University of Southern Queensland Faculty of Engineering and Surveying

Broadband Satellite Internet Service Testing

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Abstract

Currently, the satellite internet network and the Telstra's Next-G network are the two known approaches to providing internet access in rural parts of Australia. While both networks solve the same problem, they rely on significantly different mechanisms to enable internet to reach across the end users. In this paper the Quality of Service (QoS) of both these internet networks will be compared with our developed test scripts. Test scripts were developed to measure the download speed, round-trip-time and website loading performance of the networks in real-time environments. Addition tests were run using Telstra's ADSL network and the USQ campus network for comparison purposes. With the achieved test results, we hope to be able to advise internet users in rural Australia on the most appropriate network to use that best benefit their lifestyles.

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I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

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Glossary of Terms

AARnet -	AARNet or Australian Academic and Research Network offers Internet			
	services to the Australian education and research communities and			
	their research partners.			
ADSL -	Asymmetric Digital Subscriber Line (ADSL) is a type of Digital			
	Subscriber Line technology, a data communications technology that			
	enables faster data transmission over copper telephone lines than a			
	conventional voice band modem can provide. It does this by utilizing			
	frequencies that are not used by a voice telephone call			
ISP -	An Internet service provider (ISP) is a company that provides access			
	to the Internet.			
Next-G -	Next G is a third generation mobile telecommunication network			
	operated by Telstra in Australia.			
Packet Loss -	The fraction of packets which do not reach the destination. This			
	can result in noticeable performance degradation with streaming			
	traffic such as a video where retransmission is not done.			
QoE-	Quality of Experience is a subjective measure of customer's			
	experiences.			
QoS -	Quality of Experience is a subjective measure of customer's			
	perspective towards the service provided.			
RTT -	Round Trip Time is the time taken for a packet to reach the destination			
	and return. This is significant in systems that require two-way			
	interactive communication such as online commerce and gaming.			
Satellite Internet-	Internet provided via the internet			
Telstra -	Australian telecommunications and media company, building			
	telecommunications networks and marketing voice, mobile, internet			
	access and pay television.			

Chapter 1 Introduction

Australia covers an area of about 7.7 million square kilometres but only has an average population density of 2.6 people per km² (ABS, 2011). Australia's population density in rural areas is therefore even lower. For infrastructure deployment which requires cabling in rural area, low population density is a significant disadvantage as people living in rural Australia are dispersed over large areas.

However it is recognised that internet access is still critical to communities in regional and rural Australia as it serves to expand economic capacity and stimulate businesses. The central purpose of this research is to explore the Quality of Service and Quality of Experience of the Satellite Internet access and Next-G network available in rural Australia. These internet access networks will be analysed in terms of time required to download, time required to ping and time required to load simple and sophisticated in several motivated realtime environment. The aim is to determine the best possible last-mile internet connectivity solution for users living rural Australia according to their lifestyles and environments. Figure 1 shows the research overview of how our research was conducted.



Figure 1: Research Overview

1.1 Background

1.1.1 Satellite Internet Network

Communications satellites function as a microwave repeater station circulating around the earth in a fixed orbit. Satellites are used for sending, transmitting, receiving and processing of electromagnetic signals (radio waves) of frequency larger than 1 GHz. A user may transmit the signal at a given frequency to the satellite which operates a frequency translation of the received signal and finally retransmits it to the users or ground stations (Morelli and Petrone, 2011).

Morelli and Petrone (2011) states that satellite circulate around the earth at 3 different altitudes and they are categorized as LEO, MEO and GEO (or sometimes known as GSO) depending on their altitude.

Most rural area of Australia uses communication satellites which operate in Geostationary orbit. The GEO satellite is positioned at an altitude of about 35,786 km above the equator and has the same angular velocity of earth (Morelli and Petrone, 2011). It circulates around earth and is programmed to synchronize with earth's rotation speed and also in the same direction (Morelli and Petrone, 2011). Thus, it appears to be stationary with respect to certain point on earth at a particular time each day (Morelli and Petrone, 2011). When the satellite is in the equatorial plane, it appears to be permanently stationary from the earth's surface so antenna from earth stations can be positioned pointing to it without the need to track its location or adjust their focusing position periodically(Morelli and Petrone, 2011). It is important to note that the satellite's earth station is different to that of the Next-G base tower or base station. Due to its strategic altitude, one GSO satellite has coverage of about one third of earth's surface, thus only 3 GSO satellites are needed for global coverage (Morelli and Petrone, 2011). Figure 2 shows the position or altitude of LEO, MEO and GEO satellites



Figure 2: Positions of LEO, MEO and GEO Satellites, 2011 (Morelli and Petrone, 2011, pp. 4 & 5)

Satellite Internet Subscribers/ Users

Figure 3 shows that Satellite internet users require low-cost outdoor antenna dish (number 1) which ranges from 65 to 240 in diameter which is used to receive and transmit transmission from the earth station (Morelli and Petrone, 2011). It is important for subscriber's antenna to have a good Line-of-Sight (LOS). Further discussion of Line-of-Sight will be discussed below. Figure 3 shows the satellite route. When a user decided to download or upload via the internet, signal or command will be transmitted to the satellite (number 3) which in turn retransmit the signal to the ground station on earth (number 2) and finally to the internet. Users use a satellite modem which works manages satellite transmission. The demodulation and transmission optimization is often handled by software. The satellite modem can be connected directly to a PC using an USB port on the subscriber's PC.



Figure 3: Satellite Downlink and Uplink Route, 2011 (Morelli & Petrone, 2011, pp. 12)

Limits of Satellite Internet Access

Latency

A common problem with the satellite internet access is with its latency or round trip delay (RTT). Latency is the delay between when data is first requested and the receiving of a response at the other end. In the case of a one-way transmission, the delay is between the moment the signal is transmitted and when the signal reaches its destination. This problem is highly influenced by the satellite's orbital position. Due to the huge distance of 35,768km from the earth's surface, all geostationary communication satellite inevitably experience high latency (Morelli and Petrone, 2011). According to Morelli and Petrone (2011), a one-way

end-to-end transmission, there is a propagation delay of more than 119 meters per second on an uplink and more than 240 metres per second for both an uplink and downlink. A two way end-to-end transmission path with communication protocol like TCP will make the same trip like the one way end-to-end transmission twice (Morelli and Petrone, 2011). This is due to the RTT of a signal transmitted. A requesting signal from the earth station needs to travel all the way to the geostationary satellite. Then from the satellite the requesting packet needs access the internet at for example one of Telstra's base station on earth then travel all the way back to the satellite and finally back to its earth station. The one way transmission or broadcasting end has fewer issues to deal with as the delay is not noticeable to the users at the receiving end. Thus for basic internet applications such as browsing and checking your email, the satellite is a good option especially if you reside in rural Australia. In the case of TV broadcasting, the latency is nearly unnoticeable. However, using the internet for real-time application such as video conferencing, webcam communications, e-surgery and students taking certain exams in the rural area at the moment is quite impossible. This obstacle may cause lives for example; emergency cases of patients that needed immediate specific operations cannot be done locally via e-surgery. Students undertaking exams need to go to nearby towns where reliable internet is available. Interactive real time online gaming is not even remotely possible.

Weather Conditions

Satellite transmission is very susceptible to atmospheric conditions such as moisture and various forms of weather conditions like rain and thunderstorm. Although this has less impact at lower frequency, it is a serious problem at high frequencies (Morelli and Petrone, 2011). Sometimes rain water may accumulated on the antenna dishes and if proper measures are not taken to properly enclose or protect these earth station antennas, a big amount of noise may result and in worse scenarios, communications may be stop working temporarily (Morelli and Petrone, 2011). Fortunately, there are counter measures where the satellites use during these events. These counter measures include hub power adjustment, adaptive uplink control and finally reducing bit rates and large rain (Morelli and Petrone, 2011). These techniques are necessary and are a preventive requirement for communication link even though they fail to work in circumstances when atmospheric precipitations is beyond control (Morelli and Petrone, 2011).

Line-of-Sight (LOS)

An excellent line-of-sight requires careful adjusting the direction of the user's antenna in order to ensure that signals is pointing towards the satellite. Signal may be poor even when antenna's direction is positioned perfectly because the line-of-sight is obstructed by obstacles like trees, buildings or mountains (Morelli and Petrone, 2011). Generally, lower frequency has higher penetration through obstacles but unfortunately satellites communications operate at frequencies above 2-3 GHz and as a result they are sensitive to even small obstructions (Morelli and Petrone, 2011).

Frequency Conflicts

Although the frequencies used are controlled and observed carefully; sometimes, unless properly tuned; interference or more specifically adjacent satellite interference (ASI) may interrupt the system (Morelli and Petrone, 2011). A transmitting earth station could direct a portion of its radiated power unintendedly toward satellites that are working at orbital position at the same direction to that of the satellite of interest (Morelli and Petrone, 2011). And sometimes it may be caused by the earth station's antenna is not positioned properly in the direction of the satellite of interest resulting in the signal not focusing concentrated enough onto the desired direction of the satellite of interest (Morelli and Petrone, 2011). Moreover, these unintended radiations can interference with services that use the same frequency on the adjacent satellites (Morelli and Petrone, 2011). Interference into the communication satellite is controlled up to an acceptable standard by frequent maintenance and monitoring that ensures that the signal transmitting from the earth station antenna is always focused toward the direction of the satellite. Unintended radiations toward the adjacent satellites are also monitored to limit interference (Morelli and Petrone, 2011). A larger uplink antenna has a lower probability to causing adjacent satellite interference but may cost more to build and maintain and may require a satellite tracking system (Morelli and Petrone, 2011). Also, a quality earth station can both receive and transmit transmissions from adjacent satellite properly even though there are interference (Morelli and Petrone, 2011). This is because while the receive antenna of the earth station is very sensitive to wanted signals being sent from the direction of the satellite of interest, it can also filter unwanted transmissions coming from other directions (Morelli and Petrone, 2011). To summarize, bigger n quality antenna produces better transmission and reception on both ends.

Satellite Malfunction

Morelli and Petrone (2011) states that network satellite dishes earth-facing direction needs to be adjusted periodically to ensure they broadcast and receive signals effectively. However due to lack of gravity, satellites naturally wander in an elliptical path so their correct earth-facing direction must be constantly fine-tuned using small thrusters installed at appropriate surfaces of the satellite (Morelli and Petrone, 2011). These thrusters operate on fuel. When their fuel is depleted, ground control on earth is unable to control the satellite remotely thus it shifts out of position (Morelli and Petrone, 2011). Sometimes insufficient fuel and transponder failures may also cause communications malfunction. A satellite normally has multiple backup transponders so a single transponder failure may not cause the satellite to malfunction however it may lower the efficiency of the satellite's ability to receive or broadcast signal to and from the earth station (Morelli and Petrone, 2011).

1.1.2 Next-G

Introduction to Next-G

Next-G was established using 850 MHz 3G Universal Mobile Telecommunications System (UMTS) technology (Islam, 2008). Similar to the 3rd Generation mobile service which operates in the 2100 MHz band, Next-G enable transmission of data in both voice and broadband. The Next-G network builds upon the 3GPP standard which is widely used in other countries.

Figure 4: Multiple access approaches and network in a multi-network (Berezdivin et al, 2002)

Figure 4 shows a big picture of the Next-G network, where multiple networks are able to function in such a way that the interfaces are transparent and wireless to users and services, and with the multiplicity of access and service options (Berezdivin et al, 2002). Much as the internet freed users from their own local network and worrying about the interfaces to get in other networks. This enables a larger transparent and wireless coverage than that of Wi-Fi which benefits wireless users (Berezdivin et al, 2002). Figure 5 shows one view of a flexible multinetwork with multiple access options providing users the capability to connect and communicate easily and seamlessly. Nodes and devices that can implement various categories of access technologies and networks and the access technology and networks that can facilitate this are the needed capabilities (Berezdivin et al, 2002). Ultraconnectivity is enabled by:

- Wireless networks seamlessly operating with other wireless networks, and with wireline networks and the internet (Berezdivin et al, 2002).
- Seamlessness, which can lead to multiple requirements at various levels, but implies a melting away of access and interface barriers between networks and between service provides, and the emergence of a wireless true IP over-the-air technology (Berezdivin et al, 2002).
- Highly efficient use of the wireless spectrum and resources (Berezdivin et al, 2002)
- Flexible and adaptive system and networks (Berezdivin et al, 2002)

• Distributed intelligence and wireless resources (Berezdivin et al, 2002)

Next-G spurs the breaking of the wireless barriers, across both service providers and technologies (Berezdivin et al, 2002). Figure 6 depicts some of the wireless network technologies, their evolution, and their position towards the next-generation wireless system that provides seamless services across them (Berezdivin et al, 2002).

Figure 5: Ultra-connectivity enables users to connect and communicate seamlessly (Berezdivin et al, 2002)

Figure 6: Breaking the barriers across various wireless access and network technologies (Berezdivin et al, 2002)

1.1.3 Asymmetric Digital Subscriber Line (ADSL)

Introduction to ADSL

Asymmetric DSL is a type of DSL, a data communication technology that enables higher rate of data transmission over copper telephone lines than a conventional voice band modem can provide (Islam, 2008). The qualifier 'asymmetric' is used because the data transmission performance to the user is higher than the data transmission performance from the user (Islam, 2008). The maximum transmission speed ranged from 2 to 8 Mbps and the maximum range is up to 2 kilometres using a 0.4mm cable (Islam, 2008).

ADSL offers some added advantages when compared with traditional analog modems. It is compatible with existing Plain Old Telephone Service (POTS) on a single pair of wires without disruption (Islam, 2008). POTS is the basic service that provides all phone lines with access to Public Switched Telephone Network (PSTN). POTS provides the means for all voice-band related applications and technologies, such as telephony, caller identification, call waiting, analog facsimile, analog modem, etc. (Islam, 2008). ADSL systems allow the end user to access any POTS associated servies and ADSL services simultaneously (Islam, 2008). It also has the ability to dynamically adapt to varying channel conditions. ADSL systems automatically measure the characteristics of the channel and decide upon an appropriate data rate that can be effectively maintained according to a predefined acceptable bit-error rate (Islam, 2008).

1.1.4 USQ Direct Access Network

The USQ campus wired direct access network was implemented and maintained by the Division of ICT Services within the Toowoomba, Springfield and Fraser Coast campuses. It is available to all staff and students and offers wireless data connections at through put speeds up to 54Mbps (USQ website, 2011).

1.2 Project Objective

In this paper, we address the need to obtain an objective comparison of various Internet services available in rural Australia. The Quality of Experience (QoE) perceived by the end-user heavily depends on the Quality of Service (QoS) parameters such as time required to download a file and round trip time (RTT). We therefore vary those parameters in our real-time environments and measure the time it takes for an end-user to perform a typical task like browsing the internet and downloading a file. Below are the main objectives of this research:

- 1. Research information on last mile internet access, specifically satellite and wireless broadband (Next-G) access.
- 2. Define and motivate test environment, including test scenarios and test locations.
- Research and develop an automated test system to evaluate signal strength and measure the quality of various services that rely on internet connectivity. this will include
 - a. Round trip time (RTT) measurements
 - b. Timing of file downloads,
 - c. Time needed to load/interact with simple and sophisticated web pages
- 4. Undertake comprehensive tests in the defined environment using the develop test program.
- 5. Document, analyse and evaluate test results.
- 6. Evaluate more test locations for the wireless broadband access.

1.3 Dissertation Outline

The first chapter of this dissertation introduced the background study of this research namely the Satellite Internet network and Next-G. Other internet accessing alternatives like ADSL and the University's direct access network were also tested upon for comparison purposes. Chapter 2 gives a moderate overview of related work or literature review. Related work done previously like published papers and journals were used to be compared and their methods utilized to be used in this research. The measurement setups as well as the measurement methodology were explained in detail in Chapter 3. From data collected from the various tests, we analysed and evaluated the results in Chapter 4, while Chapter 5 finally concludes this research.

Chapter 2 Literature Review

Many theories have been proposed to compare the performance between networks. Although this literature covers a wide variety of different context, this review will focus on five major themes which emerge repeatedly throughout the literature reviewed. These themes are to evaluate signal strength and measure the quality of various services that rely on internet connectivity which include: Round Trip Time (RTT), Timing of file downloads, Time needed to load/interact with simple and sophisticated web pages measurements.

2.1 Performance Comparison of Windows-based Thin-Client Architectures

One of the related studies was done by Schlosser et al (Schlosser, Binzenhofer & Staehle 2007) who examined and compared the performance of the Windows Remote Desktop Protocol (RDP) and the Citrix Presentation Server under different aspects. They examined the load caused on the network layer and the feedback from the end user with the QoS achieved when using the two systems. Since performance heavily depends on the network conditions, they emulated realistic scenarios in a controlled test bed environment and measure the time required for a typical office task on application layer. To be fair, they used an open sourced tool, AutoHotKey to reproduce the same input behaviour to check whether the changes have been applied properly and to measure the duration of each task. To achieve a credible measurement result, they perform each test for an hour. They use the software, WinDump to record the speed of the network's traffic. After each tests, they reset the test bed to prepare for the next test. In one of their tests, they compare the Quality of Experience (QoE) of the 2 different thin-client architectures and analyse just how far it is influenced by the Quality of Service (QoS) parameters like the Round Trip Time (RTT). They measured the duration of the Word and Excel tests under different network conditions. Their testing overall concludes that Citrix is more sensitive to packet loss than RDP and since it is also optimized for Microsoft Office applications (Microsoft Word and Excel being their testing platform), it achieved a slightly better QoE under perfect conditions.

Instead of Microsoft's RDP and the Citrix Presentation Server, we perform tests on the Satellite internet, Next-G, ADSL and the University network and compare

their real-time performance (QoS) to the output performance manufacturers or Internet Service Providers (ISP) claim them to be. We agree with Schlosser that it is the satisfaction of the user with the service which counts at the end of the day (Schlosser, Binzenhofer & Staehle 2007). This can be quantified by how much additional time a user needs or how much time a user can save to do his work while using the 4 different networks mentioned above. Both Schlosser and we agree that our test results reveal the advantages and disadvantages of the different approaches and can thus be used as a much needed guideline for which protocol to use in different situation.

Unlike Schlosser (2007), we ran our test scripts in a real-time environment without test beds. We then compare their performance in terms of performance and user satisfaction. Our testing parameters differ compared to that of Schlosser's. Schlosser's test parameters include performing typical tasks like typing text, navigating through menu-entries or scrolling through a document (Schlosser, Binzenhofer & Staehle 2007). Our parameter includes, measuring packet loss, network round trip time (RTT), distance away from Next-G tower, Time required to download a file and to load simple and sophisticated webpages. Schlosser (2007) used specific machines (two 3.4 GHz Intel Xeon server with 3.5 GB RAM each etc.) but because our research is based on the internet network speed and not machine speed, processor and RAM specifications does not matter as much. Our test is also being tested in real time meaning different users would use different systems thus; we do not run our test on specific systems thus we run our tests on any reasonable operational machines.

As for software applications, Schlosser used Word and Excel (Schlosser, Binzenhofer & Staehle 2007) from the Microsoft family. We used Microsoft's Internet Explorer when doing the loading-a-webpage tests and we chose to download Mozilla Firefox 3.exe from the AARnet website when we do the time-required-to-download-a-file tests. Schlosser and his team was very specific with the configuration of his systems, setting the colour depth and enabling persistent bitmap cache on all his machine but it is not necessary in our internet QoS research.

We agree with Schlosser that in order to expose all our networks to the same user behaviour, the entire user input has to be done automatically (Schlosser, Binzenhofer & Staehle 2007). Schlosser's test consists of some typical office tasks being automatically performed several times. The software which enables them to perform tasks automatically is named AutoHotkey. According to Schlosser, they repeatedly perform each test for the duration of an hour. Within that hour, their network emulation settings on their machines remain unchanged. We decided to follow Schlosser by using AutoHotkey to do our automated testing. Our file download, pinging and loading a page tests are all done automatically as if all testing were done by the same person so we can

acquire credible measurement results necessary for analysis and evaluation. As for testing durations, we also used repetitive testing however our testing duration varies due to different circumstances. This will be further mentioned in the methodology section of this paper.

Schlosser and team performed their test both under perfect network conditions and self-motivated imperfect network conditions to derive what factors mainly influence the network traffic sent by thin-clients. With their obtained results, they compare both thin-clients' performance against the processes on the network layer and the user perceived quality on the application layer (Schlosser, Binzenhofer & Staehle 2007). We decided to perform our tests directly in normal network conditions so that we can obtain real-time user experience (QoS). If time permits, we will compare our final test results with the performance Internet Service Providers (ISP) claim to offer.

2.2 Performance Comparison of 3G and Metro-Scale WiFi for Vehicular Network Access

Daspande, Hou and Das (2010) from the Stone Brook University, USA performed a performance comparison between the characteristics of a 3G network provided by a nation-wide ISP and a metro-scale WiFi network provided by a commercial ISP. Their tests were done from the perspective of vehicular network access. Like Schlosser et al, they too run their tests in a controlled test bed environment using a modified Dell Latitude laptop running Linux as the client machine to be run in the car. A12 dBi Omni-directional antenna was attached to the car with the top part sticking out of the sunroof (Daspande, Hou and Das 2010). A modem was just as a 2nd network interface and a GPS receiver is connected to the laptop to log the distance and location while the test was running. A server program runs on a lab machine with a public IP address accepting coming connections from the Wi-Fi and 3G network. It transmits 1500 bytes per packet continuously to the laptop over TCP. Two driving scenarios were used: Long Drive and Short Repeated Drives. The Long Drive was done by driving 500 miles (approximately 5 hours) but this is done only once. According to them, this drive provided a reasonable "sample of quality" of the Wi-Fi access on a moving vehicle in a metropolitan area. As in the name, Short repeated drive is a 9 mile drive on a preselected route where signal coverage is reasonably good. This was done 10 times to get a credible average in the result. They concluded that though Wi-Fi has frequent disconnections, it offers a higher throughput (when connected) in mobile scenario compared to 3G. 3G on the other hand offered similar to lower throughput but generally

has a more reliable coverage. Daspande's research is similar to ours except that we are measuring the Next-G network instead of 3G and we choose not to measure the network's performance under vehicular mobility. The distance-away-from-base test is solely to test to see if there is reduce in performance when the Next-G network's performance is measured in increased distance away. This makes us ask this question: *If there is reduce in performance on the Next-G network over distance, what kind of reduction would it be? Would it be a linear reduction or unexpected reduction?* Instead of measuring the performance while the vehicle is moving, we decided to measure Next-G's performance at a pre-defined fixed distance interval (every 1 km). This will enable to see if its performance at every km and we can do an analysis and evaluation based on those results.

2.3 An Experimental Performance Comparison of 3G and Wi-Fi

Similarly Gass and Diot (2010) did an experimental evaluation of internet download and upload speed of the 3G network and an open Wi-Fi while on the move. However they performed the experiment both in a car and on foot both following the same route. A Wi-Fi and 3G mobile device were experimented at the same time for a true side-by-side comparison. The Wi-Fi mobile device was an IBM T30 laptop installed with the Ubuntu distribution of Linux while the 3G device was an Apple iPhone 3G. When performing the download test, both devices downloaded the same data which originates from the same server which streamed the data to the mobile devices. When performing an upload, the same data received from the previous download test were used to stream back to the server. The experiments were performed in a residential area of Pittsburgh, Pennsylvania near their University campus. Their experiments showed that using a default AP selection techniques and off-the-shelf equipment without the need of an antenna, they could opportunistically connect to open or community Wi-Fi Aps in an urban area and they could transfer a significant amount of data at walking and driving speeds. Their conclusion was that a reliable Wi-Fi network in an urban area can provide the same or greater quality throughput than a more expensive 3G network.

Gass's research is closely similar to our distance away from source testing. Their experiments consist of 2 mobile clients and a server that is always connected to the internet. One mobile client uses its Wi-Fi interface to transmit and receive data to/from the server and the other uses 3G. Gass's experiments were performed both on foot and in a car following the same route (Gass and Diot, 2010). Because the focus of our research is on the QoS rather than performance, we decided to download directly

from the internet instead of Gass's method of using a server obviously so that both his 3G and Wi-Fi could be downloaded from the stable unchanging source. Unlike Gass's measurement methods, we decided to do a stationary measurement every fixed interval away from the Next-G base tower. Thus we are not always connected to the internet because we only do our measurements every say 100m away from the base tower. Gass also run his test simultaneously for a true side-by-side comparison. We could not do likewise because it is not practical for our research.

Though compared to us, Gass used a completely different computer setup, it does not matter to us too much because our AutoHotkey scripts are versatile enough to run on most operating system. We did not use a fixed system as our test bed because firstly it is not practical when performing our tests in different environments and even though the quality of the computer systems may provide better results, we presume the result variations will not differ a great deal because we are more concerned about the QoS not the performance. Before performing tests, Gass's laptop first attempts to connect to the internet by scanning the area for available open or community APs (Gass and Diot, 2010). Our Next-G USB device will automatically detect the nearest base station or the base station with the strongest signal strength. There is a possibility that we may pick up transmission from a different base station thus ruining our test results, we have a special phone that will tell use from which base stations are we receiving transmission from. More detailed information could be found in the methodology chapter.

Gass's 3G server runs the apache web server and hosts large, randomly generated data files that can be downloaded by the client while his Wi-Fi server runs a simple socket program that generates data and streams it down to the Wi-Fi client (Gass and Diot, 2010). We used simple automation software, AutoHotkey which automatically download a specific file directly over the internet over and over again for a fixed amount of time.

Gass's experiment utilizes a USB global positioning system (GPS) receiver that is pluged into the laptop capturing speed, location and time once per second. The GPS device is also used to synchronize the time on the laptop which captures all data that is transmitted or received over the wireless interface (Gass and Diot, 2010). We also used a GPS mainly to show us our location and distance away from the Telstra's base tower. Gass's experiments were performed in a residential area of Pittsburgh, Pennsylvania, USA and he produced maps showing all available open access points and the route followed for their experiments. Our tests are performed in residential are of Murphy's Creek, a small country town just off the New England Highway in Toowoomba, Queensland. We chose this town because there is a base tower there which is reasonably remote and we hope to be able to capture only the signal transmitting from

that base tower. Maps of our route and base towers around the area could be found in the methodology chapter of this paper.

2.4 Fair Quality of Experience (QoE) Measurements Related with Networking Technologies

Martinez-Yelmo paper aims to give an overview on how to perform fair QoE measurements to facilitate the study and research of new networking solution and paradigms. According to Martinez, any research into new networking technologies is driven only to satisfy the user's experience and this is of the utmost mandatory (Martinez-Yelmo et al, 2010). However, different solutions exist in determining QoE thus it is difficult to make the most suitable selection. QoE is subjective and the comparison among different technologies is not trivial (Martinez-Yelmo et al, 2010).

According to Martinez, "The concept of QoE can be applied to many topics; therefore, it is necessary to find a wide definition suitable for any field. An interesting, short and concise definition for QoE is: Quality of Experience is a subjective measure of customer's experiences" (Martinez-Yelmo et al, 2010). We find Martinez's statement very true because we believe at the end of the day, it is the users' satisfaction that matters thus this research is to find out how and what the user's experience is in our motivated environment. Our target users are the ones residing in rural Australia thus we focus more on the satellite internet and the Next-G network.

Martinez claims that there are 3 elements are required in order to measure QoE. The 1st one is the fact that QoE is based on measurements, which means some mechanisms are necessary to define what measurements are the most relevant and how they can be obtained (Martinez-Yelmo et al, 2010). This is true for our research. We used the software, AutoHotkey as our measuring mechanism to do our various tests in our various motivated environments. We aim to measure the actually quality of internet usage by using AutoHotkey to repetitively download, ping and load predefined files and websites. This will give us an overview of the actually results acquired by users using the same internet service in those motivated environments. More detailed information could be found in the methodology section of this paper.

The second is the user or customer since they are the ones experiencing and paying for the service. Martinez claims that it does not matter how technologically enhanced and sophisticated the implementation of the new feature is because at the end of the day, it is how useful and satisfactory the improvements that benefits the users or customers can experience from their perspective that is of the utmost importance

(Martinez-Yelmo et al, 2010). We totally agree with Martinez because although the technology improvements of satellite or Next-G network may be impressive especially to a technology-literate user, it will still fail to serve its purpose if users refuse to buy or use it. In other words, designers, manufacturers and businesses must take into account the expectations of the users or customers; using the customer's expectations and desires as a driving force behind their work.

Finally, Martinez states that QoE measurements are subjective and dependant on the opinions and experiences of each individual (Martinez-Yelmo et al, 2010). We believe this is true as 2 different individual using the same network in the same environment may have a very different opinion on the quality of service or quality of Experience. Thus we aim to instead of informing users of the performance or speed of their download and upload, we could present them with the performance comparison of actual user's usage using a variety of networks over a variety of environments so users can see a better picture of the various networks and how it may benefit them.

Martinez claims that Internet Service Providers (ISPs) like Telstra, Optus and Vodafone use Quality of Service parameters such as bandwidth, delay or jitter to guarantee their users a good service quality. However, the proliferation of multimedia content makes more important the provision of QoS if a good QoE wants to be provided to the final user (Martinez-Yelmo et al, 2010). We believe Martinez that ISPs need to consider both the QoS and QoE as they influence and impact each other in terms of provision of user's expectations. Our testing parameters are more relaxed as we take into account not just the performance but also the consistency and reliability of the various networks we are testing on.

Martinez said that the reception quality with or without the improvements given by these solutions is measured using objective mathematical operation, comparing the original and the received stream, such as packet loss ratio and PSNR (Peak Signal to Noise Ratio). However this approach has a lack of perceptual quality measurements that should take into account the perception and the understanding of the receiver. Better receiving experience cannot be measured only using good peak values or assuring low mean packet losses because the semantic losses of the received data are not included in these parameters (Martinez-Yelmo et al, 2010). We believe Martinez is right as there are just too many parameters to consider; there is no one perfect parameter that suits all users. Also there may be certain parameters that are impossible to set. Thus in our research we used minimal parameters so that we could obtain the raw actually results an actual user may experience. We believe this is what users should see for themselves instead of a so claimed network performance.

Martinez mentioned that many applications or software rely on internet

network services in order to run. In many cases users can only appreciate the quality and satisfaction their chosen internet network can bring them via interacting with these applications. An average user mainly worries about starting up and the smooth running of their application over the internet. In many cases, users would not be biased by all the complexity that exists under any application; they only consider if it works or not (Martinez-Yelmo et al, 2010). Martinez went on claiming that a good example would be the Skype application. Skype was originally a chat and VoIP service based on a peer-topeer technology but over time it has increased its functionalities in order to get more and more customers. Martinez claims that the ongoing success of Skype is just based on its functionalities but the fact that users can install the software in any computer and use any internet network and it will work. Most users are happy with the simplicity of use of Skype but not particularly interested that this simplicity is possible because of Skype's capabilities of crossing NATs and firewalls without reconfiguring any network equipment (Martinez-Yelmo et al, 2010). Our AutoHotkey's functionality is similar to that of Skype. AutoHotkey is very versatile and can be operational in most operating systems. Users need to only download the AutoHotkey application as they would in downloading Skype from the internet and then they would be able to run our test scripts. This will show them actually performance of their internet based on their individual usage of the internet. For example a user who is constantly downloading torrents at the background may experience low internet performance as compared to a user who only use the internet to email or chat with their friends.

Martinez (2010) states that due to the great number of variable that needs to be taken into account when running QoE tests, it is therefore necessary to follow a methodology that avoids unfair comparisons because this will result in wrong conclusions. In our case, we purposely run our tests (download a file, ping a website, load simple and sophisticated websites) in the same networking conditions and environments so that we can compare the QoE of different common activities when used in a particular environment.

In all QoE researches, Martinez claims that there are input parameters and output parameters (Martinez-Yelmo et al, 2010). Input parameters are the conditions used for the evaluation of System under Test (SUT). According to Martinez, these conditions have a direct impact in the system that is being evaluated as they may impact the test results. The input parameters can be divided further into 2 different classes: Environment and Workload (Martinez-Yelmo et al, 2010). The environment is the computational and communication infrastructure as well as other relevant conditions for the assessment. The environment can also means a static condition or location where the system is under evaluation. The workload reflects the dynamic conditions of the

system under evaluation. The importance of the workload is that it distinguishes among the conditions that are imposed by the experiment itself (environment) and those conditions that gave pressure to the SUT (workload) (Martinez-Yelmo et al, 2010). In our case, we believe our environment could be the operating system and computer specification used to execute our tests. Our environment is also our motivated environments (scenarios) as mentioned in the methodology chapter of this paper. On the other hand, our workload could be the background traffic in the different links, the number of entities participating or running together while the tests are being run. We are very aware of this therefore we make sure we closed all application that relies on the internet. Our main concern in this area is automatic updates run by windows or an antivirus application which we may not have any control over.

As for the output parameters, Martinez states that they are the results obtained after the test has been run under the input parameters. The output parameters could be divided into 2 elements: Performance and Cost (Martinez-Yelmo et al, 2010). The performance is related to the efficiency of a certain internet network acquired from the test results. The cost is not limited to money as it reflects the necessary resources used to achieve the obtained performance. This is true as our test results will definitely show the difference in performance and QoS of the various internet networks and with it, we can conclude the most suitable internet networks to be used in the appropriate environments. Though we know our aim is to achieve a result that will satisfy our hypothesis, it comes with a price: Time and money. A lot of time has been thrown into this research while doing our literature review, background research and field tests. In terms of financially, we spent a lot of petrol driving to our defined location to perform our tests. Fortunately AutoHotkey is an open-sourced software and I was able to receive some support from the online community and my supervisor otherwise more resources may be used.

2.5 Techniques for measuring Quality of Experience

Kuipers believes that the *Quality of Experience (QoE) refers to the overall acceptability of an application or service as perceived subjectively by the end-user* (Kuipers et al, 2010) as appose to Martinez's simpler translation of QoE being a subjective measure of customer's experience (Martinez-Yelmo et al, 2010). We agree with Kuipers that QoE measurements walk hand in hand with the overall acceptability of specific application or service pertaining subjectively by different end-users. QoE therefore includes the complete end-to-end system effects (client, terminal, network,

sercices infrastructure, etc.), where overall acceptability may be influenced by user expectations and context.

This definition explicitly refers to QoE as a subjective measurement and properly measuring QoE should therefore involve tests with actual users, which is a timeconsuming and costly process (Kuipers et al, 2010). In our research so far, we agree with Kuipers because we found out that QoE covers a very large range of not-specific perspective of different individual users. Thus this makes our research never ending when it comes to different conditions, environments and scenarios. We also need to match our motivated environments with the motive or purpose of the usage of user's internet access, level of mastery over the use of internet or experience of the users and we must even consider the character and attitude of the users because while using the same internet connectivity, a user who lacks patient will complaint while another user who is patient n teachable will be happy with the learning process. Like Mirtinez, Kuipers thinks it is preferable to have tools that objectively reflect within reasonable accuracy the subjective mean opinion score of users(Kuipers et al, 2010). Because our test is only based on one user, we cannot carry out the calculation of mean opinion score. However because we have already developed the scripts necessary to run all tests, calculating the mean opinion score of many users is very possible for future researches.

According to Kuipers, QoE is determined by more than the QoS provided by the network. Network and service providers can only measure the performance over that their end without realizing the users or customers end (customer's level of satisfaction) ISP only have control over their own equipment / network, and therefore it is important for them to know the relation between QoS and QoE (Kuipers et al, 2010). He said that accurately measuring parameters like bandwidth and delay is a reach topic on its own, but QoE is an end-to-end measure that sees the network as a black box. This means that we can omit the details of the network and correlate the QoE of certain applications to (artificially introduce) artefacts like delay and packets losses(Kuipers et al, 2010). Our research agrees methodology agrees with Kuipers for we believe measuring QoE is an end-to-end measure that sees the any network as a black box. We ignore the details of the network and its technicality but prioritize the overall "satisfaction of use" instead. For example, instead of benchmarking a certain pinging speed and comparing them with my test results, we choose to ignore where and how the transmitting packets travelled through before they reach their destination. We ignored the details but prioritize more on the overall results of the users' experience.

2.6 Home Network Performance Diagnosis

Lucas Di Cioccio research is to develop techniques to assist users to diagnose performance problems a home environment. He claims that home networks affects end-to-end performance but there is little data to understand the diversity of home networks. In his experiments, Di Cioccio performs controlled experiments to check that home networks can have a significant impact on end-to-end performance. He also developed a "Homenet Profiler" a tool to collect data from home users' computer to characterize individual home network conditions and finally he designed a troubleshooting tool for home users (Di Cioccio, 2010).

Like Schlosser et al, Cioccio uses a control testbed to emulate a home network connected to a DSL provider with triple-play service. His testbed allows him to study independently the effect of TV, phone, competing data downloads and uploads as well as the in-home network technology on end-to-end performance. Cioccio uses testbed and metrics to capture end-to-end performance as seen by an end-user. He independently studied the most common home services: voice, TV, data upload and download. He then tests how these 5 usage scenarios affect end-to-end performance as seen by a probing computer (Di Cioccio, 2010). Similarly, our research utilized testbeds sos we can study independently the QoE and QoS in various environments such as Satellite internet, Next-G, ADSL and the University campus network. We further stretch our environments to rainy weather, 24 hours, day and night differences etc.

Cioccio's experiments show that cross traffic from home network can increase the end-to-end latency to 1 second (when competing with a TCP) and download rate dropped 4Mbps when the TV is being used. This proves that our research on QoE and QoS is important because Cioccio experiences confirms that different individual's usage of home appliances and electrical devices varies and they all have significant impacts on their networks' performance. For example, lots of watching TV, decrease internet performance thus decreasing user's satisfaction on their internet experience thus lowering QoE.

We agree with Cioccio that current existing monitoring and troubleshooting tools do not properly take the home network into account because it is hard to pinpoint if the home network cross traffic is responsible for performance degradation. Thus in our QoS and QoE measurement tests, we altogether ignore the specific detail of where the drop in performance comes from but instead measure the user's experience as a whole. We believe different users have different lifestyles and needs thus it is quite impossible to set a benchmark for any of our tests.

Similarly to our ADSL test, Cioccio's test includes having a commodity business laptop connected to the internet using an ADSL2+ line from France Telecom. Cioccio however only perform tests on RTT performance and HTTP download speed. According to Cioccio, the RTT captures the effect of the home on delay sensitive applications whereas HTTP downloads represent bandwidth intensive applications. He waited 500 miliseconds before each ping request and obtained distributions from 100 pings of size 64 bytes (Di Cioccio, 2010). Unlike Cioccio, we do not obtain from 100 pings of a particular size and have a have a ping interval of 500 miliseconds. We instead ping 20 packets and have a waiting time of 10 minutes between each pings and we think this configuration fits our purpose better because it allows easier management of the results later. For example 10 minute interval means there would be about 6 batch of 20 pings per hour and only 144 lines of data would be collected in a day. Calculating the average out of the 20 pinged packets will also provide us a more reliable answer.

For the HTTP download test, Cioccio uses the wget command line tool to download a file of 24MB. The file contains random bits to prevent transport compression. Cioccio mentioned that they used large files when measuring the bandwidth to minimize the effect of TCP slow start and as a result, each measurement takes time thus Cioccio and team only did 20 repetitions (Di Cioccio, 2010). Unlike Cloccio, we chose to download a file with a size about 8 MB. Because our test prioritized QoS thus the file size does not matter to us. Instead of using wget, we chose to use AutoHotkey which we used to write a script which helps us run the download automatically repetitively for a week to hopefully achieve a more reliable result.

When performing a measurement run, Cioccio and team first pick a metric and do all the experiments as close as possible in time for the different scenarios. Then they tested all cases for the next metric. According to Cioccio, performing measurements of a metric back-to-back ensures that the conditions of the ISP network are similar and most of the differences will then come from the emulated home (Di Cioccio, 2010). Instead of performing our tests as close as possible in terms of time of tests, we decided to perform our test over a long period for example: over a week. The reason is because it is not feasible for us to perform this due to our different environments and internet connectivity network. However, having collecting test results for over a 24 hours, we can roughly conclude an average QoS and QoE of each tests and spikes in our test graphs will lead us to investigate the reason behind the delay and decrease in QoS and QoE.

Chapter 3 Methodology

Figure 7: Research big picture

Figure 7 shows the big picture of this research. The internet's performance can be influenced by a number of factors like the type of networks, the types of environment and even the types of tests. Branching from those factors, the blue clouds shows a variety of options for those factors for example there are many types of test we perform which includes timing of file downloads, Round Trip Time, Time required to load a sophisticated and simple webpage, performance of Voice over Internet Protocol (VoIP) and performance of video streaming over the internet. Our motivated test environments are performance measured in 24 hours, performance comparison between night and day, performances measured over a week, performance during a rainy weather, performance in terms of distance away from Next-G tower and many potential others. Our chosen networks include Satellite internet, Telstra's Next-G network, ADSL and the campus network. With the results collected we can analyse, evaluate and compare the results with different networks and our pre-test hypothesis.

Network Scenario	Satellite Internet	Telstra Next-G	ADSL	University Network
Ping (RTT)	YES	YES	YES	NO
File Downloads	YES	YES	YES	YES
Loading Webpages	YES	YES	YES	YES
24 Hours	YES	YES	YES	YES
Night and Day	YES	YES	YES	YES
Distance Away from Source	NO	YES	NO	NO
Rainy Weather	YES (Weather Dependant)			

Table 1: Suitability of test for different Networks under different Scenarios

Table 1 shows that certain network tests sometimes cannot be performed in certain scenarios for various reasons. For example, the university network blocked pinging accessibility so the pinging test could not be run via the University direct access network. The "Distance away from source" test could not be perform via the Satellite Internet network because the distance between earth and the GEO satellite is fundamentally fixed due to the GEO satellite's routine orbit around earth. The distance away test could not be done on ADSL and the University's network because internet access via ADSL requires Ethernet (LAN) cables and therefore it is not practical. This however could be an interesting research for anyone who wishes to measure the performance of ADSL with respect to cable length. This test may require a lot of wires of different lengths and may not be too applicable. We already know that the University's direct access network has a limited coverage in terms of radius thus test on distance away is not practical in this retrospect as well.

Performing those tests during a rainy weather is also a challenge. Toowoomba has little rain and rain here generally lasts no more than 30 minutes so this test is highly dependent on a reasonable period of rain time adequate enough to rain all tests. All other scenarios can basically be performed in all defined networks however many require permission from certain authorities. For example, I need to make a prior arrangement and

permission grant from Telstra; set a suitable date and time for both parties in order for me to be able to perform these tests using their facilities and their Next-G network. Using the university's facilities and equipment like the netbook and satellite dish requires permission grant via my supervisor before any test can take place.

Figure 8: Overview of the Methodology

Figure 8 illustrates the overview of our research methodology. The test script which we have written and loaded on the laptop can be used to measure the performance of different internet accessing networks. By plugging in the Next-G USB Wireless antenna Telstra has provided us, we can gain access the internet via the Telstra's Next-G network. On the other hand, by plugging the Ethernet cable connected to the satellite antenna into our computer, we can access the internet via the satellite antenna. We asked Telstra from their permission to run our tests using their ADSL network. Like the satellite internet, we only need to plug the Ethernet cable into our computer to access the internet via the ADSL network. The University's wireless network could be accessed anywhere within the campus via a login then student username and password.
AutoHotkey Coding



Figure 9: Download_A_file.ahk Flow chart

Figure 9 outlines the functionality of the Download_A_file.ahk script. Double clicking the Download_A_File.ahk script automatically triggers the download of the file, Firefox 3.6.23.exe from the AARnet website, http://mirror.aarnet.edu.au/. A pop up box will appear at the lower right corner of the computer screen stating "Download beginning at Hour: Minute: Second". There will be a 10 minute interval between each download after which another pop up box will appear stating either "Download completed at Hour: Minute: Second" (if the download was successful) otherwise it will pop up "Download failed".

Once the first file has been downloaded, the date, current time, file size and time required to download Firefox 3.6.23 in seconds will be automatically recorded and saved in a log file named Download_A_File.csv which could be opened using a notepad or Microsoft Excel. Firefox 3.6.23.exe is downloaded as a temporary file which will be deleted as soon as Download_A_File.csv captured its time required to download that file.

The date and current time tells the user the current date and time during the download. The time to download the file is the most important data among these and it allows us to plot a graph so we can perform our result analysis later. The file size though seems useless is important because it tells us that we are downloading the right file. Without it, users may be downloading the wrong file or even a webpage saying there is no such file! Download_A_File.csv will be automatically saved on the desktop of the computer. 10 minutes after the first download, another download will begin and this process will repeat itself and its results will be added below the previous results successively. This script is programmed to automatically download repetitively over and over again forever. The idea is to let this script run for at least a week so we can have a more concrete and reliable result. From the data collected in a week, we can extract from it data collected each day of the week. The data collected could be put into Excel where graphs will be plotted to be used for analysis and evaluation.

This section explains the contents in the log file, Download_A_File.csv when opened in Excel. Column A shows the date and current time. For example 20111002133210 indicates the file was downloaded on the date 02/10/2011 at the time 1:32:10 in the afternoon. Column B shows the time (in seconds) required to download the file. Average time varies depending on how congested the internet was at the moment of download. Column C shows the file size of the Firefox 3.6.23.exe thus the values are all the same. However if we detect that the file size as changed, it could mean that the file has been updated or we could be downloading a webpage that says that this website does not exist or we could be downloading a webpage that says that that file no longer exist. Finally column C and D simply display the words "Download success".

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Script 2: Pinging a Website



Figure 10: Ping5.ahk Flow chart

Figure 10 outlines the functionality of the Ping5.ahk script. Double clicking the Ping5.ahk script automatically triggers the pinging of the website, http:///www.google.com from the internet. We named it Ping5 because we had 5 attempts of writing this script before it works. The script is configured to a 10 minute interval between each ping. Unlike the usual pinging of 4 times when you type "ping google.com" onto the command prompt, we decided to ping 20 times meaning we want to send and receive 10 packets. This is to ensure we get a reliable result and a good average ping time.

Once the first batch of 20 packets has been pinged, the date, current time, average time required to ping 20 packets in milliseconds (ms), number of packets successfully pinged and finally number of packets lost will be automatically recorded and saved in a log file named ping.csv which could be opened using a notepad or Microsoft Excel. The log file, ping.csv will be always automatically be created and saved onto the desktop as soon as the first batch of pinging results is available.

The date and current time tells the user the current date and time during the download. The time required to ping is the most important data among these and it allows us to plot a graph so we can perform our result analysis later. 10 minutes after the first batch of pings, another batch of 20 pings will begin and this process will repeat itself. This script is programmed to automatically ping repetitively over and over again forever and the data will be recorded onto ping.csv successively. The idea is to let this script run for at least a week so we can have a more concrete and reliable result. From the data collected in a week, we can extract from it data collected each day of the week. The data collected could be put into Excel where graphs will be plotted to be used for analysis and evaluation.

This section addresses the contents of the log file, ping when opened in Excel. Column A shows the date and current time. For example 20111002133217 indicates the file was downloaded on the date 02/10/2011 at the time 1:32:17 in the afternoon. Column B shows the average time (in milliseconds) required to ping 20 packets. As you can see the time varies depending on how congested the internet was or which pathways did the ping go through before it reaches google.com at the moment of ping. Column C shows the number of successful packets pinged out of the 20 packets. Column D shows the number of packets lost out of the 20 packets. Column C and D are important because without them we can only assume that all the 20 packets pinged have not been lost and we can only assume that the result we get (average time to ping) is the result of pinging 20 successful packets. Because in reality, packets always gets lost in between pings, we decided to add this feather into our script so we have a better perspective as to how reliable certain network is compared to others. For example if a certain network has a high rate successfully pinging 20 packets without lost, we can conclude that particular network is reliable.

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Script 3: Loading simple and sophisticated websites



Figure 11: Internet_Explorer_Timing_Script.ahk Flow chart

Figure 11 outlines the Internet_Explorer_Timing_Script.ahk script. Double clicking the Internet_Explorer_Timing_Script.ahk script automatically pops up a box showing user the settings configured on the script. Then it asks the user if any change is required before running the script. If these settings are OK, select YES to begin testing. If not, select NO and user will be directed to the script file where user can edit the script before testing. Options for change are the directory the user wants the log file to be saved to, the time interval between loading of each website, option to change the number of websites and websites of choice and finally the option whether the user wants each website to be open on a separate window or reload a new website on the existing window.

After clicking YES, the script automatically open up or load 5 pre-determined websites namely www.telstra.com.au, www.google.com.au, www.usq.edu.au, www.yahoo.com and www.bbc.co.uk. These websites will be loaded in the same window repetitively in the same order or sequence over and over again. After the first website, www.telstra.com finished loading, the URL, load time, current date and time will be recorded and saved in a log file named LoadTimes.csv onto the desktop of the computer. Each successive website loading time will be recorded and saved under the previous website and so on.

The date and current time tells the user the current date and time during the download. The time required to load each website is the most important data among these and it allows us to plot a graph so we can perform our result analysis later. 10 minutes after the first website is loaded, the next website will begin to load and this process will repeat itself. This script is programmed to automatically ping repetitively over and over again forever and the data will be recorded onto LoadTimes.csv successively. The idea is to let this script run for at least a week so we can have a more concrete and reliable result. From the data collected in a week, we can extract from it data collected each day of the week. The data collected could be put into Excel where graphs will be plotted to be used for analysis and evaluation.

This section addresses the contents of the log file, LoadTimes.csv file when opened in Excel. Column A represents the URL of the website so user will know the loading time for the correct website. Column B shows the time in seconds required to load each individual website. Column C shows the date and current time. As you can see the time varies depending on the different website and how congested the internet was or which time of the day the test was being run.

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Test 1: Distance Away from Next-G Tower

Equipment required

The elements required for this distance away from the Next-G tower test consists of

- Test scripts which will be run on a portable laptop computer.
- A Next-G USB device (Sierra Wireless USB 306)
- A special rubber holder which helps holds the Next-G USB device up right during connection.
- An external antenna which may increase the gain (in dBi) thus potentially providing us with a better signal.
- A patch cord which connects the Next-G USB device to the external antenna
- A special phone (LG550) which gives us information on which tower's signal are we receiving from and the value of signal strength (in dBm) we are receiving.
- A car charger lend to me by a friend in case my laptop and phone run out of battery.
- Global positioning System (GPS)

The aim of this test is to measure the internet performance of the Telstra's Next-G network with respect to the distance away from the Next-G tower. Unlike Gass's tests which involves measuring WiFi and 3G's performance constantly while in a moving car (Gass and Diot, 2010), we decided to measure our Next-G's performance while being stationary. Thus, at every km away from the tower we stop the car and measure its performance. Tests on performance include downloading a file, pinging a website and loading sophisticated and simple webpages; these tests run automatically at an interval of every 10 minutes.

As an initial experiment, we measured its performance at a 1 km interval away from the tower. This initial experiment gave a rough idea of how rapidly or slowly the performance is affected by distance. After comparing the test results measured from the source (0 km) and the results measured 1 km away, we realised that there is a huge gap difference. Thus, we decided to limit our tests to every 100 meters away up till 500 meters. We perform this test for a total of 5 times. Then the average speed of those tests will be produced as our final result.

Test Route

The tests were performed in a residential area of Murphy's Creek. This area lies between Highfields and Toowoomba along the Highway. Figure 12 shows the route selected in this area for our experiments. The blue star in the figure 13 represents a Telstra Next-G base tower found on Google map. From the Murphy's Creek base tower we drove northwest along the road and the total distance of the test route is about 500 meters. While driving, we obeyed all traffic laws and signs and remained as close to the indicated speed limit as possible.



Figure 12: Test Route in Murphy's Creek, Toowoomba (Google Maps, 2011)



Laptop Setup

Figure 13: Next-G test setup

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Figure 13 shows a picture of how test equipment was setup. We used an Acer Aspire model 5745G laptop computer that runs on the Intel Core i7 processor with 720QM processor speed, 4 GB of RAM with Windows 7 Home Premium as our 64-bit operating system. Although this is a laptop computer with a high end specification, we presume the processing speed of a computer would not affect the results of tests thus our scripts should run normally on any reasonably functioning laptop computer. As shown in figure 14, the Next-G USB antenna is plugged into the USB port of the laptop and a patch cord is used to connect the Next-G device to the external antenna. The external antenna is used to hopefully boost the signal strength while running the test.

The laptop attempts to connect to the internet by first scanning the area for the nearest available Next-G base tower or the strongest signal they could pick up. The special phone LG550 if keyed in a number *748#96, it will output the signal strength and the special number assigned to that base tower so we will know that we only receiving and transmitting from that particular base tower. Murphy's Creek base tower number is 4436-504. When we are certain we are receiving signal via the right base tower, we proceed with running our test scripts. Once internet connectivity is verified, we began our tests. As we do our measurements further away from the base tower nearby. We utilize a global positioning system (GPS) to tell us the speed we are driving and distance away from the base tower. Figure 14 shows the Murphy's creek base tower.



Figure 14: Murphy's Creek base tower (4436-504)

Test 2: Satellite Internet Test

Equipment required

The elements required for this distance away from the Next-G tower test consists of

- My test scripts which will be run on a portable laptop computer.
- Satellite Modem Unit
- Wireless router
- 2 coax leads for the transmission and reception of Satellite signal
- Ethernet cables
- Portable satellite antenna
- Satellite antenna setup manual (Appendix D)

The aim of this test is to measure the internet performance or specifically the QoS and QoE of the Satellite internet network. Tests on performance include downloading a file, pinging a website and loading sophisticated and simple webpages; these tests run automatically at an interval of every 10 minutes. Figure 15 shows the portable Satellite internet antenna used to in the tests to transmit and receive signal from the Satellite. Before performing the test, the satellite antenna must be set up to make sure its line of sight is correct. The setting up of the satellite antenna is in Appendix D.



Figure 15: Satellite Internet Antenna

Laptop Setup

The tests were performed in the level 5 of Z block of the USQ campus. Figure 16 shows the SkyEdge satellite Internet modem (lower left) connected to a wireless router. From the modem, two coaxial cables are plugged directly to the satellite antenna. Both the satellite modem and wireless router has an adapter connected to power. The laptop receives

the satellite's signal wirelessly via the wireless router. Detailed instructions on the setup of the modem and the laptop's communication with the satellite antenna setup are in appendix D.



Figure 16: SkyEdge Satellite Modem setup

After testing, the satellite antenna must be kept in a room where the tests were being performed. This setting up process must be done before every test because the polarization and direction the antenna is pointing will be changed every time the antenna is shifted. The configuration setup must also be done every time after the satellite antenna setup. This is because we must ensure that the satellite antenna is not pointing to the wrong antenna and during the configuration process, we can shift the antenna slightly to obtain maximum reception from the satellite. Once configuration is complete and internet connectivity established, we proceed to run our tests.

Test 3: ADSL

Equipment and environment required

The elements required for the ADSL network test consists of

- Test scripts which will be run on a portable laptop computer.
- A location where ADSL network is accessible

The aim of this test is to perform tests on ADSL (Asynchronous Digital Subscriber Line) using the 3 developed scripts. The tests include downloading a file, pinging a website

and loading sophisticated and simple webpages; these performance tests run automatically at an interval of every 10 minutes. Some of these scripts were let to run for weeks but for this research we will extract the test results run in 24 hours to be used to compare with the test results of the satellite internet network and the Next-G network.

Test Location

We require a secure location where our test could be run at least a few days without interference. Telstra offered to let us run our tests using their ADSL service and also provided us with a laptop specifically for this purpose. We were given an unused cubicle of a former Telstra employee to run our tests.

Laptop Setup

We presume the processing speed of a computer system would not affect the results of our test because we are more focused on the users' QoE and QoS rather than the speed and performance. Thus we allow our scripts to run normally on any reasonably functioning system. Figure 17 is the Toshiba laptop Telstra provided. A blue Ethernet cable is plugged into the LAN port of the laptop to access the ADSL network.



Figure 17: ADSL test laptop setup

Test 4: USQ Direct Access Network

Equipment and environment required

The elements required for the campus network test consists of

- Test scripts which will be run on a portable laptop computer.
- A location on campus that has full coverage to ensure best signal strength

The aim of this test is to perform tests on the USQ (Toowoomba campus) network using the 3 developed scripts. Tests on performance include downloading a file, pinging a website and loading sophisticated and simple webpages; these tests run automatically at an interval of every 10 minutes. The test results will be compared with the test results of the satellite internet network and Next-G network.

Test Location

We need a secure location where our test could be run at least a few days without disturbance. Dr Alexander, my supervisor offered to use his office on the 3rd floor of Z block in campus.

Laptop Setup

We presume the processing speed of a computer would not affect the results of our test because we are more focused on the users' QoE and QoS rather than the speed and performance. Thus our scripts should run normally on any reasonably functioning computer system. For this test, we used a Hewlett-Packard netbook. The netbook's Wi-Fi capabilities can automatically pick up signal without the need to install a client or configure its settings. The campus wireless internet setup could be found in the appendix.

The netbook attempts to connect to the internet after the Ethernet direct access cable is plugged into the LAN port in the netbook and once the campus direct access network is detected, internet connectivity will be established. We then proceed to run the 3 developed test scripts on the netbook and let it run for a few days.

Chapter 4 Discussion of Results

<u>4.1 Hypothetical Results on Different Networks under different</u> <u>Scenarios</u>

This hypothesis is made so that it could be compared with the actual test results. We presume in our hypothesis how our test results would be like based on logic, experiences and common sense.

Network Scenario	Hypothetical Satellite Internet Results
Ping (RTT)	Tests could be done in all scenarios except distance
File Downloads	away.
Loading Webpages	 Significant slower QoS compared to other networks.
24 Hours	• Like other networks, internet speed should be more
Night and Day	congested during the day and rainy days and less
Rainy Weather	congested during nights and weekends.

Table 2: Hypothetical results under Satellite Internet testing

Table 2 shows that compared to the other networks, satellite internet presumably provides slower QoS as it is in space orbiting the specific GEO route thus it is in a fixed distance (radius) away from earth. Thus, all results should indicate lower internet QoS due to its distance away from earth and larger RTT. Like all the other networks, internet speed should be more congested during the day and on a rainy day and less congested during nights because of the high internet activity used during the day (working and waking hour) whereas it is presumed that there will be less internet activity during nights and weekends. Rainy days generally is presumed to give bad QoS as it produces more noise.

Network Scenario	Hypothetical Telstra Next-G Results
Ping (RTT)	
File Downloads	 Test could be done in all scenarios
Loading Webpages	Linear decrease in QoS when distance is
24 Hours	further away from cell
Night and Day	Like other networks, internet speed should
Distance Away from Source	be more congested during the day and
Rainy Weather	rainy weather and less congested during nights and weekends.

Table 3: Hypothetical results under Telstra Next-G testing

Table 3 shows that a linear decrease in QoS should be expected as tests are performed further away from the Telstra's Next-G cell. Test results should be expected to indicate a stronger more reliable QoS because Telstra is generally well-known for its excellent service. All tests could be perform via this network and like other networks, internet QoS is expected to be more congested during the day and on a rainy weather and less congested during nights and weekends.





Table 4 shows that the result of the "Distance away from source" of this network should have a similar pattern to Telstra Next-G. There should be a linear decrease in internet QoS over distance. However, it is expected that internet connection will be cut-off after about 10 metres due to the limited coverage of the wireless WiFi router. Test result may be similar to Telstra's Next-G although it is presumed that Telstra should yield better results due to its reputation. All tests could be perform via this network and like other networks, internet QoS is expected to be more congested during the day and on a rainy weather and less congested during nights and weekends.

Network Scenario	Hypothetical University Direct Access Network Results
File Downloads	Test could be done in all scenarios
Loading Webpages	Linear decrease in QoS when distance is
24 Hours	further away from the access points and zero
Night and Day	QoS when exceeding coverage area.
Distance Away from Source	Like other networks, internet speed should
Rainy Weather	be more congested during the day and rainy
	weather and less congested during nights
	and weekends.

Table 5: Hypothetical results in USQ campus Direct Access tesing

Table 5 shows that the QoS is expected to be reasonably reliable in the university thus its test results should quite similar to the Next-G and ADSL network tests. Like all other networks that perform better when nearer network source, there should be a linear decrease in internet QoS when tests are perform fixed interval away from the WLAN access points throughout the campus. Internet access will be cut-off when distance exceeds broadband coverage area. Like all other networks, internet QoS is expected to be more congested during the day and rainy weather and less congested during nights and weekends.

4.2 Distance Away from Next-G Tower

4.2.1 Download A File test

Figure 18 shows the average results of our test performed 5 times at 0 meters away from the Murphy's Creek's Next-G base tower. Each test was performed over 10 minutes with a file download every minute. An average download speed of 25777.8ms with average signal strength of -47dBm was achieved. The lowest and highest download speeds recorded were 25163ms and 26676ms with a difference of 1513ms.



0 meters Away from Tower

Figure 19 shows the average results of our test performed 5 times at 100 meters away from the Murphy's Creek's Next-G base tower. Each test was performed 10 minutes with a file download every minute. An average download speed of 26123.9ms with average signal strength of -55dBm was achieved. The lowest and highest download speeds recorded were 25039ms and 26832ms with a difference of 1793ms.

Figure 18: Download A File tests done 0 meters away from source



100 meters Away from Tower

Figure 19: Download A File tests done 100 meters away from source

Figure 20 shows the average results of our test performed 5 times at 200 meters away from the Murphy's Creek's Next-G base tower. Each test was performed over 10 minutes with a file download every minute. An average download speed of 26457.9ms with average signal strength of -53dBm was achieved. The lowest and highest download speeds recorded were 25195ms and 28330ms with a difference of 3135.



200 meters Away from Tower

Figure 20: Download A File tests done 200 meters away from source

Figure 21 shows the average results of our test performed 5 times at 300 meters away from the Murphy's Creek's Next-G base tower. Each test was performed 10 minutes with a file download every minute. An average download speed of 26768.1ms with average signal strength of -47dBm was achieved. The lowest and highest download speeds recorded were 25054ms and 30109ms with a difference of 5055ms.



300 meters Away from Tower

Figure 21: Download A File tests done 300 meters away from source

Figure 22 shows the average results of our test performed 5 times at 400 meters away from the Murphy's Creek's Next-G base tower. Each test was performed 10 minutes with a file download every minute. An average download speed of 28339.2 ms with average signal strength of -51 dBm was achieved. The lowest and highest download speeds recorded were 25257 ms and 32136 ms with a difference of 6879 ms.



400 Away from Tower

Figure 22: Download A File tests done 400 meters away from source

Figure 23 shows the average of our test performed 5 times at 500 meters away from the Murphy's Creek's Next-G base tower. Each test was performed 10 minutes with a file download every minute. An average download speed of 31603.35ms with average signal strength of -65dBm was achieved. The lowest and highest download speeds recorded were 25225ms and 49187ms with a difference of 23962ms.



500 meters Away from Tower

Figure 23: Download A File tests done 500 meters away from source

Download A File test Discussion





Figure 24: 10-minute-download of each 100 meters plot side-by-side

Figure 24 is a side-by-side plot of each 10-minute-download at each 100-meter-away from the Next-G base tower. Every 10 minute represents a successive 10-meter-away from the base tower. For example the 1st 10 minutes is test results from 0-meter-away, minute 11 to minute 20 is the test results from 100-meter-away. The figure shows that our test results comply with our hypothesis that time to download a file takes longer as we move further away from the Next-G base tower. Download times also appear to be more consistent at the 20,000 millisecond to 30,000 milliseconds range for the first 400 meters before download times became unstable.

Distance Away (meters)	Average Download speed (ms)	Signal Strength (dBm)	Lowest & Highest Speed Difference (ms)
0	25777.8	-47	1513
100	26123.9	-55	1793
200	26457.9	-53	3135
300	26768.1	-47	5055
400	28339.2	-51	6879
500	31603.35	-65	23962

Table 6: Download A File results of Distance Away from Next-G Tower

The average download speed at every 100-meter-away in Table 6 again shows that our test results comply with our hypothesis of download speed generally decreases if a Next-G user were to download a file further away from the Next-G base tower. The signal strength however did not directly impact the performance of the download speed. In a perfect environment, the signal strength is presumed to decrease slightly as tests were run further away from the source. However realistically, signal strength could be impacted by various factors like the cars that drove past on the road, the houses between our test equipment and the Next-G tower and the position we placed our test equipment. The differences between the lowest and highest download speeds were extracted from the 5 tests done in every 100 meters. The difference between the lowest and highest download speed seem to increase as tests are done further away from the source. This shows that the QoS and QoE decreases Next-G users live further away from the base tower. The differences in the lowest and highest download speed shows the reliability and consistency of a file download if a Next-G subscriber were to download a file. A more reliable result could be achieved if tests were run more than 5 times and continue performing these tests until the coverage limit of the Next-G base tower is reached.

4.2.2 Ping test (Round Trip Time test)

Figure 25 shows the average results of the ping test performed 5 times at 0 meters away from the Murphy's Creek's Next-G base tower. Each test was performed over 10 minutes with 20 packets pinged every minute. All 20 packets were pinged successfully. An average ping speed of 306 ms with average signal strength of -47 dBm was achieved. The lowest and highest ping speeds recorded were 52 ms and 648 ms with a difference of 596 ms.



0 meters Away from Tower

Figure 25: Ping tests done 0 meters away from source

Figure 26 shows the average results of the ping test performed 5 times at 100 meters away from the Murphy's Creek's Next-G base tower. Each test was performed over 10 minutes with 20 packets pinged every minute. All 20 packets were pinged successfully. An average ping speed of 276.8 ms with average signal strength of -55 dBm was achieved. The lowest and highest ping speeds recorded were 53 ms and 517 ms with a difference of 464 ms.



100 meters Away from Tower

Figure 26: Ping tests done 100 meters away from source

Figure 27 shows the average results of the ping test performed 5 times at 200 meters away from the Murphy's Creek's Next-G base tower. Each test was performed over 10 minutes with 20 packets pinged every minute. All 20 packets were pinged successfully. An average ping speed of 186.1 ms with average signal strength of -53 dBm was achieved. The lowest and highest ping speeds recorded were 52 ms and 403 ms with a difference of 351 ms.



200 meters Away from Tower

Figure 27: Ping tests done 200 meters away from source

Figure 28 shows the average results of the ping test performed 5 times at 300 meters away from the Murphy's Creek's Next-G base tower. Each test was performed over 10 minutes with 20 packets pinged every minute. All 20 packets were pinged successfully. An average ping speed of 255.2 ms with average signal strength of -47 dBm was achieved. The lowest and highest ping speeds recorded were 51 ms and 593 ms with a difference of 542 ms.



300 meters Away from Tower

Figure 28: Ping tests done 300 meters away from source

Figure 29 shows the average results of the ping test performed 5 times at 400 meters away from the Murphy's Creek's Next-G base tower. Each test was performed over 10 minutes with 20 packets pinged every minute. All 20 packets were pinged successfully. An average ping speed of 222.1 ms with average signal strength of -51 dBm was achieved. The lowest and highest ping speeds recorded were 50 ms and 536 ms with a difference of 486 ms.



400 meters Away from Tower

Figure 29: Ping tests done 400 meters away from source

Figure 30 shows the average results of the ping test performed 5 times at 500 meters away from the Murphy's Creek's Next-G base tower. Each test was performed over 10 minutes with 20 packets pinged every minute. All 20 packets were pinged successfully. An average ping speed of 187.8 ms with average signal strength of -65 dBm was achieved. The lowest and highest ping speeds recorded were 54 ms and 337 ms with a difference of 283 ms.



500 meters Away from Tower

Figure 30: Ping tests done 500 meters away from source

Ping test Discussion

Distance Away (meters)	Average Ping Speed (milliseconds)	Lowest & Highest Speed Difference (ms)
0	306	596
100	276.8	464
200	186.1	351
300	255.2	542
400	222.1	486
500	187.8	283

Table 7: Ping test results of Distance Away from Next-G Tower

The average ping speed every 100-meter-away in Table 7 shows that ping speed varies thus our test results does not comply with our hypothesis of ping speed decrease if packets were pinged further away from the Next-G base tower. We have already established that the signal strength does not directly impact the results. The differences between the lowest and highest ping speeds were extracted from the 5 tests done in every 100 meters. The difference between the lowest and highest download speed seem to vary. This is because standard ping does not show us the entire internet route between our laptop and the Google website.

Additional tests such as traceroute or pathping could be used to trace the route of the packets however this is not the focus of our research. The delay of a round-trip-time could be caused by the congestion of a link or device in the middle of the ping pathway. We know our connectivity and all links between our laptop and Google worked fine because the result shows that all 20 packets had been pinged successfully for every test. The results also shows us that the lowest ping times are approximately at the 50 ms range and most highest ping speeds falls in the 500 ms range. Thus this shows that contrary to our hypothesis, the QoS and QoE cannot be determined via ping tests.

4.2.3 Load websites test

In the period of 10 minutes, a particular website can be loaded an average of 3 times. We selected 5 websites therefore the total websites loaded in that period is roughly 15 websites in which each website loaded 3 times by sequence.

Figure 31 shows the average time required to load the BBC website every 100 meters away from the Next-G base tower up to 500 meters. The lowest and highest load speeds recorded were 0.343 seconds and 15.413 seconds with a difference of 15.087 seconds.





Figure 32 shows the average time required to load the Google website every 100 meters away from the Next-G base tower up to 500 meters. The lowest and highest load speeds recorded were 0.312 seconds and 3.198 seconds with a difference of 2.886 seconds.



Figure32: Load time of the Google website over 500 meters

Figure 33 shows the average time required to load the Telstra website every 100 meters away from the Next-G base tower up to 500 meters. The lowest and highest load speeds recorded were 0.234 seconds and 18.704 seconds with a difference of 18.47 seconds.



Figure 33: Load time of Telstra website over 500 meters

Figure 34 shows the average time required to load the USQ website every 100 meters away from the Next-G base tower up to 500 meters. The lowest and highest load speeds recorded were 0.218 seconds and 15.444 seconds with a difference of 15.226 seconds.



Figure 34: Load time of the USQ website over 500 meters

Figure 35 shows the average time required to load the Yahoo website every 100 meters away from the Next-G base tower up to 500 meters. The lowest and highest load speeds recorded were 0.484 seconds and 25.803 seconds with a difference of 25.319 seconds.



Figure 35: Load time of the Yahoo website over 500 meters

Load websites test Discussion

From the data collected, the first batch of 5 websites loaded always took a longer time particularly the Telstra website since it is the first website to load. We ignored the first batch of websites loaded and only used data starting from the second batch of websites to obtain more reliable results. The individual figures of the 5 websites above shows that although the loading times for each website are not linear and not always increasing, the results shows there will be an increase in loading time over distance. Simple websites like Google and Telstra has smaller difference in load time over distance where as sophisticated websites like Yahoo and BBC has big difference in load time over distance.

Distance	Websites				
Away	BBC	Google	Telstra	USQ	Yahoo
(meters)	(seconds)	(seconds)	(seconds)	(seconds)	(seconds)
0	3.447667	1.217	1.4352	2.2088	11.986
100	4.922	1.1465	2.2622	3.96	11.1205
200	6.135667	1.52367	3.4662	5.662667	10.55325
300	5.064667	1.68433	4.415	7.456667	10.321
400	6.141	1.7222	6.942	7.0595	10.1368
500	6.645333	2.153	7.243667	8.252333	12.85425

Table 8: Average load time of websites over distance

Table 8 shows the average load times of the 5 websites over distance. Actual data differ to our hypothesis that there will be a linear increase in loading time. Our hypothesis may be accurate in a perfect environment but in reality, there will always be unavoidable noise depending on the user's location that will minimize signal strength therefore load times will never increase linearly over distance. Table 8 proves that the loading times of each website will eventually increase over distance thus lowering the QoS and QoE over distance.

4.3 Satellite Internet Access Data Analysis & Discussion

4.3.1 Download A File test results

Figure 36 shows the results of downloading of the file "Firefox 3.6.23.exe" every 10minutes for about 4 hours. The download started on the Tuesday 11th October 2011 at time 12:00pm until about 4:00pm. The file was downloaded a total of 29 times where 19 downloads were unsuccessful. Ignoring all unsuccessful downloads; the mean download speed is 154294.5ms. The standard Deviation is 51835.9. The lowest and highest download speeds (not including unsuccessful downloads) recorded were 99560ms and 250912ms with a difference of 151352ms.



Download A File test on 11 Oct 2011

Figure 36: Download a File tests done in Satellite Internet (11 Oct 2011)

Figure 37 shows the results of downloading of the file "Firefox 3.6.23.exe" every 10minutes for about 3 hours. The download started on the Thursday 13th October 2011 at time 1:00pm until about 4:00pm. The file was downloaded a total of 24 times where 11 downloads were unsuccessful. Ignoring all unsuccessful downloads; the mean download speed is 120550.4. The standard Deviation is 41508.84. The lowest and highest download speeds (not including unsuccessful downloads) recorded were 58922ms and 207325ms with a difference of 148403ms.



Download A File test (13 Oct)

Figure 37: Download a File tests done in Satellite Internet (13 Oct 2011)

Figure 38 shows the results of downloading of the file "Firefox 3.6.23.exe" every 10minutes for about 4 hours. The download started on the Monday 24th October 2011 at time 11:00am until about 3:00pm. The file was downloaded a total of 29 times where only 1

downloads were unsuccessful. Ignoring all unsuccessful downloads, the mean download speed is 130230.2. The standard Deviation is 60113.19. The lowest and highest download speeds (not including unsuccessful downloads) recorded were 84537ms and 299194ms with a difference of 214657ms.



Download A File test (24 Oct)

Figure 38: Download a File tests done in Satellite Internet (24 Oct 2011)

Date	Mean	Standard Deviation
11 October 2011	154294.5	51835.9
13 October 2011	120550.4	41508.84
24 October 2011	130230.2	60113.19

Satellite Internet Download a file Discussion

Table 9: Means and Standard Deviation of Download A File in Satellite Internet test

Due to unforeseen circumstances¹, this particular test was only run for 3 days each over a short period of time² in a day. Downloads failed many times on the 11th and 13th of October however downloads seems to be more stable on the 24th of October 2011. It was suspected we configured the antenna to a better Line of Sight pointing it towards the direction of the Satellite. It was also suspected that there may be fewer clouds on the 24th of October.

Table 9 shows the mean and standard deviation of the Satellite internet results for each day. The mean value for each 3 days are high compared to tests done on other environments. Each file took at least 2 minutes to download. The standard deviation shows that downloading speeds were not consistent thus downloading via the satellite internet may provide lower QoE and QoS.

4.3.2 Ping test results

Figure 39 shows the results of ping the website "http://www.google.com.au/" every 10 minutes for about 4 hours. The ping test was started on the Tuesday 11th October 2011 at time 12:00am until 4:00pm. The mean ping speed is 1246.966ms. The standard Deviation is 43.5443. The lowest and highest download speeds recorded were 1168ms and 1385ms with a difference of 217ms.

¹ Our original Telstra antenna malfunctioned and we failed to fix it. Delay was also caused by windy days and because it is not safe to run test during a thunderstorm. ²Satellite test could not be done over 24 hours because we were using a portable satellite antenna

²Satellite test could not be done over 24 hours because we were using a portable satellite antenna and we do not have something to fasten it to a fixed location.



Figure 39: Ping tests done using Satellite Internet (11 Oct 2011)

Figure 40 shows the number of successful pinged packets achieved every 10 minutes over the 4 hour test on the 11th October 2011.



Number of successful pinged packets

Figure 40: Number of successful pinged packets (11 Oct 2011)

Figure 41 shows the results of ping the website "http://www.google.com.au/" every 10 minutes for about 3 hours. The ping test was started on the Thursday 13th October 2011 at time 1:00pm until 4:00pm. The mean ping speed is 1289ms. The standard Deviation is 55.33698. The lowest and highest download speeds recorded were 1198ms and 1463ms with a difference of 265ms.



Figure 41: Ping tests done using Satellite Internet (13 Oct 2011)

Figure 42 shows the number of successful pinged packets achieved every 10 minutes over the 3 hour test on the 13th October 2011.



Figure 42: Number of successful pinged packets (11 Oct 2011)

Figure 43 shows the results of ping the website "http://www.google.com.au/" every 10 minutes for about 4 hours. The ping test was started on the Monday 24th October 2011 at time 11:00am until 3:00pm. The mean ping speed is 1313.686ms. The standard Deviation is 112.4408. The lowest and highest download speeds recorded were 1145ms and 1626ms with a difference of 481ms.



Figure 43: Ping tests done using Satellite Internet (24 Oct 2011)

Figure 44 shows the number of successful pinged packets achieved every 10 minutes over the 3 hour test on the 24th October 2011.



Figure 44: Number of successful pinged packets (24 Oct 2011)

Ping Test Discussion

Date (24 hours)	Mean (milliseconds)	Standard Deviation
11 October 2011	1246.966	43.5443
13 October 2011	1289	55.33698
24 October 2011	1313.686	112.4408

Table 10: Mean and Standard Deviation for Ping tests via Satellite Internet.

The ping test results were acquired over 3 days; 11th, 13th and 24th of October. Table 10 shows that the mean and standard deviation of test performed over 3 days. The mean

values are quite close to each other between the 1200ms and 1400ms range. Unlike other tests, ping test performed on the Satellite Internet has packet losses. Standard deviation is a measure of spread or variance in the data. The abnormality in standard deviation values shows that the ping test performed over the Satellite internet is inconsistent thus it has significant lower QoS and QoE when used by users or subscribers.

4.3.3 Load Websites test results

These are the test results performed over the 24th October 2011 at time 11.00am until about 4.50pm. There were 5 websites where each website had a wait time of 10 minutes. Thus a particular website loads every 50 minutes.

Tuesday 24 October (about 4 hours)

Figure 45 shows the loading of the Telstra website over about 5 hours. The mean loading speed is 5.937875 second. The standard deviation is 3.520474. The lowest and highest download speeds recorded were 1.903 seconds and 10.811 seconds with a difference of 8.908 seconds.



Figure 45: Test results of loading the Telstra website (24 Oct 2011)

Figure 46 shows the loading of the Google website over about 5 hours. The mean loading speed is 4.207875 second. The standard deviation is 0.845854. The lowest and highest download speeds recorded were 2.542 seconds and 5.195 seconds with a difference of 2.653 seconds.



Figure 46: Test results of loading the Google website (24 Oct 2011)

Figure 47 shows the loading of the USQ website over about 5 hours. The mean loading speed is 6.09375 second. The standard deviation is 1.688652. The lowest and highest download speeds recorded were 4.43 seconds and 9.407 seconds with a difference of 4.977 seconds.



Figure 47: Test results of loading the USQ website via Satellite Internet (24 Oct 2011)

Figure 48 shows the loading of the Yahoo website over about 5 hours. The mean loading speed is 38.663 second. The standard deviation is 4.854591. The lowest and highest download speeds recorded were 32.729 seconds and 44.819seconds with a difference of 12.09 seconds.


Figure 48: Test results of loading the Yahoo website via Satellite Internet (24 Oct 2011)

Figure 49 shows the loading of the BBC website over about 5 hours. The mean loading speed is 30.01663 second. The standard deviation is 4.288013. The lowest and highest download speeds recorded were 25.335 seconds and 37.862 seconds with a difference of 12.527 seconds.



Figure 49: Test results of loading the BBC website via Satellite Internet (24 Oct 2011)

Load Websites test discussion

Websites	Mean	Standard Deviation
Telstra	5.937875	3.520474
Google	4.207875	0.845854
USQ	6.09375	1.688652
Yahoo	38.663	4.854591
BBC	30.01663	4.288013

Table11: Means and Standard Deviation of load Websites result via Satellite



Figure 50: Result of Load Websites tests done via Satellite Internet

We decided to use the test results of acquired on the 24th October because the data collected is more complete. The BBC and Yahoo websites are considered to be more sophisticated website thus they take longer time to load. The Telstra, Google and USQ websites are simple websites and figure 50 shows that their loading times are quite similar at the 0 second to 10 seconds range. Table 11 shows the means and standard deviation of the all the websites loaded. The values of means and standard deviations of each websites loading time varies thus this shows that the QoS and QoE are inconsistent. Users should be aware of this when subscribing for Satellite internet access

4.4 ADSL Data Analysis & Discussion

4.4.1 Download A File test results

This particular test has been run over a week, from the 14th September until the 21st September. Below is the test results obtained in 4 days for comparison purposes.

Figure 51 shows the results of downloading of the file "Firefox 3.6.23.exe" every 10 minutes over 24 hours. The download started on the Wed 14th September 2011 at time 12:00pm until the Thursday 15th of September 2011 at time 12:00pm. The mean download speed is 8302ms. The standard Deviation is 1712. The lowest and highest download speeds recorded were 7532ms and 25203ms with a difference of 17671ms.



24 hours Download A File test on ADSL (14-15 Sept 2011)

Figure 51: 24 hours Download A File tests done in ADSL (14-15 Sept 2011)

Figure 52 shows the results of downloading of the file "Firefox 3.6.23.exe" every 10 minutes over 24 hours. The download started on the Thursday 15th September 2011 at time 12:00pm until the Friday 16th of September 2011 at time 12:00pm. The mean download speed is 8258ms. The standard deviation is 1160. The lowest and highest download speeds recorded were 7531 ms and 19343ms with a difference of 11812ms.



24 hours Download A File test on ADSL (15-16 Sept 2011)

Figure 52: 24 hours Download a File tests done in ADSL (15-16 Sept 2011)

Figure 53 shows the results of downloading of the file "Firefox 3.6.23.exe" every 10 minutes over 24 hours. The download started on the Friday 16th September 2011 at time 12:00pm until the Saturday 17th of September 2011 at time 12:00pm. The mean download speed is 8062ms. The standard deviation is 560. The lowest and highest download speeds recorded were 7531ms and 11000ms with a difference of 3469ms.



Figure 53: 24 hours Download a File tests done in ADSL (16-17 Sept 2011)

Figure 54 shows the results of downloading of the file "Firefox 3.6.23.exe" every 10 minutes over 24 hours. The download started on the Saturday 17th September 2011 at time 12:00pm until the Sunday 18th of September 2011 at time 12:00pm. The mean download speed is 8086ms. The standard deviation is 706. The lowest and highest download speeds recorded were 7531ms and 11562ms with a difference of 4031ms.



24 hours Download A File test on ADSL (17-18 Sept 2011)

Figure 54: 24 hours Download a File tests done in ADSL (17-18 Sept 2011)

Download a File test discussion

This Download A File test was perform in Telstra Country Wide's office. Although we possess the test result for a longer period, we decided to show the result of only four 24-hour results because their plots are similar. We ensure that we include both test results acquired during the working weekdays and the weekends. The 24-hour test results shows that downloading a file using the ADSL network is quite consistent except for the occasional small and large spikes which indicate short periods of medium to heavy downloading. The results also show that time to download a file over the weekends dropped significantly. There do not seem to be much difference in the download time between during the day and night. We presume that Telstra's staffs use their internal network frequently but seldom use the internet. Standard deviation is a measure of spread or variance in the data. If standard deviations between treatments do not overlap, that means that there is probably a significant difference in the means between the tests.



1 week's test results (14 -21 Sept)



Figure 55 is a side-by-side plot of each 24-hour download for the period of a week. The figure shows that our test results comply with our hypothesis that time to download via the ADSL network is fairly consistent aside from the occasion sudden high download times (spikes) in the plot during certain hours of the certain days. Download times also appear to be more consistent at the 8,000 millisecond to 15,000 milliseconds range throughout the entire week.

The average download speed at every 24-hour test result falls around the 8000ms to 8500ms range. The lowest download time is nearly always at 7531ms. There are signs of sudden spikes throughout the week even during the weekends. We presume that some Telstra staffs may be working during the weekends.

4.4.2 Ping test results

The following results were acquired over a week but results obtained over a few days (15-19 October 2011) will also be shown for comparison purposes.

Figure 56 shows the results of ping the website "http://www.google.com.au/" every 10 minutes over 24 hours. The download started on the Thursday 15th September 2011 at time 12:00am until the Friday 16th of September 2011 at time 12:00am. The mean download speed is 34.89583ms. The standard Deviation is 19.37294. The lowest and highest download speeds recorded were 31ms and 164ms with a difference of 133ms.



Ping Test (15-16 Sept)

Figure 56: 24 hours ping tests done in ADSL (15-16 Sept 2011)

Figure 57 shows the results of ping the website "http://www.google.com.au/" every 10 minutes over 24 hours. The download started on the Thursday 16th September 2011 at time 12:00am until the Friday 17th of September 2011 at time 12:00am. The mean download speed is 32.47917ms. The standard Deviation is 11.10029. The lowest and highest download speeds recorded were 31ms and 163ms with a difference of 132ms.



Figure 57: 24 hours ping tests done in ADSL (16-17 Sept 2011)

Figure 58 shows the results of ping the website "http://www.google.com.au/" every 10 minutes over 24 hours. The download started on the Thursday 17th September 2011 at time 12:00am until the Friday 18th of September 2011 at time 12:00am. The mean download speed is 32.26389ms. The standard Deviation is 11.13678. The lowest and highest download speeds recorded were 31ms and 164ms with a difference of 133ms.



Ping Test (17-18 Sept)



Figure 59 shows the results of ping the website "http://www.google.com.au/" every 10 minutes over 24 hours. The download started on the Thursday 18th September 2011 at time 12:00am until the Friday 19th of September 2011 at time 12:00am. The mean download speed is 33.15972ms. The standard Deviation is 15.61498. The lowest and highest download speeds recorded were 31ms and 164ms with a difference of 133ms.



Ping test (18-19 Sept)

Figure 59: 24 hours ping tests done in ADSL (18-19 Sept 2011)

Ping Test Discussion

Date (24 hours)	Mean (milliseconds)	Standard Deviation
15-16 Sept 2011	34.89583	19.37294
16-17 Sept 2011	32.47917	11.10029
17-18 Sept 2011	32.26389	11.13678
18-19 Sept 2011	33.15972	15.61498
19-20 Sept 2011	33.22222	15.56868
20-21 Sept 2011	33.25694	15.51122
21-22 Sept 2011	32.39583	11.03853

Table 12: Mean and Standard Deviation for Ping tests.





Thur 15 Sept - Thur 22 Sept

Figure 60: Ping test over a week for ADSL

This ping test was performed in Telstra Country Wide's office. Table 12 shows that the mean of each 24-hour tests is quite consistent with each other. Our results show that there were no packet losses. Standard deviation is a measure of spread or variance in the data.

Figure 60 is a side-by-side plot of each 24-hour download for the period of a week. The figure shows that our test results comply with our hypothesis that time to download via the ADSL network is fairly consistent aside from the occasion sudden high download times (spikes) in the plot during certain hours of the certain days.

The average ping speed at every 24-hour test result falls between the 32ms to 35ms ranges. The lowest and highest ping time is nearly always at 31ms and 164ms. The highest pings formed the spikes however what caused the spikes and why is it always consistent is unknown.

4.4.3 Load Websites test results

These are the test results performed over 2 days. The 1st day's test results were acquired from Friday the 14th October 2011 at time 2:00pm until Saturday 15th of October 2011 at time 1:20pm. 2nd day's test results were acquired from Saturday 15th October 2011 at time 2.00pm until the Sunday 16th of October 2011 at time 1:20pm. There were 5 websites where each website had a wait time of 10 minutes. Thus a particular website loads every 50 minutes.

Friday 14 October – Saturday 15 October (24 hours)

Figure 61 shows the loading of the Telstra website over 24 hours. The mean loading speed is 1.115793 second. The standard deviation is 0.065506. The lowest and highest download speeds recorded were 0.969 seconds and 1.203 seconds with a difference of 0.234 seconds.



Figure 61: 24 hours test results of loading the Telstra website (14-15 Oct 2011)

Figure 62 shows the loading of the Google website over 24 hours. The mean loading speed is 1.0646 seconds. The standard deviation is 0.046422. The lowest and highest download speeds recorded were 0.891seconds and 1.125 seconds with a difference of 0.234 seconds.



Figure62: 24 hours test results of loading the Google website (14-15 Oct 2011)

Figure 63 shows the loading of the USQ website over 24 hours. The mean loading speed is 0.7843 seconds. The standard deviation is 0.065708. The lowest and highest download speeds recorded were 0.703 seconds and 0.953 seconds with a difference of 0.25 seconds.



Figure 63: 24 hours test results of loading the USQ website (14-15 Oct 2011)

Figure 64 shows the loading of the Yahoo website over 24 hours. The mean loading speed is 10.7079 seconds. The standard deviation is 1.078521. The lowest and highest download speeds recorded were 8.563 seconds and 13.75 seconds with a difference of 5.187 seconds.



Figure 64: 24 hours test results of loading the Yahoo website (14-15 Oct 2011)

Figure 65 shows the loading of the BBC website over 24 hours. The mean loading speed is 7.1795 seconds. The standard deviation is 0.0703758. The lowest and highest download speeds recorded were 6.25 seconds and 9.391 seconds with a difference of 3.141 seconds.



Figure 65: 24 hours test results of loading the BBC website (14-15 Oct 2011)

Saturday 15 October – Sunday 16 October (24 hours)

Figure 66 shows the loading of the Telstra website over 24 hours. The mean loading speed is 1.235983 seconds. The standard deviation is 0.06664. The lowest and highest download speeds recorded were 1.109 seconds and 1.375 seconds with a difference of 0.266 seconds.





Figure 67 shows the loading of the Google website over 24 hours. The mean loading speed is 1.198036 seconds. The standard deviation is 0.04668. The lowest and highest download speeds recorded were 1.14 seconds and 1.312 seconds with a difference of 0.172 seconds.





Figure 68 shows the loading of the USQ website over 24 hours. The mean loading speed is 0.784379 seconds. The standard deviation is 0.065708. The lowest and highest download speeds recorded were 0.703seconds and 0.953 seconds with a difference of 0.25seconds.





Figure 69 shows the loading of the Yahoo website over 24 hours. The mean loading speed is 12.31932 seconds. The standard deviation is 0.909417. The lowest and highest download speeds recorded were 10.218 seconds and 14.765seconds with a difference of 4.547 seconds.



Figure 69: 24 hours test results of loading the Yahoo website (15-16 Oct 2011)

Figure 70 shows the loading of the BBC website over 24 hours. The mean loading speed is 7.469929 seconds. The standard deviation is 0.603527. The lowest and highest download speeds recorded were 6.812 seconds and 9.25 seconds with a difference of 2.438 seconds.



Figure 70: 24 hours test results of loading the BBC website (15-16 Oct 2011)

Websites	14 – 15 October 2011		15 – 16 October 2011	
	Mean	Standard Deviation	Mean	Standard Deviation
Telstra	1.115793	0.065506	1.235893	0.06664
Google	1.0646	0.046422	1.198036	0.04668
USQ	0.7843	0.065708	0.784379	0.065708
Yahoo	10.7079	1.078521	12.31932	0.909417
BBC	7.1795	0.0703758	7.469929	0.603527

Load Websites test discussion

Table 13: Means and Standard Deviation





Figure 71: 24-hour result of load websites tests done in ADSL (14-15 Sept 2011)



Figure 72: 24-hour result of Load Websites tests done in ADSL (15-16 Sept 2011)

We decided to use the test results of two 24-hour from 14 October to 16 October because these are the most complete results we have achieved and also one falls on a week day and the other is a weekend. Plotting a 24-hour figure also shows the day and night performance of loading the websites. The BBC and Yahoo websites are considered to be more sophisticated website thus they take longer time to load. The Telstra, Google and USQ websites are simple websites and figure 71 and figure 72 show that their loading times are quite similar at the 0 second to 2 seconds range. Table 13 shows the means and standard deviation of the all the websites loaded for these two days. The values of means and standard deviations of these 2 days are very similar thus this shows that the QoS and QoE are fine.

4.5 USQ Campus Direct Access Network

4.5.1 Download a File test results

This particular test had been run over 3 days, from the 18th October until the 21st Oct 2011. Below is the test results obtained in 3 days for comparison purposes.

Figure 73 shows the results of downloading of the file "Firefox 3.6.23.exe" every 10 minutes over 24 hours. The download started on the Tuesday 18th October 2011 at time 12:00am until the Wednesday 19th October 2011 at time 12:00am. The mean download speed is 9548.055ms. The standard Deviation is 4129.952. The lowest and highest download speeds recorded were 5024ms and 24211ms with a difference of 19187ms.



Figure 73: 24 hours Download a File tests done via USQ direct access (18-19 Oct 2011)

Figure 74 shows the results of downloading of the file "Firefox 3.6.23.exe" every 10 minutes over 24 hours. The download started on the Wednesday 19th October 2011 at time 12:00am until the Thursday 20th October 2011 at time 12:00am. The mean download speed

is 8794.51ms. The standard Deviation is 3329.556. The lowest and highest download speeds recorded were 4914ms and 19843ms with a difference of 14929ms.



24-hour Download A File test (19-20 Oct)

Figure 74: 24 hours Download a File tests done via USQ direct access (19-20 Oct 2011)

Figure 75 shows the results of downloading of the file "Firefox 3.6.23.exe" every 10 minutes over 24 hours. The download started on the Thursday 20th October 2011 at time 12:00am until the Friday 21th October 2011 at time 12:00am. The mean download speed is 8913.634ms. The standard Deviation is 3857.23. The lowest and highest download speeds recorded were 5070ms and 24430ms with a difference of 19360ms.



Figure 75: 24 hours Download a File tests done via USQ direct access (20-21 Oct 2011)

Download a File test discussion

This Download a File test was performed in an office environment in USQ. Although we possess the test result for a longer period, we decided to show the result of only three 24-hour results because their plots are similar. We ensure that we include both test results acquired during the working weekdays and the weekends.





Figure 76: 1 week's result of Download A File tests done via USQ campus network

Figure 76 is a side-by-side plot of each 24-hour download for the period of a week. The figure shows that our test results did not comply with our hypothesis that time to download via the USQ direct access network is fairly consistent. The test result shows that the network is more congested during office hours or classes. Time to download a file over the weekends is relatively close to that of an after working hours and night time. We suspect that there are still research students working late during the night which caused congestion even during the night.

Date	Mean (milliseconds)	Standard Deviation
18-19 Oct 2011	9548.055	4129.952
19-20 Oct 2011	8794.51	3329.556
20-21 Oct 2011	8913.634	3857.23

Table 14: Mean and Standard Deviation of Download a File test via USQ campus network

Table 14 shows that average download speed at every 24-hour test result falls around the 8700ms to 9600ms range. The lowest download time is nearly always at 5000ms range however the highest download times varies. There were signs of sudden spikes throughout the week even during the weekends. This could be caused by some research students or staffs working during the weekends.

4.5.2 Load Websites test results

These were the test results performed on Monday 17th October 2011 from 4pm until 9.50pm. There were 5 websites where each website had a wait time of 10 minutes. Thus a particular website loads every 50 minutes.

Figure 77 shows the loading times of the Telstra website. The mean loading speed is 2.024125 second. The standard deviation is 0.071012. The lowest and highest download speeds recorded were 1.95 seconds and 2.137 seconds with a difference of 0.187 seconds.



Figure 77: Results of loading the Telstra website via Campus network

Figure 78 shows the loading times of the Google website. The mean loading speed is 0.939875 second. The standard deviation is 0.14521. The lowest and highest download speeds recorded were 0.796 seconds and 1.17 seconds with a difference of 0.374 seconds.



Figure 78: Results of loading the Google website via Campus network

Figure 79 shows the loading times of the USQ website. The mean loading speed is 1.174714 second. The standard deviation is 0.312084. The lowest and highest download speeds recorded were 0.983seconds and 1.857 seconds with a difference of 0.874 seconds.



Figure 79: Results of loading the USQ website via Campus network

Figure 80 shows the loading times of the Yahoo website. The mean loading speed is 26.47513 second. The standard deviation is 3.067891. The lowest and highest download speeds recorded were 24.29 seconds and 33.29 seconds with a difference of 9 seconds.





Figure 80: Results of loading the Yahoo website via Campus network

Figure 81 shows the loading times of the BBC website. The mean loading speed is 15.92563 second. The standard deviation is 3.214688. The lowest and highest download speeds recorded were 13.104 seconds and 22.573 seconds with a difference of 9.469 seconds.





Load Websites test discussion

Website	Mean	Standard Deviation
Telstra	2.024125	0.071012
Google	0.939875	0.14521
USQ	1.174714	0.312084
Yahoo	26.47513	3.067891
BBC	15.92563	3.214688

Table 15: Means and Standard Deviation of Load website Results via Campus network



Website Loading Time Comparison

Figure 82: Result of load-websites tests done in campus network

We decided to use the test results on the 17th October because these are the most complete results we have achieved Figure 82 proved that the BBC and Yahoo websites are more sophisticated website thus they take longer time to load. The Telstra, Google and USQ

websites are simple websites and their loading times are quite similar at the 0 second to 3 seconds range. Table 15 shows the means and standard deviation of the all the websites loaded in that few hours. The value of means and standard deviations for each websites varies. Simple websites like Telstra, Google and USQ have smaller values for standard deviation which means they probably have higher QoS and QoE as compared to sophisticated websites like Yahoo and BBC which have higher values for standard deviation

Chapter 5 Conclusion

In this paper, we performed a comparison of a few internet accessing networks used in rural Australia; two of which are the Satellite Internet network and Telstra's Next-G network. Our results show that though they both serve the purpose, Telstra's Next-G network may potentially provide better QoS and QoE to customers. ADSL and the USQ campus direct access network proved to be stable networks with good QoS and QoE.

Our current results show that test run over a long period of time like 24 hours or even a week provided us with a better results. If more time were given, it would be ideal for us to run all our tests over a period of at least a week to obtain credible results.

Future work on could be done in the Voice over Internet Protocol (VoIP) and video performance over the internet. All tests could also be perform in new motivated environments.

List of References

Morelli & Petrone, 2011, 'Satellite Internet Access', Network Infrastructures A.A. 2010-2011, Sapienza Universita Di Roma, digital image, viewed 14 March, 2011, <http://net.infocom.uniroma1.it/corsi/Network%20Infrastructures/lucidi/Satellite%20Internet% 20Access.pdf>

Hu & Li, 2001, 'Satellite-Based Internet: A Tutorial' March 2001, IEEE Communications Magazine, viewed 28 March 2011, item: 0163-6804/01

Berezdivin, Breinig & Topp, Raytheon. 2002, 'Next-Generation WirelessCommunicationsConcepts and Technologies', March 2002, IEEECommunicationsMagazine, viewed28 March 2011, item: 0163-6804/02CommunicationsCommunications

Telstra, 2007. 'Telstra super-charges Next G[™] network'. Media release. [Internet].Releasedon15February2007. Viewed20May2010,<http://techtalkradio.wordpress.com/2007/02/16/telstra-announces-next-g-boost-</td>sigh/>

Telstra. 2006, 'Big Pond marks 10th anniversary with launch of national HighSpeedBroadband'. Media release. [Internet]. Released online 10 November2006. Viewed 20May 2010.http://www.telstra.com.au/abouttelstra/media/announcements.cfm

Schlosser, Binzenhofer & Staehle, 2007, 'Performance Comparison of Windows-based Thin-Client Architectures', 2007 Australasia Telecommunication Networks and Applications Conference December 2nd-5th 2007, Christchurch, New Zealand, viewed 2 May 2011,

http://ieeexplore.ieee.org.ezproxy.usq.edu.au/stamp/stamp.jsp?tp=&arnu665260

Deshpande, Hou & Das, 2010 'Performance Comparison of 3G and Metro-Scale WiFi for Vehicular Network Access' Computer Science Department, Stony Brook University, Stony Brook, NY 11794, USA, pp. 301-307, viewed 18 March 2011, <http://delivery.acm.org/10.1145/1880000/1879180/p301deshpande.pdf?key1=1879180&ke y2=3618015031&coll=DL&dl=ACM&ip=139.86.2.15&CFID=22307764&CFTOKEN=3751878 1>

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Gass and Diot, 2010, 'An Experimental Performance Comparison of 3G and Wi-Fi', A. Krishnamurthy and B. Plattner, Eds. PAM 2010, pp. 71-80, viewed 18 March 2011, Springer-Verlag Berlin Heidelberg 2010, item: LNCS 6032,

Davidson M., & Griffin, R., 2006, *Engineering Management, 4th Australian Edition*, John Wiley & Son, Queensland

ENG4111 N/A, Research project reference book, study book 2010, University of Southern Queensland, Toowoomba, Australia.

Martinez-Yelmo, Seoane and Guerrero. 'Fair Quality of Experience (QoE) Measurements Related with Networking Technologies' Wired/Wireless Internet Communications, 8th International Conference, WWIC 2010, Lulea, Sweden, June 1- 3, 2010. (Lecture notes in computer science, vol. 6074), pp. 228-239

Kuipers, Kooij, Vleeschauwer and Brunnstrom. 'Techniques for Measuring Quality of Experience' WWIC 2010, LNCS 6074, pp. 216-227,2010 viewed 5 October 2011, < http://www.springerlink.com/content/5028804658914365/fulltext.pdf>

Di Cioccio. 'Home Network Performance Diagnosis', Mid-Term Ph.D Thesis Evaluation, Technicolor – UPMC Paris Sorbonne Universites, Department of Computer Science, Dec 10, 2010, viewed 10 October 2011, http://www.thlab.net/~dicioccio/publications/mid-termdicioccio.pdf >

Islam, Selvadurai and Town, 'Wireless Broadband Technologies for Regional and Rural Australia – A Last-Mile Perspective' Telecommunications journal of Australia, volume 58, Number 2-3, 2008 Monash University Epress pp. 28.1-28.10

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Appendix A – Project Specification

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG4111/4112 Research Project PROJECT SPECIFICATION

FOR: IK SUNG LEONG

TOPIC: Broadband Satellite Internet Service Testing

SUPERVISORS: Dr. Alexander Kist Mr. Noel Sandstrom, TCW Queensland

ENROLMENT: ENG 4111 – S1, D, 2011 ENG 4112 – S2, D, 2011

PROJECT AIM: This project aims to evaluate and compare the Quality of Service of satellite Internet access and other wireless alternatives in rural areas.

SPONSORSHIP: University of Southern Queensland (USQ) Telstra Country Wide Queensland (TCW)

PROGRAMME: Issue A, 22 March 2011

- 1. Research information on last mile Internet access, specifically satellite and wireless broadband (Next-G) access.
- 2. Define and motivate test environment, including test scenarios and test locations.
- 3. Research and develop an automated test system to evaluate signal strength and measure the quality of various services that rely on internet connectivity. This will include
 - a. Round Trip Time (RTT) measurements
 - b. Timing of file downloads,
 - c. Time needed to load/interact with simple and sophisticated web pages
- 4. Undertake comprehensive tests in the defined environment using the develop test program.
- 5. Document, analyse and evaluate test results.

As time permits:

- 6. Expand the number of services and applications tested.
- 7. Evaluate more test locations for the wireless broadband access.

AGREED:

	(student)			(supervisor)
Date:	22 / 03 / 2011	Date:	22 / 03 / 2011	

Examiner

/

Co-examiner:

Appendix B – Risk Assessments

There are a few hazards were identified that need to be taken into consideration while performing tests. Below are the few:

Hazard	: Carrying laptop around to do tests may accidently damage the laptop
Risk	: Loss of data on laptop
Parts of body	: None unless laptop falls on part / parts of the body
Risk level	: Low
Safety measures	: Back up project's progress and necessary data on multiple memory
	drives. Instead of carrying laptop around, put laptop into a bag. Make
	sure laptop is placed on an appropriate well-balanced location when
	performing tests. Make sure laptop is not placed on a high location
	where probability of falling is greater.
Hazard	: Car accident may occur while driving to do tests
Risk	: Harm to driver or / and person who do tests
Parts of body	: part or all parts of the body
Risk level	: Medium
Safety measures	: Drive safely and follow all rules on the road. Make sure driver's
	attention is on the road at all times and that he or she is in a proper
	condition to drive and obey all road rules.
Hazard	: Possibility of danger arising from / during test environment
Risk	: various depending on test locations. The possibility could range from
	complaints from residents around the area to hit by lightning.
Parts of body	: various depending on incidents
Risk level	: High
Safety measures	: Always perform test with a considerate attitude and be aware of
	possible dangers around test locations before performing tests.
Perform	tests with at least another friend so in case of emergency, either one
	can call for help or assist victim.
Hazard	: Performing tests with expensive equipment like satellite antenna
Risk	: Harm to expensive equipment while doing tests
Parts of body	: None unless equipment falls on part / parts of body
Risk level	: Medium

Safety measures	: Always do an inspection of the equipment before and after tests.
	Make sure it is in working condition and proper maintenance
	measures are performed if needed to. Make sure equipment is under
	lock and key and / or kept in a safe environment away from damage
	and / or theft.
Hazard	: Performing test during rain (test environment requirement)
Risk	: exposing expensive equipment to rain may damage them
Parts of body	: None
Risk level	: Low (because hardly any rain in Toowoomba)
Safety measures	: Make sure test and equipment are perform and used in dry and safe

location

Appendix C – Test Scripts

Please refer to CD-R (too large to include here)

Appendix D – Satellite Internet Setup

Australian Nomad Technologies (ANT)

The ANT Internet Pack includes:

- Internet Kit
- DVD
- Quick Set Up Instructions
- CD with the Satellite Finder and other Software

Quick Setup Instructions

- 1. On your computer create a folder called something like "ANT" and save all files on the CD to it, and then remove the CD and store in a safe place.
- Then on your computer open the new "ANT" folder and then open the folder called "ANT Sat Finder" now create a shortcut on the desk top to the DeANTSatellitePickerV*.html file.
- 3. Open up your saved copy of *DeANTSatellitePickerV** software via the shortcut on the desktop (a browser warning message of the dangers of ACTIV X content may appear, press the allow ActiveX content to agree to all other warning messages as you are not connected to the internet and there is no danger.) On the screen you will see a box with EL number. This is specific to your individual unite and has been pre-programmed into your copy of *DeANTSatellitePickerV*. You do not need to enter anything into the EL Number Box unless advised by our support team. You can then choose the town you are in or enter the Latitude and Longitude (Remember when entering Latitude and Longitude, use decimal NOT minutes and seconds) and the Azimuth, Elevation and Polarization will populate. You need these figures to align the dish.
- 4. Please watch the Video right to the end before attempting to set up. This will help you understand setting up the dish.
- 5. If you have an Apple Mac you will be required to download Camino as your internet browser for your alignment process. Once you have finished the alignment you can use your usual internet browser.

Satellite Antenna (Dish) Setup Instruction

- 1. Open DeANT Satellite Picker and choose town that you are in or near from drop down menu or type in Longitude and Latitude.
- 2. Take note of Elevation (Angle), Azimuth (compass bearing) and Polarization (Skew).
- 3. Setup the ANT Folding Tripod with the leg with the ANT sticker on facing NNE (or towards azimuth).

- 4. Put tent peg in the ANT leg of Tripod to hold steady.
- 5. Put the Dish on the Tripod with centre of dish aiming same direction as ANT sticker tripod leg
- 6. Tighten Tripod Wing bolt until all play is removed but dish can still be turned.
- 7. Fold down boom arm and tighten wing bolt.
- 8. Attach ODU tighten wing bolts until all play removed but ODU can still be turned easily
- 9. Zero Inclinometer
- 10. Use inclinometer to ensure Dish Pole is vertical (90 degrees). Measure pole in two places back and side of pole.
- 11. Place inclinometer on fold down boom arm.
- 12. Adjust dish to the Azimuth (compass bearing) taken from DeANT Satellite Picker
- 13. Using the Turnbuckle adjust Elevation (Angle) as nominated in the DeANT Satellite Picker (as a guide use top pin for Queensland border north, and bottom pin for south of Queensland border, these pins allow for more movement).
- 14. Adjust the Polarization (Skew) on the ODU as identified in the DeANT Satellite Picker.
- 15. The Elevation, compass bearing and skew may need some further fine tuning later.
- 16. Attach Transmit (TX) and Receive cables to ODU and Modem.
- 17. Secure cables to boom arm with Velcro strap leaving ample cable length to take weight off Connectors.
- 18. Insert the Satellite Meter between the ODU Receive and Receive cable
- 19. Plug red cable into modem and the "Modem Red Cable Port" on the Router
- 20. Plug power into Modem (one green light i.e. power light should come on)
- 21. Adjust dial on Satellite Meter until it reads halfway on the scale
- 22. Turn the dish slowly left and right until you get a strong signal register on the Satellite Meter. If you don't get any signal, you may have to adjust the angle of the dish slightly up or down. Do these until you get a strong signal. The needle should register to the top of the scale. This is the satellite Optus C1. Optus C1 is the satellite that has the Free to Air TV stations.
- 23. Once you have found Optus C1, wind back the dial on the Satellite Meter until it just comes off the maximum scale.
- 24. Standing behind the dish, slowly move the dish to the East (right). You will see the needle on the satellite meter drop and the go back up this will be Optus D1 and the second light (RX).
- 25. Make small adjustments on the ODU (skew) to see if you can improve the signal strength.
- 26. Make small adjustments with turnbuckle to see if you increase signal strength.
- 27. Then make small adjustments left & right until you get maximum signal strength on the satellite meter, whilst maintaining the second light (RX) still being on.
- 28. Once you have the strongest signal strength that you can, get peg the tripod legs, tighten the rotational screw on the Tripod. Tighten ODU clamp wing nuts to "firm".
- 29. Remove Satellite Strength Meter from between ODU and cable
- 30. Connect Receive cables onto ODU receive.
- 31. You then need to fine tune the signal in the modem with SKYMANAGE.

SKYMANAGE instructions

(Do not make any changes to this router as it has already been pre-configured specifically for your service)

- 1. Plug red modem cable into back of modem.
- 2. Plug other end of red modem cable into "Modem Red Cable" port on wireless router
- 3. Insert ends of Yellow Cable into "Loop Yellow Cable" ports on wireless router
- 4. Click View Wireless Networks on your computer
- 5. Click Connect to ANT 12xxxx wireless network
- 6. It will ask you for a wireless key
- 7. Enter in your wireless key which is printed on the label on the bottom of your router.
- 8. Once connected, open your Internet Browser.
- 9. Go to your Internet Browser and type in the URL 192.168.1.1 and press enter.
- 10. This will bring up SkyManage save to favourites for later use
- 11. Select Installer
- 12. Enter user name and password as per sticker on top of modem (and on Commissioning Document)
- 13. Click Antenna
- 14. Click Start Alignment
- 15. Modem will reboot and only 2 lights, the power and receive lights will come on
- 16. The browser will refresh automatically (quick flash of screen, usually 30 seconds) you cannot proceed until this happens.
- 17. Then click on Cross Pole alignment
- 18. After all 4 lights are on, on the modem, a series of bar charts will appear on your browser (usually 3-5 mins). If this does not happen and SkyManage does not progress to this point, see alternative browser solution at the end of these instructions.
- 19. Undertake minor fine tuning, as when setting up dish, remember "fairy" adjustments, eg. Adjust Skew, elevation, compass bearing until Cross Pol (Xpol) is as close as

possible to zero but below 5. There must be a difference of 28 or more between the CoPol and Xpol.

- 20. When Delta is above 68%, you will receive a green tick and pass.
- 21. Once you have received the green tick that is stable, tighten the tripod screw and wing bolts on ODU.
- 22. After tightening all screws, you must still have a pass and green tick
- 23. If you do not have a pass, go back to step 19.
- 24. If you still have the green tick, click "End Alignment"
- 25. Close down your Internet browser
- 26. This is the end of alignment stage.

To use the Internet

After clicking "End Alignment" one or more of the lights will go off. Wait approximately 1 minute after all 4 lights come back on the modern. Then start browsing the Internet with your usual Internet Browser.

Alternate Browser

Sometimes individual configuration issues peculiar to your personal laptop will prevent your browser running SkyManage – you should be able to work around this by installing "Opera", a simple no frills browser and using Opera just to run SkyManage to align the dish. Once this is done, you can then use your usual browser to access the internet.

Procedure

- 1. From the ANT folder on your computer, or from the CD, double click on the "Opera" icon
- 2. Click install and follow prompts.
- 3. This will create a shortcut on your desktop, remove CD if necessary
- 4. Go to Desktop and Open Opera from shortcut.
- 5. Repower Modem (Power off/on).
- 6. Wait until 4 lights on modem come on
- 7. In the URL window in Opera, type 192.168.1.1 and press enter
- 8. Now continue at SkyManage Instructions at step 9.

Appendix E – USQ Campus Wireless Internet Laptop Setup

These are the steps that enable a user / student to connect to the campus wireless network. This is a one off setup that means once this is setup, users can always connect to the this wireless network indefinitely unless the server is down or discontinued.

 The Client must first be downloaded. In our case we need download from the "Staff and Student (Windows)" link on the USQ website, http://www.usq.edu.au /ict/usqwireless

2.	Begin	installation	of	the	SecureW2	Client
	🗵 Secure₩2	Installer for USQ 3.4.7_GA1 Setu	p			
	Installing Please wait	while SecureW2 Installer for USQ 3.4.	7_GA1 is being in	stalled.		
	Execute: So	ecureW2_Enterprise_Client_347.exe /1	TLS 1 /PEAP 1 /G	iTC 1 /Service 1 /S		
	Show d	etails				
	Nullsoft Install	System v2,46				
				Next > Can	cel	



3. Enter Username and Password for the USQ-Secure Network

network

Locate	the	USQ-Secur
*		
	Not connected	4 ₇ ^
	Connection	ons are available
	Wireless Network	Connection
	USQ-Secure	lte.
		<u>Connect</u>
	USQStaff	lte.
	USQdot1x	liter
	eduroam	llter
	USQStudent	line
	USQ-Welcome	Sul
	USQGuest	<u>Sal</u> -
	Open Netw	vork and Sharing Center
* 5 0		

6. Connect to USQ-Secure

Currently connected to:	4 ₂
Internet access	
Wireless Network Connection	^
USQ-Secure Cor	nected ,
USQStaff	llte.
USQdot1x	lte.
eduroam	.at
USQStudent	the.
USQ-Welcome	31
USQGuest	311
Other Network	. 116.
Open Network and Sha	ring Center

- 7. Open the browser then choose Tools > Internet Options > Connections
- 8. Click on Lan settings

nternet Options	<u>? ×</u>
General Security Privacy Content Connections	Programs Advanced
Vo set up an Internet connection, click Setup.	Setyp
Dial-up and Virtual Private Network settings	
	A <u>d</u> d
	Bemove
	Settings
Server for a connection. Never dial a connection Dial whenever a network connection is not press August dial mudels it connection.	ent
Current None	Sgt default
Local Area Network (LAN) settings	
LAN Settings do not apply to dial-up connections. Choose Settings above for dial-up settings.	LAN settings
ок (са	ncel Apply

- 1. Tick the checkbox 'Use automatic configuration script
- 2. Enter the URL as http://proxy.usq.edu.au/proxy.pac
- 3. Click OK

Local Area Network (LAN) Settings	×								
Automatic configuration Automatic configuration may override manual settings. To ensure the use of manual settings, disable automatic configuration.									
Automatically detect settings									
Use automatic configuration script									
Address http://proxy.usq.edu.au/proxy.pac									
Proxy server	5								
\square Use a proxy server for your LAN (These settings will not apply to dial-up or VPN connections).									
Address: proxy.usq.edu.a Port: 8000 Advanged	1								
Bypass proxy server for local addresses									
OK Cancel									