



STANDARDS RESEARCH

The Active Assisted Living Landscape in Canada

Insights for Standards, Policies, and Governance

May 2019

Authors

Laura Xavier Fadrique, University of Waterloo

Dia Rahman, University of Waterloo

Plinio Pelegrini Morita, University of Waterloo

Advisory Panel

Paul Boissonneault, Champlain Local Health Integration Network (LHIN)

Plinio Pelegrini Morita, University of Waterloo

Tania Donovska, CSA Group (Project Manager)

Michael Wilson, CSA Group

Hélène Vaillancourt, CSA Group

Contents

Authors	2
Advisory Panel	2
Executive Summary	7
1. Introduction	9
2. Our Process	9
3. The AAL Technology Landscape	10
3.1 What is AAL Technology?	10
3.2 The Use of AAL Technology around the World	11
3.2.1 AAL in the United States of America	11
3.2.2 AAL in Europe	12
3.2.3 AAL in Japan and South Korea	13
3.2.4 AAL in Canada	13
3.3 Standards for AAL Technology	13
3.4 Platforms and Frameworks	14
3.5 AAL Data Sharing and Data Governance	14
3.5.1 Open Data Landscape in Canada	16
3.5.2 Canadian Health Data Sharing and Storing Practices	17
4. Gaps in the AAL Innovation Ecosystem	17
4.1 End User and Purpose	18
4.2 Accessibility	19
4.3 Interoperability	20
4.4 Data Sharing	20
4.5 Privacy and Security	21

5. Future of AAL Technology In Canada	22
6. Conclusion	23
Appendix A – Relevant Standards	26
6.1 Design and Terminology	26
6.1.1.1 ISO 13485 – <i>Quality Management Systems—Requirements for Regulatory Purposes</i>	26
6.1.1.2 ISO 20282 – <i>Ease of Operation of Everyday Products—Part 1: Design Requirements for Context of Use and User Characteristics</i>	26
6.1.1.3 ISO 9241 – <i>Ergonomics of Human-System Interaction</i>	26
6.1.1.4 ISO/IEC 40500 – <i>Information Technology—W3C Web Content Accessibility Guidelines (WCAG) 2.0</i>	27
6.1.1.5 Logical Observation Identifiers Names and Codes (LOINC)	27
6.1.1.6 ISO 13482 – <i>Robots and Robotic Devices—Safety Requirements for Personal Care Robots</i>	27
6.2 Communication and Transport	27
6.2.1.1 ISO/IEEE 11073 (x73) – Personal Health Device (PHD) Family	27
6.2.1.2 Wi-Fi	28
6.2.1.3 WiMAX – Worldwide Interoperability for Microwave Access	28
6.2.1.4 IEEE 802 Local Area Network (LAN)/Metropolitan Area Network (MAN) Standards	28
6.2.1.1 ISO/IEEE 11073 (x73) – Personal Health Device (PHD) Family	28
6.2.1.2 Wi-Fi	28
6.2.1.3 WiMAX – Worldwide Interoperability for Microwave Access	28
6.2.1.5 ZigBee	28
6.2.1.6 Z-Wave	28
6.2.1.7 Bluetooth and Bluetooth LE (Low Energy or Smart)	29

6.2.1.8 Transmission Control Protocol (TCP/IP)	29
6.2.1.9 User Datagram Protocol (UDP)	29
6.2.1.10 Message Queuing Telemetry Transport (MQTT)	29
6.2.1.11 MQTT-SN – MQTT for Sensor Networks	29
6.2.1.12 Constrained Application Protocol (CoAP)	29
6.2.1.13 Universal Plug and Play (UPnP)	29
6.2.1.14 Smart Spaces and Smart Objects Interoperability Architecture (S3OiA)	29
6.2.1.15 Devices Profile for Web Services (DPWS)	30
6.3 Privacy and Security	30
6.3.1.1 Secure Sockets Layer (SSL)	30
6.3.1.2 X.509	30
6.3.1.3 ASTM E1869 – <i>Standard Guide for Confidentiality Privacy Access and Data Security Principles for Healthcare Information Including Computer-Based Patient Records</i>	30
6.3.1.4 IEEE 1888.3 – <i>IEEE Standard for Ubiquitous Green Community Control Network: Security</i>	30
6.3.1.5 ISO/IEC 29100 – <i>Information Technology—Security Techniques—Privacy Framework</i>	30
6.3.1.6 ISO/IEC 29101 – <i>Information Technology—Security Techniques—Privacy Architecture Framework</i>	31
6.3.1.7 ISO/IEC 20889 – <i>Privacy Enhancing Data De-identification Terminology and Classification of Techniques</i>	31
6.3.1.8 ISO/TR 12859 – <i>Intelligent Transport Systems—System Architecture—Privacy Aspects in ITS Standards and Systems</i>	31
6.3.1.9 ISO/IEC 29134 – <i>Information Technology—Security Techniques— Guidelines for Privacy Impact Assessment (PIA)</i>	31

6.3.1.10 ISO 25237 – <i>Health Informatics—Pseudonymization</i>	31
6.3.1.11 ISO/IEC 24745 – <i>Information Technology—Security Techniques—Biometric Information Protection</i>	31
6.4 Data Content	31
6.4.1.1 Health Level-7 (HL7)	31
6.4.1.2 Fast Healthcare Interoperability Resources (FHIR)	32
6.4.1.3 Extensible Markup Language (XML)	32
6.4.1.4 Hypertext Transfer Protocol (HTTP)	32
6.4.1.5 Simple Object Access Protocol (SOAP)	32
6.4.1.6 Representational State Transfer based (RESTful)	32
6.4.1.7 JavaScript Object Notation (JSON)	32
6.4.1.8 Web Services Description Language (WSDL)	32
6.4.1.9 Digital Imaging and Communications in Medicine (DICOM)	33
6.4.1.10 ASTM E2369 – <i>Standard Specification for Continuity of Care Record (CCR)</i>	33
7. Acknowledgements	34
8. References	35

Executive Summary

Every Canadian has a friend or loved one who is aging or is dealing with mobility issues, mental health issues, or a chronic disease. Aging populations continue to be a major concern for governments and health care systems around the world. To support independent living for aging populations, researchers and innovators have been exploring the use of wearables, sensors, and mobile health technologies to improve their quality of life.

One possible solution to promote independent living and enable aging and vulnerable populations to maintain a high quality of life is the use of Active Assisted Living (AAL) technology. A wide range of such technologies are available on the market to support people in their daily lives. AAL technologies are concepts, products, and services that combine new technologies and the social environment to improve quality of life in all stages of life. The AAL environment can integrate assistive technologies, smart homes, and telehealth using multi-sensors to gather data and monitor individuals in their homes.

Canada is not alone in facing a growing aging population; Canada does, however, lag compared to other countries in the use of AAL technology. Countries in Europe and Asia are at the forefront of developing and deploying large-scale solution platforms. Europe has the most advanced programs for leveraging AAL technology. Japan, with the world's oldest population, is one of the most advanced countries in the development and adoption of AAL technologies, with research focused on the creation of robots to support their aging population.

The focus of this report on AAL technology is on devices connected to the Internet that enable the collection and exchange of data that can be used for health monitoring or to enhance the quality of life of individuals. This report describes the standards and policy guidelines being used in the creation of AAL technologies in Canada and highlights the gaps between what is currently available for innovators and what is necessary for AAL technology. It presents the results of a literature review to identify key standards and frameworks related to AAL technology; the results of 15 interviews from stakeholders across Canada; and the discussion of these results in two workshops about AAL standards and policies and governance.

This report demonstrates that standards to support the development of base technology necessary for the creation of AAL technology is not a major challenge. The main issues are related to non-technical areas of technology development (e.g., user-centred design, privacy, purposeful design), as well as the integration between the existing technologies. The gaps identified were grouped into five themes:

- (1) the user and purpose;
- (2) accessibility;
- (3) interoperability;
- (4) data sharing; and
- (5) privacy and security.

All five theme areas identified opportunities where standards and guidelines can make a significant contribution to AAL development. Governance and data usage policies are necessary to ensure the integrity and accuracy of the data generated and consumed in this field. Improvements in education and awareness of existing AAL technologies are necessary to support the development of trust in the technology, ensure user privacy, and increase adoption. Interoperability is currently the biggest technological challenge for AAL technology data sharing, and most stakeholders consider privacy and security to be the main areas of concern related to data sharing in the AAL landscape.

1 Introduction

Aging populations are a growing concern for governments and healthcare systems in industrialized countries. As the aging population grows at a pace higher than the working age population, these countries face significant problems such as population decline, losses in economic productivity and output, and an increasing proportion of GDP spent on healthcare and pensions.¹ Apart from an increase in operational costs, economic decline, and the aging population, countries also face many uncertainties regarding quality of life and the independence of vulnerable populations.

In 2012, approximately 14% of the Canadian population over the age of 15 reported having a disability² and as of 2016, 5.9 million seniors lived in Canada.³ It is projected that about 23% to 25% of the overall Canadian population will fall within the senior range by 2036.⁴ Given the increasing proportion of older individuals in our society, it is imperative that solutions be implemented to support and extend independent living and quality of life. One possible way to enable aging and vulnerable populations to live as independently as possible within their own home for as long as possible, while maintaining an adequate quality of life is by using Active Assisted Living (AAL) technology.

AAL is an umbrella concept describing technologies that are designed to improve quality of life, bring independence, and enable healthier lifestyles for those who need assistance in any stage of life. It employs Information and Communication Technologies (ICT) combined with the environment to provide easy-to-use devices in the home and outside the home environment.⁵ As is the case with many novel technologies developed for the consumer-level market, AAL technologies are not subject to the rigorous design and evaluation protocols required for medical devices. While providing benefits to the user (e.g., step tracking, heart rate monitoring, etc.), the same users may be left with pockets of data spread across different databases owned by device manufacturers. When using a fitness tracker, for example, users have access to the information that is deemed important by the manufacturers (e.g., aggregate or average number of steps, calorie expenditure, heart rate). However, users and other

innovators often have limited access to the raw and unprocessed data when it could potentially be integrated with data coming from other sensors and technologies at home to provide a more comprehensive view of the user's health. While some companies are developing data sharing solutions to address these issues (e.g., Apple HealthKit® and Samsung Health®), there is still a long road ahead before achieving full interoperability.

This report explores some of the challenges faced by innovators working with AAL technology in industry, government, healthcare institutions, and academia. More specifically, it provides innovators in the AAL space with information about the standards that are currently available, along with insights into the current gaps that are not supported or guided by standards.

2 Our Process

The knowledge provided in this report was developed through a literature review, technology market exploration to identify available technologies, and interviews with stakeholders in the AAL ecosystem (e.g., researchers, healthcare and industry decision makers, and AAL technology users). These stakeholders were interviewed to:

- 1) develop a better understanding of the AAL ecosystem;
- 2) better understand data sharing requirements;
- 3) determine what standards are available and being used by innovators; and
- 4) identify gaps where standardization could help.

The literature review explored key standards and specifications related to the design, communication, security, and data generated by AAL technology. Academic databases and non-academic sources were both explored in this project, focusing on standards, platforms, and frameworks related to AAL technologies. A review paper by Memom et al.⁶ served as a starting point, as well as a guide to understanding the terms used in the literature. Standards related to medical devices and their related safety were excluded from the scope of the project as there are existing regulations in place and many standards exist to support the development of these devices.

Over 50 contacts involved with AAL technology were invited to participate in interviews and workshops.ⁱ Contacts were selected for being part of the following groups of stakeholders:

- 1) academics;
- 2) researchers;
- 3) industry representatives;
- 4) healthcare providers;
- 5) health IT professionals; and
- 6) provincial government executives.

Interviews and workshops took place between December 2017 and July 2018. The interviews and workshops followed a semi-structured format, where guiding questions were used to ensure that a consistent dataset was collected from each interview participant. The workshops were designed with the same guiding questions, supporting a similar evaluation framework.

3 The AAL Technology Landscape

The data-driven technology known as the Internet of Things (IoT) has been scaling within various industries over the last two decades. Such technology has transformed industrial practices by increasing analytics capabilities and changing the ways businesses and organizations serve and work with their targeted users and clients. The global IoT market is projected to grow from \$157 billion in 2016 to \$457 billion by 2020, a compound annual growth rate (CAGR) of 28.5%.⁷

The hospital-oriented healthcare industry has also seen exceptional growth. Healthcare and life sciences industries are projected to grow from \$520 billion in 2014 to \$1.335 trillion in 2020 globally, a CAGR of 17%. According to the Market Pulse Report on Internet of Things (IoT) published by GrowthEnabler, three sub-sectors are projected to dominate the global IoT market:⁸

- 1) Smart Cities (26%);
- 2) Industrial IoT (24%); and
- 3) Connected Health (20%).

IoT can enable remote patient monitoring, and it can also help providers find better ways to deliver care and support research through patient-generated data (PGD).⁹ PGD is defined as health-related data pertaining to a health or chronic condition that has been “*created, recorded, gathered, or inferred by or from patients themselves or their designees*”.

While there are early IoT adopters in various industries and the scope of healthcare IoT is scaling at a rapid rate in other parts of the world, Canada has not seen a similar significant shift in healthcare. The rules and regulations pertaining to healthcare IoT are still forming in North America and, given that IoT devices gather, store, and share patient-related data, there are big risks associated with this data exchange. Significant gaps still exist regarding the implementation of privacy and security features in healthcare IoT and AAL technology.

3.1 What is AAL Technology?

The terms “active assisted living” and “ambient assisted living” are sometimes used interchangeably. This research report follows the terminology defined by the International Electrotechnical Commission (IEC) Systems Committee on AAL (SyC AAL), which defines AAL as “active assisted living” technology.¹⁰ For the scope of this report, AAL technology will be considered as:

All technology, devices, and wearables connected to the Internet, that enable the collection and exchange of data, and are used for health monitoring or to enhance the daily life of individuals.

AAL technology overlaps with a broader concept called assistive technologies (AT) which refers to “*any item, piece of equipment, or product system, whether acquired commercially, modified, or loop customized, that is used to increase, maintain, or improve functional capabilities of individuals with disabilities*”.¹²⁵ In other words, AT can be any tool or device capable of assisting a person to achieve something that would not be possible without the support of the technology.¹²⁶ Wheelchairs, walkers, electrical jar openers, screen readers, hearing aids, and educational software are all examples of assistive technology found in society.

ⁱ Reviewed and approved by the University of Waterloo Research Ethics Board – ORE#22561



“AAL Technology: All technology, devices, and wearables connected to the Internet, that enable the collection and exchange of data, and are used for health monitoring or to enhance the daily life of individuals.”

Technology can play an important role in improving quality life for an aging society, or for assisting individuals in performing activities of daily living (Figure 1). AAL support systems for the elderly in industrialized countries help them live a healthier and better quality of life.¹⁰ Highlighting the importance of this technology, in November 2006, the International Medical Informatics Association (IMIA) approved the creation of a new workgroup on smart homes and AAL.¹¹

The AAL ecosystem can integrate assistive technologies, smart homes and telehealth, multisensors for gathering data and monitoring individuals in their homes, individual health/wellness trackers, and homecare-based ambient trackers.¹² It is designed to assist users during everyday activities by embedding ambient intelligence (Aml) into home environments.¹³ Aml applications are transparent and invisible for users, while security and privacy requirements are guaranteed.¹⁴ With dementia and Alzheimer's disease a growing concern in Canada, there is more emphasis on the use of technology to improve the overall quality of life of patients living with these conditions.

3.2 The Use of AAL Technology around the World

AAL technology markets in the United States, Europe, South Korea, Japan, and Canada were examined for this report due to the aging populations, socioeconomic status, and healthcare structure of these countries. Further, AAL initiatives in these countries are interconnected and interdependent, as many have been developed through international research collaborations.

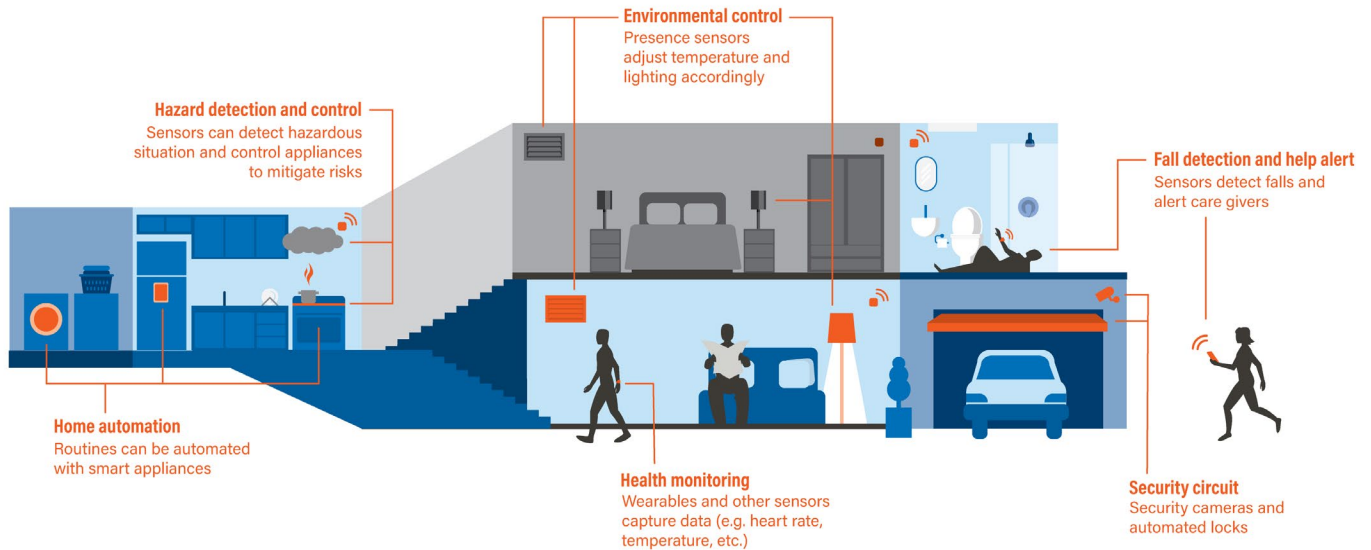
Multiple levels of AAL technology integration within the healthcare systems of these countries demonstrate a **strong relationship between the technologies and the policies required for wide-scale deployment of AAL technology**. Countries such as the United States showcase very successful deployments in siloed health systems, which are funded mostly by private insurance, while Japan takes a more universal approach to AAL technology.

3.2.1 AAL in the United States of America

Significant opportunities exist for localized AAL technology deployments in the United States through healthcare resources and funding from the private sector and private insurance plans. Given the privatized nature of the US healthcare system, healthcare insurance plays a significant role in making AAL technology available to patients. AAL technology is currently being tested in various small clusters in private home care settings in the US as well as being pilot tested by not-for-profit organizations focused on delivering care to older adults.¹⁶ In 2017 alone, approximately one million Americans lived in active-assisted home care facilities.¹⁶

Although privatized health systems and insurance providers have the capacity to scale up the use of AAL technology, the lack of knowledge and understanding about the benefits of AAL to quality of life usually limits the uptake of this technology to more educated seniors in the population. Concerns related to how the data is used and how securely the data is handled are the main

Figure 1: Examples of AAL technologies and their insertion in the home.



concerns from users, which has severely impacted the widespread use of this technology. This scenario reinforces the importance of well-established, transparent data-sharing policies.¹⁷

3.2.2 AAL in Europe

The standardization of AAL technologies and services at a market level is most advanced in European countries, where significant research has taken place in the field over the last 10 years. Research efforts have ranged from the development of new technologies, sensors, and supportive technology to the science related to implementing these novel technologies directly into the healthcare system.¹⁸ Europe is beginning to leverage lessons learned and deploy technologies developed in research programs into the healthcare system through projects like “ReAAL.” The ReAAL project was created with the goal of publishing standards, guidelines, and platforms as interoperable solutions that can help with active and independent living.¹⁹ The European Union (EU) funded the Service Oriented Programmable Smart Environments for Older Europeans (SOPRANO) project, which focused on building an AAL platform and ecosystem for older people based on an

extensible and open platform using innovative technologies. The €11.7M SOPRANO project (2007-2010) included 20 partner countries including Canada, Greece, Germany, the United Kingdom, the Netherlands, Spain, Slovenia, and Ireland.²⁰ Finally, the €700M AAL Programme (2008-2020) was introduced by the European Commission to facilitate research in innovative ICT-based services for aging well using a collaborative research approach.²¹ The AAL programme involved 17 countries and aimed to “create better quality of life for older people and to strengthen industrial opportunities in the field of healthy ageing technology and innovation”.

The EU has addressed data privacy through the General Data Protection Regulation (GDPR), which will be pivotal in shaping the industry practices for AAL technology. The main goals of the GDPR are to ensure data privacy laws across Europe are homogeneous, protect and empower all EU citizens’ data privacy, as well as change how organizations at various levels handle issues related to data privacy. This regulation is having a great impact on the overall practices of the AAL technology industry by promoting more user control and ownership of personal data handling.²²⁻²⁷

3.2.3 AAL in Japan and South Korea

Japan has one of the world's oldest populations, with more than a quarter of the population being over 65 years.²⁸ Due to an ongoing population decline over the last few decades, Japan must address how it will tackle the complexities associated with an ever-growing older population. AAL technology has presented itself as an ideal solution to support independent living. The country has allocated significant funds to research and development of certain types of AAL technology such as robotics and smart homes.²⁹ The Prime Minister of Japan allocated £14.3 million in 2013 from the national budget to develop robots to help with elderly care. One of the most well-known robots in Japan is called Paro, a therapeutic robot that was designed to care for elderly people with Alzheimer's disease and dementia. The robot acts to calm people when they are in distress and provide comfort to its users by reacting like a pet while being stroked. This technology has been shown to encourage socialization of older adults as well.³⁰

South Korea has been going through a similar process as Japan, given that its economy, demographics, and overall strategy around providing tools for its aging population is very similar.^{31,32}

3.2.4 AAL in Canada

AAL technology use in Canada has been primarily limited to research and development. While there is significant potential for improving care delivery within the current healthcare ecosystem, AAL deployments and integration with the Canadian healthcare system are still in the early stages. AAL technologies that have been explored in Canada include a combination of smart home, telehealth-based, and assistive technologies.³³ The use of technologies such as alarms and personal response systems have been relatively low.³⁴ Geographical isolation, combined with a low population density in rural or remote communities, presents socio-technical challenges that limit the expansion of the AAL market in these areas. Further, the AAL technology market is fragmented across ten provinces and three territories, with more than 100 different health authorities. This fragmentation contributes to low adoption rates compared to other countries.^{12,35,36}

While Canada lags in AAL technology deployment and use compared with other countries, opportunities exist to encourage more widespread adoption. Canada's involvement in the European AAL Programme,³⁷ in particular the membership of four Canadian research programs (Canadian Institutes for Health Research (CIHR) Institute of Aging, CIHR Institute of Health Services and Policy Research, AGE-WELL Networks of Centres of Excellence (NCE), the Canadian Frailty Network), will serve to advance this objective.³⁸

3.3 Standards for AAL Technology

Standards are used by companies in the planning, development, and production of new products and technologies. They often define minimum requirements for safety and performance of products. Without standards, interactions between products would be inconsistent and processes would not be defined and secure, which could create security- and safety-related risks.³⁹

For instance, the International Electrotechnical Commission (IEC) created a Systems Committee, called IEC SyC AAL, with the goal of developing standards for AAL technology that could keep the aging population as active as possible in the comfort of their own home.¹⁰ This committee's main objective was to create a roadmap and develop standards for AAL systems and services that ensured: (1) safety; (2) security; (3) privacy; and (4) interoperability. Additionally, IEC SyC AAL strives to ensure that users are prioritized when combining concepts, products, services, and systems. User domains are defined according to levels of assistance^{10,40} and the committee focuses on addressing gaps similar to those explored in this report.

CSA Group defines a standard as "a document that sets established benchmarks for businesses to use in developing products and processes."¹²⁷ Comparatively, IEEE Standards Association describe standards as "published documents that establish specifications and procedures designed to maximize the reliability of the materials, products, methods, and/or services people use every day."¹²⁸



Several other technology-oriented standards available in the literature were reviewed and selected based on their relevance for AAL technology.^{6,41,42} Relevant standards and protocols were categorized into the following four groups according to their respective areas of focus:

- **Design and terminology** - standards defining terminology and processes related to design, modelling, and planning (e.g., ISO 9241, *Ergonomics of Human-System Interaction*);
- **Communication and transport** - standards focused on reliable and independent information in transmission (e.g., 6.2.1.1 ISO/IEEE 11073 (x73) - Personal Health Device (PHD) Family and ZigBee);
- **Privacy and security** - standards that define administrative, physical, and technical actions to protect the confidentiality, availability, and integrity of information (e.g., ISO/IEC 29100, *Information Technology—Security techniques—Privacy Framework*); and
- **Data content** - standards that address data transfer and data format, usually using existing communication protocols (e.g., the FHIR (Fast Healthcare Interoperability Resources) Specification).

A comprehensive discussion of what is addressed in these standards is presented in Appendix A – Relevant Standards.

“Innovators working with AAL technology have collaborated to develop platforms and frameworks to combine standards and guidelines into a single ecosystem”

In addition to standards, protocols are also necessary and are defined as a set of rules or procedures for electronic devices sending and receiving data. Protocols are made of pre-existing agreements on how the information will be structured and transmitted between the parties.¹³⁰

3.4 Platforms and Frameworks

Innovators working with AAL technology have collaborated to develop platforms and frameworks that combine standards and guidelines into a single ecosystem. The overall purpose is to facilitate the integration of products and technologies that are within the scope of AAL. The table on page 35 shows some of the platforms and frameworks available within the AAL ecosystem.

3.5 AAL Data Sharing and Data Governance

Data governance is the framework that organizations follow to manage, store, and use data securely.⁵² Data governance, especially in healthcare, focuses on structuring an organization-wide framework for retrieving, storing, managing, and using health-specific information throughout the lifecycle of data.⁵² Best data-specific practices for collecting, updating, modifying, deleting, moving, storing, and utilizing data within the healthcare sector highlight the importance of patient security and privacy.⁵²

Table 1: Platforms and Frameworks Available Within the AAL Ecosystem.

Platform/Framework	Description
Continua ^{43, 44}	<ul style="list-style-type: none"> Continua Design Guidelines⁴³ were developed through a consensus process to ensure the safe, secure, and reliable exchange of data to and from personal health devices. Developed by not-for-profit Personal Connected Health Alliance (PCHAlliance) with the goal of making personalized healthcare and telehealth a reality. Design guidelines are built upon four key principles: <ol style="list-style-type: none"> 1) authentic interoperability (minimal effort from the user to ensure connectivity); 2) an open source development model (the design guideline is universally accessible, non-proprietary, and not-for-profit); 3) flexibility (maximum choice for developers and end users such as healthcare buyers, individual clinicians, and consumers); and 4) wisdom of the market (market itself as a whole has more wisdom and information than just an individual stakeholder). Design guidelines focused on the Personal Area Network (PAN) and Electronic/Personal Health Records Network (xHRN) interfaces.⁴⁴ The PAN interface describes the connection between PAN devices (i.e., sensors and actuators) and application hosting devices (AHD), such as mobile phones, PDAs, computers, and set-top boxes. The xHRN interface describes the connection between back-end services (i.e., wide area network (WAN) devices), such as electronic/personal health records (health record devices).
DACAR ⁴⁵	<ul style="list-style-type: none"> Oversees the use of digital technologies, eHealth services, service integration, large scale deployment, security, integrity, and confidentiality. Allows a single point of contact (SPoC) through a novel rule-based information sharing policy syntax and data buckets that are hosted by cloud infrastructure. The platform is scalable and cost-effective and allows secure capture, storage, and consumption of sensitive healthcare data. Being tested in a clinical environment in Europe.
PERSONA ⁴⁶	<ul style="list-style-type: none"> The objective is to develop sustainable and affordable solutions for the independent living of senior citizens. The platform is intended to be scalable to build a broad range of AAL services. A number of AAL services have been implemented over the platform to demonstrate, test, and evaluate this type of technology's social impact and scenarios. Supported by the European Commission.
UniversalAAL ⁴⁷	<ul style="list-style-type: none"> A middleware platform for AAL. The software architecture was built on the Open Services Gateway initiative (OSGi), which enables a complex system to be built with small modules using specific functionalities that can be scaled depending on the specific needs of the users. Tested by users and caregivers in Spain and UK, with promising functionalities that combine good usability and accessibility for physical, sensory, and cognitive purposes.
Microsoft HealthVault ⁴⁸	<ul style="list-style-type: none"> A platform to support the collection, storage, use, and sharing of health information for users, family members, and care providers. Allows devices such as pedometers, blood pressure monitors, and weight scales to work with HealthVault while allowing user access to health information in a single location. Sensors can be connected to HealthVault to automatically upload the data and users can share health information with others.
Cisco Umbrella ⁴⁹	<ul style="list-style-type: none"> Delivers cloud-based network security and threat intelligence for any device that is connected to its cloud. Platform employs predictive intelligence to remain proactive on possible emergent threats by re-routing every internet connection through proxies or VPN gateways.
HealthTap OS ^{50, 51}	<ul style="list-style-type: none"> Offers a platform in the form of an operating system that envisions to replace various software, tools, and even paper forms being used in hospitals. The goal is to centrally manage patient records, appointments, medications and lab prescriptions. This platform would help providers connect with patients through smartphone applications.
Apple HealthKit	<ul style="list-style-type: none"> A platform is available to iPhone users to collect and aggregate health data collected via wearables and apps that are installed or synced with the users' iPhones. Provides a standardized framework for the storage and sharing of data, giving users control over data access and integration. Anonymized data can be made available to researchers through an added framework like ResearchKit.



“Great potential can be derived from the combination of multiple datasets from different domains.”

In Canada, the responsibilities for supporting healthcare services are shared among provincial, territorial, and federal governments. Provincial and territorial governments manage, organize, and deliver health care services to their residents, while the federal government is responsible for developing and administering national principles of care for the healthcare system. Funding is allocated to support provincial and territorial health care services, and to oversee the delivery of healthcare services to special groups. Examples of these groups include First Nations living on reserves and serving members of the Canadian Armed Forces. Support is also provided for other health-related functions such as pharmaceuticals, cosmetics, chemicals, etc.⁵³

3.5.1 Open Data Landscape in Canada

The world is shifting from a knowledge-based economy to a data-driven economy. The value and insights generated by data grow with the availability of data and great potential can be derived from the combination of multiple datasets from different domains. For example, traffic data can be an excellent resource for individuals developing asthma-related interventions, as traffic-based pollution is a significant trigger for asthma. The Canadian government needs to consider different sectors of the data-driven economy as individual parts of an interconnected domain.⁵⁴

In health information systems, data currently comes from electronic medical records, provincial data repositories, and personal health platforms. From a technical perspective, the data stored in various databases should be easily accessible through secure application programming interfaces (APIs). However, many data repositories available in the market lack the capacity to be integrated due to:^{55, ii}

- 1) a lack of common data standards in healthcare;
- 2) an absence of interest from companies to open their systems to other initiatives due to proprietary algorithms (i.e., intellectual property – IP), market protectionism (i.e., their technologies all work with other products of their own lineup), or corporate disagreements (e.g., lack of integration between Fitbit and HealthKit); and
- 3) a lack of governance guidelines related to data ownership. The inability to fully share, access, and understand health information data costs society and the current healthcare system significant time and money.

3.5.2 Canadian Health Data Sharing and Storing Practices

The *Personal Information Protection and Electronic Documents Act (PIPEDA)* is the “federal privacy law for private-sector organizations. It sets out the ground rules

⁵⁴ Results for the National Digital and Data Consultation were not available at the time this report was issued.

for how businesses must handle personal information in the course of commercial activity”.⁵⁷ The Office of the Privacy Commissioner of Canada (OPC) is responsible for ensuring PIPEDA is properly applied in industries throughout Canada.⁵⁷

On a global scale, the new General Data Protection Regulation (GDPR) in Europe, released in May 2018, has stricter rules on data protection⁵⁸ compared with the Canadian legislation. The GDPR echoes the issues surrounding personal data protection around the world. For example, the new data portability right is relevant to consumer protection and consumer choice, providing users with more control over their own data. The GDPR will likely influence the future of PIPEDA in Canada, providing more direction and guidance about data governance for health innovators, particularly for AAL technology data sharing. This same effect has already been observed in other standards. For example, with respect to Fast Healthcare Interoperability Resources (FHIR),⁵⁹ guidance has been provided on how to implement the GDPR requirements within the HL7 – FHIR electronic health records interoperability standards.⁶⁰

Patient-generated data governance is still a novel concept in Canada, with several areas still undefined. The Canadian Institute of Health Information’s (CIHI) *Better Information for Improved Health* report⁶¹ outlines existing weaknesses that still need to be addressed by the Canadian healthcare system:

- priorities and a future roadmap for how to handle patient-generated data;
- information gaps and types of information that should be prioritized to help guide new policies;
- new policies under development that can be supported by quality data; and
- business incentives for the use of secondary data, especially when leveraging existing investments and avoiding redundancy in efforts made by different groups or agencies (e.g., e-Health investments for direct patient care such as virtual care visits).

4 Gaps in the AAL Innovation Ecosystem

Several issues were identified and discussed in the interviews and workshops that were conducted as part of this report. In total, 11 stakeholders participated in the first workshop, 10 stakeholders participated in the second workshop, and 15 additional stakeholders were interviewed. The participant contributions, in addition to the literature review, served to define the gaps that are described in this section. These gaps represent opportunities to develop standards to guide the AAL innovation ecosystem in Canada.

As previously stated, AAL technology in this report refers to non-medical devices and wearables connected to the Internet that enable the collection and exchange of data and that are used for healthcare monitoring or enhancing the daily lives of individuals. Several issues were raised by participants in the discussions:

- Many challenges are not related to the base technologies themselves, but occur when integrating multiple technologies or applying technologies to specific health issues such as dementia or cognitive impairment.
- Technology evolves very quickly and innovation is an ongoing process. Guidelines on the use of specific technologies might consequently become obsolete after a short period of time.
- Many technical standards and protocols (e.g., ZigBee, Z-Wave, Bluetooth, ISO/IEEE 11073, and those listed in Appendix A) currently exist or are in development.
- Existing standards from IEEE, ISO, and IECⁱⁱⁱ address basic technology requirements, hardware and devices, APIs, and the middleware necessary for developing AAL technologies.
- Various organizations are developing frameworks to combine existing standards and provide guidance. For example, IEEE 2413, *Standard for an Architectural Framework for the Internet of Things (IoT)*, is a unified approach to the development of IoT systems, and ISO/IEC JTC 1/SC 41, *Internet of Things and Related Technologies*, addresses sensor networks and wearables technologies.

ⁱⁱⁱ It is recommended that the use of international standards be reviewed by the appropriate Canadian body to determine the relevance and the need for national deviations, as applicable.



Existing standards and frameworks, and those in development tend to address specific areas of functionality such as base technology, hardware or middleware.⁶² Other areas are largely unaddressed and represent gaps for future standards development. Given that the technology is evolving at a rapid pace, most gaps and opportunities for standardization lie in the non-technical components of AAL technology design, such as: (1) human interfaces; (2) processes and methods; (3) common vocabulary; and (4) social and cultural aspects of technology use (Figure 6). For example, common vocabulary or terminology is one of the most important factors that will help consolidate the AAL domain. An interview participant confirmed this as a major issue as the AAL acronym can either be defined as “ambient assisted living” or “active assisted living” in different communities. Other terminology issues, such as the stigma associated with the word “assisted” or terms that vary in meaning across cultural domains, require thoughtful consideration.

“Standards and guidelines should not choke innovation. [We] must achieve a balance between them to keep things on track and not create bureaucracy.”

- Interview participant

“Most gaps and opportunities for standardization lie in the non-technical components of AAL technology design.”

An analysis of the discussions among stakeholders resulted in the emergence five themes: 1) end user and purpose; 2) accessibility; 3) interoperability; 4) data-sharing; and 5) privacy and security. These themes align to work by François Coallier⁶² as represented in Table 2.

4.1 End User and Purpose

User engagement and user-centered design are widely accepted concepts in the development of new systems and technologies. These concepts should also apply to AAL technology development, where there is greater potential for impact on peoples’ lives and independence and freedom at home is a desired outcome of an AAL solution.²¹ It is important to understand that the concept of “end users” within the AAL spectrum is not limited to patients, older adults, people with disabilities, or people with specific health deficiencies. Users also include therapists, healthcare providers, physicians, and family members who support the daily routine by using AAL technology. Ensuring the data is understandable, accessible, and useful while making the technology simple to use, is a challenge that requires a strong focus on user-centered design (Figure 2).⁶³

Interviewed stakeholders raised the issue of insufficient end-user consideration in the development of AAL technologies. Including the end user in the early design stages is critical to increasing the acceptability of technology, and essential for avoiding unexpected user

Table 2: Summary of gap areas in the AAL standards space versus common areas covered by technical standards according to François Coallier⁶²

	Social & Cultural	Vocabulary	Process & Methods	Human Interface	APIs & Middleware	Hardware & Devices	Base Technology
End User & Purpose	✓		✓	✓			
Accessibility	✓		✓	✓			
Interoperability		✓			✓	✓	✓
Data-Sharing	✓		✓		✓	✓	✓
Privacy & Security	✓	✓	✓	✓	✓	✓	✓

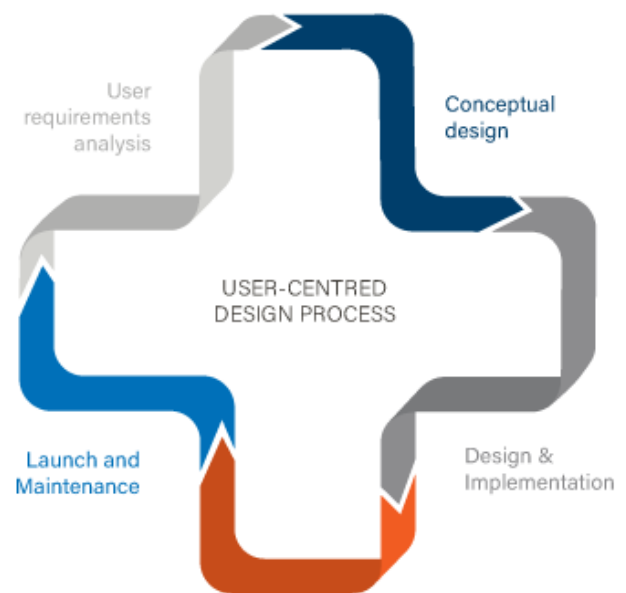
experience conflicts.³⁴ This is especially important when end-users are older adults as some of them may have limited technical expertise when handling modern devices, applications, equipment, and other infrastructural components. Cognitive, perceptual, or physical limitations of users also require special attention in design.⁶⁴ Gathering end-user feedback throughout the technology development process is critical for the creation of user-friendly technologies that integrate seamlessly with existing needs in the users' lives.

"Not enough consideration [of] the end user."
 - Interview participant

AAL technology also needs to be solution-focused and designed with the final technological purpose built in as a design principle. Some interview participants raised the concern that a significant portion of AAL technology available on the market was not originally designed to solve a clinical problem; rather, existing technology was adapted to work in a healthcare application.

*"... findings show that older people, as end users, are able to contribute in the mock-up design stage in the development of a fall detection device, by indicating what really matters to them."*¹²⁹
 - Interview participant

Figure 2 - The user-centered design process.



4.2 Accessibility

The ability to access and use the technology regardless of ability is an essential aspect of AAL technology. Along with the previous theme (end user and purpose), accessibility must be addressed in the early stages of design to develop an inclusive technology. Accessibility was a recurring challenge identified by stakeholders and the word "accessibility" appeared as one of the major gaps related to standards and guidelines within the scope of AAL technology. A lack of accessibility leads

to a decrease in the acceptability of the devices because the technology is not developed in an inclusive way.

It is important to note that most smart home wearable users and other IoT devices are technology enthusiasts and early adopters who readily accept new devices and systems. The population served by AAL technology lies at the other end of this spectrum. This population is comprised of individuals with little to no knowledge about IoT and wearables or what is available in the market, yet who have real needs and vulnerabilities and are in need of assistance. Such assistance could be provided through the use of products currently available in the market that can be adapted to individual needs. In other cases, the support required by a particular individual may demand changes in the original product to meet the specific requirements of each individual. Interviewees and workshop participants emphasized the importance of encouraging manufacturers to make their products more accessible to specific and minority audiences despite possible increases in manufacturing costs.

“Opening up for standardized device data exchange, as mandated by the Continua Alliance, does not imply that systems become more open for sharing applications and algorithms.”⁶

- Interview participant

4.3 Interoperability

A lack of interoperability between AAL technologies is one of the predominant challenges identified both through the literature review and by the interview participants. In an ecosystem where communication between devices is essential to provide services and assist users, interoperability should be a critical

“Accessibility is inherently built into the product. Focus on user, accessibility and design.”

- Interview participant

requirement of all products. However, the reality is that technologies are created in silos in which each vendor has its own solution that is typically not directly compatible with solutions from other vendors.

Several of the standards, protocols, and frameworks presented in this report strive to address this problem. However, without regulation and a centralized international standard, manufacturers risk adopting one solution to the exclusion of others, thereby limiting integrative capabilities to devices following the same protocol. Additionally, systems may be interoperable from a technical point of view, but manufacturers may opt to keep their data within their own platform to guard proprietary algorithms and data from competitors. Consequently, opportunities for innovators to develop solutions and algorithms that combine data from other manufacturers are often lost due to data isolation.

“The freedom of the individual patients for choosing the data-handling strategy has yet to be addressed by the AAL vendors, especially industry, as well as the freedom of choosing the AAL applications and services they want to use, rather than being handled as a silo package.”⁶

- Interview participant

The challenges of interoperability are not limited to data or technical challenges. User expectations and costs pose significant challenges that must also be taken into consideration.⁶⁵ Some solutions addressing interoperability are currently under discussion, such as the Unify-IoT project in Europe, which supports the idea that standardization can help break down vertical silos in industry. IEC SycAAL also intends to develop standards to allow interoperability between suppliers of AAL products, services, and systems.¹⁰

“How do we encourage manufacturers to make their products very accessible?”

- Interview participant



4.4 Data Sharing

Personal data is currently being collected 24-hours a day by smartwatches, smartphones, wearable devices, IoT technologies, and smart homes. AAL technology aims to collect even more data from individuals through monitoring devices and then use that data to enhance quality of life. The process of sharing these data between devices in a standardized format is one of the biggest challenges for AAL technologies. Most devices do not communicate effectively with each other due to a lack of interoperability. Even when devices are developed using the same technology, data exchange is not guaranteed due to differing data models and data exchange protocols. Further, varying terminology, a lack of transparency and limited control over the use of one's own data limit user confidence in data sharing activities, which consequently limit the adoption of AAL technologies.

"The ability of technologies to capture, analyse, and share data makes them a powerful tool in supporting people's health and well-being."

- Interview participant

Standards such as the ISO/IEEE 11073 "Personal Health Data" family address the interoperability of personal health data and provide a standardized way to send and receive data between different types of devices. These standards work to ensure that the data is exchanged in

"Users are often unaware of where the data is being sent, where it will be stored, what the benefit is for the user to share that data, and who will have access to the data."

a format that is understandable for both sides in a structured way, known as "syntactic interoperability". Other standards and protocols offer similar benefits and are widely used within the healthcare domain, including the HL7/FHIR protocols, which should be adapted for use by AAL technology.

"Most IoT devices [have] poorly implemented encryption or [no] encryption at all. You are limited to what is already available in the market."

- Interview participant

A unified vocabulary would help users and innovators understand what data is being stored, irrespective of the vendors or technologies being used. This would also improve accessibility by presenting data to the end user in an understandable way, without the need for technical or specialized knowledge.

"It is the responsibility of the product owner to acknowledge the fact that they collect the information for specific reasons."⁶³

- Interview participant

Transparency remains a major concern for data sharing and is a barrier to adoption. Mobile apps provide a good example of the lack of transparency and awareness about the use of collected data. Apps often work as a black box and individuals are only able to use the

application if they accept all terms and conditions for use. There is generally no option to provide access to a partial list of variables. Further, users are often unaware of where the data is being sent, where it will be stored, what the benefit is for the user to share that data, and especially who will have access to the data. Ultimately, the end user should own their data and have the right to know what is being collected, who is using the data and how, and the benefits of the data being collected. Vendors should improve the way they communicate with individuals about data use and assume the responsibility for transparency.

Education and awareness about the importance of having control over one's own data is an important step to empowering users. Having the option to opt out at any time from their data sharing agreements and deciding who they want to share their data with will help protect their personal information. Users must also be educated on the implications of providing access and delegating ownership to family members or caregivers, concerns that relate to privacy and security.

4.5 Privacy and Security

The collection of data through smart devices is ever growing, and there is a corresponding concern for user privacy and security breaches. The concern is even greater when dealing with older adults, especially those with disabilities and cognitive impairments.

Security concerns range from technical issues – whether devices are protected against viruses, hackers – to ensuring devices are designed and developed using the best algorithms and encryption available. Identifying and analyzing IoT's distinct security and privacy features, including security requirements, vulnerabilities, threat models, and countermeasures from the AAL technology perspective is essential.⁶⁶

*"Some companies (IT) don't have the expertise in medical devices. And medical device companies don't have expertise in security – cybersecurity."
- Interview participant*

Many manufacturers working to create new solutions targeting older adults do not have the security and privacy expertise to understand the security issues inherent in AAL or IoT-based healthcare. Additionally, a lack of a unified authentication process or system means that each device has its own, isolated authentication process. The multiple instances in which end users identify themselves create opportunities for vulnerabilities, adding insecurity to the process.

The design purpose of a device can also affect security. Devices that serve more than one purpose run the risk of being under-designed for security and privacy. For instance, a smart thermostat such as the ecobee™ thermostat is primarily designed and implemented to measure and control the temperature inside a house. This platform was not designed as a technology for public health surveillance or health monitoring of vulnerable individuals. If used for such purposes, security and privacy requirements may not necessarily align with existing requirements for the protection of personal health information.

In addition to security concerns, issues surrounding anonymity, ownership, and transparency must be considered to ensure adequate privacy in IoT. According to the European Commission, if privacy and security were ensured, 80% of EU citizens would agree to share their health data.⁶⁷ Innovators must ensure that the data collected will be properly anonymized and will not pose a potential risk to the end user, such as compromised employment or health insurance in the event of data leak. Further, clarity must be sought on who owns the data at the moment it is shared. Data ownership is a complex issue considering that data can move from the user's smartphone, to company storage, or to physician records. Finally, a transparent process should be applied for security and privacy. Trust of AAL technologies will only be achieved with proper end-user education, clear communication and accessible presentation of policy agreements to the end user. Without trust, the adoption of AAL technology in Canada may not reach its full potential.



“A data governance legal framework based on the principles of transparency and accountability is needed in Canada, especially in relation to health system use of data generated by AAL technologies.”

5 Future of AAL Technology in Canada

Canada’s aging population will make AAL technology a necessary innovation in the coming years, not just as a new market trend, but as a solution to improve and prolong quality of life and independence. For this reason, it is important to continue investing in products and solutions to meet market needs and to address the issues described in this report. This project emphasizes five areas that represent major challenges for current AAL technologies; these include end user and purpose, accessibility, interoperability, data sharing, and privacy and security.

An analysis of these challenges highlights several areas for improvement, with associated opportunities for the future development of supporting programs for AAL technology. These areas of focus represent the areas and initiatives that require further development before AAL technology can have a significant impact on the Canadian healthcare system.

Interoperability was highlighted as one of the main gaps of AAL technology and it is also considered one of the key areas in need of improvement. The integration of products from different manufacturers through common standards will not happen without significant effort from governments and standards development organizations. Large vendors will continue to focus on retaining customers by offering easy communication between devices from the same brand. Projects with the goal of

creating open standards and protocols for IoT devices, including AAL technology, should be created, disseminated, and followed by all innovators.

Another critical area focuses on how the data collected by AAL technology is used and shared with relevant stakeholders. Vast amounts of data generated daily through IoT devices and AAL technology are being collected at the individual level on local devices or smartphones. Innovators should focus on how to make better use of this data and how to make raw data more understandable and relevant to users and clinicians by adding context. The creation of a data exchange infrastructure, capable of aggregating and analyzing anonymized data on a population level, has the potential to provide meaningful use to anonymized AAL data.

Likewise, it is necessary to address the concerns around data collection and storage, ensuring the privacy and security of the data. It is also important to understand whether users, healthcare providers, family members, and the actual technology itself are collecting and storing data correctly, securely, privately, and with enough data quality for clinical use. The creation of guidelines to ensure the reliability of the data, trust of the data source, and trust in the processes will be critical to enabling the integration of AAL technology data into clinical practice. Following improvements on how the data is used and where it is stored, it is necessary to work on data responsibility. A data governance legal framework based on the principles of transparency and

accountability is needed in Canada, especially in relation to health system use of data generated by AAL technologies. Identifying the legal parameters on decision-making processes pertaining to health system use of AAL data, as well as the roles and responsibilities played by different stakeholders, would be the first step towards building a national legal framework.

Apart from establishing a legal framework around the use of AAL technology in Canada, policies related to financial support for AAL technologies should be in place in Canada to support the clinical prescription of these systems. Innovators are developing solutions that can have a positive impact on the healthcare system by allowing individuals to live independently longer. However, little attention is being given to how the costs of these innovative solutions will be reimbursed or these solutions will be implemented within the current paying mechanisms established by the Canadian public healthcare system.

In addition to the data, legal and financial issues, it is necessary to also focus attention on awareness and patient coaching. While hosting the first workshop on AAL technology, it became clear that it was critically important to better educate the population and to increase awareness about the benefits of the existing technologies in the market. This can be achieved using networks within local communities and by ensuring that technologies are designed with the final user in mind (end user and purpose).

Giving users the autonomy to decide who has access to their data, including AAL technology data, was thoroughly discussed during the second workshop. A discussion about who (i.e., practitioner, company, hospital) is liable and responsible in cases of a data leak and malpractice indicated that there is no clear understanding of how to handle these situations. The consequence of this uncertainty is that companies and healthcare institutions become very protective of their data and healthcare providers are skeptical about using AAL data for clinical applications.

In summary, ethics, user-friendliness, user acceptance, economic benefit, legal challenges, and data privacy

must be considered to provide sustainable and widely accepted AAL solutions to Canada.⁶ More inter-organizational collaboration and user-focused studies are necessary to explore the benefits of AAL technology nationwide.

6 Conclusion

The increase in aging populations continues to be a major concern for governments and health care systems around the world. To support older adults, researchers and innovators have been exploring the use of wearables, sensors, and mobile health technologies to improve quality of life. A possible solution is the adoption of AAL technologies that would empower vulnerable populations to live independently, within their own home, for as long as possible. The AAL environment can integrate assistive technologies, smart homes, and telehealth by using multi-sensors to gather data and monitor individuals in the confines of their own homes while keeping healthcare providers aware of how patients are doing.

With a focus on devices and wearables connected to the Internet that collect and exchange data, this report identified that standards for developing basic AAL technology are not a current need, as there are numerous existing standards. The main gaps identified were found to be in the non-technical aspects, as well as in the integration between the existing technologies. These gaps were grouped into five themes: the end user and purpose, accessibility, interoperability, data-sharing, and privacy and security. While standards, protocols, and guidelines may not address all challenges identified in this report, standards are important tools that can be combined with regulations, policies, and programs to support change.

An important consideration is that AAL is defined as the use of technology for assisted living. Defining AAL technology can become a challenge considering that most consumer technologies can be used for AAL applications. For example, Google Home, a smart-home system, is not identified as AAL technology. However, depending on the application and the use by individuals with special needs (individuals who cannot reach for

Table 3: Examples of areas that could benefit from standards, protocols, and guidelines to be developed to support AAL technology deployments.

Thematic Area	Purpose and Intended Outcome
All Thematic Areas	Further develop existing frameworks (e.g., Continua), encompassing all different areas associated with the deployment AAL technology: medical, financial, resources, education, purpose, accessibility, safety, data, privacy, and security.
End User & Purpose	Include elderly and vulnerable individuals through user-centred design in developing AAL technology and solutions that leverage AAL data to increase acceptability.
End User & Purpose	Include domain-specific and application-specific content to support AAL technology use and integration with current healthcare areas of focus (e.g., paramedics, chronic disease monitoring, population-level surveillance).
End User & Purpose	Adapt existing technologies in the market for AAL use, ensuring user privacy, data security, safety, and accessibility are in place.
Accessibility	Ensure AAL and IoT technology accessibility by design for hardware and software development (e.g., W3C).
Data-Sharing, Interoperability	Adapt data exchange and interoperability standards that are already available for health data exchange between electronic medical records to be used for AAL and IoT technologies (e.g., HL7 and FHIR).
Data-Sharing, Interoperability	Develop culturally-specific vocabularies (e.g., terminology) for AAL concepts, uses, and data.
Data-Sharing	Define data ownership and the rules that apply for each level of ownership (e.g., the U.S. Health Insurance Portability and Accountability Act – HIPPA, The Personal Information Protection and Electronic Documents Act – PIPEDA, etc.)
Interoperability	Address interoperability between technologies and vendors and to ensure compliance to interoperability standards for all AAL technology manufacturers.
Privacy & Security, Data Sharing	Create and present privacy agreements to enhance trust and transparency when sharing AAL technology data.
Privacy & Security	Apply privacy by design principles in the design, development, and prototyping phase of AAL technologies.
Privacy & Security, Data Sharing	Address the use of AAL data by the healthcare system, identifying roles and responsibilities played by different stakeholders, legal requirements related to data collection by users, data ownership, and privacy requirements.
Privacy & Security, Data Sharing	Address data ownership and protecting citizens’ rights related to their data being collected by AAL technologies and used by other stakeholders.
Privacy & Security	Assess ethical use and monetization of health-related data derived from AAL technologies.
Privacy & Security	Ensure AAL data is securely transmitted using proper technology (e.g., encryption and blockchain).
Privacy & Security	Assess data collection and storage to minimize exposure in case of security breaches.

light switches for example), Google Home can be considered an AAL device. Thus, when technology is used to support independent living, it becomes AAL technology regardless of the original intent for use. With that in mind, the **end user and purpose** gap could be bridged by standards that provide requirements and recommendations to ensure that users are incorporated into all phases of development. The **accessibility** gap could be addressed with:

- 1) hardware guidelines to ensure accessibility by design based on the purpose or use case of the technology, taking into consideration the nature of vulnerable populations; and
- 2) guidelines for the software and interface components for AAL technologies.

One critical component of the success of AAL technology is ensuring proper data exchange. Therefore, standards that provide proper **interoperability** between technologies

are critical. It may be possible to use or adapt existing standards or develop AAL-specific standards for the exchange of information. For the **interoperability** gap, standards could:

- 1) provide a common data exchange language and terminology, making the data more meaningful and global;
- 2) ensure that all devices in the network communicate with other devices and avoid vendor silos; and
- 3) enable innovators to leverage data from other sensors in the AAL network in their algorithms.

Standards focused on **data sharing** of AAL technology would benefit the space by creating:

- 1) a common data sharing vocabulary, a data model for storing and processing the data, data storage guidelines, and information on protocols for how to exchange AAL data with different types of users; and
- 2) data access governance for users, family members, and healthcare providers.

The major concern in the AAL space is guaranteeing privacy and security of users and data. Without proper trust in the technology, AAL cannot deliver all the benefits offered to its users. Issues around **privacy and security** are currently a high priority and represent the largest opportunities for creating standards and policies.

Some opportunities include:

- 1) ensuring data security for the transmission and storage process, exploring technologies like encryption and blockchain;
- 2) guiding how to collect and store data to minimize exposure in cases of a security breach;
- 3) providing guidelines related to data use by caregivers and family members of vulnerable individuals; and
- 4) ensuring a clear and unique presentation of disclaimers and privacy agreements.

In this report, the following areas of AAL technology development, deployment, and integration would also benefit from standards, protocols, and guidelines to support the wider adoption of AAL technology in Canada (see Table 3).

In conclusion, more inter-organizational collaboration and user-focused studies are necessary to explore the benefit of AAL technology and to enable this technology to make a significant impact on the Canadian healthcare system. A symbiotic ecosystem that includes novel AAL technology development and policies needs to be in place to successfully implement AAL technology on a wide-scale in Canada.

Appendix A – Relevant Standards

To organize the complex and extensive body of existing standards that are relevant to AAL technologies, sources were broken into four groups:

- 1) design and terminology;
- 2) communication and transport;
- 3) privacy and security; and
- 4) data content.

While some listed standards may fall into two or more categories, the categorization was made based on the purpose of the standard.

6.1 Design and Terminology

The standards covered in this section address the ability to represent concepts unequivocally between a sender and receiver of information using correct terminology, as well as representing concepts and processes related to AAL system design, modelling, and planning.

6.1.1.1 ISO 13485 - Medical devices - Quality Management Systems—Requirements for Regulatory Purposes

ISO 13485 defines the requirements needed for a quality management system for medical devices. This standard applies to organizations involved in any stage of the life-cycle of the device and specifies that it is the responsibility of every party to ensure quality throughout all phases of production. The quality assurance model relies on the procedural approach to ensure quality from the design and requirements of the technology, through the development of the product, to the vendor selection criteria.⁶⁸

6.1.1.2 ISO 20282 - Ease of Operation of Everyday Products— Part 1: Design Requirements for Context of Use and User Characteristics

ISO 20282 provides requirements and recommendations for the development and design of everyday products

for a universal user population. It describes three potential objectives for the design:

- 1) **universal:** usable by the widest possible range of users without use of assistive technology;
- 2) **accessible:** usable by a wider range of users with assistive technology; and
- 3) **skilled:** only usable by users with special skills or training.

The standard is primarily concerned with the design of universal products that are easy to operate, especially without instructions and without previous experience or training.⁶⁹

6.1.1.3 ISO 9241 - Ergonomics of Human-System Interaction

ISO 9241 is a multi-part standard covering the ergonomics of human-system interaction. Within the list of existing parts, three main parts fall within the scope of this report, Parts 151, 171, and 210:

- 1) ISO 9241-151, *Ergonomics of Human-System Interaction—Part 151: Guidance on World Wide Web user interfaces*, provides guidance to address the usability of World Wide Web user interfaces. The recommendations and guidelines apply primarily to a website or application's content design. The major goal is to make the Web accessible to all users.⁷⁰
- 2) ISO 9241-171, *Ergonomics of Human-System Interaction—Part 171: Guidance on Software Accessibility*, provides guidance on software design for interactive systems. The standard's purpose to increase effectiveness, efficiency, and satisfaction through accessibility. It uses a human-centred design approach to increase human-system interface accessibility (ISO 13407). Part 171 highlights the importance of incorporating accessibility goals and features into the design as early as possible in the process.⁷¹

- 3) ISO 9241-210, *Ergonomics of Human-System Interaction—Part 210: Human-Centred Design for Interactive Systems*, provides requirements and recommendations for human-centred design principles and activities for interactive systems development. Part 210 focuses on enhancing human-system interaction through software and hardware components. It provides an overview for the planning and management of human-centred design, but it does not provide details on the methods and techniques.⁷²

Other parts not listed here also present valuable information and should be consulted during the design phase of any human-interface technology.⁷³

6.1.1.4 ISO/IEC 40500 – Information Technology—W3C Web Content Accessibility Guidelines (WCAG) 2.0

ISO/IEC 40500 reflects the accessibility guidelines defined by the WCAG 2.0 (Web Content Accessibility Guidelines). They are a set of recommendations that specify how to make web content accessible, primarily for people with disabilities. The WCAG 2.0 consists of twelve guidelines organized under four principles. Websites must be:

- 1) perceivable;
- 2) operable;
- 3) understandable; and
- 4) robust.^{74,75}

6.1.1.5 Logical Observation Identifiers Names and Codes (LOINC)

LOINC is a database and universal code system standard for identifying health measurements, observations, and documents. LOINC was created in response to the demand for an electronic database for clinical care and management and is publicly available at no cost.⁷⁶

6.1.1.6 ISO 13482 – Robots and Robotic Devices – Safety Requirements for Personal Care Robots

ISO 13482 specifies requirements and guidelines for the inherently safe design, protective measures, and

information for the use of personal care robots. It focuses on the following three types of personal care robots:

- 1) mobile servant robots;
- 2) physical assistant robots; and
- 3) person carrier robots.

The scope of the standard is limited primarily to human care-related hazards. These robots typically perform tasks to improve the quality of life of intended users. ISO 13482 describes hazards associated with the use of these robots, and provides requirements to eliminate or reduce these risks to an acceptable level.⁷⁷

6.2 Communication and Transport

The standards and standardized technology listed in this section address the format of messages exchanged between computer systems, document architecture, clinical templates, and user interfaces. These are the protocols and standards responsible for ensuring that information is transmitted reliably and independently of the message sent and encompasses hardware and software solutions.

6.2.1.1 ISO/IEEE 11073 (x73) – Personal Health Device (PHD) Family

The ISO/IEEE x73 family is currently considered an important group of standards as they establish definitions of communication between medical, healthcare, and wellness devices with computer systems.^{78,79} The primary goal is the establishment of a way of communicating between different manufacturers through the use of plug-and-play interoperability, not limited to special hardware or software, and focusing on data exchange, data format, and nomenclature.⁷⁸ The standard architecture consists in three parts:

- 1) domain information model: defines the attributes of the data;
- 2) communication model: describes how the communication will be processed; and
- 3) service model: describes the directional flow of the data, or in other words, in which way the data is exchanged between the systems.⁷⁸

The standards define the message format but not the means (or protocol) of transfer. Currently, the standards support three different transport protocols: Bluetooth, USB, and ZigBee.⁷⁸

The IEEE 11073 PHD family has several device specializations with specific parts for each of them. The current list of devices covered by the standards includes: pulse oximeter, blood pressure monitor, thermometer, weighing scale, glucose meter, body composition analyzer, peak flow, cardiovascular fitness and activity monitor, strength fitness equipment, independent living activity hub, and medication monitor.⁸⁰

6.2.1.2 Wi-Fi

Wi-Fi is the most traditional and common local area network standard that uses radio frequency for communication. It uses 2.4 GHz UHF and 5.8 gigahertz SHF ISM radio bands, is based on the IEEE 802.11 protocol, and is a trademark of the Wi-Fi Alliance.⁸⁰ Using a wireless connection is considered less secure than a wired connection. For that reason, security protocols such as WEP (Wired Equivalent Privacy) and WPA2 (Wi-Fi Protected Access) were added as an additional layer of protection.⁸¹

6.2.1.3 WiMAX - Worldwide Interoperability for Microwave Access

WiMAX is a communication protocol technology that follows the same principles of the Wi-Fi but has a further range. It was created by the WiMAX Forum, a consortium with over 100 members. It was designed for commercial use with the advantages of being easier to install and cheaper than a wired network.⁸² Based on the IEEE 802.16 standard, WiMAX is considered a solution for smart cities, as it allows integration with Wi-Fi, Zigbee, among others.⁸³

6.2.1.4 IEEE 802 Local Area Network (LAN)/ Metropolitan Area Network (MAN) Standards

The IEEE 802.11 family of standards are responsible for recommending practices for local, metropolitan, and other area networks using the same basic protocol

802.11-1997 and is the base for the Wi-Fi standard. It uses domain codes to specify the different levels of allowable transmitter power for different countries. It uses Wired Equivalent Privacy (WEP) and Wi-Fi Protected Access (WPA) mechanisms for security.⁸⁴

IEEE 802.15 specifies wireless personal area network (WPAN) standards and is divided into smaller work groups or projects.⁸¹ The three main groups discussed in this document are:

- 1) IEEE 802.15.1: WPAN/Bluetooth;
- 2) IEEE 802.15.4: Low Rate WPAN/ZigBee; and
- 3) IEEE 802.15.6: Body Area Networks - a low-power and short-range wireless standard.⁸⁵

The IEEE 802.16 family of standards is responsible for recommendations and practices for broadband wireless metropolitan area network (WirelessMAN).^{86,87}

6.2.1.5 ZigBee

ZigBee is a standard for exchanging data based on the IEEE 802.15.4 standard for wireless personal area networks (WPANs). Zigbee networks are extendable with the use of routers and allow many nodes to interconnect, with a range up to 200 metres, enabling wireless low-power communication without the need for synchronization or pairing between devices. It uses AES 128-bit as an encryption mechanism.⁸⁸ Zigbee is commonly used by IoT and smart home devices such as light switches, thermostats, door locks, fobs, etc., with more than 2,500 products currently certified.⁸⁹

6.2.1.6 Z-Wave

Z-Wave is a wireless communication protocol focused on connectivity for home automation. It was born as a simpler alternative to ZigBee, allowing for wireless control of residential appliances and other devices. Z-Wave operates on the 800-900 MHz radio frequency range and the devices do not need to connect to a central hub, as they are all linked together to form a mesh network.⁹⁰

6.2.1.7 Bluetooth and Bluetooth LE (Low Energy or Smart)

Bluetooth is a short distance communication protocol used to build personal area networks (PANs). It uses a master/slave concept where only one device can serve as the master in a single piconet – a network consisting of two or more devices occupying the same physical channel – with a maximum of seven devices in each piconet. Only authorized devices can access and transmit data. Bluetooth LE uses a discovery service to find other devices within the limited range. The LE version, also known as “smart” or simply “4.0”, has a lower power consumption, allowing reduced memory requirements and has better discovery and connection procedures, making it ideal for battery-powered devices such as medical devices and other sensors.⁹¹

6.2.1.8 Transmission Control Protocol (TCP/IP)

The TCP/IP protocol suite enables computers, smartphones, and devices of all sizes, built by different manufacturers and running different software, to communicate with each other. TCP provides reliable delivery of a stream through an IP network. TCP/IP is the basis of the Internet used today.⁹²

6.2.1.9 User Datagram Protocol (UDP)

The UDP protocol is similar to the TCP protocol for data transmission. Unlike the TCP protocol however, the UDP protocol is considered an “unreliable” protocol and is commonly used when transfer speed is more important than the data, as in the case of streaming audio and/or video data. The data is not re-transmitted in case of loss to avoid problems in sequencing of audio and video information.⁹³

6.2.1.10 Message Queuing Telemetry Transport (MQTT)

MQTT is an Organization for the Advancement of Structured Information Standards (OASIS) that enables a lightweight publish/subscribe messaging model transport. It is designed for constrained devices and low-bandwidth or unreliable networks. It is ideal for

machine-to-machine (M2M)/IoT connectivity. It can be used with SSL to provide security, but this combination decreases the lightness of the protocol. TCP/IP port 1883 is reserved for use with MQTT and port 8883 for using MQTT over SSL.⁹⁴

6.2.1.11 MQTT-SN – MQTT for Sensor Networks

MQTT-SN targets embedded devices on non-TCP/IP networks, such as Zigbee. MQTT-SN is a publish/subscribe messaging protocol for wireless sensor networks (WSN), which aims to extend the MQTT protocol designed specifically for M2M and mobile applications. It uses UDP not TCP for its transport.⁹²

6.2.1.12 Constrained Application Protocol (CoAP)

CoAP is an application layer protocol specialized for use with constrained nodes and constrained networks in the Internet of Things. CoAP protocol is designed for M2M applications, like the MQTT-SN protocol. This protocol is based on REST architecture (see section 6.4.1.6) and supports request-response models like HTTP.⁹⁵

6.2.1.13 Universal Plug and Play (UPnP)

UPnP protocol (ISO/IEC 29341) allows network devices to automatically discover each other’s presence on a known network and establish a connection with zero-configuration. It assumes that the network runs over IP and leverages HTTP, UDP, TCP, and other web services to enable seamless discovery between devices.⁹⁶

6.2.1.14 Smart Spaces and Smart Objects Interoperability Architecture (S3OiA)

S3OiA is a service-oriented architecture that allows the integration of any object or device, regardless of its nature, into the IoT ecosystem and the interoperation among them. S3OiA follows the Web services and resources as the basis for a future IoT standardization. It complies with Triple-Space (TS) paradigm computing that performs a tuplespace-based communication using Resource Description Framework (RDF) triples, in which the information unit has three dimensions – subject, predicate, and object – to express this semantic data.⁹⁷

The architecture is based in dynamic SOA principles, follows a SOAP approach and it is aligned with RESTful web standards.

6.2.1.15 Devices Profile for Web Services (DPWS)

DPWS uses a set of web service protocols such as IP, TCP, UDP, HTTP, SOAP, and XML, which enable the devices to dynamically be discovered and also to exchange messages (an equivalent solution to the UPnP protocol). DPWS uses XML schema to describe the services and to exchange data. DPWS was developed to enable secure Web service capabilities on resource-constrained devices, allowing them to send secure messages to and from web services. DPWS is based on several other web services protocols, such as WS-Discovery, WS-Eventing, WS-Transfer, WS-Security, and WS-Policy.⁹⁸

6.3 Privacy and Security

The standards in this category define a set of administrative, physical, and technical actions being taken to protect the confidentiality, availability, and integrity of the information. Security and privacy can be applied on the message level or on the communication level. Some of the standards presented in this section are security-related standards that focus on electronic health records in the context of health information systems (HIS).⁹⁹

6.3.1.1 Secure Sockets Layer (SSL)

SSL is a protocol used to secure data transmission by establishing an encrypted link between a server and a client, a website and a browser, or a mail server and a mail client. It runs above TCP/IP protocol and uses both asymmetric and symmetric encryption to ensure security. To establish the connection part of the operation, the client and the server need an SSL certificate. With the certificate, it is possible to operate the data transfer.^{100,101} SSL is normally used for exchange of sensitive data like credit card information on a purchase transaction over the internet.

6.3.1.2 X.509

X.509 is a standard that defines the format for public key certification (PKI) to manage digital certificates and public-key encryption. It is a key part of the transport layer security protocol used to secure web and email communication. X.509 certificates are used in many Internet protocols, including TLS/SSL, the secure protocol for browsing the web, and in offline applications, like electronic signatures.¹⁰²

6.3.1.3 ASTM E1869 - *Standard Guide for Confidentiality Privacy Access and Data Security Principles for Healthcare Information Including Computer-Based Patient Records*

ASTM E1869 covers principles for privacy, person-identifiable information, health information systems (HIS), access rules, and security. It is focused on computer-based systems, with the intent to provide a basis for the construction of laws, regulations, systems, and policies for HIS and patient records for all entities that use, store, or handle health data.¹⁰³

6.3.1.4 IEEE 1888.3 - *IEEE Standard for Ubiquitous Green Community Control Network: Security*

IEEE 1888.3 describes remote control architecture of digital communities, intelligent building, and metropolitan networks. The standard uses the HTTP/XML communication protocol and is interoperable with ZigBee and other proprietary systems, allowing data exchange among databases and IT systems. It includes security requirements, architecture, authentication, authorization, and security procedures and protocols.¹⁰⁴

6.3.1.5 ISO/IEC 29100 - *Information Technology—Security Techniques—Privacy Framework*

ISO/IEC 29100 defines a privacy framework that:

- 1) specifies a common privacy terminology;
- 2) defines the actors and their roles in processing personally identifiable information;
- 3) describes privacy safeguarding considerations; and

4) provides references to known privacy principles for information technology.

ISO/IEC 29100 is a standard published under the ISO/IEC JTC 1/SC 27 IT Security techniques technical committee.¹⁰⁵

6.3.1.6 ISO/IEC 29101 - Information Technology – Security Techniques—Privacy Architecture Framework

ISO/IEC 29101 focuses on the definition of a privacy architectural framework that specifies concerns for information and communication technology (ICT) systems that process personally identifiable information (PII). The standard also provides guidance for planning, designing, and building ICT systems.¹⁰⁶ ISO/IEC 29100 is also published under the ISO/IEC JTC 1/SC 27 IT Security techniques technical committee.

6.3.1.7 ISO/IEC 20889 - Privacy Enhancing Data De-identification Terminology and Classification of Techniques

Published on November 2018, ISO/IEC 20889 is part of the ISO/IEC subcommittee 27 IT Security techniques. The standard aims to provide techniques to be used to describe and design de-identification measures and reduce the risk of re-identification. It follows the privacy principles in ISO/IEC 29100.¹⁰⁷

6.3.1.8 ISO/TR 12859 - Intelligent Transport Systems –System Architecture—Privacy Aspects in its Standards and Systems

ISO/TR 12859 provides general guidelines to developers of intelligent transport systems (ITS) standards and systems on data privacy aspects and associated legislative requirements for the development and revision of ITS standards and systems. Intelligent transport systems (ITS) are intrinsically linked to the movement and exchange of data.¹⁰⁸

6.3.1.9 ISO/IEC 29134 - Information Technology—Security Techniques—Guidelines for Privacy Impact Assessment (PIA)

ISO/IEC 29134 provides guidelines for a process on privacy impact assessment (PIA) and a structure and

content for a PIA report. A PIA is an instrument for assessing the potential privacy impacts of a process, information system, program, software module, device, or other initiative which processes personally identifiable information (PII).¹⁰⁹

6.3.1.10 ISO 25237 - Health Informatics - Pseudonymization

ISO 25237:

- 1) defines basic concepts for pseudonymization for the protection of personal health information privacy protection;
- 2) specifies a policy framework and minimal requirements for controlled re-identification;
- 3) gives an overview of different use cases for pseudonymization that can be both reversible and irreversible; and
- 4) provides informative requirements for interoperability to pseudonymization services.¹¹⁰

6.3.1.11 ISO/IEC 24745 - Information Technology –Security Techniques— Biometric Information Protection

ISO/IEC 24745:2011 is also published under the ISO/IEC JTC 1/SC 27 IT Security Techniques Technical Committee. The standard provides requirements and guidelines for the secure and privacy-compliant management and processing of biometric information. It also specifies security requirements for securely binding between a biometric reference and an identity reference.¹¹¹

6.4 Data Content

The standards described in this section refer to the data content and formats used for the exchange of information. All standards and protocols are focused on what is transferred, usually using the existing communication protocols described in section 6.2.

6.4.1.1 Health Level-7 (HL7)

HL7 is a standard for the healthcare industry which supports the exchange, management, and integration of

healthcare information, delivering healthcare interoperability.¹¹² The Health Level Seven International (HL7) organization was responsible for the creation of the standard, which is considered the most implemented healthcare standard in the world.⁶⁰ In addition to the HL7 standard for data exchange, there is also the HL7 Clinical Document Architecture (CDA), which is used to represent entire documents such as discharge summaries.¹¹³

The HL7 Development Framework (HDF) is a process for developing HL7 standards. The HDF is a framework that models and administers processes, policies, and deliverables, which are used by the healthcare information management community to resolve interoperability challenges and barriers. HL7 specifications target multiple interoperability issues such as:

- 1) information models, datatypes, and vocabularies;
- 2) messaging, clinical documents and context management standards; and
- 3) implementation technology, profile and conformance specifications.¹¹⁴

6.4.1.2 Fast Healthcare Interoperability Resources (FHIR)

Considered an evolution of the HL7 and CDA standards, the FHIR standard brings together the best of these two standards. Based on modern web services, using HTTP-based RESTful architecture, and JSON and XML for data representation, it allows the transfer of a single information units without the need to transfer the entire document.^{115,116}

6.4.1.3 Extensible Markup Language (XML)

XML is an open standard developed by W3C that was derived from SGML (ISO 8879) and is designed to define a set of rules for encoding documents in a format readable by humans and machines. XML is a simple text-based format for representing structured information and it is one of the most widely-used formats for sharing information.¹¹⁷

6.4.1.4 Hypertext Transfer Protocol (HTTP)

HTTP is the foundation of data communication for the World Wide Web and is an application-level protocol for distributed, collaborative hypermedia information systems. Hypertext is structured text that uses logical links (hyperlinks) between nodes containing text. HTTP is the protocol used to exchange or transfer hypertext. HTTP communication usually takes place over TCP/IP connections.¹¹⁸

6.4.1.5 Simple Object Access Protocol (SOAP)

SOAP is an XML-based protocol used to exchange structured information for web services. The main purpose is to allow the exchange of messages independent of the platform or protocol used to induce extensibility, neutrality, and independence. SOAP protocol does not define how the message will be transported and can operate over existing protocols, such as HTTP and SMTP.¹¹⁹

6.4.1.6 Representational State Transfer Based (RESTful)

RESTful web services is an architectural style used to connect cloud environments and mobile platforms. It relies on a simple URL, is easy to invoke, and the responses are usually HTTP based. It provides an easier and lighter alternative over complex XML structures.¹²⁰ RESTful is usually a good alternative to SOAP. For example, RESTful can be found in APIs used on Twitter and Amazon.

6.4.1.7 JavaScript Object Notation (JSON)

JSON is a text format that is completely language independent and is written with JavaScript object notation. It is an open-standard file format that uses human-readable text to store and exchange data objects consisting of attribute-value pairs. JSON schema is based on concepts from the XML standard.¹²¹

6.4.1.8 Web Services Description Language (WSDL)

WSDL provides a model and an XML format for describing the functionality offered by a web service. WSDL describes a Web service in terms of the messages it sends and receives and provides a machine-readable

description of how the service can be accessed, what parameters it expects, and what data structures it returns.¹²²

6.4.1.9 Digital Imaging and Communications in Medicine (DICOM)

DICOM is a message standard that provides information on how to format and exchange medical images and associated information both within and outside the hospital. The standard enables the integration of medical imaging devices from multiple manufacturers. DICOM uses TCP/IP to communicate between systems. DICOM has been fundamental to the development of modern radiological imaging.¹²³

6.4.1.10 ASTM E2369 - Standard Specification for Continuity of Care Record (CCR)

ASTM E2369 is designed to ensure the transfer of patient data (containing demographic, administrative, and clinical information from the patient's health information) from one practitioner to another. This standard provides a snapshot of the patient and is prepared using an XML schema to create a standard outcome that can be used during the post-discharge. The CCR consists of three elements: the header, body, and footer, and covers most aspects of a patient's condition.¹²⁴

7 Acknowledgements

We would like to thank all the study participants that volunteered their time to help with the development of the AAL landscape in Canada. We would also like to acknowledge the support of the volunteers in the Ubiquitous Health Technology Lab during the executing of this research project.

8 References

1. United Nations. *World Population Ageing 2015.*; 2015. http://www.un.org/en/development/desa/population/publications/pdf/ageing/WPA2015_Report.pdf. Accessed February 27, 2019.
2. Arim R. *A Profile of Persons with Disabilities among Canadians Aged 15 Years or Older, 2012.*; 2017. <https://www150.statcan.gc.ca/n1/en/pub/89-654-x/89-654-x2015001-eng.pdf?st=rYmUpOIU>. Accessed March 19, 2018.
3. Grenier E. Canadian seniors now outnumber children for 1st time, 2016 census shows. CBC News. <http://www.cbc.ca/news/politics/2016-census-age-gender-1.4095360>. Published 2017. Accessed March 19, 2018.
4. Statistics Canada: Seniors. Statistics Canada. <https://www150.statcan.gc.ca/n1/pub/11-402-x/2011000/chap/seniors-aines/seniors-aines-eng.htm>. Published 2017. Accessed February 20, 2019.
5. Pieper M, Antona M, Cortés U. Ambient Assisted Living. *ERCIM News*. 2011;(October):18-19.
6. Memon M, Wagner SR, Pedersen CF, Aysha Beevi FH, Hansen FO. Ambient Assisted Living healthcare frameworks, platforms, standards, and quality attributes. *Sensors (Switzerland)*. 2014;14(3):4312-4341. doi:10.3390/s140304312
7. Columbus L. 2017 Roundup Of Internet Of Things Forecasts. <https://www.forbes.com/sites/louiscolombus/2017/12/10/2017-roundup-of-internet-of-things-forecasts/#537665f81480>. Published 2018. Accessed April 8, 2018.
8. GrowthEnabler. Market Pulse Report, Internet of Things (IoT). *GrowthEnabler*. 2017. https://growthenabler.com/flipbook/pdf/IOT_Report.pdf. Accessed May 4, 2018.
9. Krawiec R, Nadler J, Tye E, Jarboe J. No appointment necessary: How the IoT and patient-generated data can unlock health care value. *Deloitte Insights*. August 2015. <https://www2.deloitte.com/insights/us/en/focus/internet-of-things/iot-in-health-care-industry.html>. Accessed May 4, 2018.
10. IEC. SyC AAL – Active Assisted Living. 2017. <http://www.iec.ch/public/miscfiles/sbp/SYCAAL.pdf>. Accessed October 16, 2017.
11. Demiris G. Smart Homes and Ambient Assisted Living in an Aging Society. *Methods Inf Med*. 2008;47(1):56-57.
12. Savage R, Yon Y, Campo M, Wilson A, Kahlon R, Sixsmith A. Market potential for ambient assisted living technology: the case of Canada. In: Mokhtari M., Khalil I., Bauchet J., Zhang D., Nugent C. (eds) *Ambient Assistive Health and Wellness Management in the Heart of the City. ICOST 2009. Lecture Notes in Computer Science*, vol 5597. Springer, Berlin, Heidelberg. 2009:57-65. doi:10.1007/978-3-642-02868-7_8
13. Blumendorf M, Albayrak S. Towards a Framework for the Development of Adaptive Multimodal User Interfaces for Ambient Assisted Living Environments. In: Stephanidis C. (eds) *Universal Access in Human-Computer Interaction. Intelligent and Ubiquitous Interaction Environments. UAHCI 2009. Lecture Notes in Computer Science*, vol 5615. Springer, Berlin, Heidelberg; 2009:150-159. doi:10.1007/978-3-642-02710-9_18

14. Abril-Jiménez P, Vera-Muñoz C, Cabrera-Umpierrez MF, Arredondo MT, Naranjo JC. Design Framework for Ambient Assisted Living Platforms. In: Stephanidis C. (eds) Universal Access in Human-Computer Interaction. Intelligent and Ubiquitous Interaction Environments. UAHCI 2009. *Lecture Notes in Computer Science*, vol 5615. Springer, Berlin, Heidelberg; 2009:139-142. doi:10.1007/978-3-642-02710-9_16
15. Stassen B. The Internet of Things (IoT) will Improve Quality of Life: Ambient Assisted Living (AAL). *Decompression Stop*. <https://bstassen.wordpress.com/2015/02/24/the-internet-of-things-iot-will-improve-quality-of-life-ambient-assisted-living-aal/>. Published 2015. Accessed August 15, 2018.
16. Woyke E. The Octogenarians Who Love Amazon's Alexa – MIT Technology Review. <https://www.technologyreview.com/s/608047/the-octogenarians-who-love-amazons-alexa/>. Published 2017. Accessed March 16, 2018.
17. TrustArc. 73% Open to Wearables at Work but Potential Privacy Issues Could Be a Concern. TrustArc. <https://www.trustarc.com/blog/tag/workplace/>. Published 2014.
18. European Commission. Standardisation. European Commission. https://ec.europa.eu/home-affairs/what-we-do/policies/industry-for-security/standardisation_en. Published 2018. Accessed March 16, 2018.
19. ReAAL. make it ReAAL: Project Description. <http://www.cip-reaal.eu/about/project-description/>. Published 2018. Accessed March 16, 2018.
20. European Commission. Service Oriented Programmable smart environments for older Europeans. European Commission. https://cordis.europa.eu/project/rcn/80527_en.html. Published 2008. Accessed November 26, 2018.
21. AAL Programme. Active and Assisted Living Programme – Objectives. AAL Programme. <http://www.aal-europe.eu/about/objectives/>. Published 2018. Accessed March 1, 2018.
22. Milovanovic D, Bojkovic Z. Cloud-based IoT healthcare applications: Requirements and recommendations. *Int J Internet Things Web Serv*. 2017;2:60-62. [http://www.iaras.org/iaras/filedownloads/ijitws/2017/022-0009\(2017\).pdf](http://www.iaras.org/iaras/filedownloads/ijitws/2017/022-0009(2017).pdf). Accessed January 25, 2018.
23. AAL Programme. Interoperability & Standards. AAL Programme. <http://www.aal-europe.eu/support-to-projects/interoperability-standards/>. Published 2016. Accessed March 18, 2018.
24. EU GDPR. EU GDPR. <https://www.eugdpr.org/>. Published 2018. Accessed March 16, 2018.
25. Fabbriatore C, Zucker M, Ziganki S, Karduck AP. Towards a unified architecture for smart home and Ambient Assisted Living solutions: A focus on elderly people. In: *5th IEEE International Conference on Digital Ecosystems and Technologies (IEEE DEST 2011)*. IEEE; 2011:305-311. doi:10.1109/DEST.2011.5936643
26. Sun H, De Florio V, Gui N, Blondia C. Promises and Challenges of Ambient Assisted Living Systems. *2009 Sixth Int Conf Inf Technol New Gener*. 2009:1201-1207. <https://pdfs.semanticscholar.org/3f59/53ea2d14b067893c7b49e3a632b3dc89a40c.pdf>. Accessed March 16, 2018.

27. Broek G van den., Cavallo F, Wehrmann C. *AALIANCE Ambient Assisted Living Roadmap*. Ios Press; 2010. https://books.google.ca/books?id=dDXPKWN61msC&pg=PA86&lpg=PA86&dq=ambient+assisted+living+in+japan+paper&source=bl&ots=es1b6gO3Fc&sig=0_uFYOEcnriQmB0X0dRhI_pQes&hl=en&sa=X&ved=0ahUKEwilibeD6cvZAhULRqwKHRD1AhE4ChDoAQg2MAM#v=onepage&q=AAL&f=false. Accessed March 1, 2018.
28. Yoshida R. Japan census report shows surge in elderly population, many living alone | The Japan Times. The Japan Times. <https://www.japantimes.co.jp/news/2016/06/29/national/japan-census-report-shows-surge-elderly-population-many-living-alone/#.Wq7yHKjwaUl>. Published 2016. Accessed March 18, 2018.
29. Reportlinker. Japan smart home market is predicted to be US\$ 5 Billion by 2024. Reportlinker. <https://www.prnewswire.com/news-releases/japan-smart-home-market-is-predicted-to-be-us-5-billion-by-2024-300565051.html>. Published 2017. Accessed March 16, 2018.
30. EU-Japan Centre. Report: Ambient Assisted Living Market in Japan. EU Business in Japan. <https://www.eubusinessinjapan.eu/library/publication/report-ambient-assisted-living-market-in-japan>. Published 2018. Accessed March 16, 2018.
31. Steger I. South Korea is aging faster than any other developed country. Quartz. <https://qz.com/1066613/south-korea-demographic-time-bomb-its-aging-faster-than-any-other-developed-country-with-lowest-birth-rate-of-oecd-countries/>. Published 2017. Accessed March 16, 2018.
32. Hwang AS, Truong KN, Cameron JI, Lindqvist E, Nygård L, Mihailidis A. Co-Designing Ambient Assisted Living (AAL) Environments: Unravelling the Situated Context of Informal Dementia Care. *Biomed Res Int*. 2015;2015:720483. doi:10.1155/2015/720483
33. Mokhtari M, Khalil I, Bauchet J, Zhang D, Nugent C. Ambient Assisted Health and Wellness Management in the Heart of the City. In: *7th International Conference on Smart Homes and Health Telematics, ICOST 2009*. 2009. <https://link.springer.com/content/pdf/10.1007%2F978-3-642-02868-7.pdf>. Accessed March 16, 2018.
34. Chaaaraoui AA, Florez-Revuelta F. Technologies and Applications for Active and Assisted Living. Current situation. *Act Assist Living Technol Appl*. 2016:1-8. <https://static.googleusercontent.com/media/research.google.com/en//pubs/archive/45532.pdf>. Accessed March 16, 2018.
35. Griffin K. Canada's first 'dementia village' is set to open its doors in Langley, B.C. next year. National Post. <http://nationalpost.com/news/canada/canadas-first-dementia-village-is-set-to-open-its-doors-in-langley-b-c-next-year>. Published 2018. Accessed March 16, 2018.
36. Ekeroth H. AAL-WELL: Ambient Assistive Living Technologies for Wellness, Engagement, and Long Life. Karolinska Institutet. <https://ki.se/en/nvs/aal-well-ambient-assistive-living-technologies-for-wellness-engagement-and-long-life>. Published 2016. Accessed March 16, 2018.
37. AAL Programme. Canada and the AAL programme. <http://www.aal-europe.eu/canada-to-join-the-aal-programme/>. Accessed December 11, 2018.
38. AAL Programme. *Active and Assisted Living (AAL) Programme – ICT for Ageing Well.*; 2018. http://www.cihr-irsc.gc.ca/e/documents/aal_program_e.pdf. Accessed December 11, 2018.
39. Cooper R. Harmonization of assistive technology standards. *Eng Med Biol Soc*. 1998;20(6):3367-3369. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=746225.

40. IEC. SyC AAL: Active Assisted Living & Work programme. IEC. http://www.iec.ch/dyn/www/f?p=103:214:10381790231369::::FSP_ORG_ID,FSP_LANG_ID:11827,25?q=ags. Published 2018. Accessed May 4, 2018.
41. Postscapes. IoT Standards and Protocols Guide. Postscapes. <https://www.postscapes.com/internet-of-things-protocols/>. Published 2017. Accessed October 19, 2017.
42. Salman T, Prof. Jain R. Networking Protocols and Standards for Internet of Things. 2015. https://www.cse.wustl.edu/~jain/cse570-15/ftp/iot_prot/. Accessed August 28, 2017.
43. Personal Connected Health Alliance. Continua Design Guidelines. <http://www.pchalliance.org/continua-design-guidelines>. Published 2018. Accessed July 25, 2018.
44. Wartena F, Muskens J, Schmitt L. Continua : The Impact of a Personal Telehealth Ecosystem. 2018. doi:10.1109/eTELEMED.2009.8
45. Fan L, Buchanan W, Thummler C, et al. DACAR Platform for eHealth Services Cloud. In: *2011 IEEE 4th International Conference on Cloud Computing*. IEEE; 2011:219-226. doi:10.1109/CLOUD.2011.31
46. Tazari M-R, Furfari F, Ramos J-PL, Ferro E. The PERSONA Service Platform for AAL Spaces. In: *Handbook of Ambient Intelligence and Smart Environments*. Boston, MA: Springer US; 2010:1171-1199. doi:10.1007/978-0-387-93808-0_43
47. universAAL. universAAL IoT | About. <http://www.universaal.info/page/about/>. Published 2018. Accessed May 4, 2018.
48. Microsoft. HealthVault – How it works. Microsoft. <https://international.healthvault.com/ca/en/Howitworks>. Published 2018. Accessed May 4, 2018.
49. Cisco. Cisco Umbrella Platform. Cisco. <https://learn-umbrella.cisco.com/datasheets/umbrella-platform>. Published 2018. Accessed May 4, 2018.
50. KoKalitcheva K. HealthTap unveils HOPES, an operating system for hospitals and clinics. Fortune. <http://fortune.com/2015/10/28/healthtap-hospital-operating-system/>. Published 2015. Accessed May 4, 2018.
51. Kepes B. HealthTap enables (dare I say it?) the Uberization of medical response. Computerworld. <https://www.computerworld.com/article/3021290/healthcare-it/healthtap-enables-dare-i-say-it-the-uberization-of-medical-response.html>. Published 2016. Accessed May 4, 2018.
52. UW HIMT Team. What Is Data Governance in Healthcare? University of Wisconsin. <https://himt.wisconsin.edu/experience-uw-himt/data-governance-in-healthcare/>. Published 2017. Accessed July 25, 2018.
53. Government of Canada. Canada's Health Care System. Canada.ca. <https://www.canada.ca/en/health-canada/services/health-care-system/reports-publications/health-care-system/canada.html>. Published 2018. Accessed February 22, 2019.
54. Aggarwal S. Treasure of the Commons: Global Leadership through Health Data. Centre for International Governance Innovation. <https://www.cigionline.org/articles/treasure-commons-global-leadership-through-health-data>. Published 2018. Accessed April 30, 2018.

55. Canada G of. National Digital and Data Consultations. Government of Canada. <https://www.ic.gc.ca/eic/site/084.nsf/eng/home>. Published 2018. Accessed July 10, 2018.
56. Blatchford A. Time has come for national big-data strategy, tech leaders tell governments. National Post. <https://nationalpost.com/pmnh/health-pmnh/time-has-come-for-national-big-data-strategy-tech-leaders-tell-governments>. Published 2018. Accessed July 9, 2018.
57. Office of the Privacy Commissioner of Canada. PIPEDA legislation and related regulations. https://www.priv.gc.ca/en/privacy-topics/privacy-laws-in-canada/the-personal-information-protection-and-electronic-documents-act-pipeda/r_o_p/. Published 2018. Accessed July 9, 2018.
58. European Commission. Commission Staff Working Document on the free flow of data and emerging issues of the European data economy. 2017:1-49. http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=41247.
59. Impact of the GDPR on the use of interoperability standards. Ringholm. 2017. http://www.ringholm.com/column/GDPR_impact_on_healthcare_data_interoperability.htm. Accessed May 7, 2018.
60. HL7.org. Introducing HL7 FHIR. HL7.org. <https://www.hl7.org/fhir/summary.html>. Published 2018. Accessed January 23, 2018.
61. CIHI. Better Information for Improved Health: A Vision for Health System Use of Data in Canada. *Conf Deputy Minist Heal*. 2013. https://www.cihi.ca/en/hsu_vision_report_en.pdf. Accessed April 30, 2018.
62. Coallier F. Standards in IT. https://docs.google.com/presentation/d/e/2PACX-1vRz8bJOY6Fwfp_j9Zz9cjpGELrORt-H6jALqAer1uQa03Odx-aJJ4CFD8eSizKqe_rz_4TP4I2dK2/pub?start=false&loop=false&delayms=3000&slide=id.p4. Published 2018. Accessed July 25, 2018.
63. Mihailidis A, Boger J, Hoey J, Jiancaro T. Zero Effort Technologies: Considerations, Challenges, and Use in Health, Wellness, and Rehabilitation. *Synth Lect Assist Rehabil Heal Technol*. 2011;1(2):1-94. doi:10.2200/S00380ED1V01Y201108ARH002
64. Rashidi P, Mihailidis A. A survey on ambient-assisted living tools for older adults. *IEEE J Biomed Heal Informatics*. 2013;17(3):579-590. doi:10.1109/JBHI.2012.2234129
65. Vigyanix. Healthcare Interoperability: The Opportunities, Challenges, and Solutions. Vigyanix. <https://vigyanix.com/blog/healthcare-interoperability-opportunities-challenges-solutions/>. Published 2018. Accessed August 15, 2018.
66. Islam SMR, Kwak D, Kabir H, Hossain M, Kwak K-S. The Internet of Things for Health Care : A Comprehensive Survey. *Access, IEEE*. 2015;3:678-708. doi:10.1109/ACCESS.2015.2437951
67. European Commission. Infographic Digital Health and Care in the EU. 2016. <http://dhaca.org.uk/>.
68. Basler R, Pizinger R. The Arrival of ISO 13485:2003. *Med Prod Outsourcing*. 2004. http://www.notifiedbody.org/Noblitt-Rueland_ISO13485-2003_Part1.pdf. Accessed April 5, 2018.
69. Bevan N, Schoeffel R. A proposed standard for consumer product usability. 2001. https://www.researchgate.net/profile/Nigel_Bevan/publication/221095159_A_proposed_standard_for_consumer_product_usability/links/57ad7a4608ae3765c3bb397c/A-proposed-standard-for-consumer-product-usability.pdf. Accessed April 5, 2018.

70. International Organization for Standardization. ISO 9241-151:2008(en), Ergonomics of human-system interaction – Part 151: Guidance on World Wide Web user interfaces. Published 2018. Accessed April 5, 2018.
71. International Organization for Standardization. ISO 9241-171:2008(en), Ergonomics of human-system interaction – Part 171: Guidance on software accessibility. Published 2018. Accessed April 5, 2018.
72. International Organization for Standardization. ISO 9241-210:2010(en), Ergonomics of human-system interaction – Part 210: Human-centred design for interactive systems. Published 2018. Accessed April 5, 2018.
73. International Organization for Standardization. ISO 9241-1:1997(en), Ergonomic requirements for office work with visual display terminals (VDTs) – Part 1: General introduction. Published 2018. Accessed April 5, 2018.
74. Henry S. WCAG 2.0 is now also ISO/IEC 40500! W3C Blog. <https://www.w3.org/blog/2012/10/wcag-20-is-now-also-isoiec-405/>. Published 2012. Accessed April 21, 2018.
75. W3C. Web Content Accessibility Guidelines (WCAG) 2.0. W3C. <https://www.w3.org/TR/2008/REC-WCAG20-20081211/>. Published 2018. Accessed April 21, 2018.
76. LOINC.org. What LOINC is. LOINC.org. <https://loinc.org/get-started/what-loinc-is/>. Published 2018. Accessed April 21, 2018.
77. Jacobs T, Singh VG. ISO 13482 – The new safety standard for personal care robots. *Int Symp Robot.* 2014:698-703.
78. Nieke P, Hanke S, Mayer C, Hochgatterer A, Sauermann S. Interoperability In Ambient Assisted Living (AAL) – Standardization of Sensor-data based on ISO/IEEE 11073. *Proc Third Int Conf Heal Informatics.* 2010:406-413. doi:10.5220/0002700204060413
79. Borgia DP. Supporting Personal Health Devices through Standardization and Collaboration. *IEEE International Conference on e-Health.* 2011. <https://pdfs.semanticscholar.org/c86f/5155c8336b443c07bd50ad68ad1e71a34e40.pdf>. Accessed January 25, 2018.
80. Wi-Fi Alliance. Wi-Fi Alliance. <https://www.wi-fi.org/>. Published 2018. Accessed January 30, 2018.
81. Vaughan-Nichols SJ. Achieving Wireless Broadband with WiMax. *J Computer.* 2004;37(6):10-13. Accessed January 30, 2018.
82. WiMAX Forum Initiative. Smart Cities. WiMAX Forum Initiative. <http://wimaxforum.org/Page/Initiatives/Smart-Cities>. Published 2018. Accessed January 30, 2018.
83. Greg Hackmann. *802.15 Personal Area Networks.*; 2006. <https://www.cse.wustl.edu/~jain/cse574-06/ftp/wpans/index.html>. Accessed January 24, 2018.
84. Salehi SA, Razzaque MA, Tomeo-Reyes I, Hussain N. IEEE 802.15.6 standard in wireless body area networks from a healthcare point of view. In: *2016 22nd Asia-Pacific Conference on Communications (APCC).* IEEE; 2016:523-528. doi:10.1109/APCC.2016.7581523
85. IEEE. The IEEE 802.16 Working Group on Broadband Wireless Access Standards. <http://grouper.ieee.org/groups/802/16/>. Published 2018. Accessed January 30, 2018.

86. Christensen JH. Using RESTful Web-Services and Cloud Computing to Create Next Generation Mobile Applications. 2009:627-634. doi:10.1145/1639950.1639958. https://www.researchgate.net/publication/221322065_Using_RESTful_web-services_and_cloud_computing_to_create_next_generation_mobile_applications. Accessed February 2, 2018.
87. Alliance TZ. *ZigBee 3.0*. Zigbee; 2018. <http://www.zigbee.org/zigbee-for-developers/zigbee-3-0/>. Accessed November 15, 2017.
88. Bluetooth. Bluetooth Technology Website. Bluetooth. <https://www.bluetooth.com/>. Published 2018. Accessed October 26, 2017.
89. Lamkin P. Z-Wave explained: What is Z-Wave and why is it important for your smart home? The Ambient. <https://www.the-ambient.com/guides/zwave-z-wave-smart-home-guide-281>. Published 2018. Accessed April 1, 2018.
90. Padgett J, Bahr J, Batra M, et al. Guide to Bluetooth Security. *Natl Inst Stand Technol NIST*. 2012. doi:10.6028/NIST.SP.800-121r2
91. MQTT.org. FAQ – Frequently Asked Questions. MQTT.org. <http://mqtt.org/faq>. Published 2018. Accessed April 1, 2018.
92. Reliable/non-reliable transmission of voice using TCP/UDP based on network quality of service. March 1997. <https://patents.google.com/patent/US6771594B1/en>. Accessed April 4, 2018.
93. Instruments N. What Is a Wireless Sensor Network? National Instruments. <http://www.ni.com/white-paper/7142/en/>. Published 2016. Accessed April 1, 2018.
94. MQTT.org. MQTT. MQTT.org. <http://mqtt.org/>. Published 2018. Accessed April 1, 2018.
95. Thangavel D, Ma X, Valera A, Tan H-X, Keng C, Tan -Yan. Performance Evaluation of MQTT and CoAP via a Common Middleware. 2014:21-24. <http://cgweb1.northumbria.ac.uk/SubjectAreaResources/KF7046/papers/review/iot/tmv14.pdf>. Accessed April 21, 2018.
96. Weaver AC. Secure Sockets Layer. *Computer (Long Beach Calif)*. 2006;39(4):88-90. doi:10.1109/MC.2006.138
97. Vega-Barbas M, Casado-Mansueta D, Valero MA, Lopez-De-Ipina D, Bravo J, Florez F. Smart Spaces and Smart Objects interoperability Architecture (S3OiA). *IEEE*. 2012. http://oa.upm.es/20913/1/INVE_MEM_2012_131399.pdf. Accessed April 21, 2018.
98. Sleman A, Moeller R. Integration of Wireless Sensor Network Services into other Home and Industrial networks using Device Profile for Web Services (DPWS). 2008. <https://pdfs.semanticscholar.org/363a/4c8dd1266fa8fd51301fab9e8d05bc82d629.pdf>. Accessed April 21, 2018.
99. Carvalho Jr MA de, Lúcia C, Ortolani F, Pisa IT. Health Information System (HIS) security standards and guidelines history and content analysis. *J Heal Inf Julho-Setembro*. 2016;8(3):95-102. <http://www.jhi-sbis.saude.ws/ojs-jhi/index.php/jhi-sbis/article/viewFile/417/266>. Accessed April 21, 2018.
100. Eggebraaten TJ, Tenner JW, Dubbels JC. A health-care data model based on the HL7 Reference Information Model. *IBM Syst J*. 2007;46(1):5-18. doi:10.1147/sj.461.0005

101. ASTM International. ASTM F2761 – 09 Medical Devices and Medical Systems – Essential safety requirements for equipment comprising the patient-centric integrated clinical environment (ICE). <https://www.astm.org/Standards/F2761.htm>. Published 2018. Accessed April 4, 2018.
102. Cooper D, Santesson S, Farrell S, Boeyen S, Housley R, Pol W. *Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile*.; 2008. <https://tools.ietf.org/html/rfc5280>. Accessed April 21, 2018.
103. Allaert F-A. *Security Standards for Healthcare Information Systems : A Perspective from the EU ISIS MEDSEC Project*. IOS Press; 2002. <https://books.google.ca/books?hl=en&lr=&id=IcuUKU-ElvAC&oi=fnd&pg=PR7&dq=ASTM+E1869&ots=fyYTdKrJoY&sig=Aq6lNbETu6tc7xDE8yvvd3LjDVLc#v=onepage&q=ASTM+E1869&f=false>. Accessed April 21, 2018.
104. Ochiai H, Momose T, Ishiyama M, Sakane S. IEEE1888-2011 Ubiquitous Green Community Control Network SGIP Catalog of Standards: Criteria and Analysis Report. 2011. Accessed April 21, 2018.
105. ISO/IEC. ISO/IEC 29100:2011(en), Information technology – Security techniques – Privacy framework. ISO/IEC. Published 2018. Accessed August 31, 2018.
106. ISO/IEC. ISO/IEC 29101:2013 – Information technology – Security techniques – Privacy architecture framework. ISO/IEC. <https://www.iso.org/standard/45124.html>. Published 2018. Accessed August 31, 2018.
107. ISO/IEC. ISO/IEC FDIS 20889 : Privacy Enhancing Data De-Identification Terminology and Classification of Techniques. ISO/IEC. Published 2018. Accessed August 31, 2018.
108. ISO. ISO/TR 12859:2009(en) Intelligent transport systems – System architecture – Privacy aspects in ITS standards and systems. ISO. Published 2018. Accessed September 4, 2018.
109. ISO/IEC. ISO/IEC 29134:2017(en) – Information technology – Security techniques – Guidelines for privacy impact assessment. ISO/IEC. doi:10.1109/UCC.2014.148
110. ISO. ISO 25237:2017(en), Health informatics – Pseudonymization. ISO. Published 2017. Accessed September 4, 2018.
111. ISO/IEC. ISO/IEC 24745:2011(en), Information technology – Security techniques – Biometric information protection. ISO/IEC. Published 2018. Accessed September 4, 2018.
112. Dolin RH, Alschuler L, Beebe C, et al. The HL7 Clinical Document Architecture. *J Am Med Informatics Assoc*. 2001;8(6):552-569. doi:10.1136/jamia.2001.0080552
113. Lamprinakos GC, Mousas AS, Kapsalis AP, et al. Using FHIR to develop a healthcare mobile application. *Proc 2014 4th Int Conf Wirel Mob Commun Healthc – “Transforming Healthc Through Innov Mob Wirel Technol MOBIHEALTH 2014*. 2015:132-135. doi:10.1109/MOBIHEALTH.2014.7015927
114. HL7.org. HL7 Development Framework – HL7Wiki. HL7.org. http://wiki.hl7.org/index.php?title=HL7_Development_Framework. Published 2018. Accessed May 4, 2018.

115. Curbera F, Duftler M, Khalaf R, Nagy W, Mukhi N, Weerawarana S. Unraveling the Web services web: an introduction to SOAP, WSDL, and UDDI. *IEEE Internet Comput.* 2002;6(2):86-93. doi:10.1109/4236.991449
116. Quin LRE. XML Essentials – W3C. W3C. <https://www.w3.org/standards/xml/core>. Published 2018. Accessed April 1, 2018.
117. Leach PJ, Berners-Lee T, Mogul JC, Masinter L, Fielding RT, Gettys J. Hypertext Transfer Protocol – HTTP/1.1. 1999. <https://tools.ietf.org/html/rfc2616>. Accessed April 1, 2018.
118. Spitalewsky K, Rochon J, Ganzinger M, Knaup P. Potential and requirements of IT for ambient assisted living technologies: Results of a Delphi study. *Methods Inf Med.* 2013;52(3):231-238. doi:10.3414/ME12-01-0021
119. ZigBee.org. ZigBee Wireless Sensor Applications for Health, Wellness and Fitness. 2009. <http://www.zigbee.org>. Accessed November 17, 2017.
120. Json.org. Introducing JSON. json.org. <https://www.json.org/>. Published 2018. Accessed April 1, 2018.
121. Chinnici R, Moreau J-J, Ryman A, Weerawarana S. Web Services Description Language (WSDL). W3C. <https://www.w3.org/TR/2007/REC-wsdl20-20070626/>. Published 2007. Accessed April 1, 2018.
122. Bidgood WD, Horii SC, Prior FW, Van Syckle DE, Syckle DE Van. Understanding and using DICOM, the data interchange standard for biomedical imaging. *J Am Med Inform Assoc.* 1997;4(3):199-212. <http://www.ncbi.nlm.nih.gov/pubmed/9147339>. Accessed April 1, 2018.
123. ASTM International. ASTM E2369 – 12 Standard Specification for Continuity of Care Record (CCR). <https://www.astm.org/Standards/E2369.htm>. Published 2018. Accessed April 4, 2018.
124. Knaup P, Schöpe L. Using data from ambient assisted living and smart homes in electronic health records. *Methods Inf Med.* 2014;53(3):149-151. doi:10.3414/ME14-10-0003
125. Section508.gov. Assistive Technology Act of 1998. Section508.gov. <https://section508.gov/assistive-technology-act-1998>. Published 2018. Accessed March 2, 2018.
126. Boger J, Jackson P, Mulvenna M, et al. Principles for fostering the transdisciplinary development of assistive technologies. *Disabil Rehabil Assist Technol.* 2017;12(5):480-490. doi:10.3109/17483107.2016.1151953
127. Group C. About Standards. CSA Group. <http://www.csagroup.org/codes-standards/about-standards/>. Published 2018. Accessed February 14, 2018.
128. IEEE. What Are Standards? IEEE. <https://standards.ieee.org/develop/overview.html>. Published 2018. Accessed August 13, 2018.
129. Thilo FJ, Bilger S, Halfens RJ, Schols JM, Hahn S. Involvement of the end user: exploration of older people's needs and preferences for a wearable fall detection device – a qualitative descriptive study. *Patient Prefer Adherence.* 2017;11:11-22. doi:10.2147/PPA.S119177
130. Protocol. Britannica.com. <https://www.britannica.com/technology/protocol-computer-science>. Published 2018. Accessed February 27, 2019.

CSA Group Research

In order to encourage the use of consensus-based standards solutions to promote safety and encourage innovation, CSA Group supports and conducts research in areas that address new or emerging industries, as well as topics and issues that impact a broad base of current and potential stakeholders. The output of our research programs will support the development of future standards solutions, provide interim guidance to industries on the development and adoption of new technologies, and help to demonstrate our on-going commitment to building a better, safer, more sustainable world.

