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The Impact of Ultra-Fast Broadband on Telehealth in New Zealand

by

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Abstract

In recent years, many countries around the world have introduced Information and Communications Technologies (ICTs) in their healthcare industry, in a bid to improve their productivity and the effectiveness of their services, triggering the eHealth phenomenon. As a component of eHealth, telehealth– which refers to a set of expertise and methods that integrate the world of ICT with the healthcare sector, providing medical care and education over a distance– is revolutionazing the healthcare sector.

One of the most important ICTs used in the provision of telehealth is broadband internet. The bandwidth of the broadband connection determines the speed and quality of communications. Ultra-fast broadband– currently defined as connections with bandwidth greater than 100Mbps for downloads and 50Mbps for uploads– has made possible connections and communications on a scale and of a quality never before possible. The capacity to traverse geographical boundaries in real time and transfer large amounts of information has made ultra-fast broadband a sought-after tool in many businesses.

The main objective of this research is to study the impact of ultra-fast broadband internet on the development and quality of telehealth systems, especially in New Zealand. This thesis provides an overview of current broadband technologies available for running successful telehealth services, and studies the application and importance of broadband internet in the field of healthcare. It also provides a summary of the evolution of the use of ICTs, broadband technologies in particular, by health systems and a brief look at the future of these technologies in healthcare sectors, mainly in New Zealand.

This thesis will conclude the importance of broadband internet in telehealth and its related services, and that the provision of telehealth would be near to impossible without ICTs such as broadband. This thesis will also conclude the introduction of ultra-fast broadband into telehealth in New Zealand to be a significant step forward as evident in telehealth projects overseas.

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Finally, I would like to dedicate my thesis to my grandparents who are no longer with us.

Contents

Chapter 1

Introduction

This chapter provides an overview of the research. Section 1.1 begins with a brief introduction and sets the context of the research. Section 1.2 provides formal definitions of the key terminology used throughout the thesis. Section 1.3 poses the central research question, and outlines the research objectives. Section 1.4 concludes this chapter with an outline of the thesis presented by chapter.

1.1 Background and Context

Over the past two decades, there has been an exponential increase in the utilization of Information and Communications Technologies (ICTs) in numerous industries. This has partially contributed to the growth and development of the ICT industry, and new technologies are being continually released to meet the growing demands of industries and businesses reliant on ICTs.

Some of what makes ICTs efficient and sought-after tools in many enterprises are the ease and speed of remote access to large amounts of information in real time, the ability to have a shared, unified infrastructure of information, the decrease in administrative costs, and the cost-effectiveness of distribution of information and delivery of services [1].

These and countless other industry-specific benefits have resulted in the healthcare (or health) industry in many countries, including New Zealand, employing ICTs in a bid to improve productivity and efficiency.

Developments in the ICT industry have had a considerable effect on healthcare sectors, and have conceived and shaped the eHealth phenomenon. Of the many ICT developments influencing and affecting healthcare sectors, recent advances in the areas of telecommunication and networking in particular have given rise to innovative tools and technologies, that have made possible a wide range of efficient and powerful healthcare/medical applications that were previously not possible. For instance, accessing patient records logged in a mobile digital form, performing robotically assisted surgeries remotely, phone and online consultations, medical paging systems, and remote cardiac monitoring [2].

The majority of these applications are either not possible without or rely on the use of communications networks, such as radio networks, telephone networks and the Internet. The fundamental function of these networks is the transmission and exchange of data. For the Internet, this is the communication of digital data.

The discriminating factor in accessing the quality of the type of Internet access is the bandwidth provided by the network. The bandwidth determines the average amount of data that can be transferred over time or the speed of the data transmission. Higher bandwidths are assumed to effect the efficiency and quality of many communications-based applications.

The main focus of this research is to study the effects of higher bandwidth Internet access, more precisely ultra-fast broadband Internet access, on the growth and development of remote access healthcare systems and applications within New Zealand.

1.2 Terminology

This section provides common definitions for terms used in this research. Since some terms do not yet have a single global, agreed-upon definition, sometimes more than one definition of a concept is included.

The selected definitions emphasize various aspects of the concept or simply provide a slightly varied point of view.

1.2.1 Information and Communications Technology

Information and communications technology (ICT) is an umbrella term that refers to the use of computers and telecommunication technologies used to access, communicate, store, manage, broadcast, process and manipulate information. One commonly cited definition of ICT is

- *"ICT is defined as any technology or device that has the capacity to acquire, store, process or transmit information."*, used by W. E. Steinmueller [3].

ICT includes computer hardware, software, communications networks, communications tools (such as telephones, cameras, radios, satellite systems, etc), and any other device/technology that can be used to process, transmit and exchange information (in the form of text, audio, video, image, etc).

1.2.2 Bandwidth and Ultra-Fast Broadband

The term *bandwidth* is defined as "the measure of the capacity of a circuit or channel" [4].

In digital circuits, bandwidth refers to the data transmission rate supported by the medium connecting a transmitter and a receiver. The basic unit of measurement is a bit, and bandwidth is often defined as the number of bits transmitted or processed in one unit of time (a second). The metric prefixes kilo- (k), mega- (M), giga- (G) or tera- (T) are typically used to express transmission rates; for instance, 256 kbps.

In analog circuits, bandwidth refers to the difference between the highest and the lowest frequencies in a composite signal, and here the bandwidth is measured in hertz (Hz); for instance, 5 MHz.

The channel capacity (in bps) and the bandwidth of the analog circuit (in Hz) are said to be proportional [**?**].

Often bandwidths of greater than 256 kbps (for both downloads and uploads) correspond to what is known as *high-speed* Internet access. The term "high-speed" is temporal in nature; its definition continues to change over time.

The term *broadband* in general refers to channels providing a large bandwidth. There is no set scale or standard for what constitutes as "large" and therefore, the definition of broadband is highly context-dependent and not precise. In North America, broadband corresponds to bandwidths greater than 1.544 Mbps (the ISDN standard), and in many countries, this limit is 2.048 Mbps. Broadband Internet access is a high-speed Internet access [4].

The term *ultra-fast broadband* refers to transmission rates of over 100 Mbps for downloads and over 50 Mbps for uploads [5].

1.2.3   eHealth

With its introduction following the advent of e-applications, *eHealth* (previously referred to as Health Informatics) has been the subject of much research. There have been numerous works of research dedicated to extracting a global definition of eHealth from the literature [6, 7, 8]. According to most studies the definition of eHealth is context-dependent, but most converge on its major components being health and/or healthcare and technology. Some frequently cited definitions of eHealth are:

- *"E-Health is the application of information management, systems, and technology to the planning and delivery of high-quality and cost-effective healthcare."*, suggested by T. Norris [9] who also points out that "Quality and cost-effectiveness are the generic high-level drivers and Integrated care is the key to the optimum balance."

- *"E-Health is an emerging field in the intersection of medical informatics, public health and business, referring to health services and information delivered or enhanced through the Internet and related technologies. In a broader sense, the term characterizes not only a technical development, but also a state-of-mind, a way of thinking, an attitude, and a commitment for networked, global thinking, to improve healthcare locally, regionally, and worldwide by using information and communication technology."*, suggested by G. Eysenbach [6].

- *"The cost-effective and secure use of information and communications technologies (ICTs) in support of health-related fields, including healthcare services, health surveillance, health literature, and health education, knowledge and research."*, which appears in the World Health Organisation (WHO) manuals [10].

1.2.4 Telehealth

The prefix "tele", meaning "far" or "at a distance", has its origins in the Greek language. *Telehealth* is a subset of eHealth and refers to components of eHealth that use ICTs to provide healthcare at a distance. Formal definitions of telehealth include:

- *"Telehealth is the use of electronic information and telecommunications technologies to support long-distance clinical healthcare, patient and professional health-related education, public health and health administration. Technologies include videoconferencing, the Internet, store-and-forward imaging, streaming media, and terrestrial and wireless communications."*, provided by the US Department of Health and Human Services [11].

- *"The provision of health services at a distance using a range of technologies. Examples of telehealth include telephone or video consultations to support diagnosis and management, clinical networks and health professional education."*, as set by the Scottish centre for Telehealth [12].

- *"Healthcare delivery, or closely related processes, when participants are separated by distance, and information and communications technologies and infrastructures are used to overcome that distance."*, adopted by the New Zealand Telehealth Forum [13].

1.2.5   Telemedicine

The word *telemedicine* means "healing at a distance", and refers to the use of ICTs to improve the health of patients by providing increased access to healthcare and medical information [14]. The World Health Organization (WHO) recognizes that there is no universal definition of telemedicine and adopts the following definition:

- *"The delivery of healthcare services, where distance is a critical factor, by all healthcare professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment and prevention of disease and injuries, research and evaluation, and for the continuing education of healthcare providers, all in the interests of advancing the health of individuals and their communities."* [**?**].

Telemedicine is distinguished from telehealth, since telehealth often refers to a wider range of healthcare services, which include remote training, administrative and educational services in additional to medical and care services.

1.2.6   Telecare

The exact definition of the term *telecare* is still evolving; however, most sources when referring to telecare imply the use of ICTs to care for the elderly or vulnerable individuals with physical or mental disabilities, and to assist them in living independently in their home environment. Two common definitions of telecare are:

- *"Telecare is the remote or enhanced delivery of care services to people in their own home or in a community setting by means of telecommunications and computerised services. Telecare usually refers to sensors and alerts which provide continuous, automatic and remote monitoring of care needs, emergencies and lifestyle changes, using information and communication technology (ICT) to trigger human responses, or shut down equipment to prevent hazards."* [15].

- *"The use of a combination of communications technology and sensing technologies to provide a means of manually or automatically signaling a local need to a remote service center, which can then deliver or arrange an appropriate care response to the telecare service user."*, suggested by Andreas Gregoriades et al. [16].

Telecare, Telemedicine and Telehealth are all components (or subsets) of eHealth.

1.3 Research Questions and Objectives

This thesis seeks to contribute to a growing body of literature on the effect of technological advancements in telecommunications and networking on health and healthcare systems, by exploring innovations in ICTs over the past two decades, and the utilization of ICTs in the health and medical industries in various countries, with the main focus on New Zealand.

The central question driving this research is

What effect does the introduction of ultra-fast broadband (UFB) have on the development of new and existing telehealth services in New Zealand?

This research question is an extensive one and in order to answer it, it is necessary to achieve the following research objectives:

- To understand the current state of telecommunications technologies available, and the most recent advances in these technologies.

- To study the various types of networking media and Internet connectivity, and recent advances and innovations in networking technologies.

- To investigate significant changes made in the healthcare system in New Zealand since the introduction of broadband Internet in the health and medical industries.

- To study the concept of telehealth and types of telehealth systems currently in place in New Zealand and elsewhere.

- To identify telehealth applications that require Internet connectivity, and those that are not possible without high-speed Internet connections.

- To investigate the development of telehealth systems in various countries with different health systems.

- To identify telehealth applications and services available abroad that have not yet been introduced or developed in New Zealand.

- To identify broadband technologies available abroad but not in New Zealand that may be responsible for the state of the more advanced telehealth applications and services.

- To determine trends in the adoption of ultra-fast broadband in New Zealand, trends in the development of telehealth systems in New Zealand, and the connection between the two.

1.4   Thesis Outline

This chapter provided an overview of the thesis, by setting the background and context of the research, supplying definitions of common terminology,

and discussing the central research question and research objectives.

The chapter now concludes with a brief outline of the structure and organisation of the remainder of the thesis:

Chapter 2 - This chapter presents and discusses in detail the research design and methodology used in this study.

The chapter also provides an outline of the process of collecting the various sources of literature that were used in preparing this thesis.

Chapter 3 - This chapter provides a brief review of technologies relevant to this research, such as ICTs, the Internet and broadband technologies in particular.

The chapter also includes an outline of various types of network infrastructure and a brief description of past and current infrastructures in New Zealand.

Chapter 4 - This chapter provides a detailed discussion of the concept of telehealth, its advantages and disadvantages, and various types of telehealth systems.

The chapter also provides a review of telehealth systems and the various technological and regulatory aspects of telehealth in New Zealand and elsewhere.

This chapter also includes an outline of some telehealth projects currently in place in different developed countries around the world, such as the United States of America, England, Scotlant, Australia, Norway and Denmark.

The chapter provides a review of summary case studies on some of the current telehealth projects in various regions of New Zealand.

Chapter 5 - This chapter examines, analyzes and discusses the information collected from the various resources. Using the research objectives as a guiding framework, it attempts to answer the central research question.

Chapter 6 - This chapter concludes the thesis with a brief summary of the
research findings.

Chapter 2

Design and Methodology

This chapter provides an overview of the research methodology used in collecting the information presented in this thesis, and outlines the approach used to analyze and draw inferences from the accumulated information.

The chapter also includes an outline and descriptions of some of the sources used in collecting the relevant information.

2.1   Research Methodology

This research was undertaken to study the effect of ultra-fast broadband on the future development of telehealth in New Zealand.

The research methodology used for this study is an adaptation of the historical method for Management Information Systems (MIS) research proposed by Mason et al. [17].

The research methodology, modified to suit this research, is employed to provide structure and clarity to the research process. It involves the examination and interpretive analysis of the information collected to increase understanding and draw inferences in the domain of interest, based on observations made in a global environment.

The six steps involved in the methodology employed for the purpose

of this research are the following: [17]:

1. Determining the domain of interest

2. Specifying the focusing questions

3. Collecting relevant information

4. Critiquing the collected information

5. Interpreting observations and determining patterns

6. Writing the thesis

2.1.1 Determining the Domain of Interest

According to the domain of inquiry for this research, the primary unit of analysis is the telehealth industry in New Zealand.

While telehealth developments and technological innovations in New Zealand are the central focus of this research, the use and implementation of broadband technologies (ultra-fast broadband in particular) in healthcare systems in various countries are studied in an attempt to identify possible general patterns.

2.1.2 Specifying the Focusing Questions

Focusing questions are often derived from the research questions and the objectives of the research, and aid in improving clarity by directing the research process.

> *"The key to good research lies not in choosing the right method, but rather in asking the right question ...."* ∼ Bouchard (1976) [18]

The questions put forward should guide the research while maintaining focus on the field of interest and the research question(s).

A small collection of specific focusing questions, which are deemed relevant to this research, are outlined below:

- What broadband technologies are adopted into the healthcare system in New Zealand?

- What significant changes have occurred in the healthcare system in New Zealand since the introduction of broadband Internet?

- Do telehealth services improve the quality of healthcare in general?

- Will provision of telehealth services improve the quality of healthcare in rural New Zealand?

- To what extend are telehealth services dependent on high-speed broadband?

- What is the current status of the broadband network infrastructure in New Zealand?

- What is the future plan for the broadband network infrastructure in New Zealand?

2.1.3 Collecting Relevant Information

Having set the domain of inquiry and determined the focusing questions, the next step involves the collection of information (data).

The sources of information used in this research include, but are not limited to: academic journals, books, technical reports, library databases, annual reports by organizations, trade sites, newspaper articles, educational and informational web pages, reviews, case studies, white papers, conference proceedings, theses and encyclopedias. More on the process of gathering information is presented in Section 2.2.

The majority of the quoted texts presented in this thesis are gathered from the original source of information, and every attempt has been made to preserve their form without alternation of their content or modification of their interpretation.

2.1.4 Critiquing the Collected Information

Although the information available on the subject of this thesis appears to be extensive, the credibility of some of the sources of information cannot be determined. As far as possible, ideas and concepts whose origin and credibility could not be established have been omitted.

Only a relatively small number of carefully selected sources of information have been used in this research.

Where applicable, the following points have been considered to avoid the inclusion of biased information [19]:

- The providers and purpose of the reported information;

- If and how the providers stand to gain by relating the information;

- Whether the information prominently features a single perspective;

- The objectivity of the presented arguments.

2.1.5 Interpreting Observations and Determining Patterns

Once information is collected and the credibility of the information is ascertained to the best of one's ability and reasoning, the ensuing facts need to be understood, analyzed, explained and interpreted.

In order to determine patterns, developments need to be placed in the right context. In this study, the context is global developments and innovations in telehealth that can be directly attributed to high-speed broadband (increased bandwidth). The observed patterns can then be generalized to predict trends and make inferences on developments in telehealth in New Zealand when bandwidth is increased.

The following framework of questions is set up to give structure and consistency to the process of determining patterns:

- What are the telehealth services/projects currently offered by countries studied?

- What is the ultra-fast broadband network infrastructure in each of these countries?

- To what extent do the telehealth projects in each country depend on its ultra-fast broadband network infrastructure?

2.1.6   Writing the Thesis

The purpose of this research is the study of developments in broadband technologies and their use in healthcare sectors with the main focus on developments due to increased bandwidth (high-speed Internet connectivity, namely ultra-fast broadband) on telehealth in New Zealand.

Often while doing research in an area and gathering material to build on, focusing questions posed at the onset of the study gradually evolve into more specific and applicable questions. As the research takes shape, objectives become increasingly well-defined and the course of the research becomes more apparent. To the best of this author's knowledge, these questions and objectives have been appropriately refined and improved.

The final step is the writing of the manuscript. At every point of the research process, the interpretation of the observations presented in this thesis and the rationality and soundness of subsequent statements have been questioned and they have been adjusted accordingly.

2.2   The Process of Collecting Information

In collecting the required information, the Internet was used extensively. Most sources of information used in this thesis were directly accessible online.

The starting point was the Massey University library database, where keywords and phrases constructed from these keywords were used to find articles and books on ICTs, broadband, telehealth, and other related material. The references provided in each of those materials were also exam-

ined and used when applicable. A relatively small sample of keywords used is presented in Table 2.1.

Table 2.1: Sample of keywords used in collecting information for this thesis

eHealth	Internet
Telehealth	Broadband
mHealth	Ultra-fast Broadband
Health IT	Wireless
Telehealth systems	Wired broadband
Telehealth projects	Communications technology
Telemedicine	Information systems
Telecare	History of broadband
Mobile health	ICTs in healthcare
New Zealand telehealth	New Zealand network infrastructure
EHR	Broadband in businesses
Tele-monitoring	Videoconferencing

Most of the literature on healthcare and telehealth in New Zealand (and abroad) was extracted from government web sites, educational and informational web pages, online encyclopedias, journal articles, documents on policies and healthcare systems, newspaper articles on telehealth projects, health commissions' reports and review articles by researchers in the field.

The majority of the literature on broadband technology (and ICTs), regional network infrastructures and other technology related material were sourced from books and manuals on ICT and broadband, encyclopedias, white papers, informational and educational web sites, government web pages, reports from broadband commissions, documents detailing broadband initiatives and press releases.

The full list of material accessed and used for this research is given in the bibliography section of the thesis.

Chapter 3

Broadband Technology

This chapter provides an overview of networking technologies, namely the Internet and broadband technologies including ultra-fast broadband, and outlines the various types of broadband that have been in use since the Internet was commercialized.

The chapter also includes a brief description of the current network infrastructure in New Zealand.

3.1   The Internet and Broadband

The *Internet*, a network of interconnected computers, was a project funded by the American Department of Defence (military) and developed by the Advanced Research Project Agency (ARPA). It was formerly know as the ARPANET (ARPA network). The Internet was created as a means of better communication between military establishments and within universities and other research centres [20, 21].

In 1969, Bolt, Beranek and Newman Inc. (BBN) were the first to build the Interface Message Processor (IMP), which led to the future development of the *File Transfer Protocol*, also known as FTP [21, 22].

ARPA was later renamed DARPA (Defence Advanced Research Projects Agency) and collaborated with BBN to build the Transmission Control

Protocol/Internet Protocol, abbreviated to TCP/IP [21, 22]. These were a set of communications protocols developed for the Internet.

At that stage, this technology was only available to the military and a few selected universities and research centres that were involved in the development of the technology. By the early 80s, due to the high traffic on this network, ARPANET was split into the military network (MILNET) and ARPANET between the military and the research centres. MILNET was used exclusively for the military traffic and site, and ARPANET was used for the non-military traffic. Not long after the split the military ran into the same problem of unmanageable traffic due to usage growth. To deal with this growth standardized protocols were put in place by the Secretary of Defence. This standardisation led to successful commercialization of the Internet. Using these standards the National Science Foundation (NSF) funded six centres with supercomputers and these centres later merged to form the NSF network (NSFNET), which became the backbone of the current internet [21, 22].

New Zealand established its first ever direct connection to the US Internet via the analogue ANZCAN undersea line from Hawaii to Waikato University in 1989. The bandwidth–that is, the data transmission rate supported by the medium connecting a transmitter and a receiver–of the connection was around 9.6 kbps.

Since then the Internet has come a long way. There have been many further developments in the technology, and hence, the number and types of activities for which the Internet is used. Today large volumes of data can be transferred from one end of the world to the other (regardless of the geographic location) and the transfer speeds possible nowadays are far greater than the 9.6 kbps of the earlier Internet.

Along with technological developments and advances, there has also been a substantial amount of growth in the number of internet users, especially in the last decade. According to the 2012 report from Internet World Stats, the number of internet users in the world has grown by 566.4% in

the last decade [23]. Figure 3.1 demonstrates the increase in internet users per continent [23].

Internet Users in the World by Geographic Regions - 2012 Q2

Region	Millions of Users
Asia	1076.7
Europe	518.5
North America	273.8
Latin America / Caribbean	254.9
Africa	167.3
Middle East	90.0
Oceania / Australia	24.3

Source: Internet World Stats - www.internetworldstats.com/stats.htm
2,405,518,376 Internet users estimated for June 30, 2012
Copyright © 2012, Miniwatts Marketing Group

Figure 3.1: Internet users in the world by geographic regions - 2012 (Taken from: [23]).

The number of users in New Zealand alone grew from 830,000 in 2000 (around 22% of the 3.7 million population) to 3,810,144 by June 2012 (around 88% of the 4.4 million population) [24].

The commercial Internet that is now readily available to the public did not always have the current speeds/bandwidths. The first commercial (home/business) modem[1] manufactured had the capability of transmitting (uploading) and receiving (downloading) data at a maximum speed of 28 kbps. This technology was known as Dial-up internet which required a land line phone to dial in to an Internet Service Provider (ISP) every time

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[1]A modem uses a modulator to modulate an analogue carrier signal to encode digital information and a demodulator to decode the transmitted information.

used, thus keeping the phone line occupied. The dial-up technology was available to anyone who had a land line telephone and did not have additional infrastructure. Not long after the release of this technology researchers managed to build an amplified version of the same dial-up technology that was capable of transmitting and receiving data one and half times and even twice as fast (33 kbps and 56 kbps). These days this technology is being used in remote and rural areas where the infrastructure for broadband technology has not yet been set up. Internet Service Providers (ISPs) in some countries usually provide this technology either for free or for a very low price [22, 25].

With the growth and popularity of the Internet the number of users and accessible data (e.g. file sharing, video uploads, etc.) grew substantially, thus making the dial-up technology insufficient. This gave rise to the birth of the next level of internet technology known as *broadband* internet.

Broadband is the technology used to surf the Internet. In telecommunications and networking the term "broadband" usually refers to a signal of bandwidth higher than 256 kbps [22].

Ultra-fast broadband (UFB) is a broadband connection that is capable of transmitting and receiving data at very high speeds (bandwidths). Currently, these broadband technologies are capable of producing download speeds over 100 Mbps and upload speeds over 50 Mbps [26]. Fibre-optics, wireless technologies such as 802.11ac and 802.11ad, and cellular mobile networks such as WiMAX 2 and LTE-A are some examples of ultra-fast broadband [26].

3.2   Types of Broadband

Initially, broadband technology was only in the form of "fixed-line", but in time this technology emerged in a "wireless" form [25]. The following are the various types of fixed-line and wireless broadband technologies available today, some of which are considered to be ultra-fast broadband

technologies [27].

3.2.1 Fixed-Line Broadband

3.2.1.1 Digital Subscribers Line (DSL)

DSL technology uses the existing phone connection (copper line) as its infrastructure. Through the use of special filter the signal on the copper line is divided to facilitate voice (phones calls) and data signals to be transmitted. DSL equipment (modem and line filters) provide the means for this division. There are three different types of DSL technologies [27]:

1. **Asymmetrical Digital Subscribers Line (ADSL):** ADSL has a maximum download rate 12 Mbps (Mega bytes per second) and a maximum upload rate of 640 kbps. This technology was further developed into ADSL2 and ADSL2++ which have much higher bandwidths. For Example ADSL2++ has a maximum of 26 Mbps for downloading and a maximum of 1 Mbps for uploading making it reasonably faster.

   These technologies are mainly used for home and small businesses where there is more retrieval of data rather than submission.

2. **Symmetrical Digital Subscribers Line (SDSL):** SDSL technology is the same as ADSL except for the fact that the maximum download rate is exactly the same as the maximum upload rate which is 3 Mbps. This technology is used in larger businesses and research centres [27].

3. **Very High bit rate Digital Subscribers Line (VDSL):** VDSL technology was created to support higher bandwidth than ADSL and SDSL. With the introduction of High Definition (HD) video and HD imagery the file sizes began to grow rapidly, and ADSL and SDSL were not sufficient for retrieval and submission of these high quality data.

VDSL has a maximum download rate of 52 Mbps and a maximum
upload rate of 16 Mbps [27].

The only set back to these technologies is that they are distance-sensitive,
therefore there is a loss of the quality of bandwidth depending on how
far the connection is from the main hub or exchange hubs. ADSL has a
maximum range of 5.4 km, SDSL has a maximum range of 2.7 km, ADSL2
has a maximum range of 3.6 km and VDSL has a maximum range of 1.3
km.

Overall the DSL technology does not qualify as ultra-fast broadband
due to its bandwidth [27].

3.2.1.2   Hybrid Fibre Coaxial (HFC)

HFC, also known as cable internet, uses the infrastructure of digital cable
TV network. By using a cable modem (at the user's home) and a Cable
Modem Transmission System (CMTS), a bi-directional data transfer can be
made over the coaxial cable. This cable is connected to hubs and optical
nodes, and these hubs and nodes are connected to service providers by
fibre-optics.

The bandwidth to this connection can range from 30 to 100 Mbps de-
pending on which Data Over Cable Service Interface Specification (DOC-
SIS) standard is used, DOCSIS 1.1 or DOCSIS 3.0. Unlike the DSL tech-
nology, HFC is not distance-sensitive. As long as the coaxial cable is in
good working condition and Radio Frequency (RF) amplifiers are installed
along the way the bandwidth on these connections stays strong.

The only set back from this technology comes from a shared network
architecture, the higher the number of connections made to the nodes and
hubs the slower and lower the quality of bandwidth gets.

The HFC technology has a reasonably high bandwidth but these speeds
are not enough for it to be considered as an ultra-fast broadband technol-
ogy [27].

3.2.1.3 Broadband Powerline (BPL)

BPL technology, as the name implies, uses the existing power lines as its infrastructure. The data are transmitted over these lines by low voltage power and high frequency broadband signal alongside a high voltage low frequency power signal. This technology started with a data transmission speed of 2 to 3 Mbps and had the potential to go up to 200 Mbps.

A few setbacks in this technology have held it back from evolving. One of the biggest flaws of this technology was its low frequency power signal interfering with low frequency radio signals (amateur radio). This interference caused distortion in the transmission of the radio signal when the broadband signals were transmitted and low data speeds or in some cases disconnection of the broadband signal when radio signals were being transmitted.

Like HFC, the BPL technology offers a high amount of bandwidth but not high enough to qualify it as an ultra-fast broadband technology [27].

3.2.1.4 Fibre to the Home/Curb (FTTH)

Fibre-optics is a prime example of ultra-fast broadband technology. This technology transmits data by converting it into light and sending it through a series of fibres. These fibres are nothing but transparent glass fibre similar to the human hair in diameter. The technology of bringing these fibre connections as close as possible to the user is known as FTTH. This technology is ten to hundred times faster than the usual DSL technology.

FTTH has many variations depending on what architecture is used. For example, FTTN (Fibre to the Node) is used with VDSL architecture where fibre-optic cables connect the local exchange to Nodes/Hubs and from there connect to the end user using twisted copper cable. Similarly, with FTTB (Fibre to the Building) and FTTP (Fibre to the Premises), the fibre-optic cables have been laid to a certain point (in these instances building/premises) and from there the light signal (optical) is converted back into the data signal (electronic) and sent to the end user by means of

twisted copper cables or wireless technology.

Fibre technology is the future of high speed and reliable broadband. Due to its high bandwidth, fibre-optics technology is considered an ideal candidate for ultra-fast broadband [27].

3.2.2   Wireless Broadband

3.2.2.1   Microwave Links

Microwave links are a very old fixed-wireless broadband system that have been around even before the term wireless broadband emerged. This technology uses point-to-point LOS (Line of Sight) to transmit data. The data transmission can reach speeds up to 5 Mbps and a range of up to 5 km.

Setting up Microwave links is inexpensive and simple to install compared to laying cables underground. For example, this technology is good for hilly terrains (provided that the hills are not obstructions) or even a heavily populated area where laying underground cable will cost a lot.

The disadvantage of the microwave link technology is that it has a very low data rate making it not so efficient for high capacity links and networks with high demand for bandwidth. This issue can be resolved by installing more links and amplifying the data rate. However, by doing this the cost of installing begins to exceed that of the cabled network [27].

3.2.2.2   Multichannel Multipoint Distribution Service (MMDS)

MMDS technology is used for coverage in a wider area and uses point-to-multipoint instead of the point-to-point architecture. This technology can cover distances up to 100 km when in line of sight, but it can reduce a lot when used in hilly and mountainous areas. Data signals are transmitted through a sector antenna from the base station to all the locations situated in 60 to 90 degrees of the base. This technology reduces costs by using the point-to-multipoint (instead of the point-to-point) architecture, since this way the number of links installed are reduced.

Nowadays MMDS is used to transmit cable TV signal, telephone signals and fax data signals. MMDS has been around since 1970 and it was known as wireless cable. It was used to send cable TV signals to remote and isolated areas where installation of cable was difficult and expensive. MMDS technology transmits the signal using terrestrial base radio transmitters. These transmitters use the frequencies in the lower end of the UHF (ultra-high frequency) radio spectrum that range between 2.1 and 2.7 GHz, and they are usually placed at the highest point possible to widen the line of sight. MMDS was used in America to facilitate 99 digital channels (33 analog in the past) along with 10 Mbps of data streaming and fully enabled Ethernet connectivity.

This service has a capacity of 1 Gbps, but because the radio signal is shared by a high number of users this bandwidth drops to a range between 500 Kbps to 1 Mbps. MMDS does not meet the bandwidth requirements to be considered as an ultra-fast broadband technology [27].

3.2.2.3   Local Multipoint Distribution Service (LMDS)

LMDS technology is very similar to the MMDS. It uses the same sort of sector antenna from the base station to transmit the signal. It also uses the point-to-multipoint architecture, and it is used to cover a wide area. The only difference is that the terrestrial base radio transmitters transmit in the higher end frequencies of the UHF radio spectrum, which can range between 27.5 GHz to 31 GHz. This way LMDS offers a higher bandwidth and limited coverage radius of approximately 8 km.

The LMDS technology is known to provide two-way broadband services with an upload speed of 45 Mbps and download speed of 155 Mbps. For this broadband to be functional the radio transmitters and the end users' transceivers must be in line of sight.

Like MMDS, LMDS does not offer enough bandwidth to be considered as an ultra-fast broadband technology [27].

3.2.2.4   Free Space Optics (FOS)

FOS is a technology that uses lasers or Infra-red to support transmitting data in free-space. The transmission rate can range between 10 Mbps and 1.25 Gbps, and the maximum distance between the receiver and the transmitter must not exceed 4 km. This technology requires line of sight for it to be functional and it operates at Terahertz (one THz = one trillion hertz) frequencies of the Radio Frequency (RF). FOS systems have low installation costs due to the use of light signal instead of radio waves, hence avoiding the radio licensing.

One disadvantage of this system is that it is not cost-effective for application to a large area due to its point-to-point architecture. Another disadvantage of this technology is that a change in climate and weather conditions affects its reliability.

Even though FOS technology meets the bandwidth requirements of ultra-fast broadband technology, it is not considered an ultra-fast broadband technology due to its limitations in terms of functionality (line of sight) and range [27].

3.2.2.5   Wireless Fidelity (WiFi)

WiFi is one of the most commonly used wireless technologies available. WiFi does not require line of sight to function, and the coverage can range from 30 meters (indoors) to 450 meters (outdoors) depending on the power. WiFi is based on the IEEE (Institute of Electrical and Electronics Engineers) standard 802.11x, and it transmits data on a low (2.4 GHz to 5 GHz) unlicensed frequency spectrum of the UHF.

There are many versions of the IEEE 802.11. Only a small number of WiFi technologies are able to offer high enough bandwidth to be considered as an ultra-fast broadband technology. The following is a list of some of these versions including a brief description [28]:

- **IEEE 802.11 Legacy:** The IEEE 802.11 Legacy is the original version

of the IEEE 802.11 standard. It was released in 1997, but it is no longer in use due to the release of superior versions. This version had a data transfer rate ranging between 1 to 2 Mbps and ran on the 2.4 GHz band of the frequency spectrum. The approximate range for this version was 20 meters when used indoors and 100 meters when used outdoors.

- **IEEE 802.11a:** The IEEE 802.11a is an improved version of the IEEE 802.11 Legacy with a point-to-point architecture. This version has a data transfer rate ranging between 20 to 54 Mbps and runs on the 5 GHz band of the frequency spectrum due to the increased traffic and high usage of the 2.4 GHz band. The approximate range for this version is 35 meters when used indoors and 120 meters when used outdoors.

- **IEEE 802.11b:** The IEEE 802.11b is a refined version of the IEEE 802.11 Legacy with a point-to-multipoint architecture. This version has a data transfer rate ranging between 5.9 to 11 Mbps and runs on the 5 GHz band of the frequency spectrum due to the high usage of the 2.4 GHz band and it being crowded. The approximate range for this version is 35 meters when used indoors and 140 meters when used outdoors.

- **IEEE 802.11g:** The IEEE 802.11g is a combination of both the technologies used in IEEE 802.11a and IEEE 802.11b. This version has a data transfer rate ranging between 6 to 54 Mbps and runs on the 5 GHz band of the frequency spectrum due to the high usage of the 2.4 GHz band and it being crowded. The approximate range for this version is 38 meters when used indoors and 140 meters when used outdoors.

- **IEEE 802.11n:** The IEEE 802.11n is a huge improvement compared to the IEEE 802.11a and IEEE 802.11g technologies with much higher data transfer rates, and it operates on both the 2.4 GHz band and the

5 GHz band of the frequency spectrum. This version has a data transfer rate ranging between 54 to 600 Mbps. The approximate range for this version is 70 meters when used indoors and 250 meters when used outdoors.

- **IEEE 802.11ac:** The IEEE 802.11ac is the technology was developed and released in 2012. 802.11ac routers are now available but there are currently very few devices that can use them due to compatibility. This technology is the first WiFi technology to exceed the data transfer rate of 1 Gbps. This technology will be useful for download, upload and streaming of high quality media that are large in size (e.g. High Definition (HD) video). This technology will have a maximum data transfer rate of 6.93 Gbps and will run on the 5 GHz band of the frequency spectrum.

  IEEE 802.11ac technology is a good example of ultra-fast broadband technology [29].

- **IEEE 802.11ad:** The IEEE 802.11ad was proposed by WiGig 2012 (Wireless Gigabit Alliance) and was said to be 10 times as fast as normal WiFi with data transfer rates reaching up to 7 Gbps. The proposed technology will run three different bands of the frequency spectrum: 2.4 GHz, 5 GHz and 60 GHz.

  This technology is another perfect candidate for ultra-fast broadband technology [30].

3.2.2.6   Worldwide Interoperability for Microwave Access (WiMAX)

WiMAX is an amplified version of the WiFi technology that is designed to support a greater range of customers using wireless broadband. This technology has two types: one being the LOS (Line of Sight) WiMAX and the other being NLOS (Non-Line of Sight) WiMAX. LOS WiMAX has a point-to-multipoint architecture whereas a NLOS WiMAX has a point-to-point architecture. NLOS WiMAX has a far better reach that LOS WiMAX and

has larger area coverage. WiMAX is based on the IEEE 802.16 standard [27].

Depending on whether its station is fixed or mobile, WiMAX has a range 5 to 50 km. It has a data transfer rate of 45 Mbps to 75 Mbps per channel depending of the number of customers sharing the service.

WiMAX technology has a reasonably high bandwidth but these speeds are not enough for it to be considered as an ultra-fast broadband technology [31].

3.2.2.7 Direct Broadcast Satellite (DBS)

DBS is a wireless technology for broadcasting digital TV signals via Satellite. This technology has a two-way high-speed data transmission. DBS operates in the Ku (Kurz-Unten) band radio frequency with 12 GHz downlink and 14 GHz uplink using geostationary satellites. DBS is used to receive digital TV signals and broadband data from an earth station and then transmit these signals to the subscribers. The data transfer rate for this technology is between 16 kbps and 155 Mbps.

In the past, a 250 millisecond delay was expected while connecting to the network due to the distance (22,000) of the geostationary satellite from earth. This latency was reduced to 50 milliseconds by using low-earth-orbit (LEOB) satellites that orbit at a distance of 1000 km.

The DBS technology has its limitations when it comes to bandwidth due to the use of radio frequency spectrum. Like WiMAX, DBS technology offers a high amount of bandwidth but not high enough to qualify it as an ultra-fast broadband technology [27].

3.2.2.8 Cellular Mobile Networks

Cellular Mobile Networks also known as Mobile Phone Networks are radio networks spread over large areas. The area that a cellular network covers is divided into smaller areas called cells, each of which is served by one or more transceiver. Each Cell is set to a different frequency from

its neighbouring cell, so that there is no interference between the cells and bandwidth is guaranteed in each cell. When all these Cells are joined together the radio network can service a very large geographical area. This technology is used for mobile phones and pagers [**?**, 32].

The GSM (Global Systems for Mobile) network is one of the most commonly used mobile networks, and since the introduction of GPRS (General Packet Radio Service) in GSM, this technology is considered a broadband solution. GSM networks use circuit switching and a combination of TDMA (Time Division Multiple Access) and FDMA (Frequency Division Multiple Access) standards to provide bandwidth access to its subscribers. This technology could provide data transfer rates between 14.4 kbps and 114 kbps. These networks were known as the 2G (Second Generation) and 2.5G networks [27].

A faster technology was available during this era that could provide faster data transfer speeds, know as CDMA (Code Division Multiple Access). But this technology was not adopted in the GSM network. Then came the 3G (Third Generation) and 3.5G networks which are also known as UMTCs (Universal Mobile Telecommunications Services). Subsequently, the CDMA technology evolved into CDMA 2000 and GSM networks began using EDGE (Enhanced Data Rates for Global Evolution) and WCDMA (Wideband Code Division Multiple Access) technologies to provide faster data transfer rates. The transmission range for these technologies can range between 384 kbps and 2 Mbps [27, 33].

The current mobile network technology available is the 4G (Fourth Generation) mobile network. 4G is also known as Mobile WiMAX and LTE (Long Term Evolution). Unlike 3G and other previous technologies, 4G does not use circuit switching, it uses IP-based (Internet-Protocol) communication. This involves the use of technologies such as OFDMA (Orthogonal Frequency-Division Multiple Access) and FDE (Frequency Domain Equalization) to provide high data transfer rates. Mobile WiMAX and LTE evolved even further to form Mobile WiMAX 2 and LTE-A (Long

Term Evolution - Advanced).

LTE can provide a maximum download speed of 100 Mbps and a maximum upload speed of 50 Mbps, where LTE-A can provide a maximum download speed of 1 Gbps and a maximum upload speed of 500 Mpbs making it another ideal candidate for ultra-fast broadband technology [**?**, 33, 34].

3.3 New Zealand's Network Infrastructure

New Zealand has come a long way since its early encounters with telecommunications technologies in the late-19th century. In 2005, New Zealand was the first country to launch its Digital Strategy, a vision for New Zealand to become adept at using ICTs in a bid to encourage and enhance economic and social development [35, 36]. In 2008, Digital Strategy 2.0 was developed with a focus on ways to realize the potential of digital technologies in New Zealand [37, 38]. However, the development and adoption of ICTs in New Zealand has for the most part been slower than some developed countries [38].

New Zealand is a part of the Organisation for Economic Co-operation and Development (OECD). The OECD has a "mean" for the expenditure on telecommunication infrastructure as a percentage of the gross domestic product (GDP) and New Zealand's expenditure on telecommunication infrastructure is below this mean. Furthermore, according to the OECD New Zealand is in the middle for the average advertised broadband download speeds but has the highest cost for broadband and mobile services compared to most of the countries listed by the OECD [39].

New Zealand has shown improvements in its broadband services but not enough to compensate for its growing number of service subscribers. Since 2006 the OECD has recorded New Zealand's broadband service subscribers to be increasing faster than any other OECD country [39].

In the coming years the demand for telecommunications technologies

will increase and this demand exceeds the current telecommunications infrastructure of the country. The current New Zealand telecommunications infrastructure is made up of mostly copper networks and these networks can not support the necessary upgrades to provide customers with ultra-fast broadband. The investment in wireless technology cannot provide a complete alternative either.

According to the latest infrastructure plan (July 2011), the New Zealand government has decided to invest further in the country's transport system, telecommunication infrastructure, energy, water and social infrastructure [39]. The vision they have in mind is:

> *"By 2030 New Zealand's infrastructure is resilient and coordinated, and contributes to economic growth and increased quality of life. Telecommunications services increasingly support New Zealand's position as a competitive business location and improve living standards."*

The telecommunication infrastructure investment will focus on deployment of ultra-fast broadband and broadband connectivity in rural New Zealand [39].

According to the network infrastructure plan, the New Zealand broadband market is not yet ready or does not offer adequate incentives to roll out a large scale fibre-optic network infrastructure [39].

The current fibre-optic networks set up in New Zealand have targeted the sectors that offer more on investment due to the involvement of private investors, instead of targeting organisations and users that would gain productivity with this facility (e.g. universities, schools and hospitals).

The above documents also point out the significant gap between broadband services available (speed/bandwidth) in rural and urban areas of New Zealand [39].

The New Zealand government has initiated two major projects to improve the network infrastructure in New Zealand. The following is a brief summary of each of the two projects [39].

1. The Ultra-Fast Broadband (UFB) Initiative

- The availability of broadband over fibre-optic cable to 75% of New Zealanders in the next ten years;

- Huge emphasis on availability of broadband over fibre-optics for schools, universities, health services and businesses in the next six years;

- Investment of $1.5 billion in the fibre-optic network by the government.

2. The Rural Broadband Initiative (RBI)

- Provision of quality broadband for rural schools, health services, farms, businesses and homes;

- Funding to be provided by the industry and the Telecommunications Development Levy (TDL) [40].

The New Zealand government recognizes that ICTs have the potential to boost innovations and productivity across many sectors of the economy. Currently, the government has invested over one billion in funds toward the development of an internet connectivity infrastructure (fibre-optic networks) that will bring ultra-fast broadband internet to homes, businesses and organizations in various urban centres in New Zealand.

The government has also been promoting quicker switch-over to digital television. This switch-over will free up the 700 MHz band in the radio spectrum that will later be used for 4G mobile broadband services. With the increased demand for data The Ministry of Economic Development is working on frequency and planning of band allocation in the spectrum

to roll out the 5G (fifth generation) mobile network in the the near future
[39].

Chapter 4

Telehealth:
A Review of Literature

This chapter provides a brief overview of telehealth and ehealth-related concepts. It includes descriptive review of some of the current tele-health projects in operation in various countries, including New Zealand.

The chapter also discusses the reliance of telehealth on broadband Internet and other digital/technical components of eHealth.

4.1   Telehealth

Telehealth is a component of eHealth. It is a set of expertise and methods integrating the world of Information and Communication Technology (ICT) with the healthcare sector providing medical care and medical education over a distance regardless of one's geographic location.

This integration helps the health sector with faster, more efficient and cost effective practices, which could include diagnostics, treatment, patient support, education (of patient and/or healthcare provider), telecare (remote treatment) and storing patient's health records.

Studies have shown that telehealth services can in certain situations be more efficient and cost effective than the traditional means; for instance,

the number of patient visits to healthcare centers can be reduced by providing certain services at a distance. Through the use of teleahealth services patient care quality, healthcare education and healthcare in general can be improved [41].

4.1.1 Types of Telehealth

According to The National Health Information Management Advisory Council (NHIMAC) telehealth has four main components [42]:

1. Synchronous telehealth

2. Asynchronous telehealth (store and forward)

3. Tele-homecare

4. Tele-education

4.1.1.1 Synchronous Telehealth (real time)

This involves live and real-time diagnosis of patients, consultation between patients and healthcare providers or even between medical professionals (for example, a GP and a Specialist). Usually Synchronous services involve video conferences, exchange of media (e.g. videos or images) between medical professionals and access of patient related data/records.

Telesurgery and tele-consultation are good examples of synchronous telehealth.

There is a wide range of medical fields that use synchronous telehealth, ranging from dermatology and cardiology to psychiatry [43].

4.1.1.2 Asynchronous Telehealth (store and forward)

This solution involves the storage and onward transmission of important medical data from one location to another. The medical information helps the healthcare provider in patient diagnoses or even remote consultation.

The stored data usually consists of photographs, high-definition (HD) videos, echo-cardiograms, sonograms and even x-rays [43, 44].

4.1.1.3 Tele-homecare and Tele-monitoring

These solutions involve the remote monitoring of patients, along with the transmission of health data for disease prevention and injury management.

A good example for tele-homecare and tele-monitoring is the remote monitoring of an elderly patient with a chronic disease or a patient who is undergoing dialysis treatment due to faulty kidneys [43].

Patients suffering from chronic conditions (like chronic heart disease, asthma, arthritis, diabetes, etc.) can greatly benefit from telehealth services like home-based monitoring and support from medical staff. These services can reduce hospitalization rates, as medical staff can remotely assess the patients with higher regularity and pick up on deterioration in the health of a patient long before hospitalization is needed.

4.1.1.4 Tele-education and Tele-learning

These solutions involves the transmission of informative data on medical conditions to healthcare providers and even to the general public to assist them with managing their health. A good example of this would be healthcare professionals from one center introducing and teaching new methods of diagnoses for a certain disease by means of a video conference. Online information and resources that are available to the general public and healthcare practitioners is another example of tele-education.

Patients discharged from hospital having recently undergone surgery often require post-surgery medical care and follow-up checkups. Being able to have their recovery and progress checked (via tele-monitoring) and then instructed on self-care (via tele-education) by medical professionals without leaving home, instead of visiting the hospital for follow-ups, is often more convenient and feasible to both the patient (who may not be in

a condition to travel) and the hospital [43].

4.1.2 Examples of Telehealth

Telehealth is used in many aspects of the medical world, here are some real-life examples of telehealth [45]:

- A medical image that has been sent over the network from a healthcare centre in another city being interpreted by a radiologist.

- An x-ray being accessed from the patient's electronic health records and examined by a surgeon or a general practitioner.

- A patient using his wireless device (mobile phone, tablet PC, iPad, etc.) to upload his/her vital signs to send to the healthcare centre where the signs are being monitored.

- A heart transplant patient being examined by his Cardiologist who is away on business by means of video conferencing and live access of the patient's records (patient's charts and progress reports).

- Healthcare providers using ICT (email, phone, fax, etc.) for communicating with each other or patients.

- A healthcare provider using biomedical peripherals such as micro audiometrics, vital signs monitors, spirometer, video otoscope, ECG (Electrocardiography), etc.

- A clinician using the decision support system to assist in diagnoses.

- A healthcare professional accessing the Internet and online resources to research an area of interest.

4.1.3 Advantages and Disadvantages of Telehealth

This section briefly examines some of the advantages and disadvantages of telehealth.

4.1.3.1 Advantages

Some of the main aims of implementing telehealth are to individualize the care of patients and to conquer the geographic barriers between patients and healthcare professionals. A lot of patients in rural and remote locations find it hard to commute to their healthcare centres either because of the terrain or the long distance that needs to be travelled, which can be very time consuming and inconvenient for the patient. Therefore, by bringing the required healthcare to the patient's home these issues can be avoided.

Other uses (advantages) of telehealth include the following [43]:

- Improved access to specialist knowledge.

- Remote home based monitoring of chronic diseases.

- Remote training of medical professionals and patients.

- Access to patients' Electronic Health Record (EHRs).

- Potential for significant gains to the elderly population.

- Potential for significant gains to the patients who live in rural and remote communities.

- Significant reduction to medical cost for the patient and healthcare providers

Telehealth has many other uses and potential benefits for its stakeholders. Table 4.1 outlines some of these benefits.

According to The New Zealand Telehealth Forum (NZTF), telehealth will assist healthcare professionals with diagnoses of illnesses and will help them provide the necessary treatments without them having to be in the same room as the patient. This concept of remote achievement also applies to healthcare related research, education and evaluation.

Table 4.1: Telehealth stakeholder benefits (Taken from: [43])

Client	Provider	Other stakeholders
Healthcare services and other outcomes		
Increased access to healthcare	Reduced length of hospital stay	Increased productivity of workers (less travel, less illness)
Increased health knowledge/ability for self-care	Avoided hospitalisations	Avoided cases of communicable diseases
Faster/accurate diagnosis and treatment	Avoided hospital readmissions	More efficient access to healthcare for special groups (prisoners, etc.)
Reduced waiting and/or consultation time	Avoided emergency room visits	
Increased medication adherence	Avoided laboratory tests	
	Avoided patient transportation to healthcare facilities	
	Avoided health care visits	
	Avoided referrals	
	Reduced length of consultations	
	Increased medication adherence	
	Increased knowledge transfer among practitioners	
	Increased accuracy and faster diagnosis and treatment	
	Increased patient satisfaction	
Decreased travel		
Increased employment / leisure / classroom time	Increased employment time (productivity)	
Avoided travel expenditures: transportation, accommodation, and other expenses	Avoided travel expenditures: transportation, accommodation and per diem	
Decreased risk of job loss: less time away from work for travel		
Medical effectiveness		
Reduced morbidity (higher quality of life)		
Avoided mortality		
Employment		
Higher employment participation and earnings		Higher earnings for informal carers
		More tax revenue and fewer welfare payments for governments

The following are some additional benefits of telehealth services noted by the NZTF [46]:

- People can be seen by their physicians and healthcare team without having to leave the area in which they live;

- People can better monitor and manage their health;

- Results in lower healthcare costs;

- Creates more flexibility for the healthcare workforce.

Telehealth in general has many advantages. By applying telehealth practices healthcare can be provided to the most isolated, rural and even dangerous environments. Telehealth increases the access to medical care and information for military and naval personnel at sea or in a war zone. Telehealth can also provide medical care for prisoners in prisons where most healthcare practitioners dread working [47].

4.1.3.2 Disadvantages

Many studies show that telehealth has few or no disadvantages. In the medical world, in many cases when a new concept is introduced before it is completely accepted it goes through a phase of negative criticism. The same goes for "Telehealth"; not every healthcare professional has accepted these approaches and practices. Some healthcare professionals do not like these practices, because they believe the doctor-patient time (one on one face-to-face time) cannot be replaced by the means of video conferencing and use of ICT (Information and Communication Technology), as these applications reduce social human contact in healthcare and and can possibly lead to the dehumanizing, desocializing and depersonalizing of healthcare for patients.

The ethics and laws regarding the patient information privacy and confidentiality must be reviewed and applied, thus making some practitioners sceptical about this form of practice. There have also been debates

about how healthcare professionals should be paid for their services and involvement in telehealth as it is different from regular practices. Certain clinicians have questioned the reliability of these telehealth systems and some have had concerns about the risk of developing over-dependence to these systems [48, 49].

One of the biggest disadvantages of telehealth is its dependence on ICT (Information and Communication Technology) and its related costs. Socioeconomic factors restrict some communities and areas when it comes to Internet access or being able to afford technological equipment for their homes and health centres [10, 48]. The introduction of telehealth into the healthcare system, its acceptance, and its impact on the existing services is another potential problem for this field of expertise.

4.1.4   Regulatory Aspects of Telehealth

All over the world countries are being faced with problems such as increased population size, increased ageing population and the retirement of healthcare professionals. All these problems and many more have been putting pressure on healthcare systems. To assist with these issues healthcare systems in many countires have begun implementing ICTs in their day-to-day operations.

Currently there are many changes, involving the integration of ICTs in the medical and healthcare services, taking place around the world, even though these services are provided in different mannerisms. For these changes to be effectively implemented, appropriate policies and regulations need to be developed by the decision makers (e.g. the governing bodies of the respective countries). The successful deployment of telehealth systems and strategies is highly dependent on its regulatory aspects.

In New Zealand, District Health Boards (DHBs) and government officials (e.g. the Ministry of Health) participate in setting policies and regulations for telehealth. In the last decade, New Zealand has had a sub-

stantial growth in effectively computerizing their healthcare system, and one of the main reasons for this success was adopting and implementing the essential policies developed by Health Information Technology in the healthcare system [50].

The Australia New Zealand Policy for Telehealth Committee was set up by both countries to develop and regulate their telehealth polices. These policies cover the evaluation methodologies in telehealth as a stepping stone to a larger scale acceptance and development of the national policy framework. Although these policies have been followed with great interest, New Zealand and Australia are far behind some of the other developed countries in terms of telehealth policies and related regulatory aspects [51, 52].

The integration of telehealth into the current healthcare system is a big challenge for the governments (policy makers). The development of the right policies to address issue accordingly will significantly help with the challenge of integrating telehealth services into the existing healthcare system [51, 52].

The health regulatory bodies in Canada identified the following seven areas as telehealth-related policies in need of attention [53]:

1. Credentialing, licensing, and registration;

2. Privacy and security;

3. Confidentiality, consent and authorization;

4. Reimbursement;

5. Accreditation;

6. Liability, insurance and negligence;

7. Cross-jurisdictional services.

As developments in ICTs and their integration in healthcare advance, telehealth policies and laws need to be periodically reviewed and updated.

Increasing the research and education in telehealth and telehealth related technologies will enable policy makers to set more adequate and effective policies.

4.2 Current Telehealth Projects

The world's population has been growing at a rapid pace, especially the developing countries (five times as fast as developed countries). This growth has been putting a tremendous amount of pressure on governments to meet the demands for resources and needs. One of these demands is the provision of quality healthcare for their citizens.

In addition to increased healthcare demands, the number of healthcare professionals needed to address the growing population's needs is far less than the required number [?]. Many countries have turned to telehealth as a solution to some of the resulting issues.

This section briefly studies various telehealth services and the organisations responsible for them in various developed countries. These countries are some of the leaders in the provision of telehealth services and in their adoption and uptake of ICTs in their industries [54].

The network infrastructure for most of these telehealth projects/services support high-speed broadband connectivity.

4.2.1 International Telehealth Projects

The following are examples of successful telehealth projects and services in various developed countries around the world.

4.2.1.1 Denmark

Denmark has been trialling telehealth and telemedicine practices since 1990. The Danish healthcare system in co-operation with few private organisations formed MedCom in 1994. MedCom is responsible for the de-

velopment and testing information and communication technologies such as broadband in the healthcare sector.

Denmark has been identified as one of the leading countries in terms of successful deployment of telehealth [55, 56]. Telehealth is no longer at a pilot stage but is in fact part of the mainstream healthcare services. This success is a result of secure and long term funding, appropriate governance, re-organisation of care between primary, hospital and social care, incentives for all levels of care and also the network infrastructure.

Denmark's network infrastructure is equipped with fibre-to-the-premises network. This infrastructure provides ultra-fast broadband connectivity for all the telehealth activity in the country [55, 56].

4.2.1.2 United States of America

Health Resources and Services Administration (HRSA) is an organisation working under the authority of The U.S. Department of Health and Human Services. The HRSA is responsible for the increase and the improvement of telehealth use in the United States of America.

According to the U.S. Department of Health and Human Services, HRSA's mission is:

> "*To assure quality healthcare for underserved, vulnerable, and special needs populations.*" [57].

The following are some of the key responsibilities of the HRSA [57]:

- Creation of telehealth projects in collaboration with other federal agencies and state and private sectors;

- The administration of telehealth grant programs;

- Provision of technical assistance;

- Evaluation of the use of telehealth technologies and programs;

- Development of telehealth policy initiatives for the improvement of access to quality health services;

- Promotion of knowledge exchange about the "best telehealth practices".

Within the HRSA organisation is the Office for the Advancement of Telehealth (OAT), which is partly responsible for the Rural Health Policy. The aim of OAT is the promotion of the use of telehealth technologies for various aspects of healthcare, such as the delivery of quality healthcare, education and health information services. The OAT budget for the year 2010 was estimated to be $11.6 million [57].

The following are some of the telehealth projects currently in operation in the United States of America [?]:

- The Alaska Federal Healthcare Access Network (AFHCAN) has more than 284 sites providing a huge range of healthcare services using a variety of high-speed broadband technologies including satellite. These sites include military installations, Alaskan native health facilities, regional hospitals, small village clinics, state of Alaska public health nursing stations and much more.

- The Downstate Illinois Regional Telehealth Program provides training and medical education to 52 different rural hospitals and healthcare centres using technologies such as videoconferencing, web streaming and satellite broadcasts.

  These technologies are powered by high-speed broadband technologies such as T1 lines, DSL and Cable. This programme has managed to strengthen local healthcare capabilities by developing the community-institutional partnership.

- The Missouri Telehealth Network is known to provide services in 82 sites and in more than 15 different medical specialties including radiology, mental health, dermatology, cardiology, etc. Since its estab-

lishment this network has conducted 11,000 interactive encounters and over 57,500 teleradiology exams.

The network uses T1 (Frame Relay) broadband technology to conduct these procedures. The T1 connection provides dynamic bandwidth that is allocated to voice, video and data.

- The University of Arkansas' ANGELS program provides the means for physicians to connect to more than 40 different sites with pregnant woman in rural communities. Since its establishment, this programme has improved pre-natal care and has reduced the number of low birth weight babies. In the year 2005, the programme's call centre received on average over 2,500 calls each month and it facilitated far more than 400 critical hospital transports.

- The Medical College of Georgia initiated the REACH programme in 2003. This programme provides the means for stroke specialists to get in touch with the rural hospitals and physicians through out the state of Georgia for consultation on key treatment options for stroke patients during the critical three hour period after suffering a stroke.

  The established communications are done over various mediums using a high-speed broadband connection.

4.2.1.3 Australia

The Australian health system has been under a lot of pressure due to the increase in rates of chronic illnesses, its ageing population and its insufficient healthcare workforce. Therefore the Government is making large investments in telehealth. By July 2015, the Department of Health and Ageing is expecting 495,000 telehealth consultations to have been delivered to remote, rural and outer metropolitan areas of Australia, and by the year 2020, the department expects 25% of all the specialist practitioners to have participated in the delivery of telehealth consultation to patients in remote Australia [58].

The National Broadband Network's (NBN's) Telehealth Pilot Program was set up to demonstrate the NBN infrastructure and the provision of high-speed broadband, which can enable better access to higher quality healthcare services and healthcare education by means of telehealth. This program is a new government initiative in response to the Government's Digital Economy Goal for health and aged care. It was created to enable provision of funds ($20.6 million) to successful proposals for pilot projects that develop and deliver telehealth services to NBN-enabled homes and focus on aged, palliative care services, cancer care services and advanced care planning services [59].

The following are some of the objectives of this program in terms of development and trial services [59]:

- Delivery of telehealth services to homes by new and innovative methods that are enabled by high-speed and reliable broadband provided by the NBN.

- Increase in accessibility of healthcare services in regional, rural, remote and outer metropolitan areas of Australia.

- Reduction in the need for healthcare related transportation.

- Reduction in unnecessary hospitalization of patients.

- Improvement in the quality of care and health outcomes by collaboration and communication between the customer (patient) and the healthcare provider.

- Telehealth services are scalable and are able to provide an increased volume of care without a corresponding increased cost.

- Reduction in location dependent and regional healthcare workforce skill shortage.

- The use of the NBN infrastructure may increase access to healthcare and it may also reduce social isolation.

- Improvements may occur in communications during health emergencies.

The following are some telehealth projects deployed in the Australian territories [**?**]:

- New South Wales: The telehealth initiatives in this territory began in 1996 and since then the telehealth network has developed into a state wide network consisting of 240 healthcare facilities. These facilities provide the remote and rural communities with readily available access to healthcare services. These healthcare services may include adolescent and adult mental health services, oncology, sexual health, diabetes foot care, pediatric, radiology, rehabilitation, perinatal HIV counselling, chronic pain management, hematology, surgical review, genetics services, ophthalmology and emergency services.

- Northern Territory: The Northern Territory (NT) telehealth program began in July 2010 with a focus on delivering healthcare and eLearning to the remote and rural areas of the Northern Territory. Although this program is in its infancy stage, it has managed to deliver telehealth services to a number of regional hospitals [**?**].

  The Health eTown project was set up to deliver and provide rural and remote communities of the Northern Territory (predominantly the indigenous populations) with improvements in health and education. Currently, this project has been set up in 17 different remote towns in the Northern Territory.

  The project aims to deliver specialist healthcare services to these remote and indigenous communities by assisting doctors and healthcare providers. This assistance is made possible by video, audio and data sharing facilities, and remote monitoring and consultation [**?**].

- Queensland: Telehealth services have been operating in the Queensland territory since 1995 and the two main service providers are

Queesland Health and the Centre for Online Health (COH) at the University of Queensland.

The COH is located in Brisbane at the Royal Children's Hospital. In the last ten years, the collaboration of the COH and the Royal Children's Hospital has led to the development of telehealth services such as the centralised paediatric referral centre. This service is available on 82 different sites throughout Queensland and even Northern parts of New South Wales.

According to a government report dated June 2009, the Queensland Health's StateWide Telehealth Services has managed to set up 656 videoconferencing systems across Queensland, and 67% of these systems are being used for clinical activities such as patient consultation, case management and follow-ups (with the main area of use being patient care for mental health) [?].

In 2008-2009, 50,609 videoconferences were conducted, this number was a 33.4% increase from the previous year (2007-2008) [?].

- South Australia: Telehealth services have gained popularity in Southern Australia since the 1990s. Services like videoconferencing for the purpose of clinical activity and videoconferencing for the purpose of education are some of the main telehealth services offered in this territory. These services are provided between Adelaide and the remote hospitals and health centres mainly focusing on mental health.

  An estimated 1800 to 2000 mental health consultations take place each year using these telehealth services [?].

- Tasmania: The telehealth services active in Tasmania are known as the Telehealth Tasmania Network (TTN). This network has been in operation since 1998 and provides videoconferencing services through a mix of high-speed broadband and high-speed digital phone line.

  The TTN is used to deliver telehealth services such as remote mon-

itoring, tele-consultation, clinical education and multi-disciplinary case reviewing [**?**].

4.2.1.4 England

Telehealth made its first appearance in England in the early 1990s. At that time the telehealth services concentrated on teaching hospitals and academic departments. Today England is recognized as one of the leaders in telehealth in Europe [**?**].

Currently telehealth services deliver services such as telepsychiatry, teleradiology, teleneurosurgery, videoconferencing between primary and secondary healthcare providers, electronic referrals and even transmission of echocardiographic images.

The Department of Health has been trying to introduce telehealth into the new National Health Services (NHS). Most of these services are currently delivered in small scale or in the form of pilot projects [**?**, 60].

England uses the N3 network for all national healthcare services including telehealth. The N3 network provides high-speed, secure broadband connectivity throughout the United Kingdom [**?**].

4.2.1.5 Scotland

The Scottish Centre for Telehealth (SCT) was established in 2006 by the Scottish Executive. The SCT was developed to assist the NHS (National Health Service) board with the development of telehealth in Scotland. Some of the functions of the SCT are as follows:

- To gather and share all the expertise on telehealth and best practices with the NHS board;

- To help and support the NHS board with the development and implementation of telehealth projects in Scotland;

- To support the funding process of the telehealth projects being implemented;

- To evaluate and examine nationally constructed telehealth systems;

- To assess the effect of telehealth on the delivery of health services.

In a report made for the Auditor General for Scotland, Scotland is claimed to be the only country in the European continent to have

> "*both a national organisation with a specific remit for telehealth and a national strategy for telehealth*" [61].

The ICT infrastructure for the SCT and the NHS board is provided through one of the world's largest fibre-optic networks, named N3. The N3 network infrastructure provides high-speed broadband solutions for the Scottish healthcare sector [61, 62].

4.2.1.6 Norway

Due to its low population density Norway was one of the first countries to invest in telehealth. The University Hospital of North Norway (UNN) has been providing telehealth services since the late 1980's.

These telehealth services include tele-otorhinolaryngology, telepathology, remote gastroscopy, tele-echocardiography, teledermatology, telepsychiatry, telegeriatrics, tele-ophthalmology, teledialysis, maritime telemedicine, tele-emergency medicine, teleradiology, teledentistry, tele-oncology, telecare, remote transmission of ECGs, electronic referrals and discharge letters, electronic transmission of laboratory results and clinical education. These examples make Norway very well-established in the field of telehealth and established it as a "leader of the pack" [**?**, 63].

Of the population of Norway, 99% have access to broadband. The Norwegian Health Network provides high-speed broadband connectivity for all the public hospitals and 75% of GPs in Norway [64].

4.2.2 New Zealand Telehealth Projects

The National Health IT Board funded and established the New Zealand Telehealth Forum in 2011. This forum was established to promote the use

of telehealth and to maximise the benefits of the Government's broadband programs. The Telehealth Leadership Group is also set up by the National Health IT Board. The members of this group are selected through an Expression of Interest process. The members that are appointed ensure that the telehealth sector as a whole including customers, clinical disciplines, policy makers, planning and funding managers, ICT experts, industry suppliers and even cover geographic and cultural communities of interest are well represented [46].

The following are some of the main roles of the Telehealth Leadership Group [46]:

1. Providing advice on requirements and priorities for telehealth deployment to support rural and provincial hospitals, integrated care, home monitoring and clinical networks;

2. Providing advice on matters relating to environmental considerations, e.g. barriers to uptake, technical considerations, protocols and guidelines, and standards;

3. Providing advice and support for projects undertaken by the Forum;

4. Contributing to the achievement of the overall objectives of the Telehealth Leadership Group to the maximum extent practicable.

The New Zealand Telehealth Forum is also responsible for sponsoring the NZ Telerehabilitation working group. The NZ Telerehabilitation working group is a forum that allied health professionals use to collaborate on the provision of telehealth services in New Zealand.

The purpose of Telerehabilitation is to provide therapy by means of telecommunication systems and networks. These means may include telephone, videoconferencing systems and Internet for the delivery, assessment, rehabilitation, review, training, multi-disciplinary team evaluation and supervision.

Currently, there are several telehealth initiatives underway in New Zealand. The following are the summaries of some of the latest case studies involving telehealth services. These examples appeared in a recent report published by the New Zealand Ministry of Health [65].

4.2.2.1 Videoconferencing Case Study - Northland

A renal dialysis patient regularly visits the renal unit in Kaitaia Hospital. When she experienced chest pains thus causing complications with the dialysis treatment, the patient was remotely diagnosed by means of a videoconferencing session by specialists in Whangarei Hospital. This saved the patient time and money, and also reduced the discomfort of a long trip to another hospital hours away [65].

The two Satellite units at Kaitaia and Kawakawa (in the Northland region) regularly communicate with the renal unit in Whangarei Hospital through videoconferencing systems, and Whangarei Hospital is in turn communicating with Auckland City Hospital's renal specialists [65].

The increase in the use of telecommunications technologies like videoconferencing systems in the healthcare sector is proving that people can be remotely treated and diagnosed, and their conditions can be monitored without them having to leave their locality or area of residence or even their home. Medical digital imagery, such as medical x-rays and scans, can be shared and discussed using videoconferencing tools.

Videoconferencing systems ensure real time communications between the healthcare providers and also the patients [65].

4.2.2.2 Closing the Distance Case Study - West Coast

In the rural West Coast of the South Island, visits to healthcare practitioners often involve hours of driving. High-definition video links have been set up in eight of the West Coast towns. These links provide remote consultations with specialists in town such as Graymouth and Westport [65].

During these video link consultations the nurse is always present just

in case the GP or specialist require any sort of measurements (e.g, patient's blood pressure reading, patient's temperature reading, etc.) to be carried out and for the patient's support and follow-up care [65].

Using a second hand-held video camera enables the doctor to see things like see lesions or even rashes in closeup. Also shared patient records have been provided and can be accessed by practitioners providing treatment to patients [65].

4.2.2.3   Cutting-edge Care in the "Wop Wops" Case Study - Eastern Bay of Plenty

A patient living in the Tuhoe country, suffering from lung disease and problems, has been rushed to the hospital by ambulance on a number of occasions [65].

The patient is currently being remotely monitored by means of tele-monitoring. The patient measures her heart rate, blood pressure, lung capacity and function and other vital signs, and these measurements are then transmitted back to a registered nurse.

The nurse makes appointments for the patient and provides referrals to other medical practitioners when necessary [65].

4.2.2.4   Faster Access to Diagnostics Case Study - Auckland

To successfully diagnose patients, having access to their medical/health records (such as medical scans and x-rays) is crucial [65].

In the Auckland region, GPs are gaining the ability to directly order these complex medical imaging for their patients. A computerised tool is available to all the GPs in the Auckland DHB region that helps determine what medical imaging is needed and then to be requested. This tool is currently being implimented in two DHB regions [65].

4.3 Telehealth's Reliance on Broadband

The healthcare methods and recent networking and communications technologies have come together to provide better quality healthcare and have removed geographic and time barriers. Healthcare planning and development have been progressing at a rapid pace due to this integration with ICTs. Telehealth is one of the fields in healthcare that is very dependent on technology, and many of the telehealth projects in place today would simply not be possible in the absence of the current communications technologies.

According to the NZTF:

> *"Telehealth is the term for the use of information and communication technologies to deliver healthcare when patients and care providers are not in the same physical location. To be effective, telehealth relies on fast broadband Internet services"* [46].

Broadband has widened the scope of telehealth drastically. Broadband provides fast and relitively reliable (when compared to dial-up Internet) transmission of large amounts of data between healthcare centres and patients' homes. In many cases, these data are critical for life saving services [**?**].

Most telehealth services have one thing in common and that is the requirement of sufficient broadband connectivity. Some examples of the telehealth services that rely on the Internet are real-time video consultations, video conferences for education purposes, remote monitoring of patients using communications devices trasmitting videos and images, access to electronic health records (EHRs) such as x-rays and scan images, and robotic telesurgery. For a successful execution, each of these services requires a minimum amount of broadband connectivity in terms of bandwidth and speed [66, **?**]. Figure 4.1 shows the bandwidth connectivity demand for some of the telehealth related transmissions [66].
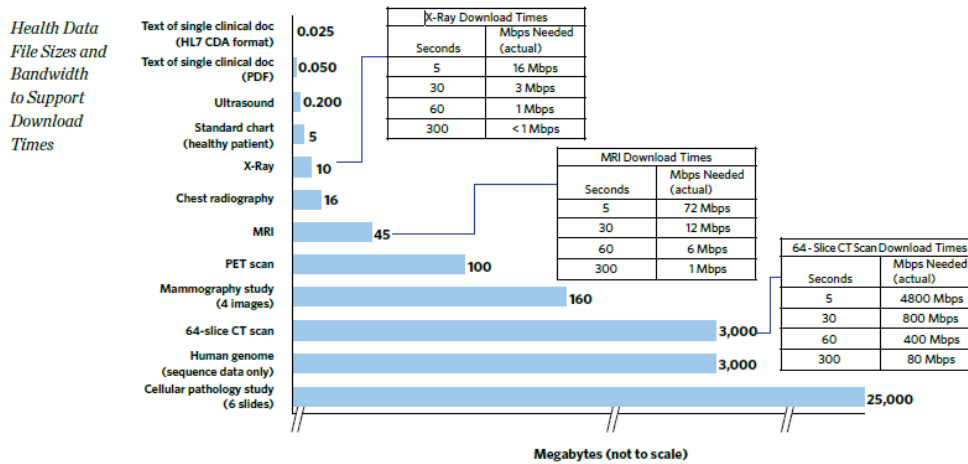
Figure 4.1: Telehealth bandwidth requirements (Taken from: [66]).

Healthcare facilities such as hospitals and outpatient clinics use a combination of these transmissions, therefore requiring higher broadband speeds and bandwidth compared to a regular healthcare centre that is run using a paper-based system, where there is minimal use of the Internet (mostly email and general web browsing) [66].

4.3.1 Medical Procedures Requiring Broadband

Most medical procedures that involve the transmission or exchange of large amounts of data require a broadband technology that supports high bandwidth. Ultra-fast broadband technology, in comparison to other broadband technologies, is superior in that it can facilitate these data transactions more effectively [67].

The following are some of the telehealth procedures that require access to broadband Internet for adequate execution and transmission of information.

4.3.1.1 Telesurgery

Advances in the field of robotics in alliance with surgical methods have given rise to a new and innovative form of surgery know as Telesurgery. Telesurgery or Telerobotics is a surgical procedure in which a trained surgeon performs surgery on a patient using robotic engineering over a distance. The procedure is usually done over a high bandwidth Internet connection. Two examples of these telerobotic surgical system are: the Da Vinci Surgical System developed by Intuitive Surgical Inc. (CA, USA) and the Zeus Robotic Surgical System developed by Computer Motion Inc. (CA, USA). These systems consist of two modules: the Master, which is the surgical console and the Slave, which is the robot performing the operation.

Performing operations over the surgical console causes lesser strain on the surgeon's hands making him perform for longer without tiring out his hands. These system are know to be very accurate and precise with their movements [68].

The first ever international telesurgery was done in 2001 over a distance of 6500 kilometres (between France and New York). A successful laparoscopic cholecystectomy procedure was done on the patient (in France) through a 10 Mpbs fibre optic connection [68].

Ultra-fast broadband can replace the existing broadband technology to ensure that the bandwidth required to perform these remote surgical operations is available.

4.3.1.2 Tele-education and Tele-learning

In recent years, the Internet has become very popular as a source of information. The type and extent of information available online has also increased with the increased use of the Internet for information retrieval. With all the health and medical information (credible or otherwise) available online, the Internet has become a primary source of information for many people trying to research treatments and their effectiveness, diseases

and their symptoms, healthcare practitioners, and other healthcare related subjects. This phenomenon has lead to the healthcare sector sharing information for the purpose of education and learning.

Videos of surgical procedures and medical encyclopaedias are good examples of online information sources that require high bandwidth intenrnet connectivity. Technologies such as ultra-fast broadband will help online medical education and learning by providing the means for high speed upload and download of medical information.

Also, in the deployment and execution of telehealth services, videoconferencing[1] systems have grown in popularity and efficiency. For instance, videoconferencing is used in healthcare education of staff and patient education.

A successful Videoconferencing system requires a reliable connection and a high amount of bandwidth to be able to capture and stream high definition video footage from either side. Ultra-fast broadband can provide the bandwidth required to run a successful videoconferencing session.

4.3.1.3 Tele-monitoring and Telecare

The increase in the number of patients with chronic diseases has led to an increase in the visits and admission of patients to hospitals [69]. Remote monitoring of these patients can reduce the number of hospital visits and admissions, and the consequent financial burdens on the patients.

Internet-based monitoring in conjunction with telemedicine techniques can provide remote healthcare services and management for patients, however they depend on the availability of high-bandwidth Internet connectivity [70]. The remote consultation of patients, surveillance of patients (camera surveillance), transmission of patient (in remote-care) information and monitoring of patient's vital signs are few of the procedures that

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[1]Videoconferencing is a method of communication in which video cameras and monitors are used alongside other telecommunication technologies for a real-time visual conversation between two or more users.

require a fast and reliable broadband connection. Ultra-fast broadband is the solution to these procedures as it offers the fastest data transfer speeds.

4.3.2 Benefits of using Broadband in Healthcare

On the subject of the importance of improved broadband in telehealth, Neal Neuberger, the President of Health Tech Strategies (Virginia, USA) and Executive Director of the HIMSS (Healthcare Information and Management Systems Society) Foundation's Institute for eHealth Policy, states that:

> "*As the United States works to improve the quality of and access to its healthcare system, it is increasingly clear that expanded broadband service can enable improved care at a reduced cost for more people*"
> [**?**].

Broadband Internet acess to medical and health organizations has become an important tool in the delivery of healthcare [**?**]. In many situations, the use of broadband in healthcare (telehealth, in particular) results in reduced costs. For example, digital records that are accessible over a high-speed (broadband) network can cut costs and reduce waste. The benefits are not in cost cutting alone. The following are some of the many benefits of the use of broadband in telehealth [71, 66]:

- Patients can have access to specialists in many areas at once, via videoconferencing.

- Patient discomfort and travel inconvenience can be reduced by remote consultation and regular monitoring of the patiends.

- Costs and wasted time can be reduced by creating Electronic Health Records (EHRs) that are remotely accessible by medical and healthcare practitioners.

- Communications speed and efficiency can be improved.

- Educational material (information) can be easiy downloaded from remotely accessible databases.

- Prescription errors can be reduced by implementing eprescribing.

- By developing broadband networks across the country, healthcare services for patients in both urban and rural areas will be made equally accessible.

- Patients empowerment can be increased by providing the means to let patients manage their own health more effectively and

- Many medical and health related tasks can be outsourced; for instance, administrative tasks and analysis of medical tests data.

- Patients with chronic diseases (e.g. diabetes, heath disease and stroke) can get speedy and accurate diagnoses and treatment.

4.4 Other Technical/Digital Components of eHealth

Like telehealth, most of the following eHealth components require a fast and reliable broadband connection to function adequately.

4.4.1 Electronic Health Records (EHRs)

An Electronic Health Record (EHR) is an element of non-paper based patient information that is stored electronically. This data consists of all the patient's past and current medical records. The information should be retrievable by health providers. Chanabhai, et al. [72] state that

> *"Ultimately the aim of the EHR is to contain all consumer health information from the cradle to the grave."*

EHR systems have been planned and implemented in many institutes and countries. Although these systems may differ, they work towards

achieving a similar objective. According to the EHR manual provided by the World Health Organisation (WHO) for developing countries, the following are some of the benefits of implementing an EHR system [73]:

- Improvement in accuracy and quality of data in health records;

- Accessibility of the records to healthcare practitioners;

- Improvement in quality of care as a result of having patient health information available immediately and at all times;

- Improvement in the efficiency of health record services;

- Reduction in the cost of healthcare;

- Creation of a paperless environment.

People often transfer from one medical practitioner to another. To effectively diagnose a patient, the medical practitioner often requires access to the patients' medical history recorded by the patient's previous physicians. Upon the request of the patient, a copy of their records can be forwarded to their most recent medical practitioner. A patient's medical records include clinical reports, medical test results, ongoing treatment programs, medical images (x-rays, MRIs, etc.), and more. Over time these records can grow large, and recording them in a digital form is greener, more cost effective, and often more accessible (ubiquitous) [74].

In the past, many terms were used to refer to the transition of health records from manual (paper based) to electronic or digital form. The following are some of the terms used accompanied by a brief description of each [73]:

- *Automated Health Record* (AHR) was a term used to describe paper based health records and images that were stored on a computer and on optical disks. The images were usually stored on optical disks and the traditional health record documents were scanned and stored on

a computer. The system addressed issues like space, access and control problems that were related to the paper based health records. The flaw in this was that it did not facilitate for input and output of the data at the patient care level [73].

- *Electronic Medical Record* (EMR) was a term used to describe automated systems that were developed for medical practices and community health centres. These records usually contain information such as the patient's identification details, patient's medication and prescription generations, laboratory results and finally healthcare information recorded by practitioners during a patient visits. Korea is one of many countries that has implemented this system in its hospitals [73].

- *Computer-based Patient Record* (CPR) is a term that was introduced in the 1990's in the United States of America (USA) and was used to define a collection of one patient's health information that was linked to a patient identifier. This health record could include various amounts of patient health information and usually contained information such as medication orders and medical alerts, provided integrated data on patient's registration, admission and financial details, and recorded information from nurses, laboratories, radiologies and pharmacies. The limitation of this record system was that the focus of exchanging health information was only on inpatient facilities [73].

An EHR system would be completely impractical if it could not be accessed when needed. Broadband provides the means of ubiquitous access to these system. With the help of ultra-fast broadband these systems can be accessed much quicker thus making provision and retrieval of patient information much faster.

4.4.2 Mobile Health

The use of different mobile information devices such as laptops, tablets, iPads, PDA's, smart phones, etc., by health practitioners and patients to provide better healthcare services is referred to as *mobile health*. Mobile health is also known as mHealth. WHO 2011 (World Health Organisation) defines mHealth as

- *"The unprecedented spread of mobile technologies as well as advancements in their innovative application to address health priorities has evolved into a new field of eHealth, known as mHealth."* [75].

Recent studies have shown that there are 5 billion mobile phone subscribers in the world and commercial wireless signals are available to 85% of the world's population.

Mobile phone networks have grown rapidly in many low and middle-income countries. This growth has overtaken most other developments (such as, infrastructure, electricity, Internet deployment, etc.), and with this growth comes cheaper calling rates alongside higher speeds of data transmission and affordable smart phones; thus transforming healthcare services.

Mobile devices and technologies can be used to access, deliver and manage health information. However, a high-speed broadband connection is required in order to perform those task. Ultra-fast broadband technologies such as WiMAX 2 and LTE-A can provide the means for this fast connectivity.

Governments worldwide have been investing in mobile and wireless technologies, investments that have led to many improvements in healthcare and emergency response services. Some of these technologies include the following [75]:

- Short Messaging Service (SMS);

- General Packet Radio Service (GPRS);

- Global Positioning Systems (GPS);

- 3G and 4G Systems;

- Bluetooth technology.

There has been rapid technological advancement in the last decade and this has contributed a substantial amount toward the growth and implementation of mHealth in eHealth services [75].

The pervasiveness and convenience of mobile devices and related technologies increase the timely exchange of health information, which in turn leads to more appropriate care and the potential for higher quality services at lower costs.

4.4.3 Cloud Computing

In the last few years, there has been much interest in a technology known as *cloud computing*. There is no set definition for the term "cloud computing", however The National Institute of Standards and Technology (NIST) defines cloud computing as:

- *"A model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction."* [76].

This technology has promised to deliver major cost cutting for businesses and any other organisations handling data. These savings could include reduction in costs of hardware and software upgrades, and reductions in costs relating to staff hire.

In 2011, the global market for cloud computing was predicted by Forrester Research to grow to $241 billion by the year 2020, and Deloitte predicted that the United States of America alone would spend over $55 billion by the year 2013 on cloud computing [77].

With the downturn of the economy and enormous cost pressures on health systems, healthcare organisations have been trying to cut costs in every possible way. Healthcare organisations have started using this technology, since cost cutting is so apparent. Cloud computing can provide data processing and storage, application development and software hosting. Users will not have to worry about the location of their data and will not need to have the expertise of its underlying technology [77, 78].

One of the major legal issues concerning the healthcare sector is the privacy and security of the medical data (most of which is confidential in nature), and this must be dealth with before successfully integrating this technology into health care systems. In some countries, policies have been set to deal with this issue. For instance, in the United States of America, to protect the protected health information (PHI), every cloud system that is integrating with an existing healthcare system must comply with the Health Information Technology for Economic and Clinical Health (HITECH) Act and the Health Insurance Portability and Accountability (HIPA) Act. These Acts were set up to protect the privacy and confidentiality of all patient information and related medical data [78, 79, **?**].

In order to access these cloud systems, and to transmit and retrieve large amounts of data, a high bandwidth broadband connection is required. Ultra-fast broadband is able to perform these tasks in much lesser time than any other broadband technology, thus making it an ideal technology for accessing cloud networks.

4.4.4 Big Data and Data Quality

The current economy is an emerging data-driven economy. The main features of this economy are the abundance and the complexity of the data and the speed at which it is changing. Big Data refers to datasets whose size and complexity make processing it using current methods difficult [80]. Having the means to collect this data, understanding it and being able to analyse it is key in helping organisations build decision models,

and hence, makes decisions. The following are some examples of "how big is Big Data?" [81]:

1. Every month over 30 billion pieces of content gets shared on Facebook.com.

2. In the year 2010, the number of mobile users reached 5 billion.

3. The chain store Wal-Mart processes 1 million customer transactions every hour. This amount of data is equal to feeding a database 2.5 petabytes of data. It is equal to 167 times the books in the Library of Congress (which, according to wikipedia.com, is the biggest library in the world).

4. In April 2011, the Library of Congress collected 235 terabytes of data.

5. In the United States of America, 15 out of 17 industry organisations store more data than the Library of Congress.

Healthcare practitioners and administration staff have realised that gathering and analysis of "Big Data" is going to help them take the field of medicine to the next level [82].

The following are some cases of Big Data usage in the healthcare sector [82]:

- Genomics is the ultimate case for Big Data in the healthcare sector. One of the main assignments in the field of Genomics is genome sequencing. This sequencing is getting cheaper by the day, thus producing copious amounts of data. Many genomics companies conduct analysis on this data in order to find cures for diseases faster.

- Using Tableau to analyse and visualise terabytes of data, doctors and staff at a children's hospital in Seattle (USA) have been extracting scattered data from the many servers and databases in their organisation. The visualisation of this data helps the healthcare providers

reduce medical errors and plan better trials. In 2011, this hospital earned $3 million through its data focused techniques.

- Apixio has created a semantic patient health record search engine that helps doctors learn about their new patients, and which patients would benefit most from a particular newly developed medical technique. Patient records are usually in different formats as they are created by different departments. This search engine reveals all the necessary information regardless of which department prepared the information.

- IBM in collaboration with WellPoint have come up with the champion question-answering system (Watson) for the doctor's office. This system is capable of answering questions (Natural language questions) by analysing vast amounts of medical research data. This medical research data is so huge that no possible practitioner or individual could read or digest.

Data quality does not have one single definition. Data is fit or of high quality when it is free of defects, customer-focused and it can be used to help the organisation with business decisions. According to Dr. T. Norris:

"Data quality is contextual; the user defines what is good data quality for each proposed use of the data, within its context of use." [83].

In many organisations the same data is used for different purposes, thus requiring the data quality to be multidimensional [83]

One of the key areas in which data quality plays a vital role is EHR (Electronic Health Record) systems. EHR systems have tried to ensure the quality of data by encouraging quality improvement practices [84].

4.4.5 Data Warehouses and Data Mining

According to E. Burtescu and C. Burtescu [**?**] a Data Warehouse is defined as

- *"A Data Warehouse is a collection of designed data for the fundamentals of management decisions."*

Data Warehousing is the gathering of pools of data to be used in support of decision making systems. This data is usually readily available for various kinds of analytical processing. These analytical processes could include Online Analytical Processing (OLAP), querying, reporting and data mining.

Data warehousing also provides a platform for historical analysis of data by having the means of a centralized repository for historical data. This function can help users gain finer knowledge from the repository data by performing finer analysis [**?**].

According to Benko and Wilson

> *"Data is a great asset to healthcare organisations, but they have to be first transformed into information."* [85].

Data mining is the process in which previously unknown patterns and trends in a database are found and used to build predictive models. These models are build by exploring the selected data form the vast amount of data that is available.

Data mining is used by organisations that have a strong focus on customers and customer relations. Data mining facilitates a link between data and the analytical systems, and with the huge amounts of data that are produced in healthcare, data mining is a less complex method for analysis compared to any other traditional method/system. Data mining is equipped with methodologies and technologies to transform huge amounts of data into pragmatic information to assist in decision making [**?**, 86].

The following are some of the benefits of data mining in the healthcare industry [86]:

- Detection of fraud and abuse in healthcare insurance;

- Making customer relationship management decisions in healthcare organisations;

- Identification of effective treatments and best practices by physicians for patients;

- Provision of affordable and improved healthcare services for patients;

- Improvement in decision making by discovering trends and patterns in copious amount of complex data.

4.4.6   Tablets and the iPad

In the year 2011, 341 US healthcare professionals were surveyed online by Aptilon Corporation and 79% of these qualified individuals chose Apple's iPad, 12% chose Windows Tablets and 9% chose Android-based Tablets as a professional tool they used. This survey also concluded that 38% of US healthcare professionals will own an Apple iPad by 2012 and the other participants were more than happy to use an iPad if it was provided to them by their employers and organisations they worked for. According to the Chief Operating Officer of Aptilon Corporation:

> *"The research indicates that the Apple iPad is going to be an ever more important part of a healthcare professional's daily life as a tool to enhance productivity and remaining up to date with the latest developments in their medical field. As the number of HCPs using iPads increases, Aptilon expects to see increasing opportunities for interactions between industry professionals and HCPs seeking relevant medical content using their tablets."* [87].

The following are the most popular tablets used by healthcare providers [**?**]:

1. **Apple iPad:** Runs on the MAC Operating System;

2. **Samsung Galaxy Tab:** Runs on the Android Operating System;

3. **Motorola Xoom:** Runs on the Android Operating System.

In a survey done by Manhattan Research, where 3000 physicians in 25 specialist fields were surveyed, it was revealed that 62% of the physicians own Tablet PCs (Personal Computers) and half the physicians that owned the Tablet PCs used them as devices at the point of care. The survey also concluded that the number of physicians that own Tablet PCs has increased by 27% since 2011. According to the vice president of research at Manhattan Research

> *"Physicians are evolving in ways we expected, only faster. The skyrocketing adoption rates of tablets mean healthcare stakeholders should revisit many of their assumptions about reaching and engaging with this audience."* [88].

Healthcare practitioners are relying on iPads and Tablet PCs more and more to deliver healthcare conveniently. Not only do these devices provide convenience to the practitioner, but are also a good source of up-to-date information (in real-time) and provide connectivity to other practitioners and other healthcare professionals. These devices are revolutionising the way medicine is practiced. Since the introduction of these technologically advanced devices, many hospitals, practices and healthcare organisations have equipped their staff with these devices. There is a huge market for applications that run on these devices. These applications help physicians with many different medical tasks from administration tasks to prescribing and diagnoses. Dr. Tom Giannulli, the Chief Medical Information Officer of Epocrates, states that

> *"Tablets will also play an important role in the future of EHR systems."* [87, 88, **?**].

Tablets and iPads are not only used by doctors but they are being used by ambulance and other emergency care providers. These devices use

broadband connections such as WiFi and 4G to connect to the local network or the Internet. Ultra-fast broadband can replace these technologies to ensure faster and more efficient connectivity.

4.4.7 Health 2.0 and Social Networking

The rapid growth of the Internet in conjunction with web services has given birth to a new generation of web services know as the Second Generation web services, also known as Web 2.0. With the help of Web 2.0 users have learnt to share their opinions and thoughts with other users online.

Web 2.0 applications, such as social networking website, blogs, search engines and other informative websites, have grown significantly encouraging users to share content and communicate their views about their day-to-day affairs. Therefore, facilitating the general public and health experts to communicate about health related issues and share their knowledge. This knowledge sharing and communication has given rise to a new phenomenon known as Health 2.0 or Medicine 2.0 [89].

Social networks such as Facebook and Twitter are a way of life for a huge population of people. Not only are these social networks used for personal purposes, but they have also been used as effective business tools. Thus making them a good platform for advertising medical and health information.

According to a study done by Hanna Spring in 2011, these platforms are used for thinking and brainstorm about exciting health issues by their user and they are furthermore used as an educational tool for students and healthcare professionals, calling it the "Invisible College" [90].

Having said this, some studies have questioned the integrity and quality of health information available on the Internet and provided by these web services [91].

For many years, doctors and healthcare providers have been the only sources of health information, but with an increasing growth in Health 2.0 and Health 2.0 applications, patients have been getting more and more

involved with their own health and welfare; in other words, there has been a rise in patient empowerment [**?**].

The following is a list of Health 2.0 web services and their purpose [**?**]:

- **Google Health and Microsoft Health Vault:**

  This service is an improved search engine that offers high quality health websites.

- **OrganizedWisdom:**

  This service offers high quality information about patient illness and treatments.

- **Vitals and rateMD:**

  These services allow for patients to rate their physicians.

- **ZocDoc:**

  This service allows patients to make appointments with physicians.

- **PatientsLikeMe:**

  This service allows patients with severe chronic conditions to gather longitudinal data on their disease courses, treatments, and side effects.

- **PharmaSurveyor, iGuard and doublecheckMD:**

  These services allow patients to check their medicine for side effects and suggests alternative and newer medicine.

- **MyMedicalRecords and MedCommons:**

  These services allow patients to keep permanent longitudinal personal health records (PHRs).

- **MyMedLab:**

  This service allows patients to lab test without intervention of a physician.

- **WhoIsSick:**

  With the help of Google maps, this website allows patients with infectious illnesses (e.g: influenza or gastrointestinal virus) to enter their location and symptoms, and this way preventing an outbreak of the viral illness.

Users require broadband in order to connect and use these web services. Ultra-fast broadband will ensure higher amounts of bandwidth to be utilised for this connectivity.

Chapter 5

Discussion

An important variable to be considered in the healthcare sector is "time". Time is finite and making the right use of it in the provision of healthcare services (especially when dealing with patients' lives) is very important.

ICTs such as broadband technologies have been known to offer assistance in the healthcare sector in order to reduce the time taken to complete certain health and medical related tasks. Sometimes this reduction in time could be the difference between a patient's life and death.

The fusion of communications technologies with healthcare has been aiding healthcare practitioners and patients by bridging distances via telehealth services, thus increasing patient comfort and improving service efficiency. Telehealth practices such as the remote monitoring, consultation and diagnoses of patients, distance education of healthcare staff and patients, remote surgeries and many other aspects of telehealth depend on adequate broadband connectivity for successful and effective execution.

In the deployment of telehealth services, high-bandwidth connections enable higher transfer rates and provide increased speeds, hence reducing time and increasing the efficiency of these services.

Just like any other industry, the healthcare industry has hugely benefited from broadband networks. These benefits include reduction in costs, increase in productivity, increase in quality of medical research and educa-

tion, improved communication and enhancement in multimedia applications [92]. The broadband network infrastructure available to the healthcare sector in a country influences the number and types of healthcare services provided remotely.

This chapter discusses the implications of using ultra-fast broadband for telehealth in New Zealand. The main research question is

> *What effect does the introduction of ultra-fast broadband (UFB)*
> *have on the development of new and existing telehealth ser-*
> *vices in New Zealand?*

5.1   Broadband in New Zealand

In December 2011 New Zealand was ranked 17th amongst the OECD countries in terms of provision and subscription of fixed or wired broadband. This ranking was slightly above the OECD mean, and as per wireless broadband provision and subscription New Zealand was ranked 9th [93].

Figures 5.1 and 5.2 display the OECD rankings of various countries, including New Zealand, and the proportions of the technologies used to produce these rankings.

Broadband providers and users in New Zealand have invested more in wireless broadband technologies rather than fixed broadband. The possible reasons for this choice include: the mobility of wireless technologies, the geographic location of users and the costs of the infrastructures.

According to the 2010 National Infrastructure Plan, higher emphasis will be given to the provision of high-speed Internet through wired (fibre) networks rather than wireless networks. Wireless networks will not be able to act as substitutes or an alternative to the current copper network [39]. These fibre networks will be a huge upgrade to the current copper network; fibre networks are a better option than a wireless network in terms of the bandwidth provided.

Therefore, the provision of fibre networks will increase the potential for
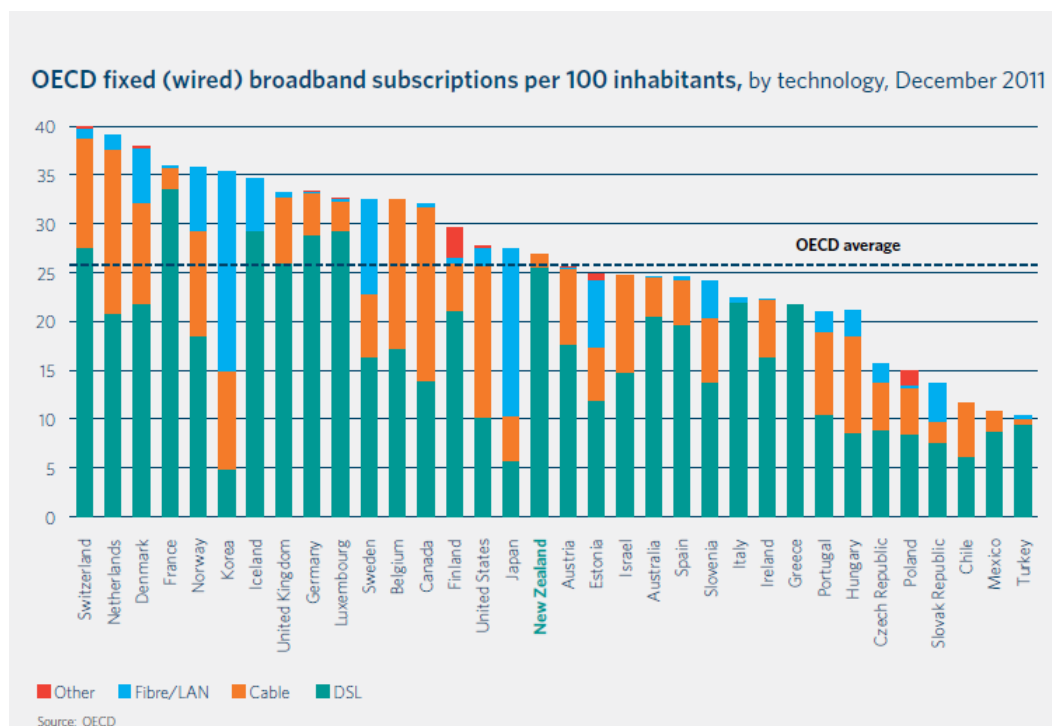
Figure 5.1: OECD Rankings for fixed (wired) broadband subscriptions (Taken from: [93]).

telehealth services thus benefiting healthcare subscribers and telehealth service providers in New Zealand.

The 2010 National Infrastructure Plan and the Infrastructure 2012 report make no mention of the deployment of any dedicated networks for the health sector in New Zealand. However, the government will be working closely with local fibre companies in charge of the infrastructure projects to speed up the deployment of the fibre network for areas such as healthcare [39]. This will ensure that priority is given to the health sector in the network's dispatch process.
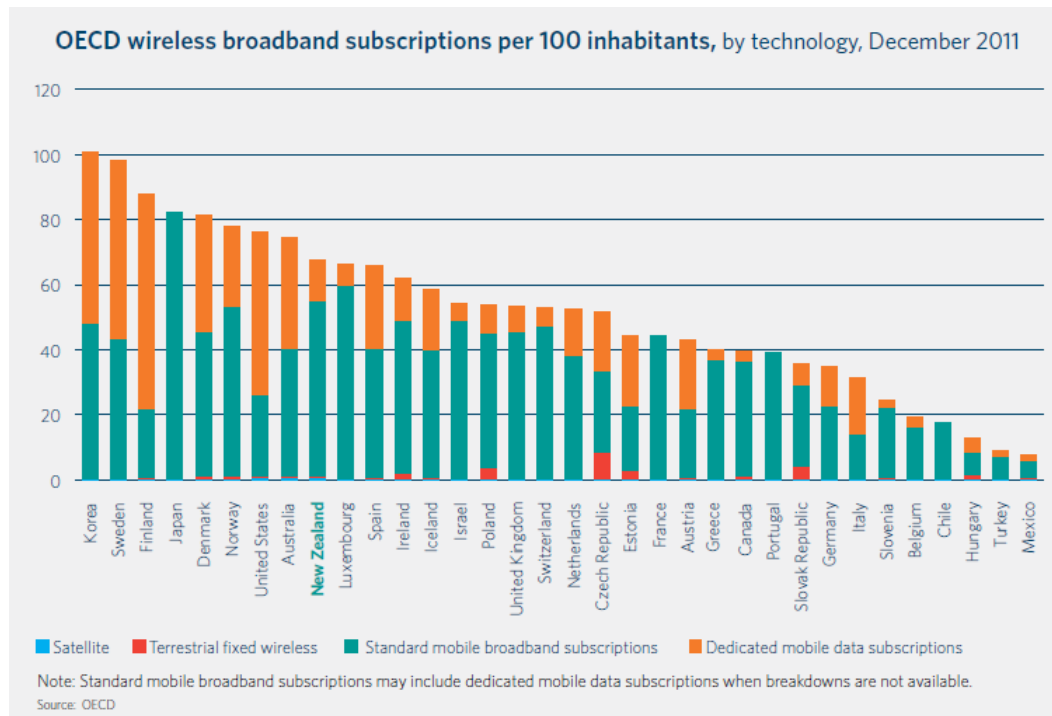
Figure 5.2: OECD Rankings for wireless broadband subscriptions (Taken from: [93]).

5.2   Impact of Ultra-fast Broadband on Telehealth

Most telehealth services use broadband technologies for services such as live and real-time diagnoses of patients, consultations, accessing records, etc. Many of these services usually involve videoconferencing and/or exchange of high-definition (HD) media, such as HD videos and HD images, between the patient and the practitioners. This exchange of vital information needs to be done in real time and over a reliable, secure and fast broadband connection in order to run successfully. The ultra-fast broadband network, once set up, will provide the high bandwidth required to enable speedy transfers and communications. For instance, for a videoconferencing system displaying HD quality video (720p/video resolution

of 25 frames per second) and transmitting at the same quality requires a bandwidth between 1.2 Mbps to 2.5 Mbps on upload and over 2.5 Mbps on download. Ultra-fast broadband provides the means to run 25 video-conferencing sessions with this quality and still have spare bandwidth to perform other communications. Nowadays medical imagery and video have high resolutions in order to display details clearly, thus making each file substantially large. These high resolution formats (720p, 1080p and 4K resolutions) require high amounts of bandwidth for transmission.

This section looks at some of the medical disciplines and telehealth services in New Zealand that will benefit from the establishment of the ultra-fast broadband network in the country.

5.2.1   Medical Disciplines that will Benefit from Ultra-fast Broadband

Telehealth services are used in most medical disciplines. For instance, areas such as dermatology, cardiology, psychiatry and radiology all use broadband-dependent telehealth services. The deployment of the ultra-fast broadband network will have an impact on all of these disciplines.

5.2.1.1   Dermatology

In the field of dermatology, practitioners use broadband to connect with patients for consultation through videoconferencing, exchange of high-definition media (HD videos and HD images) and transfer of other patient data. Videoconferencing sessions for educational purposes are, like in most other disciplines, also used in dermatology.

Increasing the bandwidth of the broadband connection– for instance, using an ultra-fast broadband connection– will ensure optimum quality video links between healthcare practitioners and patients or other healthcare practitioners. This also ensures quicker transfers of large volumes of patient/educational data.

5.2.1.2   Radiology

In radiology the transfer of x-rays, scans and other medical imagery is done using broadband connections. These files are usually larger in size compared to regular imagery due to their superior quality.

Ultra-fast broadband will ensure the transfer of these files in much lesser time when compared to the current broadband technology.

5.2.1.3   Mental Health

In medical fields such as psychiatry and psychology, patient consultation and counselling is done over videoconferencing links between the healthcare provider and the patient. Video consultations and counselling sessions provides a more personal experience for patients in comparison with voice sessions, like telephone consultations/counselling.

Ultra-fast broadband will provide the higher bandwidth needed to ensure a fast and efficient connection between the patient and the healthcare provider. Also, the higher the bandwidth, the better the quality of the videoconferencing session [?].

5.2.1.4   Cardiology

In cardiology patients are monitored before and after heart surgery. Surveillance, monitoring of vital signs and transfer of HD imagery such as angiograms can all be done from a distance using broadband technologies.

Ultra-fast broadband will result in the quick transfer of up-to-date critical patient information, thus ensuring a timely response in case of an emergency.

5.2.1.5   Speech-Language Pathology

Speech-language therapists often use videoconferencing tools and systems as part of their remote services/practices, where patients are treated in the convenience of their own homes [?].

The use of ultra-fast broadband in telehealth services being offered in most medical disciplines will increase the efficiency and quality of these services, and reduce the time taken to provide the services. Videoconferencing sessions, consultations, accessibility to medical records and information, and timely response in emergencies can all benefit from the increase in bandwidth.

5.2.2 Telehealth Services that will Benefit from Ultra-Fast Broadband

Crown Fibre Holdings (CFH), New Zealand Ministry of Health and New Zealand Health IT Board have been working together to speed up the execution of the Ultra-Fast Broadband Initiative. The goal in this joint venture is to provide the health sector with ultra-fast broadband by 2015.

Many areas of the health sector in New Zealand will benefit from the roll-out of the ultra-fast broadband network. The following is a list of some of the areas in telehealth that stand to gain from the implementation of ultra-fast broadband [94]:

5.2.2.1 Patient Health Records

Patients' health information can be remotely accessed in real time by healthcare providers and health administration staff. Patients, medical information (data) can include large files which can be easily and speedily transmitted with a high-bandwidth connection such as an ultra-fast broadband connection.

Patient information can also be stored (uploaded) securely on cloud systems and retrieved (downloaded) instantaneously when needed by means of ultra-fast broadband. Without ultra-fast broadband these transactions will require more time.

5.2.2.2   Medical Imagery

Medical imagery such as x-rays and scans can be transferred between practitioners within a short period of time with the use of ultra-fast broadband.

Medical imagery can include HD images that require high-bandwidth connectivity to be successfully and promptly transmitted. Ultra-fast broadband can ensure that transmissions and communications are performed with great speed [94].

5.2.2.3   Tele-monitoring

Ultra-fast broadband will provide the means for the remote monitoring of patients by medical staff. Patients can also self-monitor their health with the supervision of healthcare providers in the comfort of their own homes, saving the time and the money required to make a trip to the hospital or health clinic.

Video surveillance systems, videoconferencing systems and sensor data (vital signs and images) transmission systems are a few of the remote monitoring technologies that will benefit from the use of ultra-fast broadband connectivity.

5.2.2.4   Tele-consultation and Tele-education

Technologies such as videoconferencing systems used to provide remote consultation can run more efficiently with ultra-fast broadband. With the availability of high bandwidths, higher quality videos can be transmitted at higher speeds.

Videoconferencing systems can be used in the distance education of healthcare staff and practitioners, as well as patients. With ultra-fast broadband, videoconferencing sessions can be executed more efficiently, with minimum lag (in real time), thus removing geographical barriers between patients and healthcare practitioners.

5.2.2.5 Referrals and Prescriptions

Transfer of electronic referrals (eReferrals) between primary and secondary healthcare providers or between GPs and specialists can be done more efficiently using ultra-fast broadband.

Ultra-fast broadband will also provide better means for continuing patient healthcare with the dispatch of electronic prescriptions (ePrescriptions) [94].

5.2.2.6 Telesurgery

In telesurgery, surgeons use broadband services to control the robotics technologies used to perform surgical operations on patients from a distance. The success of these procedures is, among other factors, also dependent on a broadband service that can provided connectivity with a minimum lag, so that there is no delay between a surgeon's command and the robot's movement (reaction to the command) [68, **?**].

When compared to other broadband technologies ultra-fast broadband minimizes this lag, and remote surgical procedures can be performed with increased accuracy.

5.2.3 Development of Telehealth in Different Countries

Many parts of the world are handicapped due to inadequate healthcare and medical services and backward technology. Two of the major causes of this inadequacy is a shortage of healthcare providers and deficient ICT infrastructures, especially in rural areas [95].

In the past few years, telehealth has become the solution to better quality healthcare in many developed and developing countries. Telehealth has enabled healthcare systems in many countries to overcome geographic barriers, reduce time, improve emergency response services and often cut costs, thus providing better quality healthcare to patients.

In the American continents, the United States of America and Canada

are the leaders in the provision of telehealth services to their citizens. Some of the networks used in these countries are high-speed broadband connections, such as satellite, DSL and cable broadband [**?**, 63].

In Europe, Denmark, England, Scotland and Norway are known to have successfully integrated a vast number of telehealth services into their healthcare systems, making them some of the best in the world in terms of telehealth services. The broadband network infrastructures in these countries include high-speed broadband technologies, such as ADSL and Fibre [96].

In New Zealand, although currently many telehealth services have been set up and running in various regions, the scale of these services is still not what it can be. The provision of these existing telehealth services and ones that are not currently offered in New Zealand, can potentially improve with the set up of the ultra-fast broadband networks nationally.

Many other countries– such as, India, Japan, Pakistan, China and Saudi Arabia– that were not included in the brief review provided in Section 4.2, have also been successfully implementing a number of telehealth services. Although India, Malaysia and Hong Kong provide some of the highest numbers of telehealth services in the Asian continent, the extent of these services is far below those in many of the developed countries. The network infrastructure in many regions of some of these countries is still lacking. That possibly contributes to the relatively limited telehealth services provided in many of these regions [**?**, **?**].

In a 2011 telehealth assessment report prepared for the Australian Department of Health and Aging 34% of telehealth services in Asia are used to store and forward (Asynchronous telehealth), and 35% are used for videoconferencing [**?**]. The extend and range of telehealth services in these regions can improve with the availability of a fast and reliable broadband network.

Improved network infrastructures in countries around the world, also provide the means to share healthcare expertise globally. Experts in many

medical disciplines can provide guidance and education to practitioners situated elsewhere; for instance, the "A Call for Arms" telehealth conference held in Auckland, New Zealand, in 2012, experts from outside the country (who could not be physically present) presented their work in the field of telehealth via videoconferencing systems.

With the availability of high-speed broadband networks in various countries, healthcare and medical conferences can be held via videoconferencing, without practitioners having to leave their practices to travel to different locations. This can be financially beneficial to healthcare systems around the world and also, practitioners need not be away from their practices for extended periods of time.

Ultra-fast broadband networks could provide the means for many such sessions. Countries around the world should work to improve their network infrastructures to make such telehealth related services possible.

5.2.4 Development of Telehealth in Rural Areas

Many communities in rural parts of countries, such as rural New Zealand and rural Australia, solely depend on telehealth services as their means of healthcare provision due to their remote geographical location. As shown in Figure 5.3, New Zealand has a very dispersed population, therefore making provision of equal healthcare to everybody a seemingly hard task.

High-speed broadband has been known to assist countries that have some of the most dispersed populations in the world (e.g. Canada and Australia) with the provision of healthcare by means of telehealth [43]. The addition of new network infrastructures or upgrades of current New Zealand infrastructures that can supply ultra-fast broadband, such as fibre optics, ADSL 2 and ADSL 2++, play key roles in delivering telehealth services in the rural areas.

According to the New Zealand Infrastructure Plan (June 2011), the government has made substantial investment in the initiation of two major network infrastructure projects. The Ultra-Fast Broadband (UFB) initiative
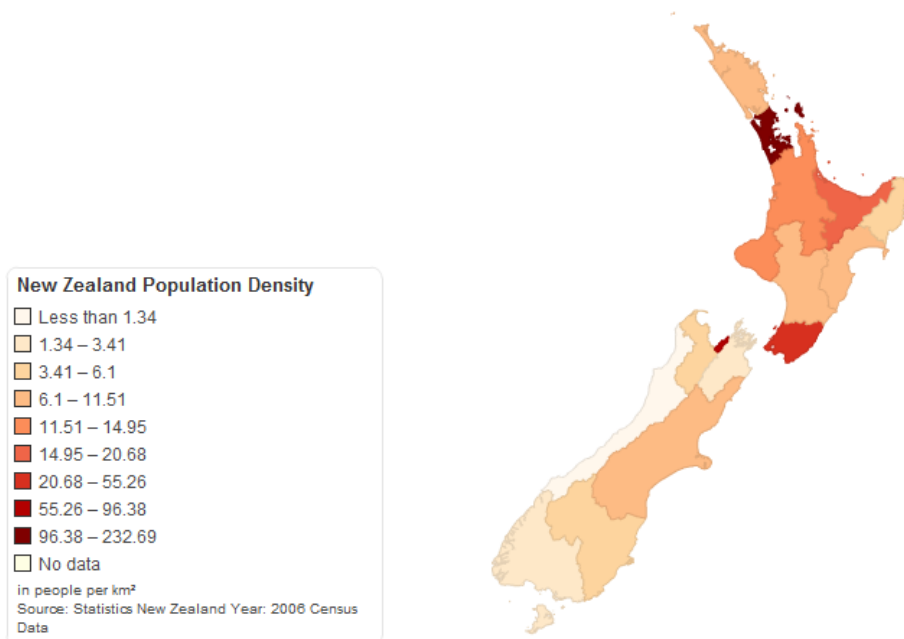
New Zealand Population Density
☐ Less than 1.34
☐ 1.34 – 3.41
☐ 3.41 – 6.1
☐ 6.1 – 11.51
☐ 11.51 – 14.95
☐ 14.95 – 20.68
☐ 20.68 – 55.26
☐ 55.26 – 96.38
☐ 96.38 – 232.69
☐ No data
in people per km²
Source: Statistics New Zealand Year: 2006 Census Data

Figure 5.3: New Zealand's population density (Taken from: [97]).

and Rural Broadband Initiative (RBI) will ensure a considerable amount of bandwidth growth when compared to the current infrastructure. The fibre optics networks will replace the copper cable networks and the broadband connections will replace the exhausted dial-up connections in the rural areas. This growth in bandwidth can be put to use to expand the current telehealth activity in rural (and urban) New Zealand.

According to the New Zealand Ministry of Business, Innovation and Employment, the Ultra-Fast Broadband Initiative and the Rural Broadband Initiative will ensure faster broadband to 97.8% of New Zealanders in the near future. This will include both the rural and the urban regions in New Zealand.

The provision of telehealth services, such as remote monitoring and tele-homecare of patients, in rural areas can be especially beneficial. For instance, with higher bandwidth the number of simultaneous videocon-

ferencing sessions can increase, helping the hospitals to reach out to many outpatient clinics in need of a specialist's consultation at the same time. Another such example would be an increase in tele-homecare and tele-monitoring programs, which will result in saving the healthcare system's resources (e.g emergency services) and providing convenience for the patient by eliminating the long distances traveled and the time taken to travel these distances. Also, response teams cannot arrive immediately when there is an emergency and patients may not be in a condition to travel to get to a healthcare center.

In a study done by the Australian Department of Broadband, Communications and the Digital Economy, tele-monitoring and tele-homecare reduced cost in [43]:

- Outpatient visits by 78%

- Home visits by 50%

- Travel time for healthcare professional 78%

- Travel time for patient 100%

- Patient productivity 100%

In terms of the effectiveness of healthcare through telehealth, reduction was seen in: [43]

- ED visits by 89%

- Hospitalisations by 89%

- Re-admissions by 100%

- Length of hospitalisation by 88%

The successful provision of telehealth services in both rural and urban New Zealand can reduce the financial burden on patients and the country's healthcare system.

Many broadband-dependent telehealth services cannot run efficiently and successfully without the availability of the right broadband network infrastructure. Even with the existence of other ICTs, the absence of a fast and reliable broadband network can limit the type and extent of telehealth services possible, especially in rural New Zealand.

The recent network initiatives in New Zealand will improve the connectedness between urban and rural communities and healthcare centers (such as city hospitals), and increase the quality of healthcare across the country.

Both rural and urban New Zealand will benefit from faster broadband, but the rural regions will benefit more, as this broadband technology will enable healthcare practices such as telehealth and telemedicine that were not existent in some regions and improve the existing programmes. Thus, New Zealand will get closer to its goal of providing equal quality healthcare to all its citizens [98].

5.3   Future of Telehealth in New Zealand

Not only is telehealth an alternative to face-to-face healthcare in regions where geographic conditions and distance are barriers, but it is also an improvement in the quality of healthcare where there are no such barriers.

The future of telehealth and that of many other ehealth components are looking very bright, and this can be, among other reasons, attributed to the rapid growth and advancements in the fields of telecommunications technology.

The introduction of broadband with higher bandwidth has made significant contributions towards telehealth in urban and rural areas and as these technologies continue to grow so will the development of telehealth.

The future development of telehealth is also dependent on the success of current telehealth projects and pilot studies. Success in these cases will gain the confidence and trust of practitioners and patients telehealth's abil-

ity to provide better quality healthcare more efficiently.

The right policies and legislations by lawmakers and the upgrade of the current network infrastructure also play key roles in the future development of telehealth. Meeting the bandwidth requirements to deploy telehealth services in rural and urban areas across New Zealand (and other countries) can only be addressed through infrastructural changes in the networks; for instance, the establishment of the ultra-fast broadband network infrastructure across the country.

The investments made in setting up the ultra-fast broadband network, will not only have a positive impact on the provision of telehealth in New Zealand, but it will also ensure universal connectivity, boost economic development and benefit many other sectors and areas (such as education) [99].

5.3.1   Barriers in the Development of Telehealth

As in any other care model, telehealth has had barriers in its development path. This section discusses some of the major barriers in the development of telehealth.

5.3.1.1   Information and Communication Technologies

The development of telehealth systems is very dependent on ICTs (for example, broadband). The absence of these technologies makes the deployment of telehealth near to impossible.

Many areas in New Zealand (and elsewhere) have been known to be deprived of these technologies, often due to socioeconomic factors or the nature of their terrain [10, 48].

5.3.1.2   Ethical Issues

Security, privacy and confidentiality of patient information (data) has been a major concern for many healthcare providers and patients. This can con-

tribute to the speed at which telehealth systems are accepted and practiced.

5.3.1.3   Mindset of Practitioners and Patients

The change from traditional practices and methods of care to telehealth has not been easily accepted by patients and healthcare providers.

In many cases, practitioners haven't been very enthusiastic about the change and prefer the conventional face-to-fact method of care. Patients have also been known to have little faith in these systems, and therefore do not make them their first choice of care.

5.3.1.4   Limited Interoperability of Telehealth Systems

Many telehealth and telemedicine systems in use are not connected to any other teleheath or telemedicine systems and operate independently. This way, each system has its own standards and models to follow, and will most likely be incompatible with other systems.

This lack of complete interoperability creates additional work; for instance, when a patient moves to a different location, practitioners may need to re-run some (previously done) tests, in order to complete the patient's medical records, if these records are not fully accessible.

5.3.1.5   Lack of Incentives and Publicizing Success Stories

Government authorities do not provide enough incentives for healthcare practitioners and healthcare staff who accept telehealth systems and put them to daily use.

Many telehealth projects run successfully over a course of time without ever being acknowledged or publicized.

Chapter 6

Conclusion

This research was undertaken to study the effect of ultra-fast broadband on telehealth in New Zealand. The thesis provided an overview of broadband technologies and a review of telehealth and telehealth related concepts, and listed examples of successful telehealth projects in various developed countries. It also provided a discussion on the current UFB initiatives underway in New Zealand and the impact of ultra-fast broadband networks on many aspects of telehealth in New Zealand and elsewhere.

This chapter concludes the thesis with a brief discussion of key observations and their implications.

Telehealth individualizes healthcare for each patient and removes the geographic barriers between patients and healthcare providers, thus making it one of the most important services in healthcare systems around the world. The implementation of telehealth services also result in reduced costs, save time and make healthcare more accessible.

The deployment and continuous provision of telehealth services is very dependent on technology, e.g. telecommunications and networking technologies. One of these ICTs is broadband Internet without which the provision of telehealth is near to impossible.

Broadband technology has integrated with many medical disciplines to provide better quality of healthcare for patients in rural and urban ar-

eas. Some of these disciplines include dermatology, cardiology, psychiatry, psychology and radiology.

Most telehealth services require high bandwidth connectivity for efficient execution. For instance, technologies like videoconferencing require a substantial amount of bandwidth for a successful execution and a multiple (simultaneous) videoconferencing session can require even more bandwidth. Transfer of large files such as HD medical x-rays and scans will be done over shorter periods of time using ultra-fast broadband. Medical data such as patient health records and medical educational information can be sourced more efficiently using ultra-fast broadband.

The New Zealand government has invested over \$1.5 billion towards the network infrastructure in New Zealand. This investment contributed a substantial amount towards the upgrade of the current infrastructure and will ensure faster and reliable connectivity throughout New Zealand. With the successful completion of the Ultra-Fast Broadband (UFB) and the Rural Broadband Initiative (RBI) projects, New Zealand telehealth is guaranteed to function more efficiently and deliver telehealth services to urban and rural New Zealand more effectively. Telehealth services such as patient health records (EHRs), tele-monitoring, tele-consultation, tele-education, telesurgery, eReferrals and eProscriptions will all receive substantial gains from the implementation of the new UFB initiatives.

Many regions in New Zealand (mostly rural) have a very dispersed population and the majority of this population does not have immediate access to quality healthcare. In order to receive quality healthcare, these population must cover long distances and travel for hours to bigger towns and cities. Development of telehealth services will benefit rural (as well as urban) communities in New Zealand. The Ultra-Fast Broadband (UFB) projects and the Rural Broadband Initiative (RBI) projects will enable the provision of these telehealth services in rural areas and improve provision of telehealth services in the urban areas.

The ultra-fast broadband will make way for New Zealand's health sys-

tem to integrate further with technology, improve the current telehealth services and implement new services as yet unavailable in New Zealand. Improvements such as implementation of a national EHR system, telesurgery, tele-monitoring (on a large scale), medical education and improvement in emergency services will be made possible.

The impact of ultra-fast broadband is seemingly obvious when overseas telehealth projects and initiatives are examined. High bandwidth broadband technologies such as satellite, fibre optic and ADSL have helped countries such as Australia, America, England, Scotland, Denmark and Norway in the deployment of successful telehealth projects. The Australian National Broadband Network (NBN) and the N3 network (the largest fibre-optic network) in England and Scotland are perfect examples for this study. These networks have provided infrastructures with high-speed broadband to meet all the expectations of their healthcare systems and telehealth services in terms of connectivity. These healthcare systems and telehealth projects are now working towards providing higher quality healthcare and healthcare education throughout the rural and urban communities.

The implementation of high-speed broadband networks on telehealth systems in various developed countries and their successful telehealth services could imply that high-speed broadband will have a positive impact on the current and future telehealth situation in New Zealand as well.

New Zealand and many other Asia-Pacific countries contributed a sum of $2 billion to the global telemedicine and telehealth markets and this contribution is expected to reach close to $8 billion by the year 2018. That is an annual growth of 21% [?].

According to the Principal Consultant, Pat Kerr, at the New Zealand Telehealth Forum the Ultra-Fast Broadband and the Rural Broadband Initiatives will provide fast broadband to communities all around New Zealand and telehealth will expand and become a crucial part of New Zealand's future healthcare system, rural areas in particular [100].

Lack of adequate network infrastructure (broadband and ultra-fast broadband networks) is not the only barrier in the implementation of telehealth in New Zealand; issues like funding, ethical problems and legal concerns (policies and regulations, security, privacy concerns) are some of the other barriers. Once these barriers are overcome, New Zealand can provide quality and effective healthcare by means of telehealth to all its citizens regardless of their geographic location in the country (rural or urban).

Telehealth will also assist in addressing issues like the shortage of skilled healthcare professionals (especially in rural regions), the shift of care in communities (e.g. between primary and secondary) and care for the ageing population [101].

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