



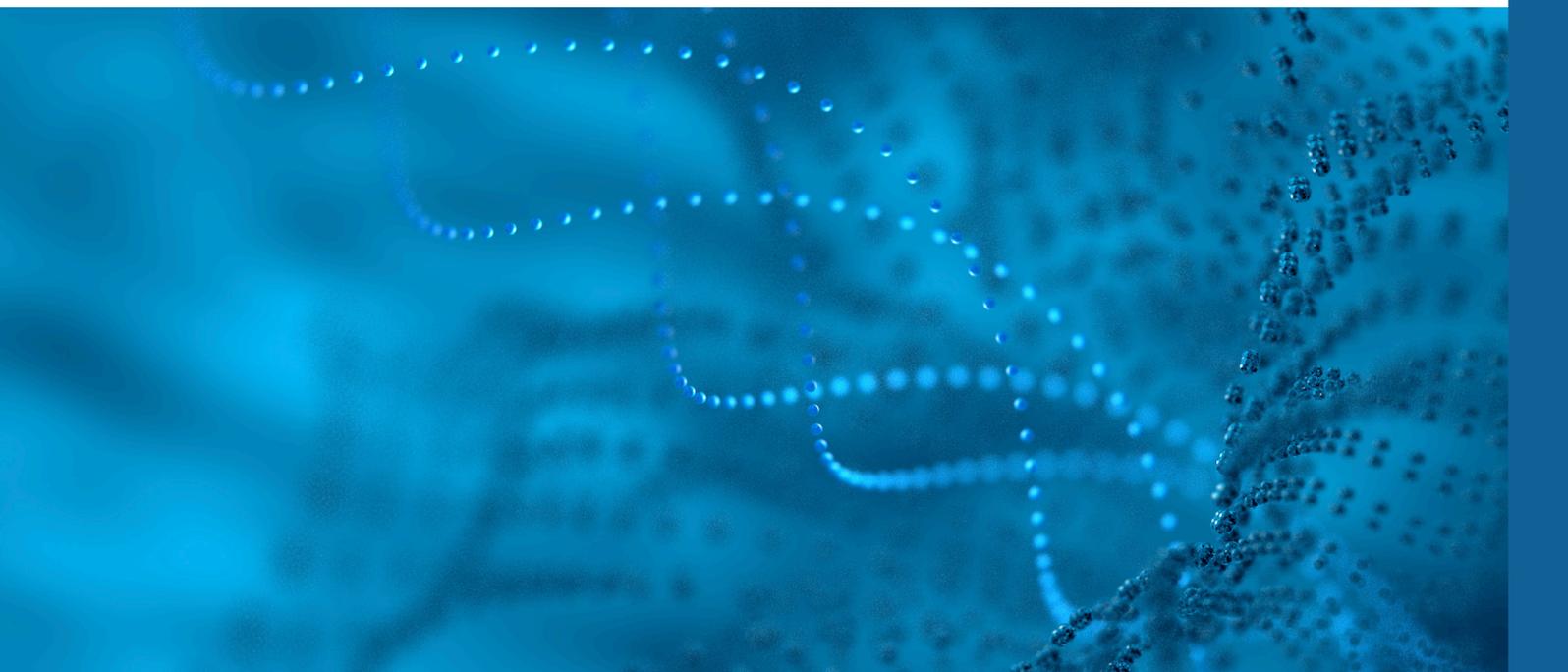
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# Health Provider Broadband Connectivity

A review of technical requirements



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## Executive Summary

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This review reports the findings of a literature review on data connectivity practices and requirements of healthcare organizations.

It forms the initial work of a joint project between the University of Melbourne and the Australian Centre for Health Innovation. The study is exploring the changes that may be necessary for Victorian healthcare organizations to enable more integrated planning and better coordinated provision of data connectivity arrangements so they can take advantage of high capacity broadband infrastructure.

The literature survey gathered over 70 documents describing technical requirements for e-health computer applications, drawn from scientific, government, academic and industry sources. Analysis of the studies revealed a diverse array of settings, methodologies and themes. Experimental or laboratory-based examples of network architectures figured widely, as did pilot studies set in limited real-world environments. Where a study described a clinical scenario, technical specifications were not always stated.

Overall, this survey found insufficient strong documentation to guide organizations adopting broadband-enabled health services. This suggests that further empirical study is required so that the answers to these questions will be revealed.

# 1 Introduction

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Health is one of the key industry sectors which could be transformed by the implementation of a high-speed broadband network.

There is recognition that existing healthcare practices will not be sustainable given the twin pressures of a limited health workforce and an increased demand for services due to the higher prevalence of chronic diseases as the population ages. Services will need to adopt smart electronic technologies that increase health workforce productivity and patient self-management, connect consumers and clinicians regardless of place, optimise hospital bed occupancy, and enable preventive screening in infant health centres, schools and aged care facilities. These technologies require high capacity data networks. The current rollout of national broadband infrastructure in Australia is directed in part to this goal.

Planning for broadband-enabled health services has to be informed by a comprehensive picture of current telecommunications network and data activities and arrangements in health provider organisations (HPOs). It's also essential to characterise the likely changes to these activities over the next five to ten years, and the health sector drivers for change, so that the implications for HPOs and network and data service providers are clear.

In industry and policy circles it is widely recognised that more integrated and better coordinated provision of connectivity will be crucial to support HPOs to take advantage of high capacity broadband infrastructure. However, to date almost no studies in the public domain have reported real-world research findings about network and data connectivity in health that could inform planning for this connectivity, as the sector moves toward the new kinds of service delivery that may be enabled by Australia's National Broadband Network and similar infrastructure elsewhere in the world.

For this discussion paper, we examined recent published literature, unpublished documents and other source material that was relevant to the topic, and have prepared a narrative summary, to describe available knowledge for current practice and identify apparent gaps.

## 2 Search Methods

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We sought publications which discussed the data connection requirements for exchanging health-related information over fixed or wireless networks either within or between healthcare organisations. Scenarios which described only mobile connections were excluded, as it was felt this is not representative of the Victorian healthcare organisations' setting.

### 2.1 Search Strategy

A selective literature review was carried out in the period December 2012 – March 2013.

Journal articles and conference papers were identified by searching a range of electronic databases using combinations of search terms and keyword phrases. The databases included major computing, science and health bibliographic and citation resources.

Search terms covered the concepts of:

- e-health or telehealth,
- broadband,
- data connectivity,
- computer infrastructure or networks,
- technical standards or protocols, and
- quality of service or network performance.

Two telehealth journals – *Journal of Telemedicine and Telecare* and *Telemedicine and e-Health* – were hand-searched back to January 2010 in order to locate any relevant articles that used broader terminology.

Industry reports, briefing papers, and government strategy documents were identified by searching grey literature and similar unpublished sources, also during December 2012 – March 2013.

In addition, advice on standards 'in development' was sought from the Technology Advisory Unit of the Department of Broadband, Communications and the Digital Economy. This proved useful in pointing to a Technical Standards Position Paper for telehealth from the Department of Health and Ageing.

A fuller outline of the search protocol is given in the Appendix.

The results pool was augmented by including relevant documents selected from the reference lists of retrieved items, and by identifying items citing key articles in the list.

## 2.2 Study Selection

To be included, items had to discuss:

- detailed technical requirements for health computer network infrastructure, or
- desirable standards for health data connectivity or transmission, or
- experimental technical configurations for a range of e-health applications, or
- quality of service or performance considerations in e-health networks.

A publication cut-off date of 2006 was chosen.

### 2.2.1 Exclusions

Items describing networks or applications in low-resource countries were omitted. Non-English language items were excluded. Article selection was not comprehensive; where multiple articles described similar applications (e.g. video streaming) then one representative article was chosen.

## 2.3 Data Extraction

The following information was extracted from each item: setting, jurisdiction, key themes, methods, and findings. The studies were not assessed for quality. Given the diversity of the source items, no synthesis was attempted, but we have analysed the main thematic sub-groups to identify similarities and differences.

A summary list of the included studies follows this section of the paper. The complete coded data for the items in the review is available in a separate data file, to accompany the web version of this paper.

### 3 Results

The searches located more than 125 items. Using the selection criteria, 75 were chosen for the final analysis. Of these, the majority were either small-scale experimental (laboratory) descriptions of specific network structures, or pilot studies assessing tools for single applications. Eleven items discussed national planning for e-health or for high-speed broadband application in health. Thirteen items covered quality of service or standards. Unhappily, discussions of clinical scenarios rarely included details of technical or data transmission aspects.

<b>Setting:</b>	Eleven settings were specified (business, community health centre, emergency room, experimental, home, hospital, international, military, nation-wide, rural, state-wide).
<b>Jurisdiction:</b>	A fifth of the items (15) discussed the Australian context; nine were based in the US
<b>Key themes:</b>	Discussion centered on ten main themes, as shown in Table 2.

Table 1: Characteristics of included studies

Theme	Number of items
Applications	24
Change Readiness	2
Current statistical data	1
Economics	4
Education	1
Informatics	1
National strategy	11
Network infrastructure	22
Quality of Service	7
Standards	6

Table 2: Distribution of themes in the items selected for review

A small number of items (e.g. Assaad 2006, Chapin 2010) described the various types of e-health traffic, with some including detailed requirements for high connectivity.

## 4 Discussion

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From the literature survey, it is clear that there is a wide range of health care services on the horizon that would benefit from high-speed broadband connectivity. The use of real-time data exchange (e.g. teleradiology, remote monitoring) has been shown to have a positive impact on health care, and uptake is increasing. Image transfer and real-time video consultation requirements need to be accommodated to provide equity of care regardless of location. Video streaming using off-the-shelf hardware can provide acceptable quality even over great distances.

However, current and future health services vary greatly in their connectivity needs. Some applications, especially those involving multi-media and video transmission, have complex connectivity and quality of experience requirements. High impact, high-priority, or time-critical traffic such as remote robotic surgery differs greatly from a store and forward application that needs minimal amounts of data transfer. While compression technologies can assist to optimise performance of image-based applications, the real-time *versus* non real-time nature of applications will also impose different requirements on connectivity.

There is a need for a detailed matrix describing the many modalities of connectivity (wired – fibre/Ethernet, wireless – 802.11 abgn/WiMax/other) and their relative expected performance parameters such as latency/delay, upload/download speeds, jitter, and packet loss. With such a matrix, it would be possible to match classes of healthcare data traffic to the required level of connectivity service. Traffic segregation into two or more levels has been proposed (in mission-critical settings such as disaster and military environments) to ensure that urgent, real-time traffic has guaranteed-delivery status.

Many of the documents identified during this review used a simulative or experimental methodology, indicating that the topic is still in early stages of development. With pilot and laboratory-based studies it is important to be aware of experimental assumptions or operating conditions that may not match “real-world” circumstances. Implementation would also have to take account of multiple, perhaps competing, perspectives.

## 5 Conclusion

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While this technical review has not identified many detailed descriptions of data connectivity arrangements or requirements for institutions adopting broadband-enabled eHealth, it has pointed to the range of relevant documents available in the public domain.

The review findings suggest that a comprehensive classification of current and future healthcare services in terms of connectivity requirements is lacking in the current literature. Such a classification will help understand the broadband connectivity requirements (bandwidth, throughput, real-time versus non real-time) for the future and the costs involved for healthcare practices.

## 6 Included Studies

Authors	Year	Title	Key themes	Methods	Findings
Vilaplana	2013	The Cloud paradigm applied to e-health	Network infrastructure; Quality of Service	Statistical modelling of cloud server requirements to meet defined e-health quality of service targets.	Used queuing system theory to show how a private cloud system could be scaled to manage varying amounts of traffic. 'Waiting time in the queue' was chosen as the QoS standard. The study lacks realistic detail on health workflows and data characteristics.
Australasian Telehealth Society	2013	Towards a national strategy for telehealth in Australia 2013-2018	National strategy	Industry expert panel	Proposes key strategies and enabling actions. Targets in connectivity are (a) identify network topologies to support networks for telehealth, including the National Broadband Network; (b) identify, promote current standards; show compliance of current telehealth products; (c) identify obstacles to interoperability between networks; foster conditions for national managed telehealth connectivity.
Communications Alliance Ltd	2012	Quality of Service parameters for networks using the Internet Protocol; industry guideline G632:2012	Network infrastructure; Quality of Service	Industry expert panel	With the NBN shift to fibre-based networks in Australia, network traffic is more sensitive to disruption by delays and similar faults. G632:2012 updates the industry guideline used by service providers to minimise quality-degrading factors such as delay, jitter and packet loss.
Alamri	2012	Cloud-based e-health multimedia framework for heterogeneous network	Network infrastructure	Simulation	Demonstrates a cloud computing framework that uses scalable video compression techniques to transmit high-resolution digital images such as those generated in teleradiology and telepathology. Simulation tests with 2 compressed videos (lung MRI and multislice CT scan) successfully transmitted files via cloud computing, suggesting this may be viable for sending patient videos over heterogeneous networks and devices.

Authors	Year	Title	Key themes	Methods	Findings
Australia Dept of Health and Ageing	2012	Telehealth technical standards position paper	Applications; Standards	Industry expert panel	Summarises the current and required standards to implement the telehealth services that are rebatable under the MBS at 1 July 2011. Includes telehealth clinical guidelines from peak medical bodies. Comments on gaps at the levels of infrastructure, videoconferencing systems and broader operations. Highlights interoperability between videoconferencing systems as a key obstacle to wider adoption of telehealth.
Australian Bureau of Statistics	2012	8153.0 - Internet activity, Australia, June 2012	Current data	Survey of internet service providers operating in Australia at 30 June 2012.	Internet subscriber numbers increased 10% in the past year to 12 million; almost half were using mobile handset broadband. These figures exclude mobile handset subscribers. Three quarters of the connections were at speeds between 1.5 Mbps - 24 Mbps. One in 8 connections were at higher speeds (25-100+ Mbps) and this sector showed much higher growth (20-35% increase since Dec 2011).
Barbier	2012	Near real-time echocardiography teleconsultation using low bandwidth and MPEG-4 compression: feasibility, image adequacy and clinical implications	Applications	Prospective study of 101 tele-echocardiography consultations over 12 months.	The compressed echocardiograms were transmitted on a low-bandwidth ADSL Internet connection to a remote consultant cardiologist, after conversion to digital format. Patient clinical details were sent separately as text files. Files for urgent cases (25% of the total) were sent in near real time, routine exam files were transmitted offline. Over 80% of the consultations were judged to have changed clinical case management. The study demonstrated successful use of video compression with low-bandwidth store and forward transmission of tele-echo image data, in contrast to usual protocols that use minimal compression and high-bandwidth connections.

Authors	Year	Title	Key themes	Methods	Findings
Chen	2012	An information technology framework for strengthening telehealthcare service delivery.	Network infrastructure	Proposal for a telehealth system architecture and network transmission model to streamline biometric data exchange between hospital and home.	The model adopts a multiple-layer design, using standards where possible, to enable integration of data from diverse systems and biometric devices. It uses Internet or 3G service networks to ensure portability and availability to patients' homes. Trial results from monitoring outpatients with heart failure or chronic disease over 9 months showed satisfactory uptake.
HealthShare NSW	2012	ICT Profile.	Applications; Strategy	Government strategic plan	Presents a 5-year plan for NSW Health's ICT development for e-Health. Predicts "hospital connectivity within zones" by June 2015; 'HealtheNet' for NSW by June 2018. Greater Western Sydney is the pilot site.
Ito	2012	Interactive multicentre teleconferences using open source software in a team of thoracic surgeons	Applications	Pilot test of sharing screen images to enable real-time consultation on thoracic surgical cases.	Four sites were connected via ethernet, WiMAX or ADSL for viewing multislice CT images and voice communication. The WiMAX connection was too poor for image sharing, but the other applications successfully displayed images and enabled team members to discuss each case.
Liu	2012	eHealth interconnection infrastructure challenges and solutions overview	Network infrastructure	A theoretical discussion of challenges in constructing a national e-health infrastructure.	A more detailed proposal than Liu (2011) on connecting diverse systems for a national e-health network. It presents solutions to issues of interoperability, security and quality of service guarantees. Details on feasibility or practicality are lacking.
Markarian	2012	Video distribution techniques over WiMAX networks for m-health applications	Applications	Simulation of video distribution over IEEE 802.16 networks for mobile health uses.	The experiment appears to show feasibility of video streaming over IEEE 802.16/WiMAX networks while meeting all Quality of Service standards. The article includes a service mapping scheme used for transferring m-health data over WiMAX networks, showing priority levels for classes of transmissions.

Authors	Year	Title	Key themes	Methods	Findings
NBN Co	2012	Corporate plan 2012-15	National strategy	Report issued 6 August 2012 to comply with statutory requirements.	Updates rollout and financial data since 2011. The current implementation has two traffic classes based on capability and performance: Class 1 commits to providing 'premium capacity' for real-time interactive applications such as voice which are sensitive to packet loss, while Class 4 offers 'best effort' capability aimed at browser-based apps such as email and web use. In 2013 NBN Co will introduce a third traffic class for business-specific applications (such as e-health) and a fourth class for networking.
Paulus	2012	Inexpensive, realtime tele-ultrasound using a commercial, web-based video streaming device	Applications	Pilot testing in real-time conditions.	Used off-the-shelf video streaming equipment to test transmission of 14 ultrasound images over distances from 3km to 4800sm. With a broadband internet connection, both the received ultrasound image quality and the delay were acceptable.
Ruthven	2012	A snapshot of Australia's digital future to 2050	Economics; National strategy	Report commissioned by IBM with input from an Industry Impact Panel (consultants at IBISWorld, Resilient Futures and IBES)	Attempts to forecast the effect of high-speed broadband on 13 key industries in Australia. Predicts that in health implementation of fast broadband will be transformative and is essential to prevent huge cost increases and to accommodate changing models of health care. The major part of the report looks at forecasts for individual industries.
Siraj	2012	Minimizing interference in wireless mesh networks based telemedicine system	Network infrastructure	Laboratory simulation of wireless network to test protocol that minimises interference	Throughput with the test AODV LBIARM protocol was greater - it creates quality links with fewer delays. Test bed implementation is required to assess practicality.
Ullah	2012	On the ambiguity of Quality of Service and Quality of Experience requirements for e-Health services	Quality of Service; Applications	Uses case studies in telesurgery and emergency (disaster) care to illustrate differing views of Quality requirements.	Demonstrates the weak subjective definitions used for QoS in e-health; argues users' <i>quality of experience</i> should also be specified. Recommends a detailed classification of e-health services to describe the acceptable thresholds of QoS and QoE for each service.

Authors	Year	Title	Key themes	Methods	Findings
Australia Dept of Broadband Communications and the Digital Economy	2011	#au 20: National digital economy strategy	National strategy		
Australia. Parliament. House of Representatives Standing Committee on Infrastructure and Communications	2011	Broadening the debate: Inquiry into the role and potential of the National Broadband Network	National strategy		
Bashshur	2011	The taxonomy of telemedicine	Informatics	Taxonomy development	Briefly outlines the scope of three domains: telehealth, e-health and m-health, but then concentrates only on taxonomy development for telemedicine. Describes functionality, applications and technical configurations as the defining dimensions for the telemedicine taxonomy. Within technology dimension, Bashshur identifies three sets of variables - synchronicity, network design and connectivity.
Budde	2011	Broadband: A platform for progress	National strategy		
Chowdhury	2011	Radio over fiber technology for next-generation e-health in converged optical and wireless access network	Network infrastructure	Experimental demonstration of a unified fibre and wireless network in a health setting	The test network architecture used optical and wireless radio-over-fibre technology. Successfully sent high-resolution pathology images to a remote terminal, demonstrating ultra low-latency real-time transmission of uncompressed super-high resolution images.
Courcoubetis	2011	Inter-carrier interconnection services: QoS, economics and business issues			
Hisatomi	2011	Data prioritisation mechanism for remote healthcare services	Network infrastructure		

Authors	Year	Title	Key themes	Methods	Findings
Jayasundara	2011	Australia's digital economy @100MBPS and beyond: the potential social and economic benefits from a next generation national broadband network infrastructure	Economics		
Kuo	2011	Opportunities and challenges of cloud computing to improve health care services	Network infrastructure	Survey of opportunities and challenges posed by cloud computing models.	The review highlights benefits and drawbacks in management, technology, security and legal aspects (many of which impinge on system performance and service quality). It proposes a model strategic plan for a healthcare organisation intending to migrate to cloud-based services.
Liu	2011	e-Health Service Characteristics and QoS Guarantee	Network infrastructure; Quality of Service	Specifies quality of service requirements needed to ensure e-health messages can successfully be transmitted across diverse systems in the US national e-health network.	This theoretical paper summarises the layers in an e-health network infrastructure, then lists QoS requirements for data communication, voice and data processing components. The authors propose a QoS management model to handle the elements in service guarantees.
Maeder	2011	Next generation telehealth: Working Group contribution	Applications; Standards	Review of telehealth adoption and forecast of future enabling factors.	Notes limitations in current telehealth adoption. Suggests that future take-up will be driven by a) improved ICT and interoperability of systems, b) new health care models and solutions to legal, ethical, clinical, usability issues, c) better evidence of benefit.
NICTA	2011	Telehealth infrastructure services: report by NICTA for Northern Territory Department of Health	Network infrastructure		
Rocke	2011	Gaps in telecommunications public policy: end to end service delivery in the NBN world.	National strategy		

Authors	Year	Title	Key themes	Methods	Findings
Shimizu	2011	Significance of telemedicine for video image transmission of endoscopic retrograde cholangiopancreatography and endoscopic ultrasonography procedures	Applications		
Swiatek	2011	Providing strict QoS guaranties for flows with time-varying capacity requirements	Network infrastructure; Quality of Service	Theoretical statistical modelling	Experimental results suggest flow control algorithms are efficient, but real-time scenarios may be more challenging.
Wamala	2011	Feasibility and diagnostic accuracy of Internet-based dynamic telepathology between Uganda and Germany	Applications	96 slides shared by dynamic telepathology between rural hospital and consultant pathologists in Germany.	The remote pathologists were able to manipulate the robotic connection; image quality was assessed as good; diagnostic consensus was > 90%; turnaround times greatly improved.
Wilson	2011	Potential telehealth benefits of high speed broadband	Applications	Workshops conducted with approx. 100 medical staff viewing low-grade and clinical-grade video consultations between doctor, patient and psychologist.	Participants felt more positive towards use of telemedicine if/when clinical-grade services are available, and identified many benefits to patients and practitioners.
Access Economics	2010	Financial and externality impacts of high-speed broadband for telehealth	Economics		
Alinejad	2010	Performance analysis of medical video streaming over mobile WiMAX	Applications		

Authors	Year	Title	Key themes	Methods	Findings
Chapin	2010	Ultra high connectivity military networks	Network infrastructure	Experimental analysis of a revised design for military networks.	Defines network connectivity as the fraction of messages that are delivered on time. In a military network, connectivity-centric applications have typically low data capacity requirements but high needs for reliable delivery. Describes a possible military network architecture with 2 separate services: one to handle high-connectivity messages, the other for more traditional high-capacity applications.
Chapman	2010	Teleconsultation roadmap - the path to telemedicine.	Applications		
Chowdhury	2010	Next-generation e-health communication infrastructure using converged super-broadband optical and wireless access system.	Network infrastructure		
Légaré	2010	Telehealth readiness assessment tools	Change readiness		
Panayides	2010	An overview of recent end-to-end wireless medical video telemedicine systems using 3G	Applications		
Skorin-Kapov	2010	Analysis of QoS Requirements for e-Health Services and Mapping to Evolved Packet System QoS Classes	Quality of Service	Classification of Data Flows;	QoS requirements for e-Health services are more complex than individual data flows. This paper maps applications to standard service requirements, taking account of the service context. A teleconsultation is considered as a case study.
Su	2010	Deployment of broadband wireless access for e-health in Chinese rural areas	Applications	Pilot project with Univ Southern Queensland using satellite and wireless technologies	VSAT and WiMAX successfully used to enable 'last mile' connectivity in remote mountainous Henan province.

Authors	Year	Title	Key themes	Methods	Findings
US Federal Communications Commission	2010	Connecting America: the national broadband plan. Chapter 10: Health	National strategy		
Van Hoecke	2010	Design and implementation of a secure and user-friendly broker platform supporting the end-to-end provisioning of e-homecare services	Applications	Developed and tested a platform to integrate e-homecare service modules into one interface.	The prototype platform increases usability of e-homecare services, as it uses one sign-on, presents tailored applications and shields users from confusing interfaces. Users rated it highly for quality of experience.
Wang	2010	Hybrid network combining PLC and IEEE802.16 for hospital environment	Network infrastructure		
Wilson	2010	Telehealth on advanced networks	Applications	Four hospital-based high-speed broadband projects are described.	All 4 projects successfully enabled high-quality communication, real-time access to clinical data, and patient interaction with clinicians, in complex settings (e.g. resuscitation). Wilson attributed their success to the fact that each case arose from user-driven requirements. Noted that leased lines were used for some of the projects.
Communio	2009	Broadband for health evaluation report	National strategy		Prepared for Australian Department of Health and Ageing.
Istepanian	2009	Provisioning for medical quality of services for HSPDA and mobile WiMAX in healthcare applications.	Quality of service		
Khan	2009	Survey of challenges in hybrid optical wireless broadband network (HOW-B) for e-health systems.	Network infrastructure		
Kyriacou	2009	An overview of recent health care support systems for e-Emergency and mHealth applications.	Applications		

Authors	Year	Title	Key themes	Methods	Findings
Maeder	2009	Telehealth standards directions for new models of care.	Personal health records; Standards	Describes a framework of technical and application elements in telehealth.	Notes that retaining a 'clinician-oriented' viewpoint of telehealth services may restrict development of new models of telehealth care (e.g. multiparty teams) and hinder adoption by other specialties. Describes work by Standards Australia IT-14-12 subcommittee on a technical and application framework for telehealth, using two rural scenarios: home-based health monitoring and personally-held health records.
Niyato	2009	Remote patient monitoring service using heterogeneous wireless access networks: Architecture and optimization.	Network infrastructure	Theoretical statistical modelling	Calculates the bandwidth or connections required to transmit continuous biosignals from a remote mobile patient back to the healthcare institution. Also models the scheduling of signals according to priority.
Shimizu	2009	One hundred case studies of Asia-Pacific telemedicine using a digital video transport system over a research and education network.	Applications; Quality of Service	Case studies; proof of concept	The 100 telemedicine sessions linked multiple sites to transmit video images over the Asia Pacific Advanced Network (research & education consortium). One quarter were live surgical or endoscopic procedures, the others were videoconferences. Reported bandwidth was 30 Mbps per channel. Participants assessed > 95% of images were good or very good quality. The standard configuration for the digital video transport system does not use an image compression process.
Zvikhachevskaya	2009	Quality of Service consideration for the wireless telemedicine and e-health services.	Quality of Service; Standards	Simulation of data delivery in e-health emergency scenarios	Tested the IEEE 802.11 wireless standard as a platform to guarantee QoS. When experimental ambulance data flows are prioritised, average delay is greater (due to waiting time for a channel free to transmit urgent data). When greater bandwidth is available, less threshold is needed.
Brennan	2008	Visioning technology for the future of telehealth.	Applications		
Chattopadhyay	2008	A framework for assessing ICT preparedness for e-health implementations.	Change readiness		

Authors	Year	Title	Key themes	Methods	Findings
Garguilo	2008	Medical device communication: a standards based conformance testing approach.	Applications		
Grechenig	2008	Challenging interoperability and bandwidth issues in national e-Health strategies by a bottom-up approach: Establishing a performant IT infrastructure network in a Middle East state.	Applications		
Huo	2008	eHealth for hospital environment: Incorporating IEEE802.16 and HomePlug AV standards	Standards	A theoretical hybrid network proposal using wireless to connect physical sites, with a HomePlug AV network for in-hospital data delivery.	The IEEE802.16 broadband wireless network connects hospital buildings. The HomePlug network is used for connecting different services in one building; it avoids interference with in-hospital devices, while offering potential speeds of 200 MBps. The proposal integrates Quality of Service for the hybrid network by use of a QoS broker. Four classes of medical data traffic are listed, with their optimum data rates and delay requirements.
Lam	2008	Telemedicine deployments within NATO military forces: a data analysis of current and projected capabilities	Network infrastructure		
Salehi	2008	E-health applications implementation considerations	Applications		
Tracy	2008	Critical steps to scaling telehealth for national reform	National strategy		
American Telemedicine Association	2007	Core standards for telemedicine operations	Standards	Consensus guideline (practitioners and industry)	The ATA Telehealth Standards are statements of principle in the domains of administration, clinical practice and technical issues. These statements define best-quality services, but have no detail on the specific technical requirements.

Authors	Year	Title	Key themes	Methods	Findings
Baardsgaard	2007	The Scandinavian Health Network: Connecting the Scandinavian countries' health networks	National strategy; Network infrastructure	Academic thesis, with industry input.	Examined health network infrastructure in Denmark, Norway and Sweden to determine whether a Scandinavian Health Network was technically feasible. Concluded that significant work would be required to harmonise infrastructure before the networks could be inter-connected. Probably limited application for Australian setting at this time.
Geissbuhler	2007	The RAFT network: 5 years of distance continuing medical education and tele-consultations over the Internet in French-speaking Africa.	Education		
Hossain	2007	IEEE 802.16/WiMAX-based broadband wireless networks: Protocol engineering, applications, and services.	Network infrastructure		
Martínez	2007	Users Dimensioning and Traffic Modelling in Rural e-Health Services	Applications		
Nakashima	2007	Development of a broadband telemedical network based on internet protocol in the Asia-Pacific region	Network infrastructure		
Niyato	2007	IEEE 802.16/WiMAX-based broadband wireless access and its application for telemedicine/E-health services	Network infrastructure; Standards		
Schneider	2007	Wireless live streaming video of surgical operations: an evaluation of communication quality	Applications	Wireless LAN used to transmit audio & video from theatre	Showed feasibility of spontaneous mobile videoconsultation using a PDA. Accuracy of image recognition was fair, though improved to 80% if viewed on a 50cm screen.
Vergados	2007	Simulation and modeling bandwidth control in wireless healthcare information systems	Network infrastructure; Quality of Service	Simulation of a proposed adaptive wireless network architecture for e-health services to guarantee quality of service.	The proposed architecture for multi-class Quality of Service provision in wireless connections successfully managed prioritisation and degradation policies. It allocated network resources for each application according to these policies, achieving good performance over the entire scheme.

Authors	Year	Title	Key themes	Methods	Findings
Assaad	2006	General hospitals network models for the support of e-Health applications	Network infrastructure	Simulation	Explored a range of network models for three general hospitals in Ontario. Simulations were conducted with different network configurations to support nominal and peak traffic for database access, HTTP, FTP, email and videoconferencing. The assessment of results is based on performance rather than cost.
Babulak	2006	Quality of service provision assessment in the healthcare information and telecommunications infrastructures.	Quality of service		
MacDonald	2006	Development of a universal interface between medical devices, IT and communications systems with an associated secure data distribution network.	Laboratory; Theoretical	Simulation	
Martinez	2006	Application parameters optimization to guarantee QoS in e-Health service.	Quality of Service		
Martinez	2006	Performance Evaluation of Rural e-Health Scenarios: Users and QoS Management	Quality of Service		

## 7 Appendix – Search Protocol

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A scoping search in early December 2012 tested the precise phrase “**health data connectivity**” in four broad databases: Scirus, Scopus, Web of Knowledge and PubMed. This phrase retrieved fewer than ten items altogether, and demonstrated the need to expand the range of search terms and resources. The full search covered the resources and terms shown below.

### 7.1 Databases

- Compendex (Engineering Village)
- Computers & Applied Sciences Complete (via EBSCO)
- Google Scholar
- IEEE Xplore
- Medline (in PubMed)
- Scirus (Elsevier)
- Scopus (Elsevier)
- Web of Knowledge (ISI)

### 7.2 Search terms and phrases

#### 7.2.1 MeSH Terms:

- computer communication networks (NT internet)
- quality of health care (NT quality assurance, health care)
- telecommunications (NT telemedicine)

#### 7.2.2 Keywords:

- broadband
- clinical grade
- data connectiv\*
- e-Health and variants (ehealth, e health)
- health data
- interoperab\*
- medical grade
- network performance
- protocol
- quality of experience
- quality of service
- technical standard
- telehealth and variants (teleconsultation, teledermatology, telemedicine, telemental, telemonitoring, telenursing, telepathology, telepsychiatry, teleradiology, telesurgery etc.)

\* Keywords were truncated to include variant endings.

Selected items were in English, and were published from 2006-2012.

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