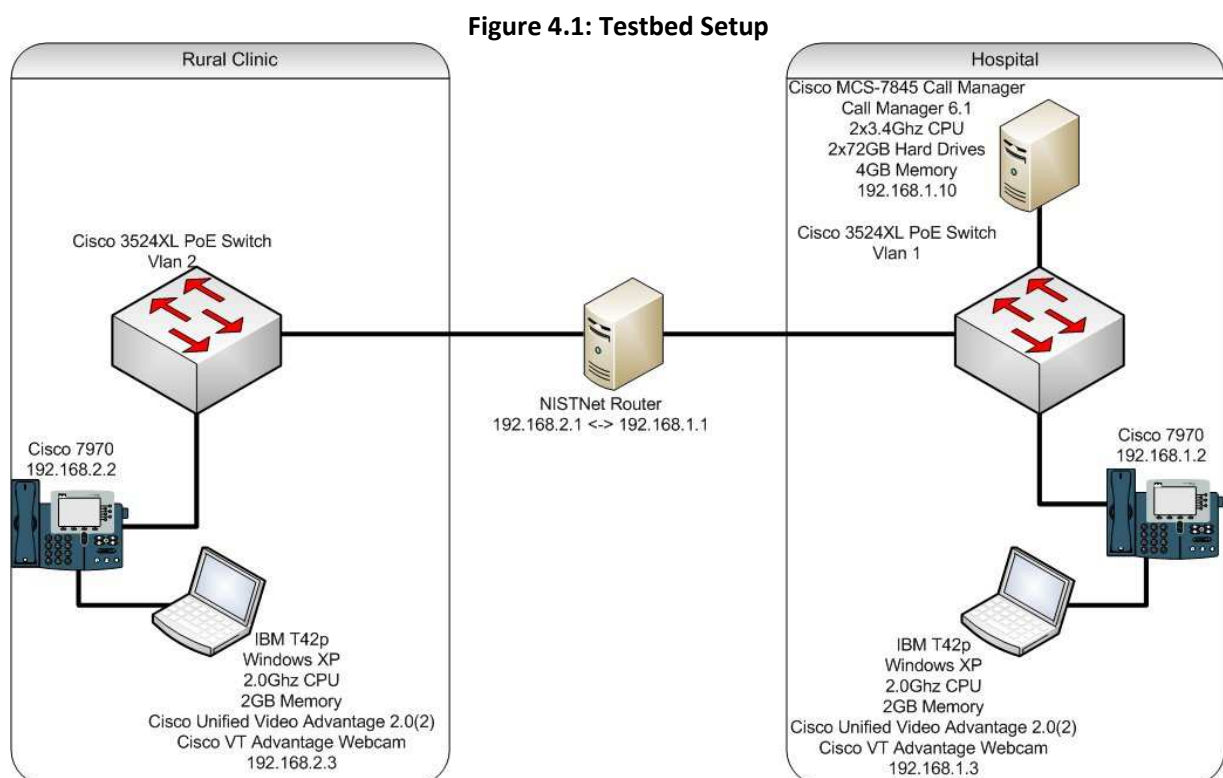


Figure 4.2: CUVA Software during call



Figure 4.4: Patient Station



Figure 4.4: Counselor Station



Figure 4.5: NIST Net Router



4.2 Equipment Configurations on the Testbed

There are several different configurations that needed to be made on the network switch in order to get the testbed functioning as intended. Certain ports have to be configured in a specific manner on the network switch. This will ensure the best possible experience to the user and also ensure that all the software features are fully operational. The details of the configuration can be found below.

- Hospital Router Port – Interface fa0/1
 - no spanning-tree portfast
 - switchport mode access
 - switchport access vlan 1
- Rural Clinic Router Port – Interface fa0/13
 - no spanning-tree portfast
 - switchport mode access
 - switchport access vlan 2
- Hospital IP Phone ports - Interface fa0/3
 - spanning-tree portfast
 - switchport mode access
 - switchport access vlan 1
 - switch voice vlan 1
- Hospital IP Phone ports - Interface fa0/14
 - spanning-tree portfast
 - switchport mode access
 - switchport access vlan 2
 - switch voice vlan 2
- Hospital Call Manager port – Interface fa0/2
 - spanning-tree portfast
 - switchport mode access
 - switchport access vlan 1

4.3 Testing

Testing results for this experiment were obtained in a subjective manner. The reasoning for this is that although there are tools available to measure the quality of a video transmission between two endpoints, they are not able to measure the call quality on a live IP Voice/Video call.

The feedback and testing of the network variables were designed to be an interactive experience for the users. There were two parties involved, one at each site that made test calls to one another. These test calls were to simulate a mock telemental health diagnostic. The party at the hospital first started by asking a series of questions to the patient at the rural clinic the patient at the rural clinic then responded with an answer as if it were an actual telemental health diagnostic call. Throughout these dialogue exchanges, after each question, network variables were adjusted. There was an evaluation sheet that both participants had a copy of on each side of the setup. This provided the participants the opportunity to rate their experience with the audio and video quality after each network anomaly was introduced. The decision of when to present a user with evaluation materials was not an easy one to make; however, I feel that the end users provided a much more accurate description of their experience because they were asked the questions immediately after they experienced the call with a particular variable. This helped to avoid an issue in which the users might only remember the worst parts of the scenario and creating a jaded view of the entire experiment.

4.3.1 Testing Variables

Constant

- **Bandwidth** – Set at 3mbps.
 - The bandwidth was set at 3mbps to represent the average Internet connection speed that is available to a majority of the users around the country.^{xvi}

Variables

The variables being tested were Drop, Jitter, and Delay. Drop is the non completion of packets through the network. Packets are sent from one end and not received at the other. Jitter is the variation in the delay that the packet is received at the receiving end. Delay is the amount of time it takes a packet to reach the receiving end once sent. The variables that were selected (as seen in Table 4.1) are variables in which a Cisco Voice/Video call is known to work. Level 3 represents the max variable for each factor in which the call is expected to become unusable.

Table 4.1: Network Variables Levels that will be tested

Factor	Baseline	Level 1	Level 2	Level 3
Drop	0	1%	3%	5%
Delay	0	50ms	100ms	150ms
Jitter	0	50ms	100ms	150ms

4.3.2 Testing Scenario

Testing in this experiment was carried out by creating a mock mental health diagnosis between a patient at a rural clinic and a counselor at a hospital. More specifically, this was a depression diagnosis utilizing the Burns 15 Question Depression Checklist^{xvii}, illustrated in Figure 4.6.

Figure 4.6: Burns Depression Checklist

The Burns Depression Checklist*

Directions: After reading each symptom, write the number that best describes how you have felt during the past week.

Rating Scale

0 = not at all

1 = somewhat

2 = moderately

3 = a lot

- SADNESS:** Have you been feeling blue or "down in the dumps"?
- DISCOURAGEMENT:** Have you been feeling that the future is bleak and hopeless, that things will never change, or that problems will never be solved?
- LOW SELF-ESTEEM:** Have you been feeling inadequate or worthless?
- GUILT:** Have you been blaming yourself for your weaknesses, shortcomings or mistakes?
- INDECISIVENESS:** Have you been struggling with making decisions?
- IRRITABILITY, FRUSTRATION:** Have you been feeling resentful or angry a good deal of the time?
- LOSS OF INTEREST IN LIFE:** Have you lost interest in your career, hobbies or daily activities?
- LOSS OF INTEREST IN PEOPLE:** Have you lost interest in your friends, family and partner?
- LOSS OF MOTIVATION:** Have you needed to push yourself hard to do things? Have you been procrastinating?
- POOR SELF-IMAGE:** Have you been feeling negative about your appearance?
- APPETITE CHANGES:** Have you lost your appetite or have you been overeating or bingeing?
- SLEEP CHANGES:** Have you had difficulty falling asleep and sleeping soundly? Or conversely, have you been excessively tired and sleeping too much?
- LOSS OF LIBIDO:** Have you lost interest in sex? Are people whom you once found attractive no longer appealing to you?
- HYPOCHONDRIA:** Have you been excessively worried about your health or preoccupied with your aches and pains?
- SUICIDAL IMPULSES:** Have you thought that life is not worth living and that you would rather be dead? Have you been having suicidal fantasies or impulses or making suicide plans?

Your Score

Score:

0-4 = minimal or no depression

5-10 = borderline depression

11-15 = mild depression

16-25 = moderate depression

26-45 = severe depression

Professional help is recommended with a score over 11 points.

* created by David D. Burns, MD, author of *Feeling Good: The New Mood Therapy*

The testing was accomplished by utilizing the assistance of 5 counselors (to simulate the counselor at the hospital) and 10 student patients (to simulate the patient at the rural clinic). There are 28 different scenarios that had to be tested (27 of the variables from Levels 1,2,3 as can be seen from Table 4.1 plus the baseline which represents the case with no network impairments). Each counselor interviewed two student patients. Due to the fact that there were 15 questions that needed to be asked to each student, I had to add in two more additional baselines in order to ensure that there were enough scenarios.

Then, as can be seen from Table 4.2 I assigned each possible a scenario a number from 1 through 30.

Table 4.2: All Possible Network Scenarios

Scenario	Delay	Jitter	Drop
1	50	50	1%
2	100	50	1%
3	150	50	1%
4	50	100	1%
5	100	100	1%
6	150	100	1%
7	50	150	1%
8	100	150	1%
9	150	150	1%
10	50	50	3%
11	100	50	3%
12	150	50	3%
13	50	100	3%
14	100	100	3%
15	150	100	3%
16	50	150	3%
17	100	150	3%
18	150	150	3%
19	50	50	5%
20	100	50	5%
21	150	50	5%
22	50	100	5%
23	100	100	5%
24	150	100	5%
25	50	150	5%
26	100	150	5%
27	150	150	5%
28	0	0	0%
29	0	0	0%
30	0	0	0%

In order to ensure that these numbers were randomly distributed for each iteration of the test, I used the following method of randomization.

I first ran the following perl script to randomize the first 28 scenarios (27 variable tests plus 1 baseline).

```
#!/usr/bin/perl
use List::Util 'shuffle';
@array =
("1\n","2\n","3\n","4\n","5\n","6\n","7\n","8\n","9\n","10\n","11\n","12\n","13\n","14\n","15\n",
"16\n","17\n","18\n","19\n","20\n","21\n","22\n","23\n","24\n","25\n","26\n","27\n","28\n");
@array = shuffle(@array);
print @array;
```

This script printed out a randomized list of the numbers 1 through 28 by utilizing the shuffle function in the Perl List Utilities module. I then took the results of this shuffle and split them down the middle so that there were 14 scenarios for each of the 2 patients that each counselor was interviewing. Then in order to insert the two additional baselines required to reach the required 15 scenarios, I used the following perl script to randomly pick a number between two integers.

```
#!/usr/bin/perl
sub random_int_between {
    my($min, $max) = @_ ;
    return $min if $min == $max;
    ($min, $max) = ($max, $min) if $min > $max;
    return $min + int rand(1 + $max - $min);
}
print random_int_between(1,14);
print "\n";
```

I ran this script twice (once for each patient) and inserted the additional baselines at the integer points that were generated for this script. This ensured that the additional baselines would be inserted at a random point in the list. Utilizing this method, there was one patient that had two baselines in their tests and one that only had done.

I then repeated these steps 4 additional times to generate the 5 test iterations that I would need for the experiment. These results can be seen in Tables 4.3-4.7

Table 4.3: Network Scenario order for Experiment 1

Counselor#: 1								
Patient#: 1					Patient#: 2			
Scenario	Delay	Jitter	Drop		Scenario	Delay	Jitter	Drop
9	150	150	1%		20	100	150	5%
5	100	100	1%		12	150	50	3%
28	0	0	0%		11	100	50	3%
19	50	50	5%		23	100	100	5%
22	50	100	5%		21	150	50	5%
3	150	50	1%		8	100	150	1%
2	100	50	1%		25	50	150	5%
17	100	150	3%		30	0	0	0%
1	50	50	1%		24	150	100	5%
26	100	150	5%		4	50	100	1%
13	50	100	3%		15	150	100	3%
7	50	150	1%		27	150	150	5%
16	50	150	3%		6	150	100	1%
10	50	50	3%		18	150	150	3%
29	0	0	0%		14	100	100	3%

Table 4.4: Network Scenario order for Experiment 2

Counselor#: 2								
Patient#: 3					Patient#: 4			
Scenario	Delay	Jitter	Drop		Scenario	Delay	Jitter	Drop
7	50	150	1%		26	100	150	5%
25	50	150	5%		8	100	150	1%
19	50	50	5%		12	150	50	3%
10	50	50	3%		2	100	50	1%
29	0	0	0%		3	150	50	1%
28	0	0	0%		16	50	150	3%
11	100	50	3%		30	0	0	0%
20	100	50	5%		27	150	150	5%
21	150	50	5%		18	150	150	3%
15	150	100	3%		5	100	100	1%
6	150	100	1%		1	50	50	1%
23	100	100	5%		14	100	100	3%
22	50	100	5%		24	150	100	5%
4	50	100	1%		17	100	150	3%
9	150	150	1%		13	50	100	3%

Table 4.5: Network Scenario order for Experiment 3

Counselor#:3				Patient#:6			
Patient#:5				Patient#:6			
Scenario	Delay	Jitter	Drop	Scenario	Delay	Jitter	Drop
4	50	100	1%	26	100	150	5%
22	50	100	5%	17	100	150	3%
15	150	100	3%	30	0	0	0%
9	150	150	1%	1	50	50	1%
3	150	50	1%	23	100	100	5%
12	150	50	3%	14	100	100	3%
28	0	0	0%	11	100	50	3%
6	150	100	1%	13	50	100	3%
18	150	150	3%	25	50	150	5%
21	150	50	5%	8	100	150	1%
5	100	100	1%	16	50	150	3%
27	150	150	5%	7	50	150	1%
19	50	50	5%	10	50	50	3%
24	150	100	5%	2	100	50	1%
29	0	0	0%	20	100	50	5%

Table 4.6: Network Scenario order for Experiment 4

Counselor#:4				Patient#:8			
Patient#:7				Patient#:8			
Scenario	Delay	Jitter	Drop	Scenario	Delay	Jitter	Drop
25	50	150	5%	27	150	150	5%
29	0	0	0%	19	50	50	5%
1	50	50	1%	28	0	0	0%
6	150	100	1%	9	150	150	1%
8	100	150	1%	14	100	100	3%
17	100	150	3%	21	150	50	5%
16	50	150	3%	24	150	100	5%
22	50	100	5%	20	100	50	5%
2	100	50	1%	18	150	150	3%
3	150	50	1%	30	0	0	0%
23	100	100	5%	12	150	50	3%
15	150	100	3%	4	50	100	1%
11	100	50	3%	26	100	150	5%
7	50	150	1%	13	50	100	3%
10	50	50	3%	5	100	100	1%

Table 4.7: Network Scenario order for Experiment 5

Counselor#:5				Counselor#:10			
Patient#:9	Delay	Jitter	Drop	Patient#:10	Delay	Jitter	Drop
22	50	100	5%	15	150	100	3%
11	100	50	3%	14	100	100	3%
1	50	50	1%	30	0	0	0%
19	50	50	5%	17	100	150	3%
6	150	100	1%	10	50	50	3%
24	150	100	5%	5	100	100	1%
27	150	150	5%	7	50	150	1%
29	0	0	0%	26	100	150	5%
8	100	150	1%	21	150	50	5%
20	100	50	5%	18	150	150	3%
3	150	50	1%	9	150	150	1%
25	50	150	5%	23	100	100	5%
13	50	100	3%	4	50	100	1%
12	150	50	3%	2	100	50	1%
28	0	0	0%	16	50	150	3%

I created scripts that were read to both the counselors and the patients to ensure that all required information was conveyed and to avoid any possible bias during the testing. These scripts are as follows:

Patient Testing Script

- Initial Information
 - First off, I would like to thank you for taking the time out of your schedule to help me complete my MQP study.
 - The counselor will conduct a depression evaluation simulation with you. The purpose of this project is to test the impact of network effects on telemental health consultations. This is primarily a technical study; however, it requires that we gain close to real data. We need you to act as a patient in a remote site and we will bring you a counselor on the hospital side via video conferencing. You're acting as the patient. The counselor on the other side of the call will ask you 15 questions about how you are feeling. You can answer anything, but please make sure that you are role playing. Answers will not be recorded or evaluated; only the quality information provided by you and the counselor is recorded. Please answer the question with any answer that makes you comfortable, even if it is made up.
 - In front of you, you will find your patient folder, in it you will find:
 - Demographic information, age and gender
 - 15 Question Evaluation sheets.

- Scenario
 - Sit in front of the camera
 - You will initiate the call. If you are more comfortable using the handset, pick up the receiver. If you wish to use the speaker phone, use the speaker phone button. Then press the button that says “1001” Please wait for my cue.
 - After initial greetings are exchanged, the counselor will initiate the session.
 - Once the counselor asks the question and you provide an answer, record your evaluation of the audio and video quality for that particular question, please put down comments if you have any. Take as much time as you need to fill this out. (Explain evaluation sheet in full).
 - The counselor will ask you if you are ready to move on to the next question. Answer yes if you are and the simulation will continue.
 - Any questions?

Counselor Testing Script

- Initial Information
 - First off, I would like to thank you for taking the time out of your schedule to help me complete my MQP study.
 - You will be playing the role of the counselor, conducting a depression evaluation simulation with a patient at a remote site. The purpose of this project is to test the impact of network effects on telemental health consultations. This is primarily a technical study; however, it requires that we gain close to real data. We need you to act as a counselor at a Hospital and we will bring you a patient on the rural clinic side via video conferencing. You’re acting as the counselor. You will ask the patient on the other side 15 questions about how he is feeling. The answers being provided by the patients do not bear any weight. The patients were informed that they could answer the question in any fashion that makes them comfortable, even if the answer is not truthful. Answers will not be recorded or evaluated; only the quality information provided by you and the patient is recorded.
 - In front of you, you will find your counselor folder, in it you will find:
 - Demographic information, age and gender
 - Question sheet
 - 15 Question Evaluation sheets.
- Scenario
 - Sit in front of the camera
 - The patient will initiate the call. If you are more comfortable using the handset, pick up the receiver. If you wish to use the speaker phone, use the speaker phone button.
 - After initial greetings are exchanged, you will initiate the session by asking the first question.
 - Once you ask a question and the patient provides an answer, record your evaluation of the audio and video quality for that particular question, please put down comments if you have any. Take as much time as you need to fill this out. (Explain evaluation sheet in full).
 - Please then ask the patient if they are ready to move on to the next question, if they are, please ask the next question.
 - Any questions?

As the counselor asked the patient each question from the depression diagnosis sheet, the operator (myself) made the appropriate changes on the NISTNet router. After each question, both sides paused for a moment and filled out their evaluation sheet (see Appendix B) for that particular question (and in turn, the particular scenario being tested). The counselor then asked the patient if they were ready to move on, if they were, the testing continued. This repeated until the pair went through all 15 questions in the depression diagnostic.

5. Results

Testing results were obtained for each of the test runs. There were 15 evaluation sheets for both the patient and the counselor for each of the 2 counseling sessions, in each of the experiments. In total, there were 300 evaluation sheets produced. In addition to the same evaluation the patients were asked to fill out, the counselors were asked to make a decision if they believe they would be able to make an effective mental health diagnosis using this technology. In order to simplify correlating these results into meaningful data, I went through the stack and wrote in the upper right corner, the network scenario that the evaluation sheet corresponded to. I then separated the stacks into separate piles for each question. I then went through each stack and assigned decimal number from 0 (Bad) through 5 (Excellent) for both the audio and video quality. I then went through each of these stacks and recorded the quantified audio and video qualities into an excel spreadsheet. This raw data can be seen in Appendix C.

5.1 Statistics

I first calculated the mean, median, and standard deviation for the dataset in several different ways. The first collection was for all of the test participants, as illustrated in Table 5.1. The second collection was for only the counselors, as illustrated in Table 5.2. The third collection was for only the patients, as illustrated in Table 5.3. I also collected the average age of both the patients and counselors, as illustrated in Table 5.4

Table 5.1: Statistics for All Participants

Scenario	Delay	Jitter	Drop	Audio - Mean	Audio - Median	Audio - STDEV	Video - Mean	Video - Median	Video - STDEV
1	50	50	1%	3.04	3.125	1.006	1.31	1.5	0.58
2	100	50	1%	3.24	3.45	0.779	1.6	1.75	0.831
3	150	50	1%	2.76	3.175	1.044	1.73	1.95	0.662
4	50	100	1%	2.63	2.5	1.164	1.545	1.625	0.779
5	100	100	1%	2.725	3	1.139	1.095	1.225	0.525
6	150	100	1%	2.605	2.5	0.902	0.895	0.85	0.56
7	50	150	1%	2.595	2.875	1.197	1.285	0.55	1.203
8	100	150	1%	3.025	3.125	0.869	1.365	1.375	0.556
9	150	150	1%	2.47	2.5	1.039	1.235	1.275	0.539
10	50	50	3%	2.85	2.65	0.509	1.44	1.45	0.631
11	100	50	3%	3.55	3.5	0.513	1.895	1.85	0.914
12	150	50	3%	3.255	3.375	0.768	1.73	1.65	0.741
13	50	100	3%	3.05	3.375	0.815	1.235	1.375	0.545
14	100	100	3%	3.445	3.5	0.558	1.48	1.55	0.675
15	150	100	3%	2.705	3	1.18	1.15	1.125	0.56
16	50	150	3%	2.905	3.125	0.754	1.365	1.5	0.963
17	100	150	3%	2.945	3	0.796	1.46	1.225	0.989
18	150	150	3%	2.54	3	1.552	1	1.125	0.66
19	50	50	5%	3.085	3.325	0.744	1.785	1.5	0.599
20	100	50	5%	3.26	3.375	0.717	1.51	1.55	0.94
21	150	50	5%	3.08	3.5	1.25	1.57	1.5	0.75
22	50	100	5%	2.57	2.9	1.112	1.285	1.425	0.459
23	100	100	5%	2.38	2.25	0.712	1.385	1.5	0.449
24	150	100	5%	3.28	3.5	0.807	1.59	1.45	0.853
25	50	150	5%	3.16	3.45	0.787	1.555	1.5	0.677
26	100	150	5%	2.68	2.85	0.938	1.225	1.25	0.629
27	150	150	5%	2.575	2.85	1.406	1.52	1.5	1.186
28	0	0	0%	3.655	3.5	0.6	3.76	3.55	0.642
29	0	0	0%	3.455	3.5	1.184	3.73	3.5	0.576
30	0	0	0%	3.585	3.75	0.891	4	4.1	0.533

Table 5.2: Statistics for Counselor Participants

Scenario	Delay	Jitter	Drop	Audio - Mean	Audio - Median	Audio - STDEV	Video - Mean	Video - Median	Video - STDEV
1	50	50	1%	3.11	3	0.47223	1.2	1.5	0.64711
2	100	50	1%	3.03	3.25	0.93113	1.4	1.5	0.88671
3	150	50	1%	2.97	3.1	0.45222	1.6	1.5	0.57554
4	50	100	1%	3.07	3.25	0.76616	1.28	1.5	0.58481
5	100	100	1%	3.26	3.5	0.71624	1.31	1.5	0.50794
6	150	100	1%	2.4	2.5	0.54772	0.64	0.5	0.63581
7	50	150	1%	2.69	3.25	1.30403	0.87	0.5	0.52154
8	100	150	1%	3.37	3.5	0.40712	1	0.9	0.38568
9	150	150	1%	2.7	2.5	0.92128	1.12	1.25	0.39147
10	50	50	3%	2.81	2.5	0.54129	1.09	1	0.4588
11	100	50	3%	3.63	3.5	0.49699	1.93	2.75	1.30843
12	150	50	3%	3.36	3.5	0.52844	1.65	1.5	0.78262
13	50	100	3%	2.95	3.25	0.95851	1.1	1.25	0.57554
14	100	100	3%	3.4	3.5	0.6275	1.04	1.2	0.53782
15	150	100	3%	3.17	3.5	0.61806	1	1	0.5
16	50	150	3%	2.75	3	0.79057	1.45	1.5	0.57009
17	100	150	3%	3.24	3	0.75033	1.02	1	0.37014
18	150	150	3%	3.05	3.5	1.50416	1.1	1.5	0.67546
19	50	50	5%	3.25	3.25	0.76322	1.75	1.5	0.5
20	100	50	5%	3.32	3.5	0.56745	0.79	0.85	0.52726
21	150	50	5%	3.8	3.5	0.41079	1.25	1	0.93541
22	50	100	5%	2.54	3	1.14149	1.42	1.5	0.11511
23	100	100	5%	2.44	2.5	0.51889	1.15	1.25	0.41833
24	150	100	5%	3.11	3.5	0.92087	1.35	1.25	0.91173
25	50	150	5%	3.39	3.5	0.2924	1.35	1.5	0.48734
26	100	150	5%	2.64	3.2	1.06266	1.1	1.25	0.45415
27	150	150	5%	2.79	2.5	1.01637	1.47	1.5	1.19823
28	0	0	0%	4	4	0.53033	3.8	4	0.85513
29	0	0	0%	3.1	3.5	1.52684	3.87	3.85	0.37517
30	0	0	0%	3.67	3.5	0.6261	4	4	0.54314

Table 5.3: Statistics for Patient Participants

Scenario	Delay	Jitter	Drop	Audio - Mean	Audio - Median	Audio - STDEV	Video - Mean	Video - Median	Video - STDEV
1	50	50	1%	2.97	3.5	1.429	1.42	1.5	0.554076
2	100	50	1%	3.45	3.5	0.6225	1.8	1.75	0.817771
3	150	50	1%	2.55	3.5	1.462	1.86	2.25	0.782144
4	50	100	1%	2.19	2.2	1.4055	1.81	2	0.921548
5	100	100	1%	2.19	2.25	1.2992	0.88	1.2	0.495732
6	150	100	1%	2.81	2.5	1.1939	1.15	1.25	0.374166
7	50	150	1%	2.5	2.5	1.2247	1.7	0.6	1.598437
8	100	150	1%	2.68	2.5	1.1122	1.73	1.5	0.463141
9	150	150	1%	2.24	2.3	1.2028	1.35	1.3	0.68374
10	50	50	3%	2.89	2.85	0.5355	1.79	1.5	0.616847
11	100	50	3%	3.47	3.6	0.574	1.86	1.7	0.403733
12	150	50	3%	3.15	3	1.0093	1.81	1.8	0.778139
13	50	100	3%	3.15	3.5	0.7416	1.37	1.5	0.539212
14	100	100	3%	3.49	3.5	0.5493	1.92	1.75	0.500749
15	150	100	3%	2.24	2.75	1.4859	1.3	1.25	0.631467
16	50	150	3%	3.06	3.5	0.7701	1.28	0.5	1.319848
17	100	150	3%	2.65	2.75	0.8023	1.9	1.5	1.257478
18	150	150	3%	2.03	2.5	1.5826	0.9	0.75	0.706222
19	50	50	5%	2.92	3.4	0.7702	1.82	1.4	0.743808
20	100	50	5%	3.2	3.25	0.9083	2.23	2.1	0.643817
21	150	50	5%	2.36	2.75	1.432	1.89	2	0.368103
22	50	100	5%	2.6	2.8	1.215	1.15	1	0.644205
23	100	100	5%	2.32	1.85	0.9284	1.62	1.5	0.375167
24	150	100	5%	3.45	3.5	0.7374	1.83	1.5	0.814402
25	50	150	5%	2.93	3.4	1.0837	1.76	1.8	0.829458
26	100	150	5%	2.72	2.5	0.921	1.35	1.25	0.80234
27	150	150	5%	2.36	3.25	1.8171	1.57	1.5	1.313202
28	0	0	0%	3.31	3.5	0.4801	3.72	3.5	0.438178
29	0	0	0%	3.81	3.5	0.711	3.59	3.5	0.745319
30	0	0	0%	3.5	4	1.1726	4	4.25	0.586302

Table 5.4: Average age for Participants

	Counselor	Patient
Average Age	37	23.8

As can be seen from Tables 5.1 through 5.4, there were no scenarios, including the three baselines, where the mean rating for audio and video quality were rated at 5 (excellent). The main reason for this is most likely the quality of the video call was not as high a quality as a person might be used to seeing on TV or in person. The reason being for this is that the target was a rural clinic that did

not have an enormously large budget to spend on video conferencing equipment. The solution that was deployed did not have High-Definition video streams, but yet provided an effective solution for a rather low cost.

Another trait that can be noticed in Table 5.1 is that for the audio quality over both counselors and patients, Scenario 23 had the most drastic impact on perceived audio, this scenario was 100ms delay, 100ms jitter, and 5% drop. Scenario 8 had the greatest impact on video quality, this scenario was 50ms delay, 150ms jitter, and 5% drop. This would initially suggest that all variables had a strong impact on audio quality and that jitter had a strong impact on video quality. However, this will be examined in the Correlation Analysis in the next section of this report.

5.2 Correlation Analysis

Next I calculated correlations in the audio video quality for all participants, just the counselors, and just the patient. These correlations can be seen in Tables 5.5 – 5.7. I also calculated a correlation for the audio and video quality in relation to a subject type (patient or counselor); this is illustrated in Table 5.8.

Table 5.5: Correlation between audio and video quality for all participants

		Audio_Qual	Video_Qual	Delay	Jitter	Drop
Audio_Qual	Pearson Correlation	1	.327**	-.145*	-.236**	-.064
	Sig. (2-tailed)		.000	.012	.000	.272
	N	300	300	300	300	300
Video_Qual	Pearson Correlation	.327**	1	-.430**	-.504**	-.288**
	Sig. (2-tailed)	.000		.000	.000	.000
	N	300	300	300	300	300
Delay	Pearson Correlation	-.145*	-.430**	1	.375**	.308**
	Sig. (2-tailed)	.012	.000		.000	.000
	N	300	300	300	300	300
Jitter	Pearson Correlation	-.236**	-.504**	.375**	1	.308**
	Sig. (2-tailed)	.000	.000	.000		.000
	N	300	300	300	300	300
Drop	Pearson Correlation	-.064	-.288**	.308**	.308**	1
	Sig. (2-tailed)	.272	.000	.000	.000	
	N	300	300	300	300	300

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Table 5.6: Correlation between audio and video quality for all counselor participants

		Audio_Qual	Video_Qual	Delay	Jitter	Drop
Audio_Qual	Pearson Correlation	1	.312**	-.088	-.230**	-.068
	Sig. (2-tailed)		.000	.283	.005	.405
	N	150	150	150	150	150
Video_Qual	Pearson Correlation	.312**	1	-.467**	-.536**	-.327**
	Sig. (2-tailed)	.000		.000	.000	.000
	N	150	150	150	150	150
Delay	Pearson Correlation	-.088	-.467**	1	.375**	.308**
	Sig. (2-tailed)	.283	.000		.000	.000
	N	150	150	150	150	150
Jitter	Pearson Correlation	-.230**	-.536**	.375**	1	.308**
	Sig. (2-tailed)	.005	.000	.000		.000
	N	150	150	150	150	150
Drop	Pearson Correlation	-.068	-.327**	.308**	.308**	1
	Sig. (2-tailed)	.405	.000	.000	.000	
	N	150	150	150	150	150

** . Correlation is significant at the 0.01 level (2-tailed).

Table 5.7: Correlation between audio and video quality for patient participants

		Audio_Qual	Video_Qual	Delay	Jitter	Drop
Audio_Qual	Pearson Correlation	1	.393**	-.192*	-.249**	-.062
	Sig. (2-tailed)		.000	.019	.002	.451
	N	150	150	150	150	150
Video_Qual	Pearson Correlation	.393**	1	-.402**	-.483**	-.254**
	Sig. (2-tailed)	.000		.000	.000	.002
	N	150	150	150	150	150
Delay	Pearson Correlation	-.192*	-.402**	1	.375**	.308**
	Sig. (2-tailed)	.019	.000		.000	.000
	N	150	150	150	150	150
Jitter	Pearson Correlation	-.249**	-.483**	.375**	1	.308**
	Sig. (2-tailed)	.002	.000	.000		.000
	N	150	150	150	150	150
Drop	Pearson Correlation	-.062	-.254**	.308**	.308**	1
	Sig. (2-tailed)	.451	.002	.000	.000	
	N	150	150	150	150	150

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Table 5.8: Correlation between audio and video quality for subject type

		Audio Qual	Video Qual	Type
Audio_Qual	Pearson Correlation	1	.327**	-.134*
	Sig. (2-tailed)		.000	.020
	N	300	300	300
Video_Qual	Pearson Correlation	.327**	1	.149**
	Sig. (2-tailed)	.000		.010
	N	300	300	300
Type	Pearson Correlation	-.134*	.149**	1
	Sig. (2-tailed)	.020	.010	
	N	300	300	300

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

As illustrated in Tables 5.5 through 5.7, audio quality is most significantly affected by jitter; neither drop nor delay had a significant impact on the perceived audio quality. In contrast, video quality was significantly altered by all three of the network impairment variables. The most significant variable impacting video quality as seen in this analysis is jitter.

Table 5.8 compares audio and video quality when based on patient type. This correlation shows that there is a negative correlation between the patient type and audio quality. However, through several different test runs of this scenario, it was determined that this is probably not related to the patient type but related to the location of the call manager. The counselors rated a higher audio quality than the patients; however, this was most likely due to a reduced delay in signaling to the Call Manager, as it was on their side of the NISTNet router. The correlation analysis done in the next section on audio quality vs. the subject's age will reaffirm this behavior.

I next calculated the correlation between the patient and counselor's ages and their perceived audio and video quality. The correlation presented in Table 5.9 contains audio and video quality plotted both against exact age as well as age groups.

Table 5.9: Correlation between audio and video quality and age

		Age	Age Group	Audio Qual	Video Qual
Age	Pearson Correlation	1	.733**	.222**	-.145*
	Sig. (2-tailed)		.000	.000	.012
	N	300	300	300	300
Age_Group	Pearson Correlation	.733**	1	.133*	-.161**
	Sig. (2-tailed)	.000		.021	.005
	N	300	300	300	300
Audio_Qual	Pearson Correlation	.222**	.133*	1	.327**
	Sig. (2-tailed)	.000	.021		.000
	N	300	300	300	300
Video_Qual	Pearson Correlation	-.145*	-.161**	.327**	1
	Sig. (2-tailed)	.012	.005	.000	
	N	300	300	300	300

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

As can be seen from the correlation presented in Table 5.9 there is a positive correlation between age groups and audio quality. The older age groups were the counselors present on the hospital side. Consistent with the findings of the previous section, this side contained the Call Manager and rated higher on the audio quality than the patient side. Again, this was most likely due to non-existent delay in signaling between the call manager and the counselor's IP Phone.

Calculating a correlation based on a test subject's gender would not be accurate. First of all, there was only a very small sample size, 15 test subjects. This is too small of a sample base to obtain accurate results. Second, there was not close to an even distribution of males and females. The entire set patient volunteers were males as was 1 out of the 5 counselor volunteers. This left only 4 female counselors in the study. The results presented in a gender correlation would not have been an accurate reflection.

I then calculated which network impairment variable affected counselors and patients the most. The resulting ANOVA Analysis table can be seen in Table 5.10.

Table 5.10: ANOVA Analysis

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Audio_Qual	38.194 ^a	27	1.415	1.541	.046
	Video_Qual	174.401 ^b	27	6.459	11.448	.000
Intercept	Audio_Qual	2602.939	1	2602.939	2834.773	.000
	Video_Qual	929.790	1	929.790	1647.846	.000
Delay	Audio_Qual	2.298	2	1.149	1.251	.288
	Video_Qual	.160	2	.080	.141	.868
Jitter	Audio_Qual	6.748	2	3.374	3.675	.027
	Video_Qual	5.384	2	2.692	4.771	.009
Drop	Audio_Qual	2.650	2	1.325	1.443	.238
	Video_Qual	1.718	2	.859	1.522	.220
Delay * Jitter	Audio_Qual	2.830	4	.708	.771	.545
	Video_Qual	1.156	4	.289	.512	.727
Delay * Drop	Audio_Qual	4.541	4	1.135	1.236	.296
	Video_Qual	2.249	4	.562	.996	.410
Jitter * Drop	Audio_Qual	1.139	4	.285	.310	.871
	Video_Qual	.791	4	.198	.351	.844
Delay * Jitter * Drop	Audio_Qual	6.152	8	.769	.837	.570
	Video_Qual	3.812	8	.476	.844	.564
Error	Audio_Qual	249.755	272	.918		
	Video_Qual	153.475	272	.564		
Total	Audio_Qual	2932.616	300			
	Video_Qual	1139.749	300			
Corrected Total	Audio_Qual	287.949	299			
	Video_Qual	327.876	299			

a. R Squared = .133 (Adjusted R Squared = .047)

b. R Squared = .532 (Adjusted R Squared = .485)

The ANOVA in Table 5.10 shows that jitter had the most significant impact on both the audio and video quality. As can be seen from the table, the significance value for jitter for audio and video quality was .027 and .009 respectively. This is far below the significance threshold of .05.

The Adjusted R Squared values towards the bottom of the ANOVA analysis show which percentage of the variance of audio quality and video quality in the model is affected by delay drop and

jitter. As can be seen in the table, the Adjusted R Squared value for audio quality was relatively small, at only 5%. As jitter had the most significance in this value, it accounts for most of the contribution to it. Contrary to this, the Adjusted R Squared value for video quality was much greater than that of audio, at 49%. Jitter had a much more significant impact in this value than it did in the audio Adjusted R Squared value.

The significance of the impact from jitter is obvious in both its extremely low significance value (.009) as well as the high Adjusted R Squared value of 49%. This shows that in relation to the other network impairment values, delay and drop, jitter has the greatest impact on audio quality and video quality. These results are comparable to the results of an earlier study of telemedicine in a different area performed by Professor Bengisu Tulu of Worcester Polytechnic Institute and Professor Samir Chatterjee of Claremont Graduate University^{xviii}.

5.3 Decision Making

When the counselors were asked if they would be willing to handle the case of a patient over a Voice/Video over IP call, all but one answered that they would be able to make a medical decision up to a reasonable certainty. The counselor that answered differently said they would rather not make a medical decision utilizing this method of communication. The printed results can be found in Appendix C.

One of the counselors stated that at first it might be more awkward to make decisions in a manner such as this, but they believed that as time went on and they became more and more accustomed to utilizing the equipment and this type of diagnosis, that their opinion of the solution would improve.

Three of the counselors stated that the reason they would only feel comfortable on making a medical decision up to a reasonable certainty. From two of their comment sections, they stated that the main reason for this was the loss and variation in video quality. One of them stated that a lot of the body language and unspoken communication was "lost" when the video quality of the call was poor. The third counselor did not provide any comments as to this reason.

The counselor that rated that they would rather not make a medical decision based on this message did not submit any comments with their evaluation sheets.

6. Conclusion & Recommendation

As can be seen from Section 5 – Results, there are a great number of variables and factors that must be taken into account before one would be able to deploy a fully functional and effective telemental health video conferencing solution.

Deploying a solution to allow video communication between a hospital and a rural clinic is not as simple as having enough money to buy it, having the equipment available, or the people to run it. There are many other factors that come into the scenario. As this research stated, and as anyone deploying a system like this in the “real world” has found out, quality is not a fully quantitative property. Quality is not something that we can simply attach a number to and have it represent the opinions of 100% of the people using it. The best that we can do is to obtain subjective measurements, assign quantitative values to these, and pull statistical data out of these values. That was the goal and purpose of this project, to provide a “real life” measurement of the system and to highlight some possible issues with deployment.

As can be seen from the statistical data presented in Tables 5.1 through 5.3, there is no scenario that received an excellent score of 5, not even the three baselines (network impairment variables all at 0’s). This is in part due to the subjective nature of the study. The definition of quality is not static, and every person that is using a system is likely to rate it differently on a scale. Part of it might also be due to quality levels that people are used to. In the age of High-Definition video, people are accustomed to fully crisp and clear pictures. The video conferencing solution utilized in this testbed was an affordable solution that would realistically be available to rural clinics looking to deploy technology based off it. As a result, it does not have the same level of video quality as say a million dollar enterprise video conferencing solution.

Tables 5.8 and 5.9 show a rather interesting correlation involving the placement of the Call Manager and its relation to audio quality. Table 5.8 was an age comparison to both audio and video quality. This table shows that the older groups of volunteers noticed an increase on quality. Coincidentally, the older group of volunteers (minus one of the patient volunteers) was mostly located on the counselor (hospital side). This is the same side that the Call Manager was located on. The correlation based off type of volunteer (counselor or patient) in Table 5.9 reaffirmed these findings. There was a higher perceived audio quality rating from the counselors than the patients. This is most likely due to the fact that the counselor’s are not experiencing a delay when communicating to the Call Manager, where the patients are experiencing not only a delay communicating to the Call Manager, but also to the IP Phone at the hospital side. From this data it can be concluded that the placement of the Call Manager and the network impairments affecting it can have a significant impact on audio quality.

The ANOVA Analysis in Table 5.10 shows that of all the three tested network impairment variables, jitter has the greatest effect. Jitter has a significance level of .027 and .009 against audio and video quality respectively. Also, by analyzing the Adjusted R Squared values, it is also reaffirmed of the significant impact jitter had on the quality. The Adjusted R Squared value for audio was 5%, although jitter had a significant impact to this, it is not nearly as severe as the impact it had to video quality. The Adjusted R Squared value for video quality was 49%, with jitter accounting for a significant portion of this, a much greater effect than on audio quality.

In order to provide a reliable and functional testbed, there are several recommended steps that should be taken to ensure an optimal experience.

First and foremost, the network path over the Internet between the two sites should be analyzed. Several different analyses should be done on this link to measure the levels of drop delay and jitter. Although all network variables had an impact on audio and video quality, jitter was the most severe and should be limited as much as possible. There are several possible ways to limit network

impairment levels such as working to choose the same ISP (Internet Service Provider) on both ends, working with ISPs to identify and eliminate bottlenecks, and deploy QoS (Quality of Service) when possible.

If two telemental health sites are utilizing the same ISP, it is less likely that they will encounter network problems on the connection between the two sites. While the data is still traveling over the Internet, chances are if the ISP is large enough, the path the data is traveling on is owned and operated by them. The advantages of this solution is that it provides a single contact point of troubleshooting, if they own the entire network path in between both sites, they are the main contact you will have to work with to troubleshoot issues.

Also, when possible, Quality of Service should be deployed on the networks. For the most part, on small networks, this is not worth deploying. However on an application as sensitive as Voice/Video over IP, it might be worthwhile. Quality of Service works by tagging packets that are used for Voice/Video applications. When these packets reach network routers, the router will look at the tag on the packet, and give it higher preference over say an email or http packet as this communication is much more time sensitive.

Another recommended step derived from the research is the placement of the Call Manager. It was shown from the data that if there is a delay in a site being able to reach the Call Manager, this can adversely affect the audio quality. Care should be taken to ensure that the network connection between the Call Manager and all end points is as trouble free as possible. While all data does not pass through the Call Manager, it is responsible for a great deal of signaling, and if there is an issue with an IP Phone reaching it, it will affect the overall quality.

Finally, the last recommendation for deploying a telemental healthcare solution is adequate user training. When the counselors were evaluating the solutions, one of the most common comments that was mentioned was that the solution was awkward at first. People for the most part are not accustomed to video calls; the technology is relatively new, and the infrastructure for carrying them has not been in place for that long. As broadband proliferates more and more of the market place and faster connections are rolled out to homes everywhere, familiarity with technology like this will no doubt increase. However, until that point, users must be adequately trained on the technology and must become accustomed to any nuances that may be present. However, as human beings are plagued by instant gratification syndrome and are constantly looking for ways to get things faster and to save time, energy, and money, a telemental health solution is simply the next logical step healthcare.

Appendix A. (Equipment List)

- Network Switch (Cisco Powered Switch)



The network switch is responsible for providing connectivity to both the computers and the IP Phones. The switch is also responsible for applying Quality of Service depending on the type of device connected to the endpoint. The switch also provides 48V Power over Ethernet which is used to provide inline power to the IP Phones.

- PC



The PC is used to provide a video endpoint for the site. The software utilized is Cisco Unified Video Advantage (CUVA). The PC connects through the IP Phone and CUVA deciphers the video portion of the data stream.

- Cisco 7970 IP Phone



Cisco 7970 is the IP phone to provide end to end voice communications for the users. The Pc is connected into the back of the phone to allow the phone to provide the appropriate connection for the Cisco video software.

- Cisco VT Advantage Video Camera



The Cisco VT Advantage video camera is responsible for capturing video of end users at each of the sites.

- Cisco MCS-7845-H1
 - Call Manager



The Cisco MCS 7845 is responsible for running the Call Manager software. This server has dual

3.4ghz processors, 4GB, of ram, and 2x72GB Hard Drives. The MCS server provides Call Manager service to the phones, the CUVA software to drive the video portion and provides end to end call signaling.

Appendix B. (Evaluation Sheet)

Patient #: _____

Experiment #: _____

Counselor #: _____

Evaluation Sheet

Question # 1 - Sadness

Audio	Video
Excellent	Excellent
Good	Good
Fair	Fair
Poor	Poor
Bad	Bad

If you have comments, please place them in the following section:

Last Evaluation Sheet with Decision Making

Experiment #: _____

Counselor #: _____

Subject #: _____

Evaluation Sheet

Question # 15 – Suicidal Impulses

Audio	Video
Excellent	Excellent
Good	Good
Fair	Fair
Poor	Poor
Bad	Bad

Assuming you were asked to handle the case of this patient based off the Voice/Video over IP call, which one of the following would best represent your opinion?

- ___ I can easily make a medical decision
- ___ I can make a medical decision up to a reasonable certainty
- ___ I can make a medical decision only if this is an emergency case
- ___ I would rather not make a medical decision
- ___ I cannot make a medical decision

If you have comments, please place them in the following section:

Appendix C. (Data)

Raw Data Collected

Scenario	A	V	A	V	A	V	A	V	A	V	A	V	A	V	A	V	A	V	A	V
1	2.5	0.5	3.5	0.5	3	1.5	0.75	2	3.25	1.75	2.5	1.5	3	1.75	4.5	1.5	3.8	0.5	3.6	1.6
2	1.5	1.5	3.5	0.5	4	2.5	3.5	2.5	3.4	1.85	2.5	2.5	3	1	4.25	1.75	3.25	0.15	3.5	1.75
3	2.5	1.5	3.5	0.5	2.5	2	0.5	2.25	3.5	2.25	1.5	2.25	3.1	1.5	3.75	2.4	3.25	0.75	3.5	1.9
4	3.5	0.5	2.5	2.25	2.5	2	2.2	2	3.25	1.5	0.3	0.3	4	1.5	4.2	2.75	2.1	0.9	1.75	1.75
5	3.5	1.5	2.5	0.5	2	1.5	1.5	0.2	3.5	1.85	0.6	1.25	3.8	1.2	4.1	1.25	3.5	0.5	2.25	1.2
6	2.5	0.5	3.5	1.25	1.5	0.5	1.25	1.4	2.5	1.75	2.4	0.5	3	0.25	4.4	1.2	2.5	0.2	2.5	1.4
7	2.5	0.5	3.5	0.5	0.5	0.5	0.5	0.5	3.6	1.6	2.5	3.5	3.25	1.25	3.5	3.4	3.6	0.5	2.5	0.6
8	3.5	0.5	3	2	3.5	1.5	2	1.25	3.25	1.25	2.5	1.5	2.75	0.9	4.4	2.4	3.85	0.85	1.5	1.5
9	2.5	0.5	3	0.5	2.5	1	1.4	1.4	3.25	1.5	0.75	1.15	3.85	1.25	3.75	2.4	1.4	1.35	2.3	1.3
10	2.5	0.5	3.5	2.5	2.5	1	2.25	1.4	2.8	1.5	2.5	1.5	3.75	1.6	2.85	1.15	2.5	0.85	3.35	2.4
11	3.5	0.5	4	2	3.5	3	2.5	2.5	3.25	2.75	3.5	1.5	3.4	2.9	3.75	1.7	4.5	0.5	3.6	1.6
12	2.5	0.5	4	2	3.5	1.5	3	1	3.25	2.25	1.75	1.8	3.75	1.5	4.25	3	3.8	2.5	2.75	1.25
13	2.5	0.5	3.5	0.5	1.5	0.5	2.5	1.85	3.25	1.75	3.5	1.5	3.75	1.25	4	1.25	3.75	1.5	2.25	1.75
14	3.5	0.5	3.75	2.75	2.5	1.25	2.85	2	3.25	1.75	3.5	1.5	4.25	1.2	4.25	1.6	3.5	0.5	3.1	1.75
15	2.5	0.5	3.25	2.25	2.5	1.5	0.5	0.6	3.5	1.5	0.85	0.9	3.6	1	3.85	1.5	3.75	0.5	2.75	1.25
16	1.5	0.5	3.5	3.5	2.5	2	2	0.5	3.25	1.75	2.5	0.5	3	1.5	3.8	0.4	3.5	1.5	3.5	1.5
17	2.5	0.5	3.5	0.5	3	1	2.25	1.25	3.2	1.2	1.5	2.5	3	0.9	2.75	3.75	4.5	1.5	3.25	1.5
18	3.5	0.5	2.75	1.5	3.5	1.5	0.9	0.1	3.25	1.75	0	0.4	4.5	1.5	4	1.75	0.5	0.25	2.5	0.75
19	2.5	1.5	3.5	2.5	2.5	2	1.85	1.25	3.25	2.5	2.35	1.2	4.2	1.5	3.4	2.75	3.8	1.25	3.5	1.4
20	2.5	0.5	3.25	1.75	3	1	1.75	1.6	3.5	0.85	3.5	2.5	3.7	1.5	4.25	3.2	3.9	0.1	3.25	2.1
21	3.5	0.5	3.25	2	3.5	1	1.75	1.5	3.5	2.75	0.2	2.2	4.25	1.5	3.85	2.25	4.25	0.5	2.75	1.5
22	2.5	1.5	3.5	0.5	0.6	1.25	2.25	1.85	3.1	1.5	0.7	1	3	1.5	3.75	1.8	3.5	1.35	2.8	0.6
23	2.5	0.5	2.75	2.25	2	1.5	1.85	1.25	2.75	1.5	1.5	1.5	3.1	1	3.75	1.6	1.85	1.25	1.75	1.5
24	3.5	1.5	3.5	3.25	1.5	1	2.25	1.25	3.25	1.25	3.75	1.5	3.8	2.75	4.25	1.75	3.5	0.25	3.5	1.4
25	3.5	0.5	4	2.5	3	1.5	1.25	1.5	3.2	1.75	2.5	2.5	3.75	1.5	3.5	0.5	3.5	1.5	3.4	1.8
26	1.5	0.5	3.5	0.5	1.5	1.5	2	1.25	3.2	1.25	2.5	2.5	3.75	1.5	3.85	1.75	3.25	0.75	1.75	0.75
27	1.5	0.5	3.25	2	2.5	1.5	0.85	0.85	3.2	1.85	0	0	4.25	3.25	4.1	3.5	2.5	0.25	3.6	1.5
28	3.5	2.5	3.5	3.5	4	4	2.5	3.5	3.5	4.25	3.5	4.5	4.25	3.5	3.75	3.5	4.75	4.75	3.3	3.6
29	0.5	3.5	3.5	3.5	3.5	3.5	3	2.75	3.25	4.25	4.8	4.8	3.75	3.85	4.25	3.5	4.5	4.25	3.5	3.4
30	3.5	3.5	4	4.25	3	4	1.5	3.25	3.2	4.2	3.5	3.5	4.4	3.5	4	4.5	4.25	4.8	4.5	4.5

*Any value above 1.5 is poor, but acceptable.

Legend

Light Yellow – Counselor, first 15 questions.

Dark Yellow – Counselor, last 15 questions.

Light Green – Patient, first 15 questions.

Dark Green – Patient, last 15 questions.

A = Audio

V = Video

Each of the 5 experiments is encased within the bold lines.

Age and Gender

	Age	Gender
Counselor 1	33	Female
Counselor 2	26	Female
Counselor 3	48	Male
Counselor 4	26	Female
Counselor 5	52	Female
Patient 1	50	Male
Patient 2	21	Male
Patient 3	21	Male
Patient 4	19	Male
Patient 5	21	Male
Patient 6	23	Male
Patient 7	22	Male
Patient 8	22	Male
Patient 9	19	Male
Patient 10	20	Male

Decision Making Evaluations

Counselor 1

Assuming you were asked to handle the case of this patient based off the Voice/Video over IP call, which one of the following would best represent your opinion?

- I can easily make a medical decision
- I can make a medical decision up to a reasonable certainty
- I can make a medical decision only if this is an emergency case
- I would rather not make a medical decision
- I cannot make a medical decision

If you have comments, please place them in the following section:

I believe that I could make a decision based on the phone-audio interaction the visual was poor + therefore would not have helped.

Counselor 2

Assuming you were asked to handle the case of this patient based off the Voice/Video over IP call, which one of the following would best represent your opinion?

- I can easily make a medical decision
- I can make a medical decision up to a reasonable certainty
- I can make a medical decision only if this is an emergency case
- I would rather not make a medical decision
- I cannot make a medical decision

If you have comments, please place them in the following section:

I could note somewhere between this & emergency case.
You lose a lot of information communicating/assessing this way
(ie body language, posture, tone...). Much more goes into making an
accurate assessment than just hearing the voice even w/
seeing facial expressions. In many of the responses even
facial expressions were lost due to poor video.

Counselor 3

Assuming you were asked to handle the case of this patient based off the Voice/Video over IP call, which one of the following would best represent your opinion?

- I can easily make a medical decision
- I can make a medical decision up to a reasonable certainty
- I can make a medical decision only if this is an emergency case
- I would rather not make a medical decision
- I cannot make a medical decision

If you have comments, please place them in the following section:

Initially it would be more awkward to make a decision,
but I believe if I used the system more regularly
my confidence & ability to use system would
improve

Counselor 4

Assuming you were asked to handle the case of this patient based off the Voice/Video over IP call, which one of the following would best represent your opinion?

- I can easily make a medical decision
- I can make a medical decision up to a reasonable certainty
- I can make a medical decision only if this is an emergency case
- I would rather not make a medical decision
- I cannot make a medical decision

If you have comments, please place them in the following section:

Counselor 5

Assuming you were asked to handle the case of this patient based off the Voice/Video over IP call, which one of the following would best represent your opinion?

- I can easily make a medical decision
- I can make a medical decision up to a reasonable certainty
- I can make a medical decision only if this is an emergency case
- I would rather not make a medical decision
- I cannot make a medical decision

If you have comments, please place them in the following section:

Glossary

CCM – Cisco Call Manager

CUVA – Cisco Unified Video Advantage

IOS – Internetwork Operating System

PoE – Power over Ethernet

VoIP – Voice over IP

VVoIP – Voice/Video over IP

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