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Caring for the Last 3%: Telehealth Potential and Broadband Implications for Remote Australia

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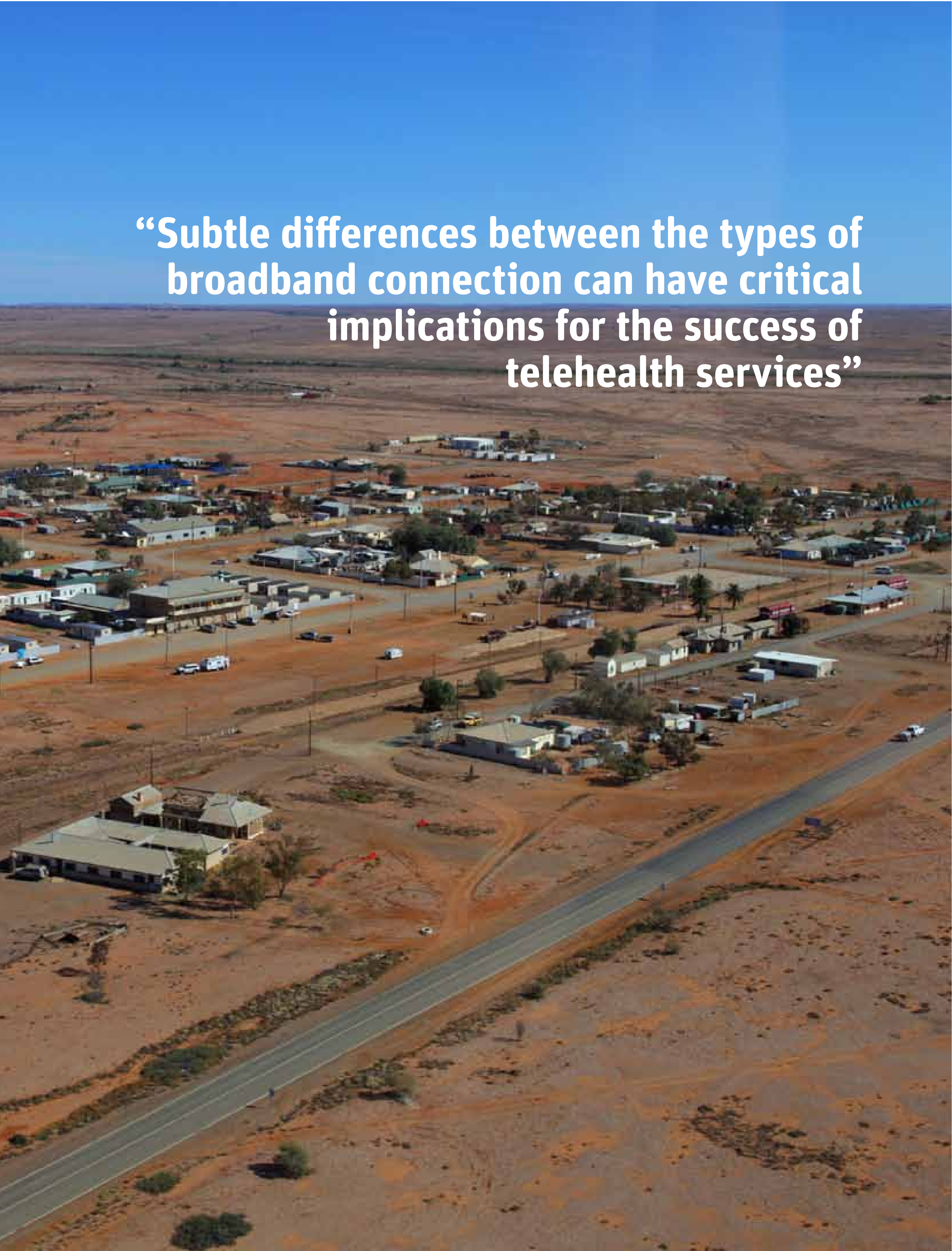

“Subtle differences between the types of broadband connection can have critical implications for the success of telehealth services”

Australians living in remote regions of our nation live with far poorer health outcomes than those in our regional and urban areas. The gaps in health service availability and outcomes between people in urban areas and those in remote parts of our country are well known. Telehealth, the provision of health related services at a distance using technology assisted communications, offers a means to narrow this gap by improving the level and diversity of services in remote areas.

The current rollout of nationwide broadband connectivity brings new potential for Telehealth services. While 93% of premises (the urban areas) are expected to connect with broadband using optical fibre, the 3% of the most remote premises will receive satellite services. When considering telehealth, it is easy to concentrate on the services themselves, and assume that the connection, whether fibre, wireless or satellite, can deliver what is needed. However, the subtle differences between these types of broadband connection can have critical implications for success of telehealth services. This paper will explore these subtle differences, and their implications in the use of satellite broadband to deliver telehealth services to remote Australia.

The health gap

Statistics show that people living in remote parts of Australia have a life expectancy around four years shorter than those in cities, and for under 65s, the mortality rate for remote areas has been reported to be twice as high as in major cities (DoHAa, 2012). Remote areas also have less access to health care professionals, including nurses, general practitioners and specialists. In remote Australia, there are 589 nurses and 58 GPs per 100,000 residents compared with 978 nurses and 196 GPs in major cities (AIHW, 2009). The shortage of professionals is coupled with a similar scarcity of medical facilities, and results in people from remote communities ending up in hospitals far more often than city dwellers, for preventable conditions [DoHAa, 2012]. As Figure 1 shows, there are around 50 hospitalisations per 1000 people living in remote and very remote locations with chronic disease, which is around 30 more than for city dwellers.

Each of these visits to the hospital comes with significant social and economic costs to both individuals and the public health system. The hospital bed utilisation alone has a direct cost of over $50m/year . Travel to reach the hospital, family disruption and time away from work also contribute to this cost.

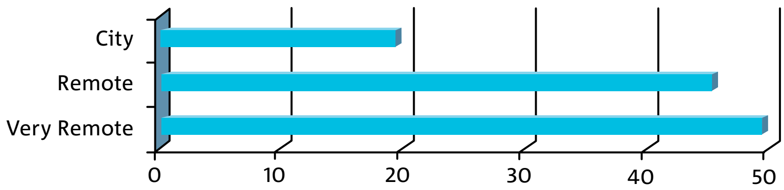

Figure 1 Hospitalisation ratio among the population of ABS remoteness categories (city, remote, very remote)

Telehealth services are emerging as an effective solution to this challenge of increasing the availability of health services and improving health outcomes for those in remote Australia.

Telehealth can:

- deliver many health services into remote communities, reducing the need for travel
- provide timely access to services and specialists, improving the ability to identify developing conditions
- provide a means to educate and train and support remote healthcare workers on location
- support people with chronic disease to manage their health.

All Broadband is not the same

The goal of Australia's new national broadband infrastructure rollout is stated as giving every Australian premises access to high speed broadband, and broadband enabled services (NBN Co, 2012). The program will see a combination of fibre, wireless and satellite broadband services delivered by 2015 (Figure 2, right) (NBN Co, 2010). The homes, school and businesses of our most densely populated areas (93% of total premises) will be connected with fibre to the premises technology. The next 4% of premises will receive fixed wireless connection wireless, while the most remote 3% of areas will connect using satellite broadband. Figure 2 shows a side by side comparison of the Australian population density [ASGC] and the planned NBN rollout.

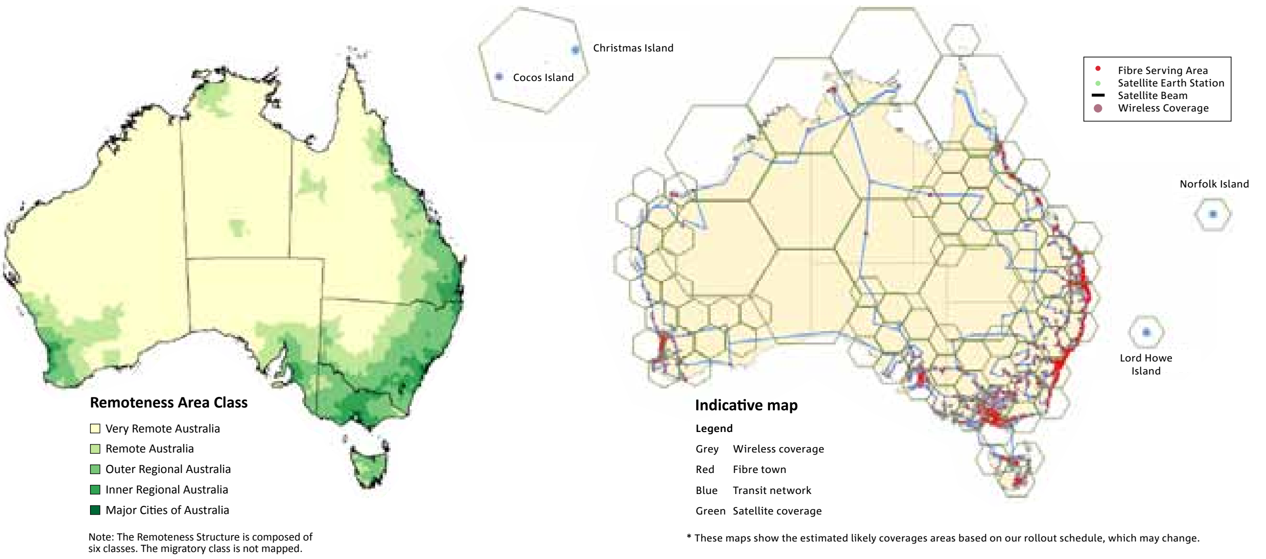

Figure 2 Left: Australian standard geographic classification of remoteness structure Source: Australian Bureau of Statistics: Statistical geography volume 1. Right: NBN Co's illustrative satellite footprint Source: NBN Co. 2010. Satellite Access Services – Product Overview.

Figure 2 highlights that those regions classified as remote or very remote by the ABS and with known poor health outcomes are the same part of the population that will be served with satellite broadband. Therefore, the features and differences between satellite communication and other kinds of broadband need to be taken into account when considering the development of telehealth applications and the services they can deliver.

FIBRE-OPTIC BROADBAND transmits information by sending pulses of laser light through an optical fibre. It is capable of sending extremely high volumes of data over long distances, but requires cables to be laid to transmit the signals.

WIRELESS BROADBAND transmits information using radio waves from antennae on fixed towers. The capacity of each tower is shared amongst all connections, and the signal strength fades with distance, so high data rates are possible with few connections, but is reduced when there are many connections, or at the edge of the antenna range.

SATELLITE BROADBAND transmits information using radio waves to satellites orbiting above the earth, which bounce the signal down to a satellite receiver. Most communication satellites are geostationary and remain in a fixed position orbiting above the earth. Satellite broadband is useful for very low population densities, as there are no infrastructure requirements other than a satellite dish for each connection point. However, the path travelled by the signal is much greater than for fibre-optic or wireless connections, which can result in signal delay or latency.

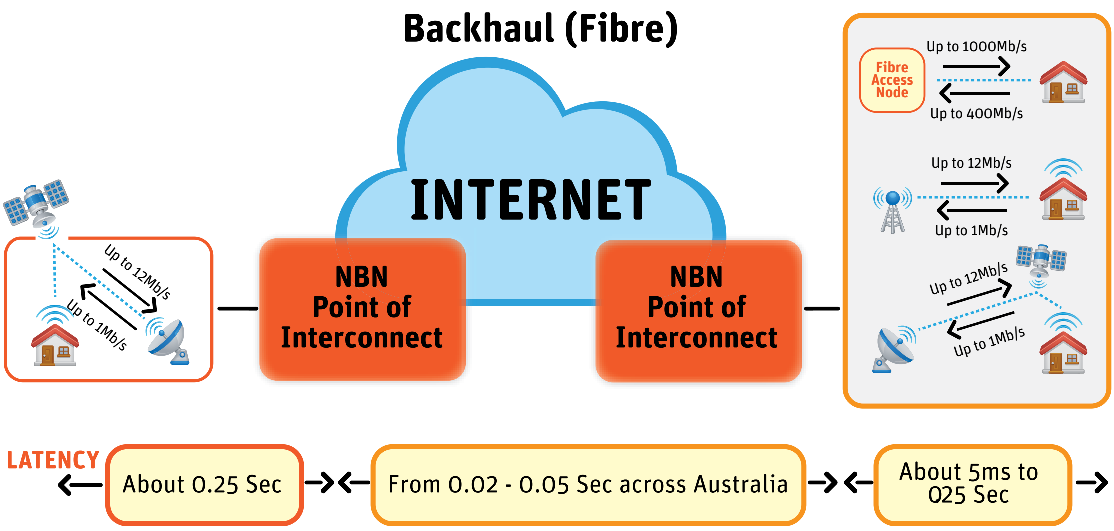

Figure 3 NBN configuration showing latency and bandwidth of fibre, wireless and satellite. Source: NBN Co. 2010. Satellite Access Services – Product Overview.

There are two main types of difference between fibre-optic, wireless and satellite broadband technologies. These are bandwidth, or how fast information can be sent, and latency, or signal time delay; both are shown in Figure 3. Whilst the bandwidth implications are fairly well understood, the differences in latency between these technologies and the implications for service delivery are not well researched.

BANDWIDTH defines the maximum rate at which data can be transmitted between source and destination points. In the planned National Broadband Network (NBN) architecture, downstream bandwidth (from the network towards the end user) is greater than the upstream bandwidth (from the end user into the network) (NBN Co, 2012). Bandwidth is generally determined by the signal transmitter and receiver design, and so is likely to increase as technology develops. For telehealth services with two-way information sharing, it is generally the lower upstream bandwidth that will set the limitations on the types of services that can be delivered. The upstream and downstream bandwidth from fibre connections will be much higher than from wireless or satellite connections.

LATENCY is the time delay for data to be transmitted between source and destination points. Latency has three elements; time to encode the data at the transmitter, time for the signal to be transmitted to the receiver, and time to decode the data at the receiver. For all three of the broadband technologies discussed, the signals travel at close to the speed of light. However, satellite signals have to travel much further which introduces additional signal delay. NBN's Long Term Satellite Service uses geostationary satellites at a height of about 36,000 km above the Earth. The distance introduces transmission latency of around 250 milliseconds (ms) (or a quarter of a second) from the ground and back for each satellite trip, as shown in Figure 3. This compares with around 5ms per 1000km of optical fibre. In comparison, the encoding and decoding latencies are around 20-25ms; depending on the complexity (satellite is usually the most complex). If both ends of a service are serviced by satellite, then there will be two 'hops,' and the latency will double (see Figure 3).

Unwrapping telehealth applications into service elements

Telehealth applications are specifically, developed for a medical domain or a process (E.g. ophthalmology or consultation) and are informed by the needs of the patients and practitioners. These applications can also be thought of as made up from a number of telehealth service elements, which are combined into an integrated service. Each telehealth services element enables a certain type of interaction or communication, such as file sharing, audio communication or video conferencing (Nepal, 2012). An application's sensitivity to bandwidth is generally determined by the element that requires the most information to be transmitted within the interaction time. On the other hand, sensitivity to latency is generally determined by the type of activity these telehealth elements are used for.

The reason that latency causes problems in service delivery is that human reaction time is around 200 – 250ms. Fibre and wireless broadband have latencies much smaller than human reaction time, and so latency does not pose a problem. Latency from geostationary satellites however is similar to human reaction times, and so becomes an issue for applications requiring interaction between the two ends of the connection where real time interactions are required. This could include the control of remote objects, or reacting in real time to communication such as video conferencing (ACBI 2012).

In Figure 4, we show a graphical framework for general interaction timescales and bandwidth requirements for the telehealth service elements we have identified (details in Table 1). Each element can operate in a range of interaction timescales, depending on its intended use. Videoconferencing, for example, can be used for low interactivity communication (two people having a general discussion) or high interactivity communication (multiple parties requiring empathetic responses).

The shaded area in Figure 4 indicates the realm where telehealth service elements might be possible over current satellite broadband. The telehealth service elements that fall within the dark green areas are those that are likely to give satisfactory performance over satellite. Those on the edges of the shaded areas are also suitable for satellite delivered applications but may have marginal performance, and so be useful in applications requiring lower interactivity timescales.

Table 1 - Telehealth services elements

◆ **Speech:** facilitates audio communication to multiple parties
◆ **Social media:** facilitates the use of Web 2.0 services (blogs, micro blogs, social networks, video sharing) to create and share user-generated content in order to promote collaboration between any combination of patients, caregivers, medical professionals, and others in synchronous and asynchronous modes.
◆ **Asynchronous Information Sharing store and forward:** facilitates the transfer of images, or clinical data between locations to be used at a later time.
◆ **Rich media sensor monitoring:** facilitates the transfer of images, or clinical data between locations in real time such as ultrasound and stroke care.
◆ **Simple sensor monitoring:** gathers patient data from remote measuring devices for interpretation.
◆ **Video Streaming:** facilitates transmission of video or audio data on demand. Live streaming streams content that is generated immediately from the source. Archived streaming facilitates streaming of previously archived data.
◆ **Low resolution video conferencing:** facilitates a two-way transmission of low resolution digitised video images between multiple locations.
◆ **Remote guidance:** facilitates the use of various telecommunications and electronic information processing technologies to provide individual guidance or direction.
◆ **High Resolution video conferencing:** facilitates a two-way transmission of high resolution digitised video images between multiple locations.
◆ **Immersive telepresence:** facilitates an interoperable, consistent, predicable and reliable collaboration experience close to direct human interaction through various telecommunications and electronic information processing technologies and three-dimensional visualisation.
◆ **Remote operation:** facilitates the operation of a device or machine in a synchronous mode from a distance through telecommunication and information processing technologies.

Bandwidth and interactivity

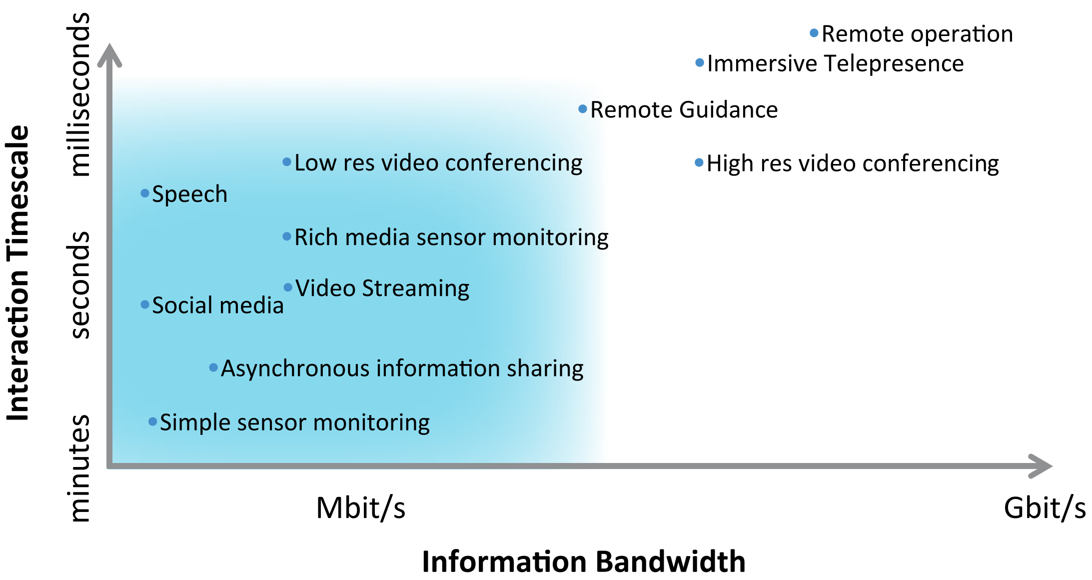

Figure 4 - Telehealth service element framework

Working with the framework

Telehealth services have the potential to provide timely, convenient and cost effective access to specialists, education, support and guidance to close the gap in health outcomes in remote Australian communities. The framework is a tool to be used when designing telehealth applications. It can inform the practicalities of including particular service elements into applications designed for delivery to remote Australia and encourage creative thinking about what elements could be used to create new services suitable for satellite delivery. To demonstrate how to use the framework, we look at examples of some current and potential new telehealth applications.

TELECONSULTATION

The Department of Health and Aging (DoHA) already supports telehealthcare services in the form of teleconsultations with specialists, through financial incentives and rebates. Applications designed for teleconsultations typically consist of a low resolution videoconferencing service element. Low resolution videoconferencing, according to our framework is typically achievable over satellite. Two factors further inform whether a teleconsultation can be satisfactorily achieved via satellite; the type of interactions expected (chat between two people, versus an emotionally charged therapy session) and the location of the participants i.e. remote to city connection or remote to remote, connection. The use of teleconsultation when more than one party is in a remote area is likely to be less satisfactory, The two satellite hops in each direction could lead to delays as high as one second, which have a very noticeable impact on the flow of a conversation

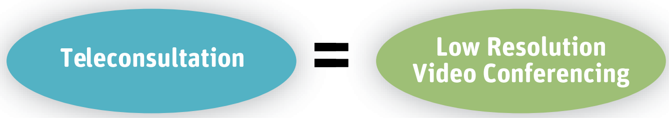

Figure 5 Telehealth service element combination for Teleconsultation

OFFLINE CONSULTATION

Offline consultations, also known as store and forward telemedicine, are a different form of consultation where patient details, medical information and images are collected in a face-to-face consultation with a local clinician or health worker, and transmitted as a package to a remote specialist for case review. The instructions on follow up actions are communicated to and carried out by the health worker. As an example of this application, CSIRO's Remote-i has been trialed to improve access to specialists for those in remote Australia with glaucoma, diabetic retinopathy and other eye diseases. The system transmits store and forward records about a patient's retinas to city-based ophthalmologists for analysis, who determine whether the patient needs to travel, or if they can supervise their ongoing care in their own community (Gliddon, 2011).

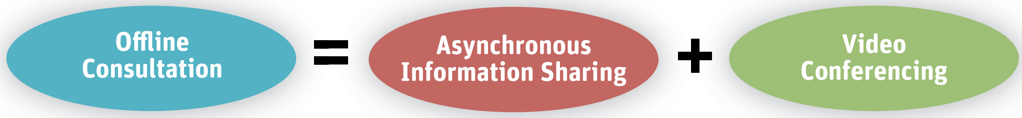

Figure 6 Telehealth service element combination for Offline Consultation

AUGMENTED CONSULTATION

Teleconferencing systems were designed for communication, not medical examinations. The effectiveness of teleconsultations would be increased enormously if other telehealth elements such as rich media sensor information sharing were used for real-time observation and analysis of objects in motion. Access to real time examination data such as video would enable more accurate and potentially earlier diagnosis to reduce the need for hospitalisations. Suitable domains include gait analysis, viewing an echocardiogram during a cardiology examination, wound care, or looking through the endoscope during an endoscopy procedure (Wootton 2006). In this case latency itself isn't a deciding factor but variations, in latency may show up as irregularities in the motion observed, which could affect the diagnosis. Our framework shows that elements suggested for augmented consultation are within the realm of what is possible to deliver by satellite, subject to application demands.

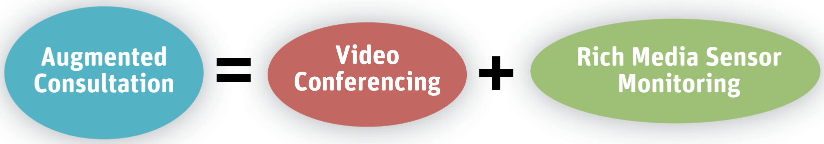

Figure 7 Telehealth service element combination for Augmented Consultation

TELEPRESENCE CONSULTATIONS

In applications such as those used for telepsychiatry, patient and practitioner requirements might suggest the inclusion of a teleconference element for consultation and social media for peer support and education. These types of telepsychiatry applications are in common use (Yellowlees, 2010).

The use of high quality video capture can enable real time analysis and response to triggers such as body language, expression, and mood in telepsychiatry applications. High resolution video conferencing is right on the edge of what is practical to deliver via satellite in terms of both latency and bandwidth, so careful consideration of their application usage would be required before being included. For example, clinician response to body language, expression or mood may require latency lower than typical current satellite broadband performance.

Figure 8 Telehealth service elements combination for Telepsychiatry.

HOME-BASED MONITORING

Home-based monitoring applications are of particular importance given Australia's aging population and the associated cost of the retiring baby boomers. Remote monitoring applications seek to manage risk (falls, illness, etc.) as well as supported health self-management, through information gathered from in-home sensors. Monitoring applications can also include elements such low resolution video conferencing, allowing communication with family and/or health care providers, and video streaming for health education purposes. Recent reports from the Total Systems Demonstrator trial in the UK claimed a 20% reduction in accident and emergency admissions and a 45% reduction in mortality rates [DHS London]. The technical requirements of these elements are suitable for satellite broadband delivery.

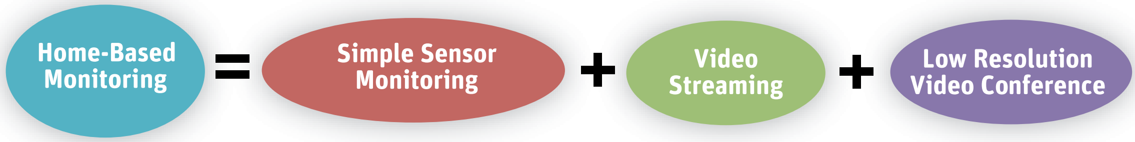

Figure 9 Telehealth service element combination for Home-Based Monitoring

REMOTE REHABILITATION

Remote rehabilitation applications deliver accredited rehabilitation programs to patients who are geographically remote from where services are offered. These applications monitor patient progress over a fixed duration with goals, feedback and mentoring. They aim to address the low uptake of rehabilitation programs currently observed, and facilitate monitoring without the need for patients to return to outpatient clinics (Varnfield, 2011). The telehealth service elements included in remote rehabilitation applications are similar to those in home-based monitoring applications. These include asynchronous information sharing and video streaming for patient education, speech for feedback and mentoring, and simple sensor monitoring to examine progress. Each of these components has relatively low interaction and bandwidth requirements, making them satellite friendly.

Figure 10 Telehealth service element combination for Remote Rehabilitation.

WORKFORCE REMOTE TRAINING

Telehealth can also enable onsite training and education for remote health workers. Elements such as remote guidance, video streaming and video conferencing can provide rich learning environments.

On site practical training and mentoring could be enabled through remote guidance. These applications allow off site specialists or trainers to guide local health workers in real time to conduct tasks using speech and hand gestures via wearable technologies and augmented reality video. As an example, CSIRO's ReMote guidance platform technology, is suitable for a range of applications, including health and mining (Alem and Huang, 2011).

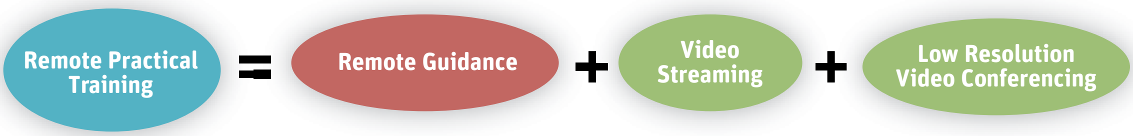

Figure 11 Telehealth service element combination for Remote Practical Training.

Video conferencing and *video streaming* could provide remote access to classroom-based training, such as seminars, specialists or discussions in real time from around the world.

Figure 12 Telehealth service element combinations for Remote Classroom Training.

Due to a high sensitivity to latency, applications using remote guidance and high definition video conferencing, require careful consideration if their intended delivery is via satellite. The tasks for which the telehealth element will be used will inform its feasibility over satellite. For example, guiding a health worker to use a piece of medical equipment has different interactivity requirements, than guiding them to carry out a medical procedure.

TELESURGERY

Telesurgery involves a practitioner carrying out a procedure on a patient when the patient and practitioner are in different locations (Anvari, 2005). Remote operation of medical equipment interacting with patients requires a rich perception of the remote environment, and very fast interaction and response timescales. Telesurgery typically combines remote operation, and immersive telepresence. Both of these service elements are well outside the range of current satellite performance due to their high interactivity and bandwidth requirements. This indicates remote operation is clearly unlikely to be satisfactory using either the current or envisaged technical capabilities of satellite broadband. Remote operation has been successfully achieved by the mining industry for industrial equipment, but required the laying of fibre cables over long distances in remote Australia to replace the satellite broadband service.

Figure 13 Telehealth service element combination for Telesurgery

Flexibility and the future

Australian ingenuity means that we expect new kinds of telehealth applications to be invented as we adapt to broadband availability. The framework here is intended to provide a flexible tool to enable creative thinking around the application of new services. We expect that through technological advancement telehealth applications will change, new service elements will appear and we will see creative uses of these and other elements in novel applications.

Bandwidth availability is likely to change over time. In parallel there is expected to be an emergence of more bandwidth hungry service elements. Latency, on the other hand, is largely determined by the laws of nature. Current latency is caused by the distance the signal travels to and from geostationary satellites orbiting 36,000 km above the earth, and is limited by the speed of light. Low earth orbit satellites would reduce latency significantly by reducing the distance a signal travels; if this technology became available, then the framework presented here can be easily adapted to this scenario by considering the revised latency against the interaction time scale boundaries required by service elements for satisfactory performance.

Human reaction times are also not going to change. Individuals tolerate some latency, but we require further research into tolerance for latency is required to identify the hard limits in varying contexts. Future effort into the use of using smart technologies and configuration of interfaces could see technology developments to compensate for some latency challenges to extend the window of possibility.

This framework has been provided as a tool to assist policy makers, service designers and providers in the development and implementation of telehealth applications to address the health gap in rural and remote Australia. This framework has shown how to unwrap a proposed application into its elements, and how these elements map against current technology constraints. We hope that this framework encourages creativity and innovation in the design of telehealth applications for the future of remote Australia.

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