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Internet of Things (IoT) for Automated and Smart Applications

Edited by Yasser Ismail

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Meet the editor

Dr. Yasser Ismail received his M.S. and Ph.D. degrees in Computer Engineering from the University of Louisiana at Lafayette - USA in 2007 and 2010. Dr. Ismail is currently working as an assistant professor in the Electrical Engineering Department, Southern University and A&M College-Baton Rouge, Louisiana, USA. His area of expertise is digital video processing algorithms/architectures levels, Internet of Things (IoT), VLSI and FPGA design (low-power and high-speed performance embedded systems), automotive transportation, robotics, RFID, and wireless and digital communication systems. He has published two books, three book chapters, and more than 35 articles in related journals and conferences. Dr. Ismail served as a PI and Co-PI for several funded grants from international fund agencies.

Contents

Preface

Internet of Things (IoT) is a recent technology paradigm that creates a global network of machines and devices that are capable of communicating with each other. Security cameras, sensors, vehicles, buildings, and software are examples of devices that can exchange data bewteen each other. IoT is recognized as one of the most important areas of future technologies and is gaining vast recognition in a wide range of applications and fields related to smart homes and cities, military, education, hospitals, homeland security systems, transportation and autonomous connected cars, agriculture, intelligent shopping systems, and other modern technologies. This book explores the most important IoT automated and smart applications to help the reader understand the principle of using IoT in such applications.

A smart home system is one of the applications discussed in this book. A smart home system uses the IoT infrastructure to remotely control all home devices. Smart home systems have achieved great popularity in the last decades as they increase the comfort and quality of life. Most smart home systems are controlled by smartphones and microcontrollers. Remote healthcare is also discussed as it has become a vital service with the growing rate of senior citizens. Remote healthcare offers promising technology for health monitoring, rehabilitation, and assisted living for elderly and medically challenged patients. Securing the transmitted data between devices is a very important issue that will be discussed in the book. Securing the transmitted data between devices that use the IoT infrastructure requires an optimized Internet of Things Network (IoTN) topology that allows fast and secure data transmission between devices. The book will also discuss the use of Artificial Intelligence (AI) to facilitate and secure connecting devices through the IoT infrastructure. In the centenarian era, it has become even more imperative to address the physical and cognitive changes faced by children, the elderly, and disabled persons.

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Section 1

Internet of Things (IoT) Importance and Its Applications

Chapter 1

Introductory Chapter: Internet of Things (IoT) Importance and Its Applications

Yasser Ismail

1. What is the Internet of Things?

Internet of Things is a recent technology that creates a global network of machines and devices that are capable of communicating and exchanging data with each other through the Internet. There is a difference between the Internet of Things and the Internet. Internet of Things can create information about the connected objects, analyze it, and make decisions; in other words, one can tell that the Internet of Things is smarter than the Internet. Security cameras, sensors, vehicles, buildings, and software are examples of things that can exchange data among each other.

2. Internet of Things challenges

As the number of real-time applications (devices) that need smart connections among each other is increased, the Internet of Things challenges will also increase. Such challenges are as follows.

2.1 Smart connectivity

Sensors and devices that are connected and communicated together through the Internet of Things infrastructure may need to update their trends or feature to be suited to the changes of surrounding environments. The Internet of Things is a smart infrastructure that can process the collected data and make the required decisions to improve itself and to change the trends or features of the connected devices to accommodate the surrounding environments' changes. Internet of Things is a smart technology that helps all connected devices to update themselves according to changes in the surrounding environment and to be able to be adopted and work in any other strange environment with high accuracy. As a result, smart connected system can be produced if smart infrastructure is well designed to treat the collected data from devices correctly, to make the needed decisions.

2.2 Keeping high privacy and security of all connected devices

The main idea of using the Internet of Things is to have a smart system and to connect billions of devices over the whole world. The expected devices to be connected together are expected to be 50 billion through the Internet of Things devices by 2020. **Figure 1** shows the growth of the world population and the connected devices by 2020. Connecting such a huge number of devices required high-security levels to prevent scams and to allow high level of data protection. As a result, achieving high level of security is a big challenge to get the needed trust from both industries and individuals to share their data utilizing the Internet of Things.

2.3 Treating big data

The most important challenge of using the Internet of Things is the tremendous growth of the data transmitted between the connected devices. As seen in **Figure 2**, The basic three sources of data are (1) the database used in the business process; (2) the human daily activities such as email, Facebook, and weblogs; and (3) the connection of physical devices such as cameras and microphones. It is worth mentioning that a full 90% of all the data in the world has been generated over the last 2 years. This makes it more challenging for the Internet of Things infrastructure designers to deal with such growth of the generated data.

2.4 Reducing the overall data latency among machine-to-machine interactions

While connecting many devices through the Internet of Things infrastructure, the shared data among them will also tremendously increase. This will cause some delay or latency of data delivery among the connected devices. This opens a new challenge to be addressed by the Internet of Things to reduce such latency to be sure a robust Internet of Things infrastructure will be obtained.

2.5 Reducing bandwidth and power consumption

Both bandwidth and power consumption of the numerous number of devices that are connecting, communicating, and sharing data among each other through the Internet of Things are tremendously increased. This is why when designing an Internet of Things infrastructure, both bandwidth and power consumption challenges should be considered. The main trend nowadays is to reduce the size of the connected devices,

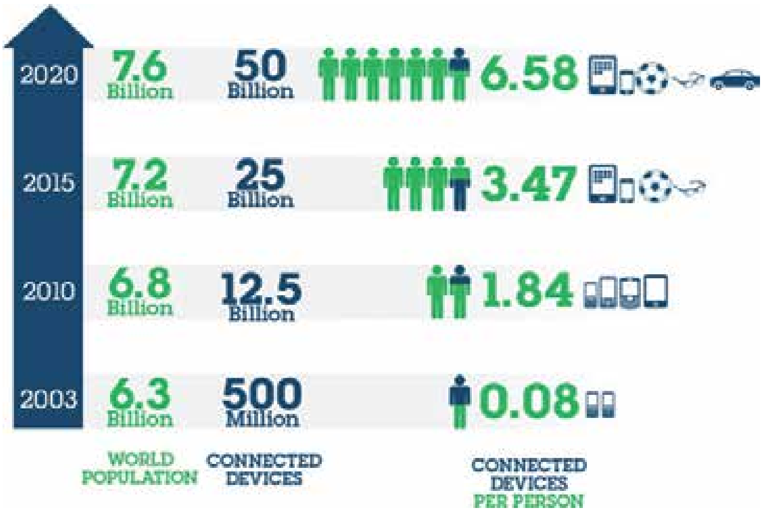

Figure 1.
The overall world population and the connected devices by 2020.

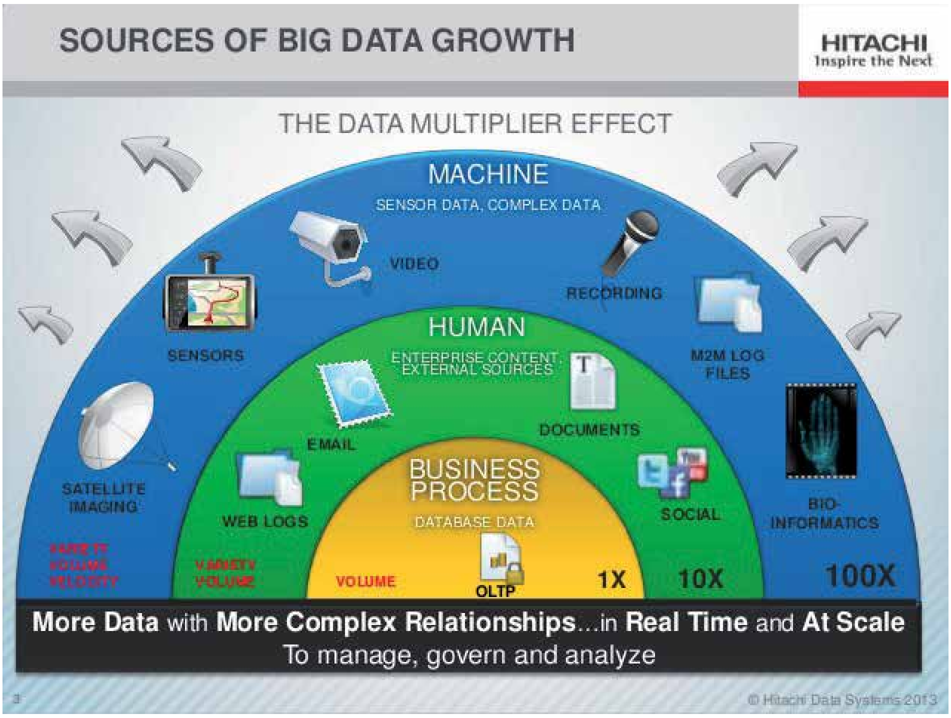

Figure 2.
Different sources of data growth (https://www.slideshare.net/bjorna/big-data-in-oil-and-gas).

and as a result, the power consumption will decrease. The transmitted data rate is still an issue to be solved due to the huge shared data among devices.

2.6 Complexity

Sharing data and connecting devices together through the Internet of Things can be implemented through several levels and layers of software/hardware and some standard protocols. With the tremendous increase in the shared data and connected devices, the used software/hardware and standard protocols will be more complicated. As a result, there is a challenge to reduce the complexity of the Internet of Things technology as the number of connected devices increases.

3. Internet of Things applications

The Internet of Things is recognized as one of the most important areas of future technologies and is gaining vast recognition in a wide range of applications and fields related to smart cities, military, education, hospitals, homeland security systems, transportation and autonomous connected cars, agriculture, intelligent shopping systems, and other modern technologies. The smart home is one of the main applications that use the Internet of Things infrastructure to connect several sensors. The sensors can sense and collect surrounding information that is used to fully control different home systems such as lighting and security as seen in **Figure 3**.

There are many other applications that use the Internet of Things infrastructures such as smart bridges and smart tunnels. Temperature and vibration sensors, as well as video surveillance cameras, can be fixed on a bridge to detect any abnormal

Figure 3.
SMART home sensors communication through the internet of things. (http://www.nibib.nih.gov/sites/default/files/SMART-HOUSE_2_DCook.jpg).

activity and send warnings via SMS. Also video processing analysis can be performed to control the traffic density on a bridge. The smart tunnel can use several sensors to monitor humidity, displacement, and temperature to call for appropriate maintenance if a problem is detected. All of these applications are using sensors to detect and collect data that are used to give a proper decision that maintains a high level of security of the installations.

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Section 2

Smart Home Applications

Chapter 2

Privacy of IoT-Enabled Smart Home Systems

Avirup Dasgupta, Asif Qumer Gill and Farookh Hussain

Abstract

Digital ecosystems are going through a period of change due to the advancement in technologies such as Internet of Things (IoT) as well as proliferation of less expensive hardware sensors. Through this chapter, we present current emerging trends in IoT in different industry sectors as well as discuss the key privacy challenges impeding the growth of IoT to reach its potential in the smart home context. The majority of the existing literature on IoT smart home platforms focuses on functionalities provided by smarter connected devices; however, it does not address the concerns from a consumer's viewpoint. Thus, the key questions are: What are the privacy concerns related to IoT, particularly from a "smart home device" consumer viewpoint? What are the existing remedial approaches for privacy management? This chapter proposes a framework to assist smart home user and IoT device manufacturer to make informed privacy management decisions. The findings of this research intend to help practitioners and researchers interested in the privacy of IoT-enabled smart systems.

Keywords: IoT, smart sensors, data governance, privacy, framework

1. Introduction

In last few years, we have observed a growing interest in IoT applications, which are being developed for the industries and ecosystems such as healthcare, smart home, manufacturing and agriculture ecosystems [1]. Presently, it is anticipated that there are about 16 billion IoT units installed worldwide generating vast amount of data. According to forecast reports from Frost and Sullivan, the number of interconnected objects is expected to increase above 60 billion by 2024 [2]. Aggregated data collected from different sensors are being used by organizations increasingly to gain data-driven business insights.

The growth of IoT has been possible due to the advancement of technologies like cheaper hardware sensors, ipv6, wireless coverage, smartphones and processing power of CPU [3]. While the use of IoT worldwide has been high, the maturity level of the solutions using this technology is varied. In this chapter, we highlight the various components making up IoT, evolution of IoT and the concerns related to privacy. We particularly focus on the IoT uses in the smart home context.

IoT ecosystem stands on the building blocks of multiple underlying technologies such as sensing (sensors and actuators), connectivity (mobile), analytics and computing. A typical IoT ecosystem involves the following stages [4].

- Things are fitted with electronics, software, actuators and sensors. They can be battery operated, electricity powered or use RFID transponders. Things collect raw data from the environments. Each thing has a unique identifiable address and of varying computational capability and complexity.

- Data collected from things are processed by applications.

- Using various connectivity technologies such as Wi-Fi, Zigbee, NFC, Bluetooth, cellular (2G/3G/4G/5G) and low-powered WAN, data are transmitted.

- Applications collect data in real time from different things to store, process and analyze in computing platforms.

- Insights are derived from the collated data using robust analytics enabling informed business decisions to be taken involving process and people.

The term "Internet of Things" was officially introduced in 1998–1999 by Kevin Ashton of automatic identification center (Auto-Id) at Massachusetts Institute of technology (MIT). Kevin suggested that Internet-connected RFID technologies can be used in supply chains to keep track of items without human involvement [5]. The philosophy of IoT further gained momentum in 2005, thanks to the formal acceptance of IoT in a world summit on information society (WSIS) in Tunisia [6]. However, the concept of IoT applications can be traced back to 1982 when one of the first attempts of an IoT application was developed at Carnegie Mellon University. The Internet-connected coke machine was able to report the drinks contained and whether the drinks were cold [7] (**Table 1**).

Year	Discovery
1747	Electricity (lightning)
1819	Practical electromagnetism
1831	Faraday: Electromagnetic induction
1873	Maxwell: Theory of electromagnetism
1887	Hertz: Radio waves
1895	Marconi: Radio telegraph
1907	First public use of radio
1911	First mobile transmitter (Zeppelin)
1915	First wireless voice transmission
1927	First car radio
1928	First TV broadcast
1933	First mobile phone (Germany, in-car)
1950s	UNIVAC(UNIVersal Automatic Computer) Ia mainframe
1958	First hand-held mobile phone
1961	Cloud computing precursor (John McCarthy)
1969	Internet precursor (ARPANET)
1973	1G cellular mobile (NTT, Japan)
1981	First wireless IoT connection(Coke machine, GSM)
1982	International Internet
1988/89	World Wide Web
1990	2G cellular mobile (GSM)

Year	Discovery
1991	Bluetooth
1994	Wi-Fi (CSIRO, IEEE)
1997	3G cellular mobile (UMTS)
1998	4G cellular mobile (LTE)
1999	IoT term coined
2005	United Nations mention IoT
2008	5G cellular mobile
2008	Cloud computing term coined
2012	Cisco introduces fog computing
2020	Industry expects 20 billion IoT devices worldwide

Table 1.
IoT evolution (adapted from [3, 8, 9]).

Industry	Use case
Smart City	Smartbin offers Smart Waste Monitoring through Smart Sensors & Route Optimization Technologies [10].
Transport	Spanish train operator RENFE uses Siemens' high-speed train and monitors train developing abnormal patterns and sends them back for inspection to prevent failure on the track [11].
Agriculture	Semios uses sensors and machine vision technology to track pest populations in orchards, vineyards, and other agricultural settings [12]
Financial Sector	Progressive Insurance uses Snapshot to determine Insurance premium for car drivers [13].
Healthcare	Abilify MyCite (aripiprazole tablets with sensor) has an ingestible sensor embedded in the pill that records that the medication was taken [14].
Government	US municipality has implemented smart meter monitoring for the entire town's residential and commercial water meters. The project involved placing water meter sensors on 66,000 devices that used to be manually read and recorded [15].
Utility	US oil and gas company is optimizing oilfield production with the Internet of Things. In this IoT example, the company is using sensors to measure oil extraction rates, temperatures, well pressure and more for 21,000 wells [15].
Environment	Autonomous sailboats and watercraft are already patrolling the oceans carrying sophisticated sensor instruments, collecting data on changes in Arctic ice [16].

Table 2.
IoT applications.

IoT has produced a number of sophisticated solutions that are growing in popularity among businesses. Many sectors have already graduated to this technology, and are putting IoT to use for digitizing their daily activities. The prominent adapters of IoT are Smart City, Retail, and Manufacturing. Some of the most notable applications rolled out in the marketplace are given in **Table 2**.

Although, there is a growing interest in IoT applications in different industry sectors, challenges in adoption exist. The key questions are: What are the privacy concerns related to IoT, particularly from a "smart home device" consumer viewpoint? What are the existing remedial approaches for privacy management? This chapter aims to address the above-mentioned questions. The remainder of this chapter is organized as follows. Section 2 presents various privacy concerns of IoT before proposing a novel framework to address IoT concerns from a consumer's perspective in Section 3. This is followed by an initial validation of the framework in Section 4 before we draw conclusions in Section 5.

2. Review of privacy literature with specific IoT focus

Privacy is defined by Clarke as the attention that individuals have in sustaining a personal space, free from interference by other people and organizations [17]. An intrinsic part of privacy issue is the exposure of sensitive data such as Personal Identifiable Information (PII) to non-intended recipients. Personal Identifiable Information (PII) comprises of details such as title, first name, last name, date of birth, address, and phone number, constituting some of the sensitive personal information (SPI). In addition, financial and health details and the geophysical location of an IoT user are also considered as sensitive information.

Internet of Things devices may collect data including sensitive data and store the data for further use for commercial purposes. It comprises of several stakeholders such as customer whose PII is collected; manufacturers who develop the sensors and other networking components and third parties who create IoT mobile apps or use the data for commercial advantage. According to McKinsey global report from 2015 [18], consumers are cautious about embracing IoT-based systems, particularly due to lack of privacy and the data at risk. OECD reported [19] that privacy incidents are growing in both number and sophistication. Similar concerns are expressed by several academic articles which suggest lack of privacy including unauthorized surveillance or eavesdropping [20] as a major concern for individuals.

Some researchers or practitioners confuse privacy with security. While security deals with the management of controlling who can access information, privacy is predominantly focused on granular control of what data can be collected, who can access what, when they can access specific data, and how long the data should be retained.

Protecting user's privacy comprises of technical, human and legal aspects. Other relevant aspects can also be considered.

2.1 Potential scenarios of privacy violation in smart home

Smart home segment comprises of connected appliances like TV set, thermostat, refrigerator, oven, home security, self-guided vacuum cleaners, cleaning and maintenance devices. Additionally, cameras, motion sensors and light sensors also collect data. Most of these data contain private and/or sensitive information such as locations, addresses, pictures and network access information. The data can be accessible to device manufacturer, mobile application owner, third-party vendors or public depending on use cases. There are several scenarios involving data collection such as:

- Movement of individuals (unauthorized surveillance) using motion sensors, camera and GPS tracker.
- Monitoring of actions of customers.
- Sharing of health data publicly from wearable devices or implantable devices such as Abilify MyCite, and Bluetooth-enabled oximeter [18].
- Sharing of data (e.g., financial, health, PII, Payment Card Information and geophysical data) to third party without explicit consent [21].
- Search query of user shows his preference traits (**Figure 1**).

There are very few contributions that address privacy in the context of smart home [22]. While several studies conducted surveys and interviews with IoT end user consumers to investigate the factors affecting privacy including data processing and information risk [23], none proposed a feasible solution to fix them.

Figure 1.
Key data exchanges in smart home.

2.2 Legal aspects of privacy in IoT era

Government organizations are taking significant interest in IoT security, privacy and interoperability from legal aspects. This is in alignment with the studies which advocated further collaboration and dialogs between the regulators and manufacturers of IoT devices to develop appropriate methods to tackle the relevant problems [24]. From regulatory perspective, some of the most important legislative requirements are HIPAA for healthcare, MA risk for supply chain management, California's Senate Bill 327, IoT Cybersecurity Improvement Act of 2017 and General Data Protection Regulation (GDPR).

Data privacy requirements are complex and differ by jurisdictions in regard to the definition of data and the relevant laws/regulations. In Europe, GDPR was introduced on May 25, 2018. GDPR is a new regulation approved by EU parliament, Council and European Commission. It aims to safeguard the personal data rights of EU citizens and residents in this era of new technological advancements. As per GDPR, organizations are required to

- Get explicit and affirmative consent before processing personal data. This includes financial, economic and health data and online information.
- Notify within 72 hours to the regulator and individual about any data breaches.
- Facilitate customers and employees' right to the removal of data from their system.
- Give the right of portability, and increased right of access and right to be forgotten by customer.
- Maintain records of processing activities.

GDPR non-compliance instances may incur penalties up to 2–4% of global revenue or 20 million Euros [25] to organizations based on the infringement. GDPR applies to any company, irrespective of their geographic location, that offers goods and services to European citizens and handles their data including IoT ecosystem-generated data.

In USA, California Senate Bill 327 [26] was introduced recently which allows the State of California ability to bring enforcement complaints against those companies that do not build adequate security safeguards into their Internet-connected IoT devices [27]. It provides the state the right to hold IoT device makers more accountable for consumer's data security. IoT Cybersecurity Improvement Act of 2017 [28] requires: (i) that IoT devices are patchable, (ii) that devices do not contain known vulnerabilities, (iii) that devices rely on standard protocols, (iv) that devices do not contain hard-coded password and (v) technical aspects of privacy in IoT era.

At present, different privacy-enhancing technologies (PETs) exist to protect privacy. Prevention, by means of access restrictions, is an effective way to safeguard customer privacy. In [29], the authors put forward a concept of using access control list (ACL) and data classification model, to classify data according to its sensitivity and assign tag value to each category. In [30], the authors presented the idea of using Certification Authority (CA)-based encryption to confirm the authenticity of sensor. Some authors argue that it adds overheads and hence it cannot be used as a viable solution. Instead, they proposed incorporating a chaos-based cryptographic scheme and Message Authentication Codes (MAC) for data transmission. In a recent research, authors from IT service firm Tata Consultancy Services recommended that the IoT stakeholders can adopt Preventive Privacy (3P) Framework [31] in order to build trust and confidence among end users.

Privacy by Design (PbD) is defined as another popular approach that enables privacy to be "built in" to the design of the information systems and business processes, ensuring that privacy is considered before, and throughout, the development and implementation of all initiatives that involve personal information [32]. Dr. Ann Cavoukian first proposed it in Canada in the 1990s. PbD is one of the highly recommended approaches to protect individual's privacy [31, 33] concerns in IoT. Unfortunately, even though the USA Federal Trade commission (FTC) and the European Commission accepted PbD to be effective [34], not all manufacturers consider PbD when developing IoT devices and applications.

2.3 People aspects of privacy in IoT era

According to a survey conducted by Cisco in 2017, "human factors" such as organization, culture and leadership contributed to the success of IoT implementations 75% of the time—which was higher than technical aspects [35]. A number of stakeholders are involved in IoT digital ecosystem such as the end users, product suppliers, Internet service providers, cloud storage functionalities and retailers. As mentioned earlier, a significant aspect of the value of IoT for consumers refers to: aggregating data collected from many source systems, generating new knowledge and making fact-based choices. The utilization of data to add value is best explained by the well-known DIKW hierarchy from Ackoff [36]. DIKW is a four-layer hierarchy comprising of data, information, knowledge and wisdom where each layer adds certain characteristics over and above the previous one. **Table 3** shows DIKW in an IoT context.

Hierarchy level	Description
Data	Most basic level of facts. Collected from things and used for storage and processing.
Information	Computing platform adds context to data (who, what, where, when) ingested.
Knowledge	This layer answers the question on how data are used. Analytics is applied in computing platform.
Wisdom	Evaluated understanding of when and why data are used

Table 3.
DIKW in an IoT context.

3. Consumer-centric approach

While IoT organizations are aware of the need for adopting PET and incorporating PbD, there is little guidance available on how to do so. Though there are PbD-driven frameworks available [34], no concrete solutions to establish auditing mechanism or control method systems have been developed (**Table 4**).

The lifecycle of an IoT service or product is shown in **Figure 2**.

Figure 3 summarizes: what can be done, at the minimal level, by consumer to safeguard his/her privacy. This provides the basis for the further development of

Pre-purchase		Setup/post purchase	Decommission
Awareness omni channels	**Research + solution purchase**	**Use + feedback**	
• Web • Social • Mobile • In-store • Media • Advertising • Direct Marketing	• Products which provide audit mechanism while dealing with PII [20] • Products which notify user to provide dynamic consent for data use [37] • Products which stop working properly when consent is not given by user [38] • Firmware upgrade and patchability of IoT devices [24] are available. • Products transparent on how disclosed data are used by the developer of the IoT system or application [39] • Established reputed product with no or negligible data breach history	• Setting up, configuring and registering to IoT services • Signing Consents authorizing data to be collected and used by IoT service provider. • Update Firmware and mobile applications	• Remove authoriza-tion of IoT vendor to use your data • Deregister and destroy data.

Table 4.
Consumer's perspective of IoT product lifespan.

Figure 2.
IoT product lifecycle.

Figure 3.
Mitigation options for consumers (based on [31, 46, 47]).

Consumer questions	Risk factors
Who has access to the data? Will third parties have access to the data? What information can be inferred from the data?	Unacceptable usage of data without consent such as spamming
Will my data be shared outside my country?	Data sovereignty constraints
How will I be informed in case my data are compromised?	Data detection and notification of breach
Are there any known breaches or vulnerabilities about this device?	Outdated Firmware
What happens when I stop using the product or service?	De-authorization
Can my location be tracked from data?	Unveiling of physical address
What can I do if my PII is compromised?	Password renewal
How can I rectify my data?	Outdated information
Can I get a copy of my data or access my data?	Portability
Can I ask you to remove my digital footprint captured by the IoT service?	Unaligned data erasure

Table 5.
Key questions in IoT for consumers.

an IoT privacy tool or framework, which can address the concerns of the consumer [31, 40–45] compiled in **Table 5**.

4. Proposed framework

As mentioned in earlier section, the existing frameworks are relevant primarily for thing manufacturer and do not involve end thing consumers. Through this chapter, we seek to provide answers to the questions mentioned in **Table 5** by leveraging a four-phased data governance-driven 4I framework (Identify, Insulate, Inspect and Improve). The Identify phase of the 4I framework (**Figure 4**) comprises of seven key dimensions such as risk, compliance, policy, process, people, data asset and technology (**Table 6**).

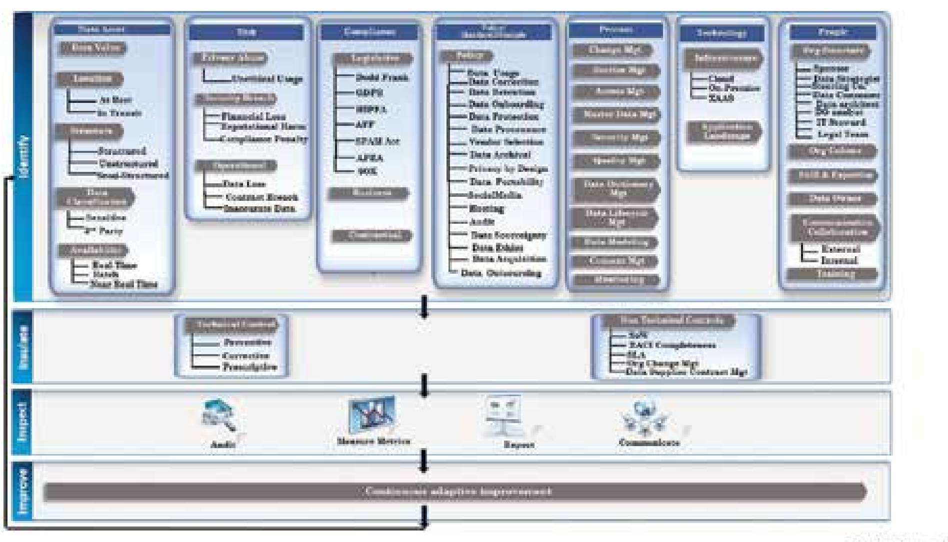

Figure 4.
The 4I framework.

Dimension	Description
Risk	Risk dimension comprises of the factors that influence both the IoT end user and thing manufacturer. It includes attributes such as lack of consent data breach, legal penalties, service level agreement violation, and lack of upgradability, interoperability and security [20, 41, 48, 49].
Compliance	Includes legal requirements (e.g., user consent), controls and baselines to be operationally compliant. There are a number of regulations such as SOX, GDPR, SPAM Act, Australian APP Privacy law, HIPPA and COPPA which are relevant for IoT [50].
Policy, standards and principles	This dimension spans the lifecycle from inception to deletion of data including items such as data sharing, acceptable use of data, data classification and storing rules. A well-defined and enforced governance providing the structure that works for the benefit of everyone concerned by ensuring that the IoT stakeholders adhere to accepted ethical standards [44, 51].
Data asset	Describes the benefit of the data and the salient features of the data [52, 53].
Process	Defines how various interfaces and functionalities are to deliver a functioning and solution [54].
People	The different stakeholders and their accountability in the IoT ecosystem such as consumer, ombudsman, policy maker, IoT thing manufacturer, IoT cloud provider, Internet service provider and the IoT service operators. People dimension also includes leadership and organization structures [55, 56].
Technology	This dimension includes hardware infrastructure, platforms and software agents that notify potential compliance violation through monitoring and workflows [34, 53].

Table 6.
Key dimensions of the Identify phase of the 4I framework.

Identify stage or phase refers to the key risks, requirements and context. Insulate stage refers to the precautionary measures taken to prevent lapses using technologies and non-technical risk remediation techniques. Inspect stage contains the essential toolkits such as maturity models, audit mechanisms, software agents required to continuously monitor, report and assess the IoT Data Governance Maturity from risk and value perspectives. The final stage focuses on continuous improvement.

4.1 The 4I framework applied to privacy context

To illustrate how the proposed 4I framework will work in an IoT-enabled home, a use case involving smart refrigerator is discussed in this section. Currently, when consumers buy an IoT device directly from vendors or service providers, they may have very little understanding when agreeing to the privacy policy (PP) and terms and conditions (T&C) before they start using the product or services or application. However, there are several risks associated with the data collected to render the services.

For example, the smart refrigerator can track our food preferences, search and order food from online stores [31]. Various traits of the fridge owners' eating behaviors can be inferred based on the search queries. If these data are sent to third-party business, they can use the information for the purpose of undesirable targeted advertisements. This can lead to the potential breach of privacy violating regulatory laws if explicit consent was not obtained from the consumer (**Figure 5**).

The **Identify** phase of the 4I framework discerns the potential risks associated with the consumer's data shared among the data processors in data supply chain. For example, it reviews the laws such as GDPR to understand the data protection rights of a smart home user [57] and ascertains the risk related to privacy and security breach. Policies related to data retention, service level agreement with vendors and data management are implemented in the **Insulation** phase of the framework. For instance, an agent called checkmyprivacyrules (CPMRs) can be installed at user's home router to ensure privacy policy and laws like GDPR are not violated based on a search query (**Figure 6**).

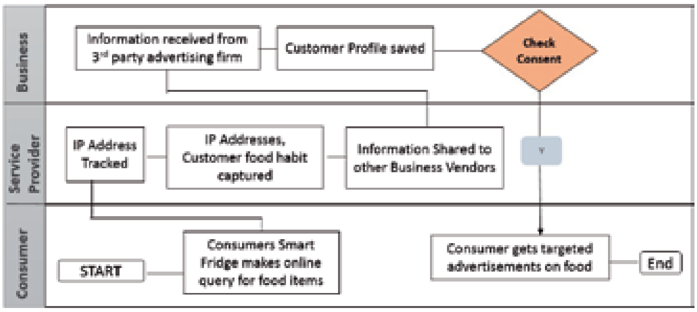

Figure 5.
Business process in smart home refrigerator.

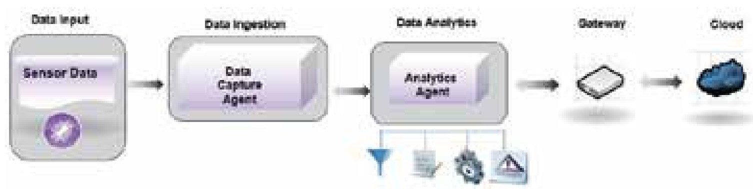

Figure 6.
Smart home 4I (filters, policies, rules, permissions) (adopted from [58]).

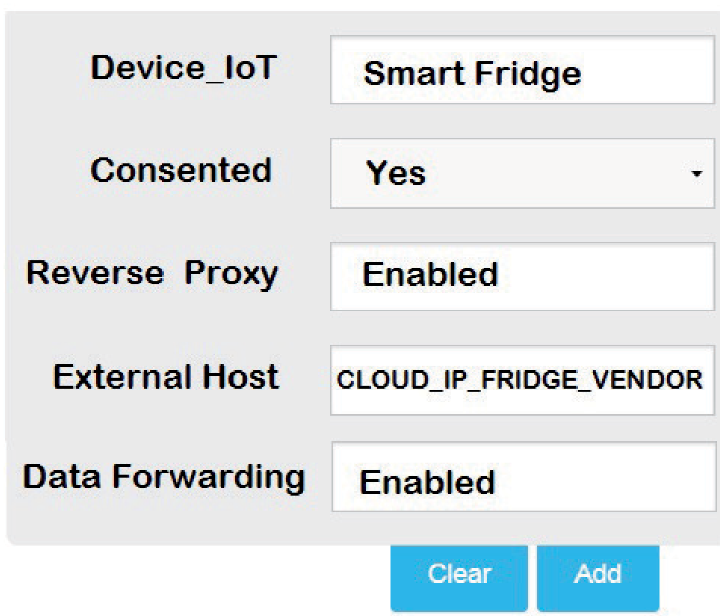

Figure 7.
Web configuration to add privacy rule for smart fridge.

Figure 7 shows a screen where smart fridge user can setup who can access the data. With the above settings, smart fridge can send data to cloud if

a. Device has latest firmware updates. This can be verified from Firmware update version captured periodically from Vendor Website by the agent installed in the router

b. Intended address to push data in the packet states matches external host IP address

c. Consent is set to "Yes"

d. Reverse Proxy is enabled. This will ensure even if the ISP or business gets IP address, it will not be accurate.

Listing 1 shows the Pseudo code of the agent.

CheckMyPrivacyRules (Di) *Di - > device_* *Rij - > rule j for device Di* *Begin* *For each Di in domain D* *For each rule Rij* *If substring(Pi)- = Rij.* *Transmit Data;* *Else* *Send SMS/email to user* *Stop polling Di* *Endif* *Endif*	Di is the set of all smart IoT devices in a "Smart Home" and Di ⊂ D Rij is the ruleset j applied to Device Di before it leaves home network Pi is the packet send by Di to the router.

Listing 1.
Pseudocode for CPM.

The Inspection phase comprises of performing audit reviews periodically to assure the compliance of the process, systems and data flow. The **Inspect** phase can comprise of automated data quality checks and data access log monitoring. In the I**mprove** phase, continuous improvement is done to ensure the continuous adaptation in response to changing data privacy requirements and landscape. For example, improving the agent to ensure software is not only patched to current version, but also data are secured using tokenization techniques [59] can be an outcome of this final phase of the 4I framework.

5. Conclusion

IoT's business growth potential is undeniable. Advancement in IoT has opened up new prospects for growth in the diversified areas such as health, energy, transport and smart home. In this chapter, we provided an overview of the IoT technology and real-life examples of usage of this technology. Next, we discussed the privacy problems in IoT from a consumer's perspective. A review of the related work was presented along with research gaps. Next, we proposed and provided an overview of a data governance-driven 4I framework. Finally, we provided the pseudocode and demonstrated the applicability of the 4I framework to address the privacy concerns in a smart home refrigerator context. This involved the policies, rules and configurations using time-tested data governance principles. In future, we intend to further test and improve the 4I framework in the overall context of data governance in digital ecosystem.

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Conflict of interest

There is no conflict of interest.

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Chapter 3

Smart Home Systems Based on Internet of Things

Menachem Domb

Abstract

Smart home systems achieved great popularity in the last decades as they increase the comfort and quality of life. Most smart home systems are controlled by smartphones and microcontrollers. A smartphone application is used to control and monitor home functions using wireless communication techniques. We explore the concept of smart home with the integration of IoT services and cloud computing to it, by embedding intelligence into sensors and actuators, networking of smart things using the corresponding technology, facilitating interactions with smart things using cloud computing for easy access in different locations, increasing computation power, storage space and improving data exchange efficiency. In this chapter we present a composition of three components to build a robust approach of an advanced smart home concept and implementation.

Keywords: smart home, IoT, cloud computing, event processing, home appliances, rule-based event processing

1. Introduction

Classic smart home, internet of things, cloud computing and rule-based event processing, are the building blocks of our proposed advanced smart home integrated compound. Each component contributes its core attributes and technologies to the proposed composition. IoT contributes the internet connection and remote management of mobile appliances, incorporated with a variety of sensors. Sensors may be attached to home related appliances, such as air-conditioning, lights and other environmental devices. And so, it embeds computer intelligence into home devices to provide ways to measure home conditions and monitor home appliances' functionality. Cloud computing provides scalable computing power, storage space and applications, for developing, maintaining, running home services, and accessing home devices anywhere at anytime. The rule-based event processing system provides the control and orchestration of the entire advanced smart home composition.

Combining technologies in order to generate a best of breed product, already appear in recent literature in various ways. Christos Stergioua et al. [1] merge cloud computing and IoT to show how the cloud computing technology improves the functionality of the IoT. Majid Al-Kuwari [2] focus on embedded IoT for using analyzed data to remotely execute commands of home appliances in a smart home. Trisha Datta et al. [3] propose a privacy-preserving library to embed traffic shaping in home appliances. Jian Mao et al. [4] enhance machine learning algorithms to play a role in the security in a smart home ecosystem. Faisal Saeed et al. [5] propose using sensors to sense and provide in real-time, fire detection with high accuracy.

In this chapter we explain the integration of classic smart home, IoT and cloud computing. Starting by analyzing the basics of smart home, IoT, cloud computing and event processing systems. We discuss their complementarity and synergy, detailing what is currently driving to their integration. We also discuss what is already available in terms of platforms, and projects implementing the smart home, cloud and IoT paradigm. From the connectivity perspective, the added IoT appliances and the cloud, are connected to the internet and in this context also to the home local area network. These connections complement the overall setup to a complete unified and interconnected composition with extended processing power, powerful 3rd party tools, comprehensive applications and an extensive storage space.

In the rest of this chapter we elaborate on each of the four components. In Section 1, we describe the classic smart home, in Section 2, we introduce the internet of things [IoT], in Section 3, we outline cloud computing and in Section 4, we present the event processing module. In Section 5, we describe the composition of an advanced smart home, incorporating these four components. In Section 6, we provide some practical information and relevant selection considerations, for building a practical advanced smart home implementation. In Section 7, we describe our experiment introducing three examples presenting the essence of our integrated proposal. Finally, we identify open issues and future directions in the future of advanced smart home components and applications.

2. Classic smart home overview

Smart home is the residential extension of building automation and involves the control and automation of all its embedded technology. It defines a residence that has appliances, lighting, heating, air conditioning, TVs, computers, entertainment systems, big home appliances such as washers/dryers and refrigerators/freezers, security and camera systems capable of communicating with each other and being controlled remotely by a time schedule, phone, mobile or internet. These systems consist of switches and sensors connected to a central hub controlled by the home resident using wall-mounted terminal or mobile unit connected to internet cloud services.

Smart home provides, security, energy efficiency, low operating costs and convenience. Installation of smart products provide convenience and savings of time, money and energy. Such systems are adaptive and adjustable to meet the ongoing changing needs of the home residents. In most cases its infrastructure is flexible enough to integrate with a wide range of devices from different providers and standards.

The basic architecture enables measuring home conditions, process instrumented data, utilizing microcontroller-enabled sensors for measuring home conditions and actuators for monitoring home embedded devices.

The popularity and penetration of the smart home concept is growing in a good pace, as it became part of the modernization and reduction of cost trends. This is achieved by embedding the capability to maintain a centralized event log, execute machine learning processes to provide main cost elements, saving recommendations and other useful reports.

2.1 Smart home services

2.1.1 Measuring home conditions

A typical smart home is equipped with a set of sensors for measuring home conditions, such as: temperature, humidity, light and proximity. Each sensor is dedicated to capture one or more measurement. Temperature and humidity may be measured by one sensor, other sensors calculate the light ratio for a given area and the distance from it to each object exposed to it. All sensors allow storing the data and visualizing it so that the user can view it anywhere and anytime. To do so, it includes a signal processer, a communication interface and a host on a cloud infrastructure.

2.1.2 Managing home appliances

Creates the cloud service for managing home appliances which will be hosted on a cloud infrastructure. The managing service allows the user, controlling the outputs of smart actuators associated with home appliances, such as such as lamps and fans. Smart actuators are devices, such as valves and switches, which perform actions such as turning things on or off or adjusting an operational system. Actuators provides a variety of functionalities, such as on/off valve service, positioning to percentage open, modulating to control changes on flow conditions, emergency shutdown (ESD). To activate an actuator, a digital write command is issued to the actuator.

2.1.3 Controlling home access

Home access technologies are commonly used for public access doors. A common system uses a database with the identification attributes of authorized people. When a person is approaching the access control system, the person's identification attributes are collected instantly and compared to the database. If it matches the database data, the access is allowed, otherwise, the access is denied. For a wide distributed institute, we may employ cloud services for centrally collecting persons' data and processing it. Some use magnetic or proximity identification cards, other use face recognition systems, finger print and RFID.

In an example implementation, an RFID card and an RFID reader have been used. Every authorized person has an RFID card. The person scanned the card via RFID reader located near the door. The scanned ID has been sent via the internet to the cloud system. The system posted the ID to the controlling service which compares the scanned ID against the authorized IDs in the database.

2.2 The main components

To enable all of the above described activities and data management, the system is composed of the following components, as described in **Figure 1**.

a. Sensors to collect internal and external home data and measure home conditions. These sensors are connected to the home itself and to the attached-to-home devices. These sensors are not internet of things sensors, which are attached to home appliances. The sensors' data is collected and continually transferred via the local network, to the smart home server.

b. Processors for performing local and integrated actions. It may also be connected to the cloud for applications requiring extended resources. The sensors' data is then processed by the local server processes.

c. A collection of software components wrapped as APIs, allowing external applications execute it, given it follows the pre-defined parameters format. Such an API can process sensors data or manage necessary actions.

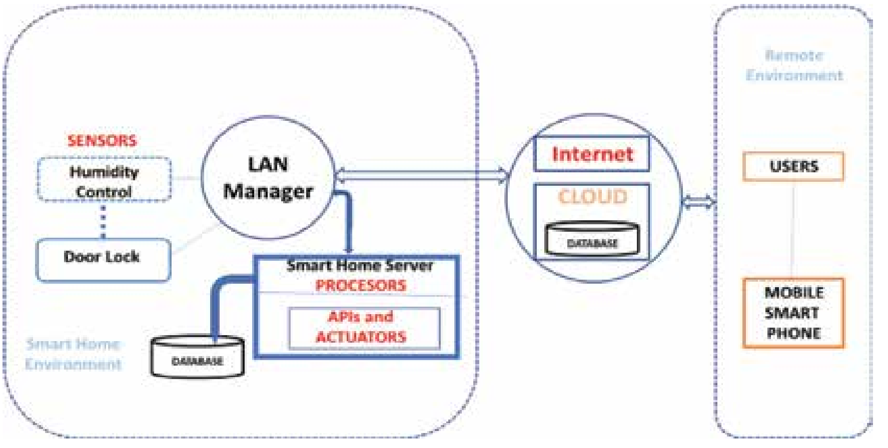

Figure 1.
Smart home paradigm with optional cloud connectivity.

d. Actuators to provision and execute commands in the server or other control devices. It translates the required activity to the command syntax; the device can execute. During processing the received sensors' data, the task checks if any rule became true. In such case the system may launch a command to the proper device processor.

e. Database to store the processed data collected from the sensors [and cloud services]. It will also be used for data analysis, data presentation and visualization. The processed data is saved in the attached database for future use.

3. Internet of things [IoT] overview

The internet of things (IoT) paradigm refers to devices connected to the internet. Devices are objects such as sensors and actuators, equipped with a telecommunication interface, a processing unit, limited storage and software applications. It enables the integration of objects into the internet, establishing the interaction between people and devices among devices. The key technology of IoT includes radio frequency identification (RFID), sensor technology and intelligence technology. RFID is the foundation and networking core of the construction of IoT. Its processing and communication capabilities along with unique algorithms allows the integration of a variety of elements to operate as an integrated unit but at the same time allow easy addition and removal of components with minimum impact, making IoT robust but flexible to absorb changes in the environment and user preferences. To minimize bandwidth usage, it is using JSON, a lightweight version of XML, for inter components and external messaging.

4. Cloud computing and its contribution to IoT and smart home

Cloud computing is a shared pool of computing resources ready to provide a variety of computing services in different levels, from basic infrastructure to most sophisticated application services, easily allocated and released with minimal efforts or service provider interaction [6, 7]. In practice, it manages computing, storage, and communication resources that are shared by multiple users in a virtualized and isolated environment. **Figure 2** depicts the overall cloud paradigm.

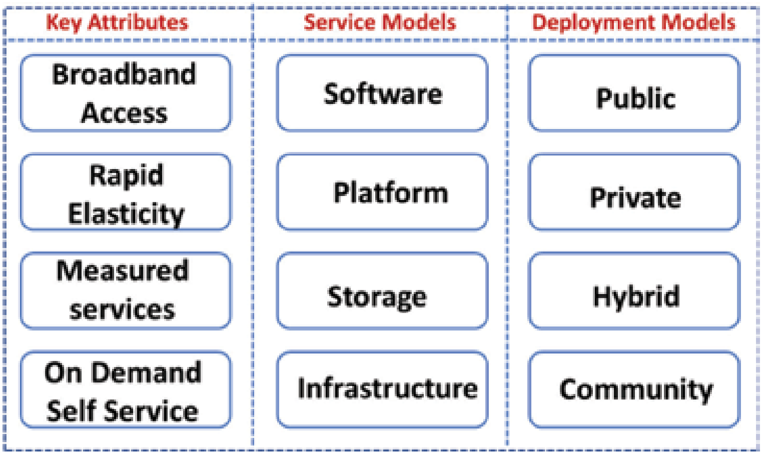

Figure 2.
Cloud computing paradigm.

IoT and smart home can benefit from the wide resources and functionalities of cloud to compensate its limitation in storage, processing, communication, support in pick demand, backup and recovery. For example, cloud can support IoT service management and fulfillment and execute complementary applications using the data produced by it. Smart home can be condensed and focus just on the basic and critical functions and so minimize the local home resources and rely on the cloud capabilities and resources. Smart home and IoT will focus on data collection, basic processing, and transmission to the cloud for further processing. To cope with security challenges, cloud may be private for highly secured data and public for the rest.

IoT, smart home and cloud computing are not just a merge of technologies. But rather, a balance between local and central computing along with optimization of resources consumption. A computing task can be either executed on the IoT and smart home devices or outsourced to the cloud. Where to compute depends on the overhead tradeoffs, data availability, data dependency, amount of data transportation, communications dependency and security considerations. On the one hand, the triple computing model involving the cloud, IoT and smart home, should minimize the entire system cost, usually with more focus on reducing resource consumptions at home. On the other hand, an IoT and smart home computing service model, should improve IoT users to fulfill their demand when using cloud applications and address complex problems arising from the new IoT, smart home and cloud service model.

Some examples of healthcare services provided by cloud and IoT integration: properly managing information, sharing electronic healthcare records enable high-quality medical services, managing healthcare sensor data, makes mobile devices suited for health data delivery, security, privacy, and reliability, by enhancing medical data security and service availability and redundancy and assisted-living services in real-time, and cloud execution of multimedia-based health services.

5. Centralized event processing, a rule-based system

Smart home and IoT are rich with sensors, which generate massive data flows in the form of messages or events. Processing this data is above the capacity of a human being's capabilities [8–10]. Hence, event processing systems have been developed and used to respond faster to classified events. In this section, we focus on rule management systems which can sense and evaluate events to respond to changes in values or interrupts. The user can define event-triggered rule and to control the proper delivery of services. A rule is composed of event conditions, event pattern and correlation-related information which can be combined for modeling complex situations. It was implemented in a typical smart home and proved its suitability for a service-oriented system.

The system can process large amounts of events, execute functions to monitor, navigate and optimize processes in real-time. It discovers and analyzes anomalies or exceptions and creates reactive/proactive responses, such as warnings and preventing damage actions. Situations are modeled by a user-friendly modeling interface for event-triggered rules. When required, it breaks them down into simple, understandable elements. The proposed model can be seamlessly integrated into the distributed and service-oriented event processing platform.

The evaluation process is triggered by events delivering the most recent state and information from the relevant environment. The outcome is a decision graph representing the rule. It can break down complex situations to simple conditions, and combine them with each other, composing complex conditions. The output is a response event raised when a rule fires. The fired events may be used as input for other rules for further evaluation. Event patterns are discovered when multiple events occur and match a pre-defined pattern. Due to the graphical model and modular approach for constructing rules, rules can be easily adapted to domain changes. New event conditions or event patterns can be added or removed from the rule model. Rules are executed by event services, which supply the rule engine with events and process the evaluation result. To ensure the availability of suitable processing resources, the system can run in a distributed mode, on multiple machines and facilitate the integration with external systems, as well. The definition of relationships and dependencies among events that are relevant for the rule processing, are performed using sequence sets, generated by the rule engine. The rule engine constructs sequences of events relevant to a specific rule condition to allow associating events by their context data. Rules automatically perform actions in response when stated conditions hold. Actions generate response events, which trigger response activities. Event patterns can match temporal event sequences, allowing the description of home situations where the occurrences of events are relevant. For example, when the door is kept open too long.

The following challenges are known with this model: structure for the processed events and data, configuration of services and adapters for processing steps, including their input and output parameters, interfaces to external systems for sensing data and for responding by executing transactions, structure for the processed events and data, data transformations, data analysis and persistence. It allows to model which events should be processed by the rule service and how the response events should be forwarded to other event services. The process is simple: data is collected and received from adapters which forward events to event services that consume them. Initially the events are enriched to prepare the event data for the rule processing. For example, the response events are sent to a service for sending notifications to a call agent, or to services which transmit event delay notifications and event updates back to the event management system.

5.1 Event processing languages

Event processing is concerned with real-time capturing and managing predefined events. It starts from managing the receptors of events right from the event occurrence, even identification, data collection, process association and activation of the response action. To allow rapid and flexible event handling, an event processing language is used, which allows fast configuration of the resources required to handle the expected sequence of activities per event type. It is composed of two modules, ESP and CEP. ESP efficiently handles the event, analyzes it and selects the appropriate occurrence. CEP handles aggregated events. Event languages describe complex event-types applied over the event log.

5.2 Rediscovering workflow from events

In some cases, rules relate to discrepancies in a sequence of events in a workflow. In such cases, it is mandatory to precisely understand the workflow and its associated events. To overcome this, we propose a reverse engineering process to automatically rediscover the workflows from the events log collected over time, assuming these events are ordered, and each event refers to one task being executed for a single case. The rediscovering process can be used to validate workflow sequences by measuring the discrepancies between prescriptive models and actual process executions. The rediscovery process consists of the following three steps: (1) construction of the dependency/frequency table. (2) Induction of dependency/frequency graphs. (3) Generating WF-nets from D/F-graphs.

6. Advanced smart home

In this section, we focus on the integration of smart home, IoT and cloud computing to define a new computing paradigm. We can find in the literature section [11–14] surveys and research work on smart home, IoT and cloud computing separately, emphasizing their unique properties, features, technologies, and drawbacks. However, our approach is the opposite. We are looking at the synergy among these three concepts and searching for ways to integrate them into a new comprehensive paradigm, utilizing its common underlying concepts as well as its unique attributes, to allow the execution of new processes, which could not be processed otherwise.

Figure 3 depicts the advanced smart-home main components and their interconnectivity. On the left block, the smart home environment, we can see the typical

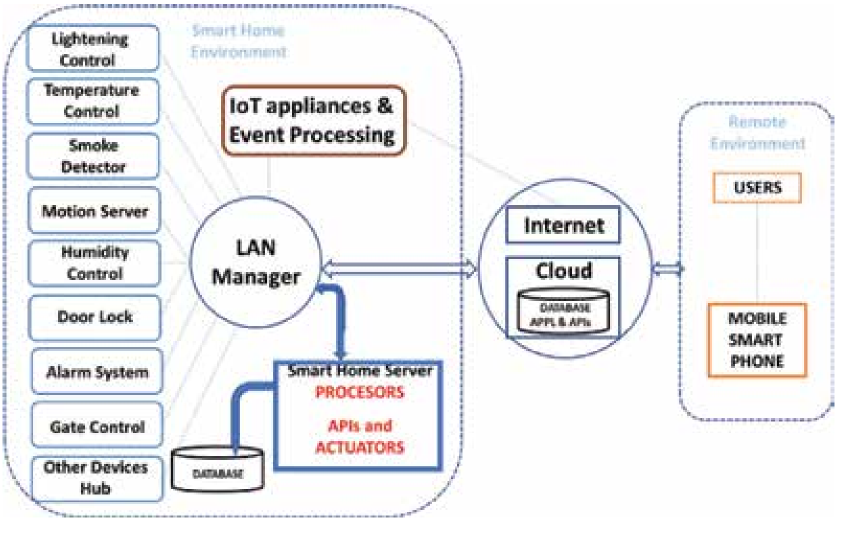

Figure 3.
Advanced smart home—integrating smart home, IoT and cloud computing.

devices connected to a local area network [LAN]. This enables the communication among the devices and outside of it. Connected to the LAN is a server and its database. The server controls the devices, logs its activities, provides reports, answers queries and executes the appropriate commands. For more comprehensive or common tasks, the smart home server, transfers data to the cloud and remotely activate tasks in it using APIs, application programming interface processes. In addition, IoT home appliances are connected to the internet and to the LAN, and so expands smart home to include IoT. The connection to the internet allows the end user, resident, to communicate with the smart home to get current information and remotely activate tasks.

To demonstrate the benefits of the advanced smart home, we use RSA, a robust asymmetric cryptography algorithm, which generates a public and private key and encrypts/decrypts messages. Using the public key, everyone can encrypt a message, but only these who hold the private key can decrypt the sent message. Generating the keys and encrypting/decrypting messages, involves extensive calculations, which require considerable memory space and processing power. Therefore, it is usually processed on powerful computers built to cope with the required resources. However, due to its limited resources, running RSA in an IoT device is almost impossible, and so, it opens a security gap in the Internet, where attackers may easily utilize. To cope with it, we combine the power of the local smart home processors to compute some RSA calculations and forward more complicated computing tasks to be processed in the cloud. The results will then be transferred back to the IoT sensor to be compiled and assembled together, to generate the RSA encryption/decryption code, and so close the mentioned IoT security gap. This example demonstrates the data flow among the advanced smart home components. Where, each component performs its own stack of operations to generate its unique output. However, in case of complicated and long tasks it will split the task to sub tasks to be executed by more powerful components. Referring to the RSA example, the IoT device initiates the need to generate an encryption key and so, sends a request message to the RSA application, running in the smart home computer. The smart home computer then asks the "prime numbers generation" application running on cloud, to provide p and q prime numbers. Once p and q are accepted, the encryption code is generated. In a later stage, an IoT device issues a request to the smart home computer to encrypt a message, using the recent generated RSA encryption key. The encrypted message is then transferred back to the IoT device for further execution. A similar scenario may be in the opposite direction, when an IoT device gets a message it may request the smart home to decrypt it.

To summarize, the RSA scenarios depict the utilization of the strength of the cloud computing power, the smart home secured computing capabilities and at the end the limited power of the IoT device. It proves that without this automatic cooperation, RSA would not be able to be executed at the IoT level.

A more practical example is where several detached appliances, such as an oven, a slow cooker and a pan on the gas stove top, are active in fulfilling the resident request. The resident is getting an urgent phone call and leaves home immediately, without shutting off the active appliances. In case the relevant IoTs have been tuned to automatically shut down based on a predefined rule, it will be taken care at the IoT level. Otherwise, the smart home realizes the resident has left home [the home door has been opened and then locked, the garage has been opened, the resident's car left, the main gate was opened and then closed, no one was at home] and will shut down all active devices classified as risk in case of absence. It will send an appropriate message to the mailing list defined for such an occasion.

7. Practical aspects and implementation considerations for IoT and smart home

Smart home has three components: hardware, software and communication protocols. It has a wide variety of applications for the digital consumer. Some of the areas of home automation led IoT enabled connectivity, such as: lighting control, gardening, safety and security, air quality, water-quality monitoring, voice assistants, switches, locks, energy and water meters.

Advanced smart home components include: IoT sensors, gateways, protocols, firmware, cloud computing, databases, middleware and gateways. IoT cloud can be divided into a platform-as-a-service (PaaS) and infrastructure-as-a-service (IaaS). **Figure 4** demonstrates the main components of the proposed advanced smart home and the connection and data flow among its components.

The smart home application updates the home database in the cloud to allow remote people access it and get the latest status of the home. A typical IoT platform contains: device security and authentication, message brokers and message queuing, device administration, protocols, data collection, visualization, analysis capabilities, integration with other web services, scalability, APIs for real-time information flow and open source libraries. IoT sensors for home automation are known by their sensing capabilities, such as: temperature, lux, water level, air composition, surveillance video cameras, voice/sound, pressure, humidity, accelerometers, infrared, vibrations and ultrasonic. Some of the most commonly used smart home sensors are temperature sensors, most are digital sensors, but some are analog and can be extremely accurate. Lux sensors measure the luminosity. Water level ultrasonic sensors.

Float level sensors offer a more precise measurement capability to IoT developers. Air composition sensors are used by developers to measure specific components in the air: CO monitoring, hydrogen gas levels measuring, nitrogen oxide measure, hazardous gas levels. Most of them have a heating time, which means that it requires a certain time before presenting accurate values. It relies on detecting gas

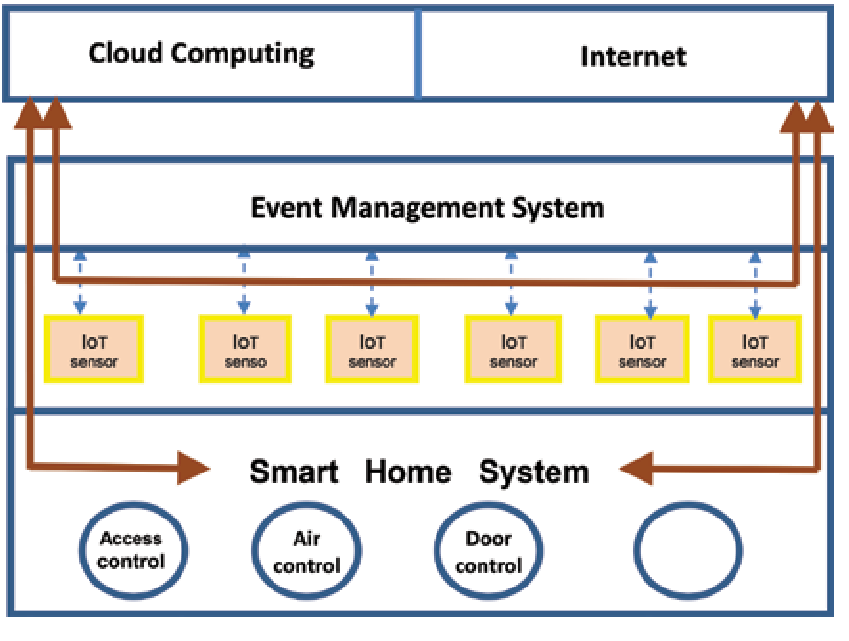

Figure 4.
Advanced smart home composition.

components on a surface only after the surface is heated enough, values start to show up. Video cameras for surveillance and analytics. A range of cameras, with a high-speed connection. Using Raspberry Pi processor is recommended as its camera module is very efficient due to its flex connector, connected directly to the board.

Sound detectors are widely used for monitoring purposes, detecting sounds and acting accordingly. Some can even detect ultra-low levels of noise, and fine tune among various noise levels.

Humidity sensors sense the humidity levels in the air for smart homes. Its accuracy and precision depend on the sensor design and placement. Certain sensors like the DHT22, built for rapid prototyping, will always perform poorly when compared to high-quality sensors like HIH6100. For open spaces, the distribution around the sensor is expected to be uniform requiring fewer corrective actions for the right calibration.

Smart home communication protocols: bluetooth, Wi-Fi, or GSM. Bluetooth smart or low energy wireless protocols with mesh capabilities and data encryption algorithms. Zigbee is mesh networked, low power radio frequency-based protocol for IoT. X10 protocol that utilizes powerline wiring for signaling and control. Insteon, wireless and wireline communication. Z-wave specializes in secured home automation. UPB, uses existing power lines. Thread, a royalty-free protocol for smart home automation. ANT, an ultra-low-power protocol for building low-powered sensors with a mesh distribution capability. The preferred protocols are bluetooth low energy, Z-wave, Zigbee, and thread. Considerations for incorporating a gateway may include: cloud connectivity, supported protocols, customization complexity and prototyping support. Home control is composed of the following: state machine, event bus, service log and timer.

Modularity: enables the bundle concept, runtime dynamics, software components can be managed at runtime, service orientation, manage dependencies among bundles, life cycle layer: controls the life cycle of the bundles, service layers: defines a dynamic model of communication between various modules, actual services: this is the application layer. Security layer: optional, leverages Java 2 security architecture and manages permissions from different modules.

OpenHAB is a framework, combining home automation and IoT gateway for smart homes. Its features: rules engine, logging mechanism and UI abstraction. Automation rules that focus on time, mood, or ambiance, easy configuration, common supported hardware:

Domoticz architecture: very few people know about the architecture of Domoticz, making it extremely difficult to build applications on it without taking unnecessary risks in building the product itself. For example, the entire design of general architecture feels a little weird when you look at the concept of a sensor to control to an actuator. Building advanced applications with Domoticz can be done using OO based languages.

Deployment of blockchain into home networks can easily be done with Raspberry Pi. A blockchain secured layer between devices and gateways can be implemented without a massive revamp of the existing code base. Blockchain is a technology that will play a role in the future to reassure them with revolutionary and new business models like dynamic renting for Airbnb.

8. Smart home and IoT examples

We can find in the literature and practical reports, many implementations of various integrations among part of the main three building blocks, smart home, IoT and cloud computing. For example, refer to [12–14]. In this section we outline three implementations, which clearly demonstrate the need and the benefits of interconnecting or integrating all three components, as illustrated in **Figure 5**. Each component is numbered, 1–6. In the left side, we describe for each implementation, the sequence of messages/commands among components, from left to right and from bottom up. Take for example the third implementation, a control task constantly runing at the home server (2) discovers the fact that all residents left home and automatically, initiates actuators to shut down all IoT appliances (3), then it issues messages to the relevant users/residents, updating them about the situation and the applied actions it took (6).

The use of (i) in the implementations explanation, corresponds to the circled numbers in **Figure 5**.

8.1 Discovery of water leaks and its prevention

First step is deploying water sensors under every reasonable potential leak source and an automated master water valve sensor for the whole house, which now means the house is considered as an IoT.

In case the water sensor detects a leak of water (3), it sends an event to the hub (2), which triggers the "turn valve off" application. The home control application then sends a "turn off" command to all IoT (3) appliances defined as sensitive to water stopping and then sends the "turn off" command to the main water valve (1). An update message is sent via the messaging system to these appearing in the notification list (6). This setup helps defending against scenarios where the source of the water is from the house plumbing. The underlying configuration assumes an integration via messages and commands between the smart home and the IoT control system. It demonstrates the dependency and the resulting benefits of combining smart home and IoT.

8.2 Smoke detectors

Most houses already have the typical collection of smoke detectors (1), but there is no bridge to send data from the sensor to a smart home hub. Connecting these sensors to a smart home app (2), enables a comprehensive smoke detection system. It is further expanded to notify the elevator sensor to block the use of it due to fire condition (1), and so, it is even further expanded to any IoT sensor (3), who may be activated due to the detected smoke alert.

In [5] they designed a wireless sensor network for early detection of house fires. They simulated a fire in a smart home using the fire dynamics simulator and a language program. The simulation results showed that the system detects fire early.

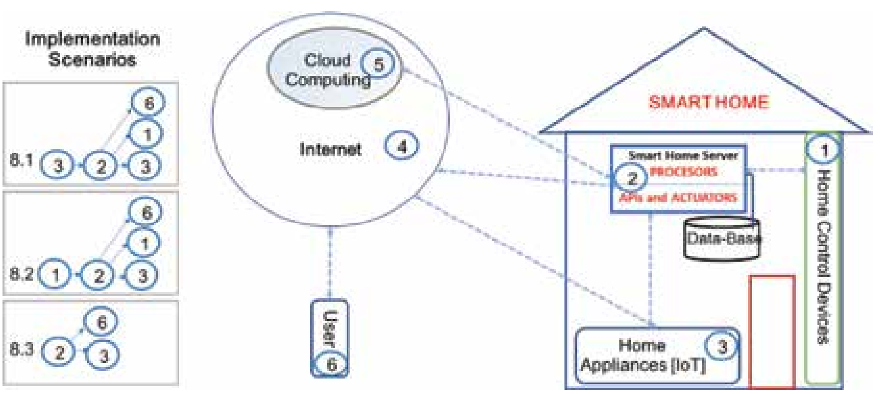

Figure 5.
Advanced smart home implementations chart.

8.3 Incident management to control home appliances

Consider the scenario where you leave home while some of the appliances are still on. In case your absence is long enough, some of the appliances may over heat and are about to blowout. To avoid such situations, we connect all IoT appliances' sensors to the home application (2), so that when all leave home it will automatically adjust all the appliances' sensors accordingly (3), to avoid damages. Note that the indication of an empty home is generated by the Smart Home application, while the "on" indication of the appliance, is generated by IoT. Hence, this scenario is possible due to the integration between smart home and IoT systems.

9. Conclusions and summary

In this chapter we described the integration of three loosely coupled components, smart home, Iot, and cloud computing. To orchestrate and timely manage the vast data flow in an efficient and balanced way, utilizing the strengths of each component we propose a centralized real time event processing application.

We describe the advantages and benefits of each standalone component and its possible complements, which may be achieved by integrating it with the other components providing new benefits raised from the whole compound system. Since these components are still at its development stage, the integration among them may change and provide a robust paradigm that generates a new generation of infrastructure and applications.

As we follow-up on the progress of each component and its corresponding impact on the integrated compound, we will constantly consider additional components to be added, resulting with new service models and applications.

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Section 3

Healthcare Applications

Chapter 4

IOT Service Utilisation in Healthcare

Mohammed Dauwed and Ahmed Meri

Abstract

Utilising the new trend technologies in healthcare sector could offer alternative ways in managing the patients' health records and also improve the healthcare quality. As such, this chapter provides an overview of utilising the Internet of Things (IoT) technology in healthcare sector as an emerging research and practical trend nowadays. The main benefits and advantages have been discussed in this chapter. On the other hand, it has been found that most of the hospitals in different countries are still facing many issues regarding their health information exchange. Recently, various studies in the area of healthcare information system mentioned that the fragmentations of the health information are one of the most important challenges with the distribution of patient information records. Therefore, in this chapter, we gave an in detail overview regarding the current issues facing the health sector in line with the IoT technologies. Additionally, a full description of advantages and disadvantages has been highlighted for using IoT in healthcare that can be considered as solutions for the mentioned issues.

Keywords: IoT, Internet of Things, healthcare, e-Health, health information exchange

1. Introduction

The Internet of Things (IoT) is a new technology that aims to connect the world via smart devices or objects with capabilities of collecting and sharing various types of information at any location, time, media and environments. By assigning a unique identification to each object in the network, IoT allows its users to live smart, safe lives. In healthcare systems, IoT is mainly used to gain quick access to health information. IoT can be defined as an interconnected network that links a large number of devices to one another for purposes of making large-scale information accessible to all. This technology can be seen as a grid of computers that deliver software and data via the Internet. As illustrated in **Figure 1**, Cisco defines IoT as a revolution of the 'Internet of Everything' that involves people, processes, data and things [1].

Many health organisations need to exchange data with one another to address their problems and to improve their performance [1]. Health-related data are especially important for these organisations to provide their patients with better healthcare services. The exchange of health information among these organisations has been termed 'health information exchange (HIE)', which has become a pervasive global phenomenon [2, 3]. Although not a novel concept in the health industry, HIE needs to reinvent itself every 2.5 years to adapt to the current technological advancements and the changes in the environment [4]. According to the 'Evolution of State Health Information Exchange in the U.S. (2006)', HIE offers

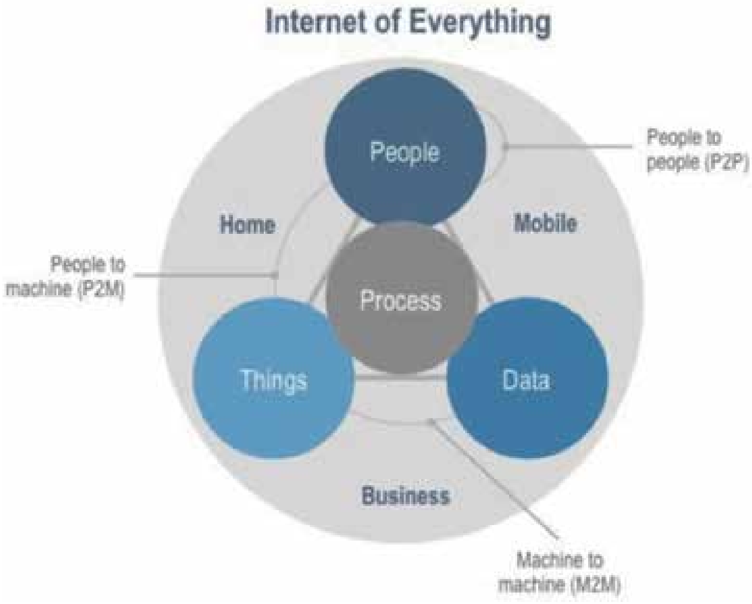

Figure 1.
IoT revolution [1].

many significant contributions to the designing of different projects, such as financing, identifying patterns of success, ensuring programmatic sustainability and highlighting challenges, trends and best practices [5]. HIE also provides many opportunities to improve the quality and reduce the cost of healthcare, improve the workflows of clinical organisations and facilitate the administration of data within the healthcare system [5]. However, HIE also poses one of the most complex problems in electronic health record (EHR) management [6]. Therefore, dissemination and communication are essential attributes of health information systems [7].

The medical records of each patient are stored in physical and electronic databases. However, when patients decide to move to new healthcare providers, the latter have no tools or directories that they can use to check where the medical records of these patients are stored. Such inaccessibility of medical records can lead to unnecessary procedures, duplicate tests and many other problems, such as adverse drug interaction. According to Tharmalingam et al. [8], Canada faces many difficulties related to HIE, including complex systems, lack of knowledge as to the location of patients' medical records, lack of access to information and lack of data standards that allow the exchange of clinical information. Some non-technological barriers also exist, including care burden, issues related to patient consent, differences in business models, limited understanding of procedures and loss of competitive advantage [2, 9].

Virtually storing patient data and making them ubiquitously accessible to all healthcare personnel is the first step in HIE [10]. Recent years have witnessed an increasing interest in the application of sensing technologies and widely available smart devices for monitoring personal health, fitness and activity. Continuously recording key physiological parameters via sensors can provide healthcare practitioners with the necessary data to produce rich longitudinal records [11]. Meanwhile, data from physical examinations provide doctors with comprehensive information that allows them to measure the physiological and metabolic states of their patients. Accessing a large number of observation data via health information systems can also help doctors improve their prognosis for their patients and recommend effective treatment, intervention and lifestyle choices to improve their health quality [12].

With the massive advancements in communication and computer technologies, organisations must urgently apply and utilise these technologies to compete effectively and survive in the market. IoT cannot improve the performance of hospitals if such technology is not being utilised to measure the success of a system [13]. A vast and multi-layered infrastructure of ubiquitous computing technologies and applications is also emerging. Mobile phones, laptops, Wi-Fi, Bluetooth, personal digital assistants and various forms of sensing devices based on digital and radio frequency identification (RFID) technologies have also penetrated the healthcare industry. IoT establishes connections among different entities, including humans (e.g. patients and medical staff), medical devices, intelligent wheelchairs, wireless sensors and mobile robots. People in the healthcare industry also rely on this technology to provide high-quality and affordable healthcare services, minimise medical errors, guarantee the safety of their patients and optimise their healthcare processes [14].

However, despite the wide availability of smart devices and novel communication technologies, healthcare professionals and patients are still generally unwilling to exchange health information while a large number of hospitals are yet to implement advanced technologies to promote their HIE capability [15–17]. IoT provides new opportunities for healthcare professionals to deliver health information to hard-to-reach populations. Utilising such technology often requires an organisation to spend a considerable amount of resources at different stages [18]. Unfortunately, most health organisations in developing countries only have few resources to spare for using new technologies, including IoT [19]. Many other issues also prevent these hospitals from receiving financial incentives that will enable them to adopt new technologies for facilitating HIE.

In sum, using IoT is in great demand in the healthcare sector. To effectively utilise IoT, hospitals must possess the necessary resources to produce the maximum value possible and to prevent failure [20]. Therefore, this chapter focuses on those problems being faced by the healthcare industry in its implementation of advanced technologies. Over the past 5 years, many health information systems have faced several concerns with regard to medical records. Most of these systems have focused on accelerating their provision of services to patients and improving the performance of hospitals by reconstructing their current workflows.

2. Internet of Things (IoT) in healthcare

The rapid proliferation of smart devices offers unprecedented opportunities for patients and health care professionals to exchange health information electronically [16]. The IoT is one of the smart technologies to integrate the smart devices on network. On the other hand, IoT is a global information infrastructure that enables advanced services by interconnecting devices based on existing and evolving interoperable information and communication technologies [21]. Thus, it is a collection of several opportunities that have wellness providing for the hospitals such as optimising the resources through automated workflows as well as process excellence. For instance, a majority of hospitals use IoT services for asset management and controlling humidity and temperature within operating rooms [22].
The collection of health data has multiple benefits to interdisciplinary healthcare collaboration, while most of the research focuses on the personal fitness plan and has a lack of compatibility and extensibility among a large number of devices and their business models. Compatibility involves in information exchanging, communication and events processing. There is a strong need for an efficient interface mechanism to simplify the management and interconnection of things. However,

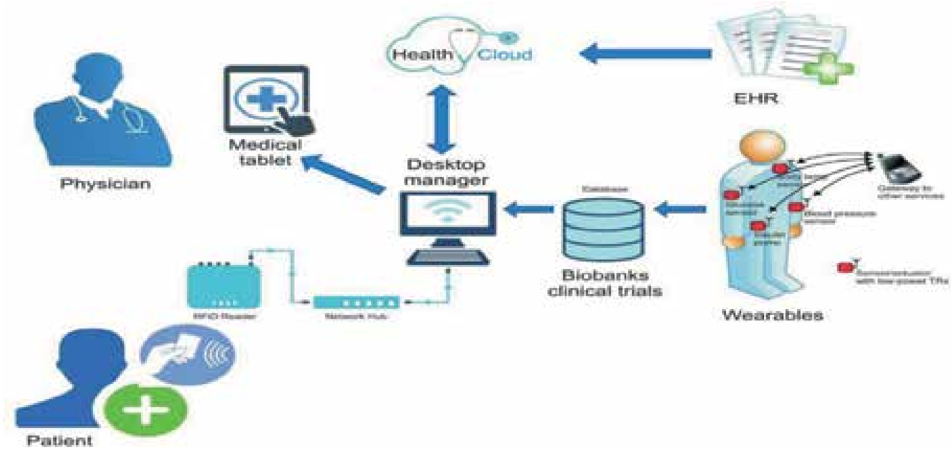

Figure 2.
IoT-hospital scenario [66].

the compatibility issue among the heterogeneous devices should be taken into consideration and addressed for the interactions among things [23].

Figure 2 illustrates how this revolution in the medical will look in a typical IoT hospital, in practice. The patient will have an ID card, which, when scanned, links to a secure cloud which stores their electronic health record vitals and lab results and medical and prescription histories.

The IoT has the potential to several benefits for health applications such as remote health monitoring, fitness programs, chronic diseases, children care and elderly care. Furthermore, it allows sharing and controlling the information between human to human or human-object or between objects using the Internet via ubiquitous sensors [24]. Therefore, various medical devices, sensors, and diagnostic and imaging devices can be viewed as smart devices or objects constituting a core part of the IoT [12]. The IoT-based e-Health monitoring method will help in reducing the number of visits to a doctor, and even the doctor can monitor his or her patient from anywhere. As this is a technology not so feasible now, but in coming years, this technology will meet the physical world definitely. The e-Health solutions provided through IoT devices are more accurate and accountable in the emerging IoT business landscape, which offers and provides various opportunities and challenges to an industry [25].

The IoT technology is still understudy to utilise it in the health sector in different regions in order to combine the information with control and monitoring such as China, US, Canada, etc. As a historical background, the Internet of Things was discovered by Kevin Ashton in 1998 to facilitate information exchange over the wide-world where every physical object connected through the Internet with a unique identification and can be monitored everywhere. One of the facilities of IoT for information systems is that it can provide services anywhere, anytime, and on any media [24]. In healthcare, the Internet of Things enables the potential benefits to achieve a high rate of exchange of massive information among organisations and organisation itself.

Some advantages of using Internet treatments included self-paced, interactive, of tailored service, multimedia format, greater accuracy reporting symptoms, timely information, accessibility, low cost, standardisation and increased user and supplier control of the intervention. Sensor technology and automated data collection enable passive monitoring of psychological states that can alert patients and healthcare providers to acute and chronic stress states [26]. These sensors

		Explanation	Sources
Advantage	Monitoring	Remote patient monitoring continues to grow and help physicians diagnose and treat illnesses and diseases with obtaining reliable information with a negligible error rate.	[27, 28]
	Sensing	IoT with intelligent medical sensors will enhance the quality of life significantly and prevent the occurrence of health problems.	[22]
	Low-cost solutions	Reduce unnecessary visits by doctors, and readmissions come from patients with chronic diseases and reduce testing cost.	[29]
	Ubiquitous access	Allow and increase the accessibility from anywhere, any time and any media allowing flexibility and mobility to the users. Enable real-time access services to the healthcare provider to access patient information and help them to make better decisions.	[30]
	Better quality of healthcare management	Increase the care quality and control by enhancing the management of drugs, reduce the medical error, enhance the patient experience, improve the disease management and improve outcome of treatment.	[31, 32]
	Unified information	Automated data collection enabled from health information resources such as monitoring, first aid, tracking, analysis, diagnosis, alarm-triggering, locating and collaboration with medical healthcare under unified communication platform and exchanged the health record.	[27]
	Time	This facilitates the interaction among the parts of an enterprise and allows for reducing the time necessary to adapt itself to the changes imposed by the market evolution.	[33]
Disadvantage	Complexity	The IoT is a diverse and complex network. There is a need of multiple services to grow device counts, massive increases of Internet bandwidth with a need to drive requirements for lower latency, greater determinism and processing closer to the edge of the network. Thus, any failure or bugs in the software or hardware will have serious consequences. Even power failure can cause a lot of trouble.	[34, 35]
	Compatibility	Although different manufacturers will be interconnected, the problem issue of compatibility when manufacturers do not agree to a common standard will make the people buy appliances from a certain manufacturer, leading to its monopoly in the market.	[23]
	Security and privacy	A location tracking and collect inappropriately information for any person considering as a challenge in the using of IoT services in the healthcare system. The patient concern of attacks his personal identity and privacy maybe arise. Therefore, bring big data from millions of things in a healthcare system can cause many security challenges.	[36, 37]
	Massive health data	In IoT, devices assemble and communicate information directly with each other via Internet and the cloud manages to collect record and analyse data blocks. But the 'things or devices' which are producing a massive amount of data are blowing out day-to-day, which needs to be treated and managed.	[38, 39]

Table 1.
The IoT advantages and disadvantages.

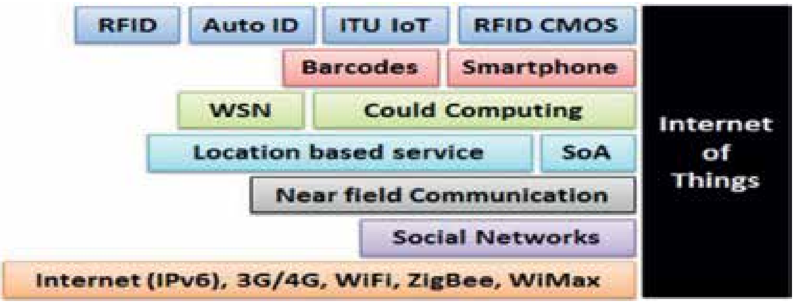

Figure 3.
Technologies associated with IoT [67].

can be used in monitoring patients, tracking daily activities, and caring for the chronic disease people or patients who have special states [27]. This information offers treatment that is evidence based from the information obtained from sensors and monitoring activities. All the applications of this technology culminated in increased comfort, convenience, and better management, thereby improving the quality of life. **Table 1** shows the multiple advantages and disadvantages of Internet of Things-based healthcare monitoring and management of health system.

Many open challenges need to be addressed by new research and investigation, mostly due to the complex deployment characteristics of such systems and the stringent requirements imposed by various services wishing to make use of such complex systems. Thus, it becomes critically important to study how the current approaches to standardisation in this area can be improved and at the same time better understand the opportunities for the research community to contribute to the IoT field [36]. In addition, many other technologies and devices such as barcodes, smart phones, social networks, and cloud computing are being used to form an extensive network for supporting IoT [12, 23] (as shown in **Figure 3**).

3. HIoT applications and device features

The healthcare applications and system have adopted several types of innovation technologies/devices in order to enhance the performance of healthcare services delivered. Most of these systems and applications are contributing to use IoT or smart technology devices to perform better advantage in healthcare services. These IoT applications and healthcare devices are called HIoT. The healthcare device implements dedicated sensor, and holds high collecting precision advantage, while it is also having a number of disadvantages such as insufficient portability, high cost and usability. This type of device possesses the following features:

- Wearability: most of the HIoT applications offer sensing on the human body so they collect data exactly and take vital signs of the human body as collecting targets. Thus, most of the existing medical health devices make the wearability as the basic requirement of collection of human body vital signs. On this vein, the users feel more comfortable and can be enhanced and the accuracy of the collected health data can be guaranteed through the collecting procedure. The layout of common human body sensors is shown in **Figure 4**.

- Long working time: the ways of dedicated health collecting data are several for instance universal mobile devices, wearable devices, pedometer, etc. The

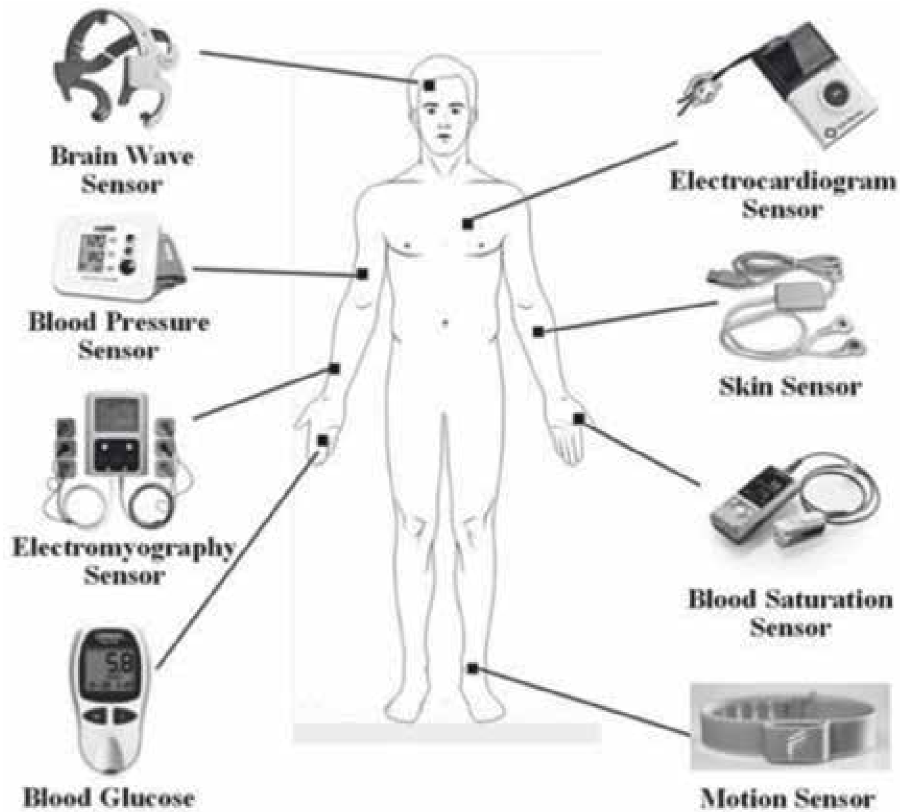

Figure 4.
Layout of common human body sensors.

purpose of these devices is to collect data from the human body for a relatively long time period that requires high power and capability.

- Constancy or stability: HIoT has high ability to collect data very normally even though the users are under strenuous exercise or in an extreme environment.
- Low participation degree of users: the functionality of HIoT applications and devices are relatively independent, as well as most HIoT devices do not require the intervention of users during the collecting data procedure. In addition, the users need to start up the power source only, and the HIoT device will start collecting data.
- Possessing data interim storage mechanism: the dimensions and weight of HIoT maybe limited strictly in order to meet the wearable feature. Thus, most HIoT devices do not integrate the data transmission module, but can select the data storage module with relatively small dimensions and adopt the data interim storage mechanism in order to store the collected data in advance, and then transmit the data through other network access devices accurately.

4. IoT scenario in the healthcare industry

Using IoT can improve and modify the delivered healthcare services in the following aspects:

1. Relying on sensing-based screening and assessment technologies in home and community environments can reduce the physical pressure on the environment of hospitals and turn this information into an electronic flow of information.

2. Changing the medication process from a reactive model to a proactive and preventative model can significantly minimise the hospital admission expenses for acute events.

3. Improving the personalisation of healthcare processes allows individuals to monitor and identify their risk factors, seek preventative intervention and treatment and live independently. In this way, personalising healthcare processes has a significant positive impact on the psychological and physiological states of patients.

4. Improving the management of clinical workloads can allow healthcare systems to effectively prioritise those patients who have the highest need for medical services.

5. Supporting self-care diagnostic processes for monitoring vital signs and other various measurements can produce data that are shared with physicians either personally or by phone in order for them to make effective diagnoses. These diagnoses can sometimes be automated for simple illnesses, such as flu.

Point-of-care tests can be optimised by reducing the time of diagnosis, which in turn can be achieved by reducing the requirements for sending samples to be tested. For example, automatic testing by using blood pressure cuffs and digital thermometers can help physicians review the history of their patients while performing the necessary measurements. Among its practical advantages, IoT can encourage the development of smart systems that support and improve biomedical and healthcare processes. Monitoring the physiological parameters of patients in real time can also facilitate the early detection of clinical deterioration, automatic people identification and tracking by using biomedical devices in smart hospitals and monitoring drug-patient associations [40].

Figure 5 illustrates the IoT scenario in smart hospitals. A patient with an emergency case is given a wearable device that detects the nearest ED that offers the required services. Upon being notified of an emergency case, the ED dispatches an ambulance to the location of the patient and delivers the necessary care services.

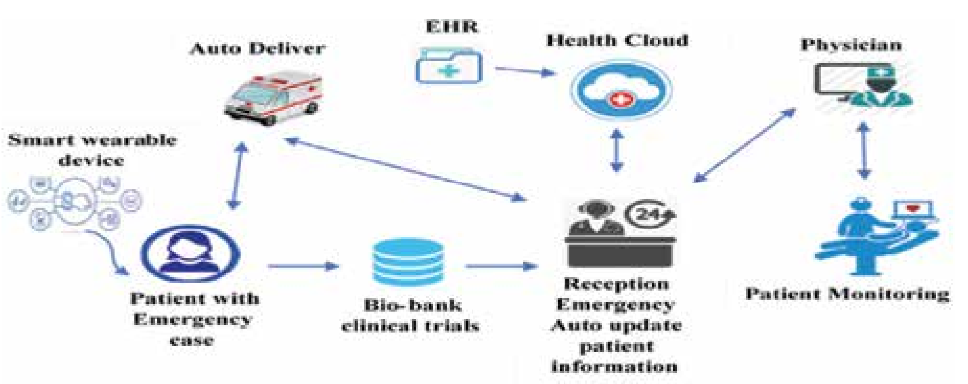

Figure 5.
IoT in the healthcare scenario.

Upon its arrival, the ambulance links the bio-bank of patient information to a secure cloud that stores the EHRs, laboratory test results and medical and prescription histories of the patient. This process can help health practitioners understand the status of their patients quickly, easily and effectively.

IoT in HIE systems is mostly designed to store, enter, receive and exchange health information. This system increases the number of devices and enhances the mobility of information to support health professionals in their consultations. Despite the benefits of using IoT in hospitals, several challenges related to availability, reliability, mobility, performance, management scalability, interoperability, security and privacy must be considered during its application [41].

5. Healthcare system challenges

Collecting and exchanging health information have become challenging due to the increasing population and demands for health services. These challenges can hinder the successful adoption of HIE. The following issues and challenges related to HIE adoption have been identified from the literature:

- Unified patients' data: this challenge refers to the combination of patient's data that are obtained from EHR systems that are being operated by healthcare providers (e.g. aged care providers, hospitals and healthcare specialists) for the purpose of sharing information. The unification of patient data provides excellent opportunities in continuing care, improving care quality and analysing and monitoring care service delivery and patient health outcomes.

- Teamwork of care: teamwork refers to collaboration among healthcare practitioners with the shared aim of exchanging information [42]. The communication deficiency among groups of healthcare professionals, departments or clinics has been identified as the main driver of critical safety incidents in tertiary care clinics. However, with the growing complexity of healthcare provision, the availability of patient information has been considered highly significant in the healthcare industry. Therefore, teamwork places less effort in promoting the availability of information. A survey of primary care doctors from 10 countries identified the overall communication, coordination of healthcare and teamwork as common challenges in HIE adoption. The lack of integration among primary care, specialty care and hospitals can also put patients at risk and lead to duplicative care, particularly for those patients suffering from complex chronic illnesses [43]. The full potential of teamwork is seldom realised due to training problems and the lack of trust in the reliability of healthcare services. Physicians are also often blamed for the errors that may occur during the provision of these services.

- Security and privacy: due to security and privacy concerns [44–46], many physicians and healthcare providers prefer to store patient records on computers or local systems that are not connected to the Internet [47]. Despite the benefits of large-scale HIE, a comparative study of the medical record exchange practices in Australia, Canada Germany, Netherlands, New Zealand, the UK and the US [48] revealed that Germany lacks a single approach for HIE and that healthcare software companies have achieved minimal success in their development of infrastructures where physicians can exchange clinical data due to security concerns. Similar to other countries, the substantial privacy and security concerns in the UK and the Netherlands have driven the resistance of healthcare professionals to HIE despite the benefits of this practice.

- Address shortage: another important issue that hinders the adoption of HIE is the storage of health information in a single pool. Cloud computing or other related technologies may be used as storage to allow healthcare practitioners to access and utilise health information at any time and place. Storing information online emerges as the most popular choice even though most users have expressed their concerns about storing their personal information on the Internet. In addition, the collected data must be managed and comply with standard formats and protocols in order for them to be retrieved and used by other healthcare providers. However, a common standard protocol for these data is yet to be devised [45]. Furthermore, patients should be allowed to access to their own data and be given the right to dispose of these data freely and ensure that their information is kept secure.

- Patient consent: the success of HIE also depends on public support, the willingness of patients to share their health information and their consent to have their health information shared with other parties via HIE [49, 50]. A study that examined the attitudes of patients towards giving consent revealed that the majority (91%) of the participating adult patients expect to be asked for their consent before their identifiable records are accessed and used for health provision, research or planning while only 9.2% of these respondents do not expect to be asked for their consent [51].

- Compatibility: compatibility refers to the degree to which the potential adopters perceive innovation as consistent with their values, previous experiences and needs. Therefore, based on physicians' expectations, the HIE system should be compatible with their work style and needs to motivate them to adopt such technology. This issue has a significant effect on the usage of innovation to promote HIE among hospitals [52].

- Hospital workflow: Healthcare professionals need to transform the HIE system to satisfy their demand for a faster access to patient information, which in turn can reduce their workflow. Issues related to workflow are important barriers that prevent the implementation of technologies in some health practices. Physicians in practices without EMR are generally reluctant to use computers to write prescriptions because these technologies are unavailable in many examination rooms. Therefore, HIE must promote consistency in workflows by facilitating staff training to improve their efficiency and by providing clinical information with minimal effort at any time or location [53, 54].

- System capacity: in order to facilitate HIE, the systems being used in hospitals should be effective and sustainable. Zhang et al. [15] attributed the limitation of system capacity to the following causes:

  - The failure to implement tecihnological advancements in most hospitals and the need to upgrade the HIE system to improve its capability.

  - The delayed development of a standard-compliant HIE system in many hospitals.

  - The overlapping functions among the needs of several regions, which reduce the need for information exchange.

However, exchanging patient records, including summaries and test results, among healthcare practitioners is not yet considered a norm in many countries. In the US, New Zealand and Canada, the current capacity of healthcare practitioners to share health information only ranges between 14 and 55% [43, 55]. With the technological advancements in networking, EHRs can be accessed by using various devices and stored in remote data centres.

6. Models/frameworks for IoT use in healthcare

To further understand the current utilisation of IoT in the healthcare sector, the related models/frameworks are reviewed as follows:

6.1 Tyagi et al.

Given the increasing demand of health organisations for access to patient records around the world, Tyagi et al. developed a cloud IoT-based healthcare framework and proposed *Platform as a Service* (PaaS) and *Infrastructure as a Service* (IaaS), which help patients find the best care at the optimal cost by allowing them to securely store and share their health information to healthcare organisations [56]. Patients can perform self-assessment to monitor their conditions and find hospitals that provide the healthcare services they need the most. However, the benefits of the cloud-IoT-based healthcare framework are offset by issues related to trust, privacy and security, all of which must be addressed before healthcare providers decide to adopt this framework. Moreover, the security requirements for the implementation of this model are yet to be fulfilled and its results need to be tested [56]. **Figures 6** and **7** summarise this framework.

6.2 Manate et al.

Collecting data from things, devices and multiple sources presents a significant problem. Patients can be classified into those patients who are having elective treatment and those emergency patients who require immediate treatment [57]. Those elective patients who do not require emergency treatment may experience health deterioration and eventually require emergency treatment or tests. A hospital setting is characterised by dynamic uncertainty and a frequent need to dynamically change the treatment pathway. Manate et al. proposed the intelligent context-aware

Figure 6.
Cloud-IoT-based healthcare framework [56].

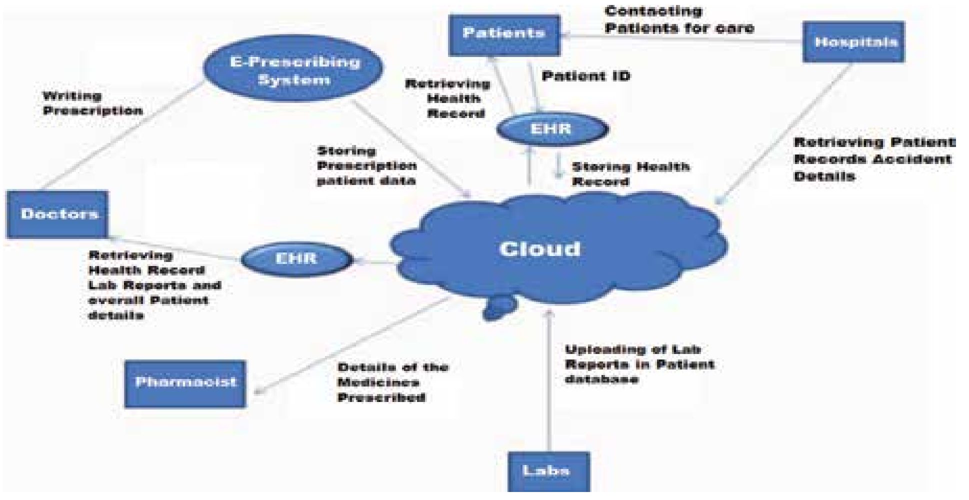

Figure 7.
Actors in the cloud-IoT-based healthcare framework [56].

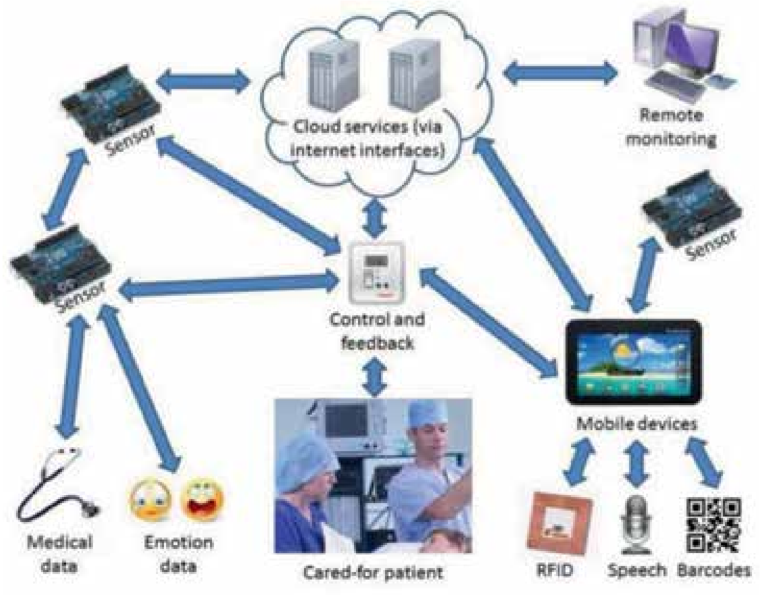

Figure 8.
Model of a typical ICADS [31].

decision support (ICADS) system, which provides an effective basis for rescheduling and prioritising essential services while maximising the effectiveness of the staff in knowing the health status of their patients, planning emergency treatment requirements and providing quality care. Even though this system can produce exciting benefits for the stakeholders of the healthcare industry, several complexities and challenges in hospital settings need to be addressed before implementing ICADS [31]. **Figure 8** summarises this system.

6.3 Datta et al.

Many mobile health applications are still operating offline and are yet to be integrated into the semantic Web technologies for e-Health services [58].

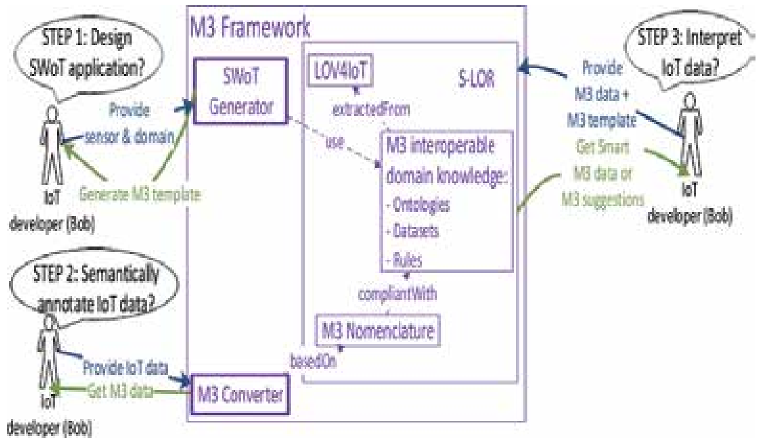

Figure 9.
Operational flow of the M3 framework [58].

Moreover, a unified rationale for developing healthcare development applications and middleware solutions is lacking. Therefore, users must build generic IoT applications to combine several domains. Datta et al. proposed the machine-to-machine (M3) framework, which enables the provision of smart, connected and personalised healthcare and wellness services to people living in smart homes [59]. This framework involves the use of wearable devices that collect patient data, which are then transmitted to smartphones that act as intermediate gateways. These data are then transmitted to remote cloud Web interfaces to maintain end-to-end security. The cloud computing platform is mainly targeted to manage patient data. However, this method does not allow patients to receive a high-level abstraction of the data collected by wearable devices [58]. **Figure 9** summarises this framework.

6.4 Prayoga and Abraham

Prayoga and Abraham iteratively tested, applied, refined and validated the behavioural intention in technology acceptance model (TAM) as one of the most prominent models used in Greater Jakarta to identify those variables that could predict the intention of individuals to utilise IoT health devices and integrate them into a theoretical model [60]. They analysed technology acceptance from the perspective of TAM and used perceived usefulness as the main predictor of behavioural intention. They also proposed a theoretical model to outline some important predictors of the behavioural intention of individuals to use IoT health devices. They performed a questionnaire survey among 186 college students from different faculties to test the hypothesised relationships between factors. As shown in the survey results, 91% of the respondents agreed that health trackers can help them achieve their personal health goals, 89% believed that these devices can change their health patterns and 90% thought that these devices will revolutionise healthcare systems. Although 87% of these respondents had searched for health-related information online while 35% had heard about such technology, only 13% of them had actually used health trackers [60]. **Figure 10** summarises the IoT behavioural intention model.

6.5 Roy et al.

Roy et al. proposed a model that facilitates the adoption of IoT-based innovations in urban poor communities [21]. This model identifies five sources of innovation,

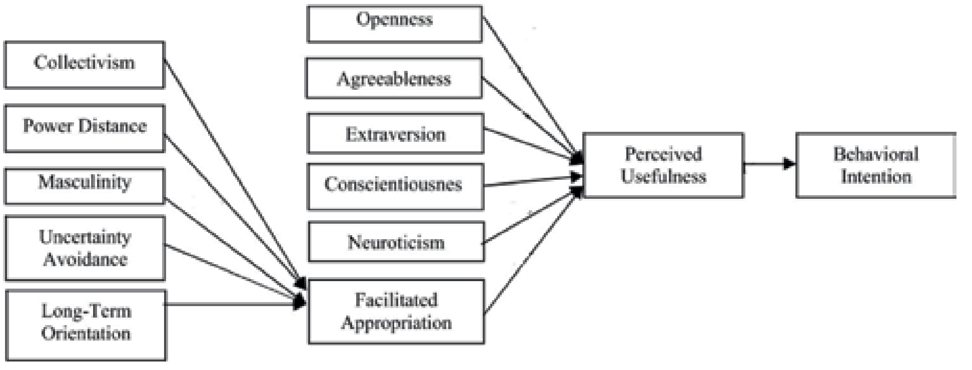

Figure 10.
IoT behavioural intention model [60].

namely, nutrition, healthcare, employment, education and finances. They also argued that IoT can positively affect the urban poor by providing them access to various types of services, including healthcare, education and food security. Their study was conducted in four stages, including a literature review, a survey of the target users, interviews with experts and a usability test of a prototype technology system. They assumed that the implemented system needs to provide quality service to its users and that users should experience tangible benefits and receive some training. These factors can help service providers deliver excellent services to their consumers and subsequently drive a higher consumer satisfaction [21]. This model is summarised in **Figure 11**.

6.6 Jagatheesan et al.

Jagatheesan et al. argued that multiple sensors with various applications from each manufacturer are easily configurable yet are generally not preferred by their users [61]. Therefore, they proposed the multiple producer multiple consumer (MPMC) network that aggregates human interfaces to allow users to control any part of the data distribution framework. This framework includes a scenario where IoT-based multiple sensors are used as producers of data and multiple IoT services are used as consumers of these data. Their findings highlighted how the experiences and perspectives of users affect the data framework design in MPMC environments by using the drop data framework infrastructure. However, this network does not serve the needs of IoT users, and service providers are unable to choose among multiple options and the security or actual data transfer protocols are usually lacking [61]. The MPMC framework is illustrated in **Figure 12**.

6.7 Bui et al.

The researchers investigated a case of a diabetic patient in an emergency situation [29]. They proposed the IoT communication framework as the main enabler of distributed worldwide healthcare applications. The main actors in this model include the monitored patients, physicians and distributed information databases. Their findings contribute to the actual implementation of a comprehensive healthcare system within IoT. They also highlighted the importance of using different devices, networks and processes in analysing diabetes progression. However, this framework is not yet completely available, the components presented in the use case are at different stages of realisation and the proposed framework does not integrate runtime sensing information into healthcare records [29]. This model is summarised in **Figures 13** and **14**.

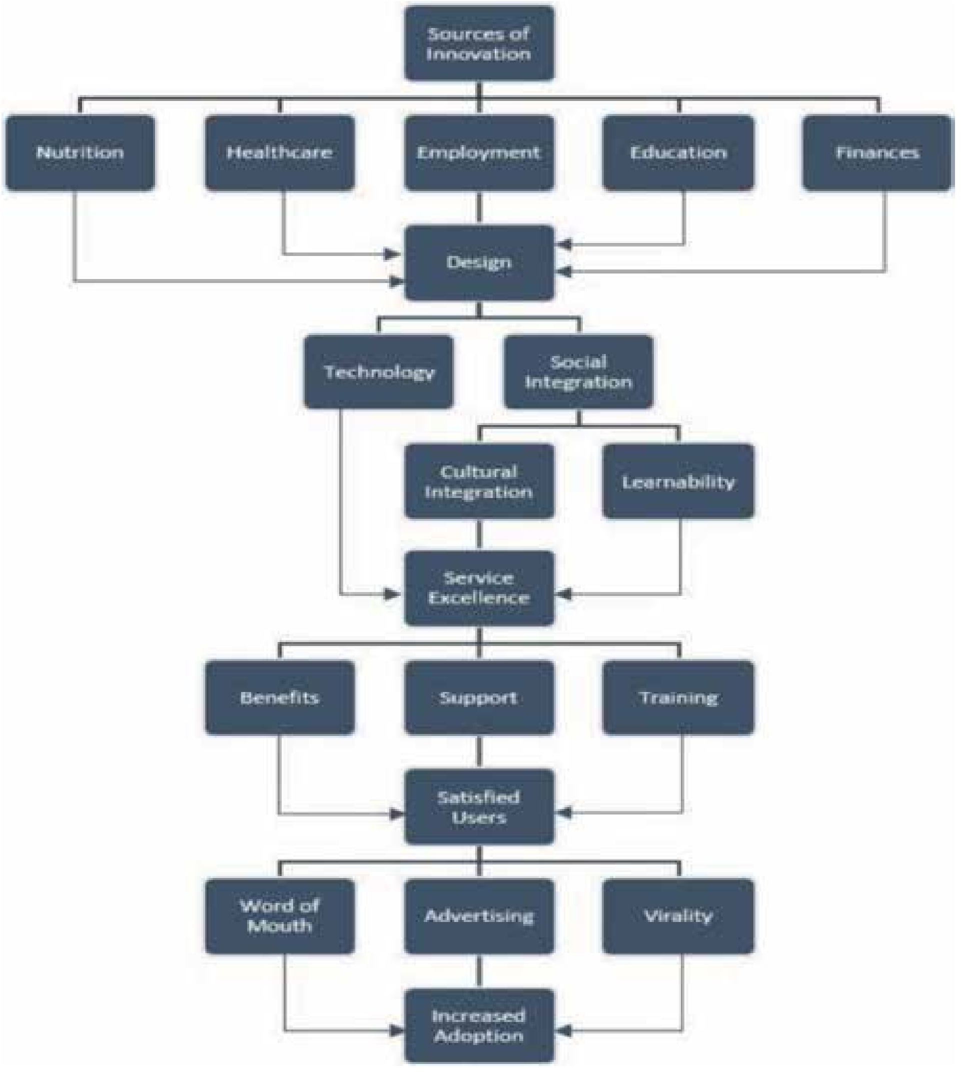

Figure 11.
Model of IoT-based innovations for the urban poor [21].

6.8 Manashty et al.

Manashty et al. aimed to fill the gap between symptoms and diagnosis trend data in order to predict health anomalies accurately and quickly [62]. Not one of the existing systems can act as a bridge between different systems to facilitate knowledge transfer and to enhance their detection and prediction capabilities. These systems are also unable to use the data and knowledge provided by similar systems due to the complexity involved in the data sharing process. Storing information also presents a challenge due to the high volume of data generated by each sensor. Therefore, Manashty et al. proposed the healthcare event aggregation lab (HEAL) model, a platform that provides services to developers and leverages the previously processed data and the corresponding detected symptoms. The proposed architecture is cloud-based and provides services for input sensors, IoT devices and context providers. The HEAL platform is an integrated system for high-level behaviour monitoring that supports many users and systems in their long-term analysis, thereby bridging the gap among many systems. However, Manashty et al. did not

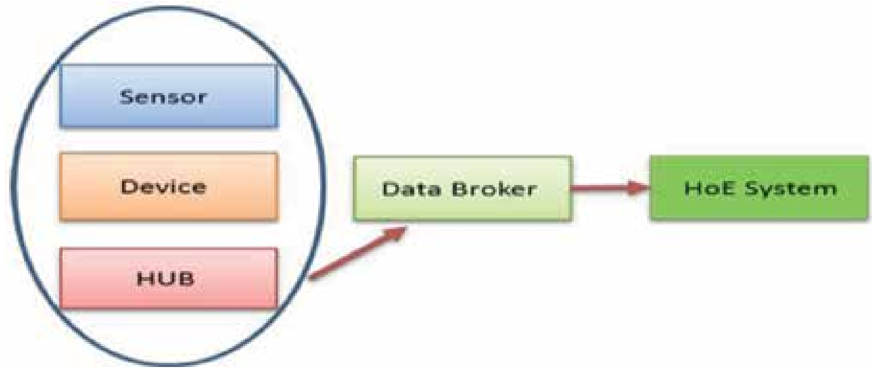

Figure 12.
MPMC framework [61].

Figure 13.
IoT e-Health system model [29].

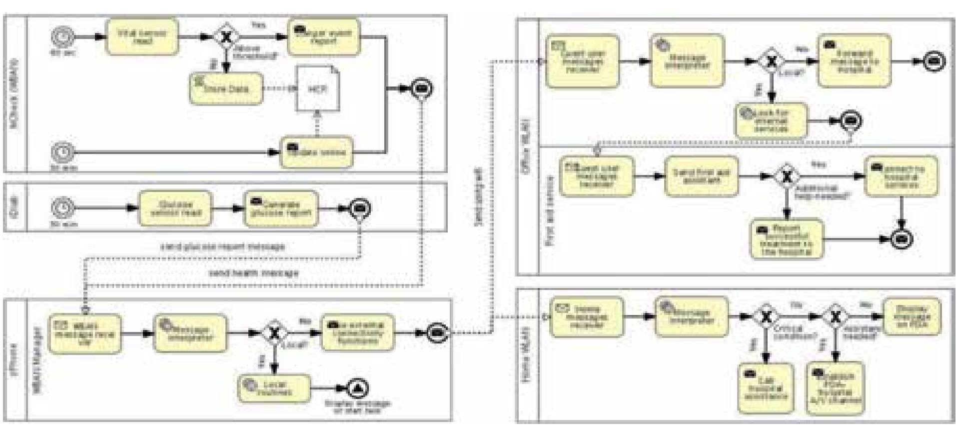

Figure 14.
IoT e-Health process model [29].

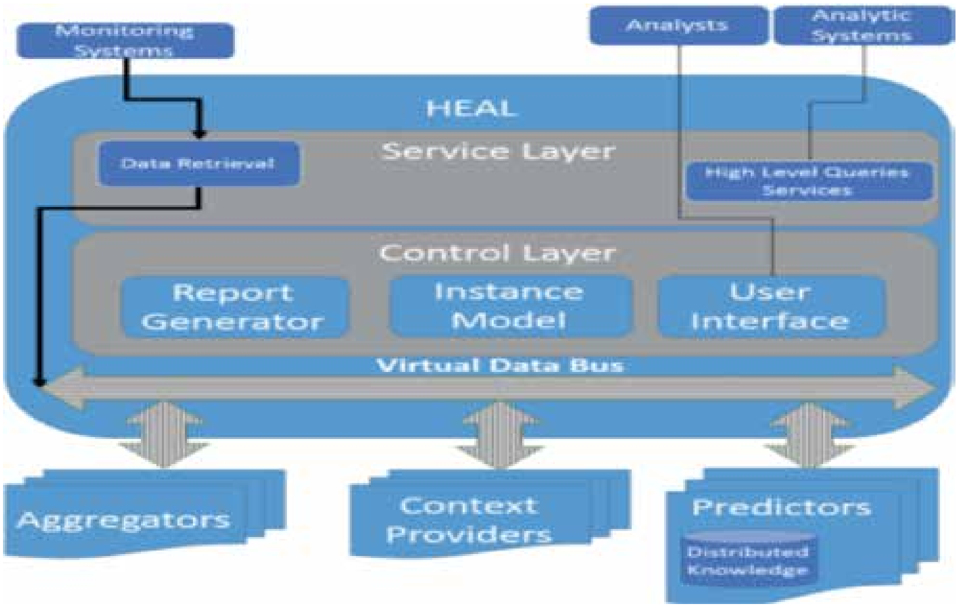

Figure 15.
Cloud-based HEAL platform model [62].

perform multiple case studies to evaluate the performance of the proposed system in complex heterogeneous scenarios with knowledge sharing [62]. This model is summarised in **Figure 15**.

6.9 Sheriff et al.

Sheriff et al. proposed a reference framework for healthcare informatics and analytics by integrating IoT, complex event processing (CEP) and big data analytics [63]. This framework can serve as a reference in implementing a holistic healthcare informatics and analytics ecosystem. Integrating IoT, CEP and big data analytics technologies can solve specific problems. Specifically, CEP can support the real-time and near-real-time analytical processing of patient events from different sources by using big data and ubiquitous communication via IoT. In the future, Sheriff et al. are planning to use this framework as a foundation for developing a healthcare application system that can address the informatics and analytic needs of healthcare and other dependent industries. However, they did not test the performance of this framework [63]. This framework is illustrated in **Figure 16**.

6.10 Pir et al.

Pir et al. developed the HMIS framework with context awareness for developing the management systems of smart hospitals based on IoT [64]. They introduced context awareness as a middleware of the IoT architecture to overcome the problems in large data management. This framework consists of three layers, including a physical layer, network layer and application layer. The physical layer, also known as the perception layer, collects data and communicates them to the network layer. The network layer then processes and transmits these data to the application layer. Context awareness, which is located above the network layer as middleware, analyses the data and transfers only the required data to the application layer. Afterwards, the application layer defines the context of the data based on the

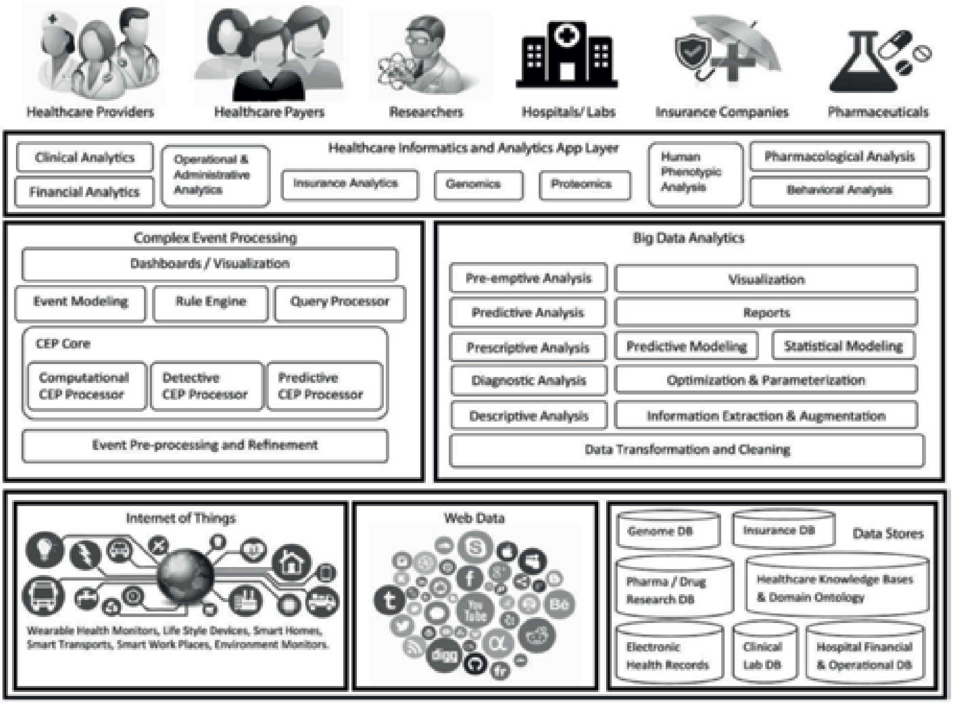

Figure 16.
Reference framework [63].

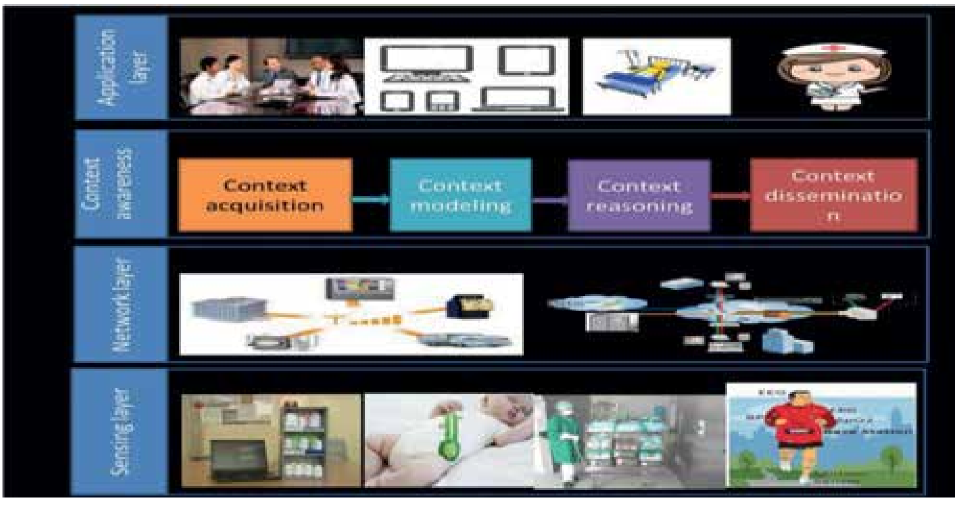

Figure 17.
HMIS framework [64].

problems faced by users when interacting with the system. However, Pir et al. did not test the applicability of this framework for users from a specific hospital [64]. Their proposed HMIS framework is presented in **Figure 17**.

6.11 Chatterjee and Armentano

Chatterjee and Armentano identified several issues, such as the availability of a live data connection and the security structure of a system, which prompted them to

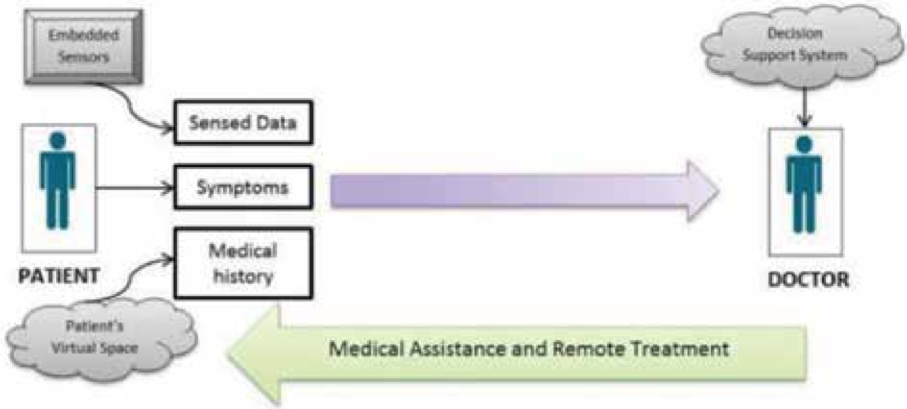

Figure 18.
Schematic diagram of the IoT-based remote treatment model [10].

develop a system for a smart medical environment that provides ubiquitous services [10]. Specifically, they proposed a model with an inclusive approach for applying IoT in a smart medical environment that provides ubiquitous services. This model virtually stores patient data and makes them ubiquitously accessible to the concerned healthcare personnel in order to be shared. Another important aspect of using these data lies in the design of an intelligent clinical decision support system that can help doctors when delivering treatment. However, Chatterjee and Armentano failed to address the requirements for adopting IoT and only focused on the inclusion of technologies in the healthcare sector, thereby limiting the generalisability of the factors that they proposed for different types of hospitals in various countries [10]. The schematic diagram of their IoT-based remote treatment model is summarised in **Figure 18**.

6.12 Gupta et al.

Gupta et al. examined the design and implementation of an IoT-based health monitoring system for emergency medical services [65]. This system demonstrates the flexible collection, integration and interoperation of IoT data that can provide support to emergency medical services. Their proposed model allows users to improve health-related risks and reduce healthcare costs by collecting, recording, analysing and sharing large amounts of data in real time. This system uses smart sensors that collect and send raw data to a database server where they are further analysed and statistically maintained to be used by medical experts. The results are deployed and tested on a patient whose personal details are inputted into a Web portal. This patient is then connected to a health monitoring system that includes a heart rate sensor and a temperature sensor. However, Gupta et al. did not consider in their work some factors in the organisational and system domain as identified in the literature review. They also did not consider the actual examination of healthcare professionals [65]. The proposed health monitoring system is illustrated in **Figure 19**.

The aforementioned models/framework for IoT use in healthcare can be classified based on the technological, system and individual aspects as summarised in **Table 2**.

In sum, most studies on IoT use in healthcare have some limitations related to their context of use, antecedents of implementation and need of use. Moreover, these studies have only focused on specific domains to achieve certain needs for using IoT in the healthcare context. Their models/frameworks are only designed for certain circumstances and environments related to the context and needs for which they are developed. Meanwhile, very few researchers have examined the actual

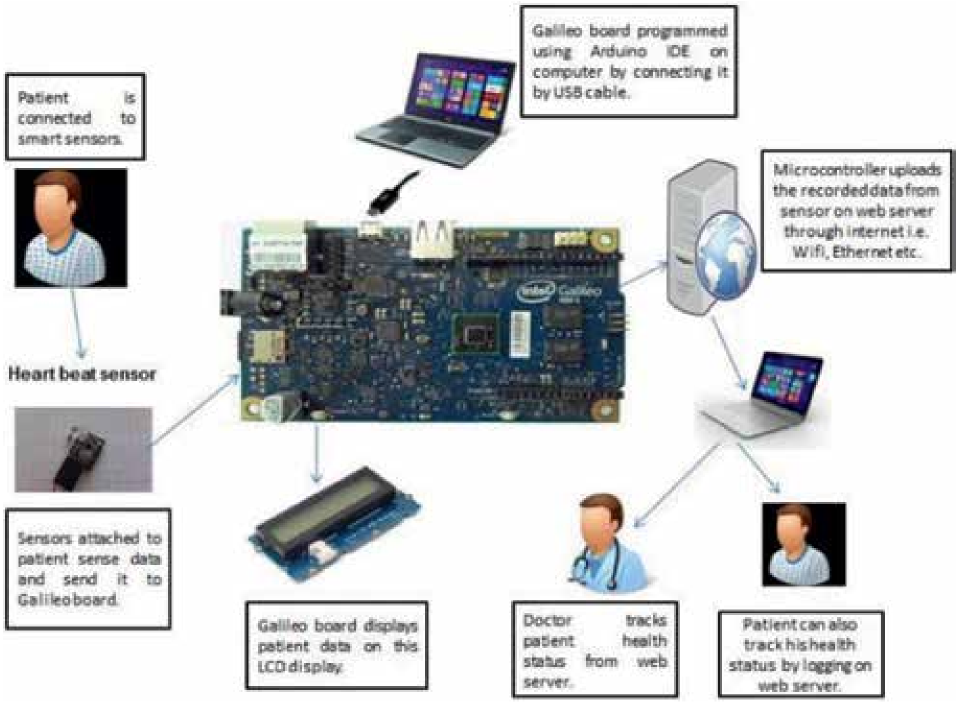

Figure 19.
IoT-based smart healthcare kit model [65].

Source	Technological	System	Individual	Context
[56]	x			Healthcare-based cloud computing network
[31]	x			Intelligent support system in hospitals
[58]	x	x		Healthcare in smart homes
[60]		x	x	Behaviour of using IoT health devices
[21]	x			Use of IoT in urban poor communities
[61]	x			Controlling via a human interface system
[24]	x			Monitoring via smartphones
[62]		x		Knowledge-based healthcare system
[29]		x		Healthcare application process
[63]	x	x		Healthcare informatics and analytics
[64]	x	x		Context awareness
[10]		x		Remote treatment
[65]		x		Healthcare monitoring

Table 2.
Models/frameworks for IoT use in healthcare.

implementation of IoT in hospitals. Therefore, further study must be conducted to generalise the application of these frameworks for hospitals. The literature review shows that the direct effect of technological and system-related factors on the utilisation behaviour of individuals has received no to limited input from previous research. The limitations of the aforementioned frameworks/models are summarised in **Table 3**.

No.	Source	Limitation
1	[29]	Requires the availability of several elements, including interoperability, reliability, privacy, authentication and integrity for exchanging EHRs across the network.
2	[31]	The system should identify the patients' conditions and notify the responsible staff who then review if the case of a patient needs to be treated as an emergency case depending on the information collected by sensors. Hospitals are facing several challenges in their implementation of IoT that should be acknowledged when designing an ICADS system.
3	[58]	This model focuses on smart home healthcare and the data collected from individuals must be managed and stored by decision makers in hospitals.
4	[61]	This study did not examine the requirements of IoT users and some issues related to data security transfer protocols.
5	[63]	This framework only focuses on the health information scenario and ignores those critical issues and challenges that may be faced by healthcare professionals.
6	[56]	Despite offering the benefits of trust and privacy to healthcare providers, several issues related to security remain unaddressed. This model needs to improve its security and test its results.
7	[60]	Model behavioural intention has been tested, applied, refined and validated many times in TAM to identify those variables that can predict the intention of individuals to use IoT health devices and integrate them into a theoretical model.
8	[21]	This model focuses on the use of IoT in urban poor communities, which is not considered part of a healthcare context.
9	[24]	This model focuses on the collection and uploading of health data by using smartphones as part of personal monitoring. The full utilisation of IoT has not been taken in consideration in this model.
10	[62]	Multiple case studies are not performed to assess the performance of the actual system in complex heterogeneous scenarios with knowledge sharing.
11	[64]	These results may satisfy certain hospitals in which no testing is performed in order to address the issues that they are facing.
12	[10]	This model only focuses on the inclusion of technologies in the health sector. Moreover, no experimental study has been performed, thereby limiting the generalisability of the proposed factors for different types of hospitals in various countries.
13	[65]	Those factors identified in the previous literature have not been considered and no actual examination of healthcare professionals has been performed.

Table 3.
Limitations of models/frameworks for IoT use in healthcare.

7. Conclusion

IoT use has become an urgent need for public hospitals and their technical and management activities. A successful IoT use is influenced by how well this technology fulfils the expectations of its users. The implementers of this technology must identify the implementation requirements from the management's perspective and align the implementation with the goals of hospitals in order to ensure a successful implementation and utilisation. **Table 3** shows that most studies on IoT use in healthcare have some limitations related to their identified factors as well as their context and purpose of use. These factors are also limited to certain developed and developing countries. In addition, the actual use of IoT in HIE has never been reviewed in the literature.

Specifically, some models and frameworks have been designed only for specific contexts, circumstances and environments. Meanwhile, other scholars have merely proposed models/frameworks without any post examination or evaluation, thereby making these models/frameworks unsuitable for examining IoT use in HIE for different reasons. These studies also do not focus on the HIE context and ignore the organisational, technological and individual aspects. Some of the proposed models have merely focused on security and privacy concerns and ignored all the other aspects related to organisational and technological issues. Very few studies have examined e-Health and m-Health architectures that use smartphone sensors and wearable devices to sense and transmit important patient data.

As a summary, this chapter shows that a model/framework specifically for IoT use in HIE is yet to be developed and that only few studies have examined the use of IoT in this type of exchange. However, most of the extant studies have identified HIE as a huge challenge for most countries and that the HIE among healthcare providers is very limited at present.

This study was motivated by the gaps in the literature and several issues related to HIE, including the limited capabilities of clinical centres and the perceived need for early detection. Another concern related to the interoperability of various smart electronic devices has also been raised. The findings presented in this chapter offer a foundation for future work on this topic. Proposing a process or framework may also be considered in future research from the perspectives of healthcare providers and management to offer solutions for the development of successful IoT services in the health sector.

This finding offers a foundation for further researchers in several ways. The success factors and proposed IoT implementation process identified and revealed in this study may be considered in future research from perspectives of healthcare providers and management, and thus offer a solution to develop successful IoT services in the health sector.

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Chapter 5

IoT-Enabled Health Monitoring and Assistive Systems for in Place Aging Dementia Patient and Elderly

Thierry Edoh and Jules Degila

Abstract

Hospitals and nursing care homes are facing severe challenges such as lack of skilled workforces and cost explosion, among others. Especially, the western healthcare systems are headed over a cliff. German nursing care houses, hospitals, and government are working hard on solutions to overcome the crucial workforce's crises. Therefore, they are planning to hire nursing-workforces from abroad. They would also like to motivate families with monetary incentives, such as tax-reduction, if they can care for their elderly and/or dementia family members at home. However, caring for a sick person at home is challenging for a working family member especially in the case the patient requests around-the-clock nursing care since elderly with cognitive impairments, people with physical disabilities, and people with dementia need (medical) assistance around the clock. The present study reveals an increasing tendency for family members to care for their sick family member at home despite the challenges and issues faced like the lack of time to intensively care for the sick person due to today's family lifestyle, challenging employment market, financial constraints, etc. The study reported in this chapter aims at providing family members willing to care for their sick member at home as long as possible with smart home automation enabled Patient@Home solution to effectively and efficiently care for their sick member despite working full time. People living in nursing care homes can also take benefit of the proposed system. Evidence shows the potential of the proposed system to effectively and efficiently assist in caring for people requesting nursing care around the clock. Though the health-related quality of life is positively impacted, patient's satisfaction is increased (better quality of experience).

Keywords: remote care, dementia, Parkinson, elderly patient, Internet of things, smart, home automation, age-related impairments, cognitive impairments, health-related quality of life, patient's satisfaction and quality of experience

1. Introduction

Nursing care is facing (is going through) an unprecedented crisis in terms of lack of skilled (health) care workforces. Like all high-income countries (HIC), Germany is going through the said crisis, which is continuously accentuating year after year.

The workforce's needs for long-term care in German nursing houses have been estimated in [1] for the period from 2009 to 2030, expecting an increase:

1. from 94.000 to 331.000 professional nursing and

2. from 157.000 to 298.000 care staff.

Elke Peters et al. have estimated in [2] the number of people living in Germany requesting nursing care to 3 million and to 5 million by 2050. The authors present a recent assessment of the nursing care services at nursing homes and at patient's home and point out the needs for patients to live at home despite the benefit of all care services.

In November 2016, in Mondorf-les-Bains (Germany), a workshop [3] on nursing care had taken place. The topic of the workshop was: Nursing Care at the (German) border Regions? (Ger. Pflege an der Grenze?). The workshop's main objectives were to strengthen the social aspect of nursing care and to more consider the nursing care to be taken place at the place of residence of the patient because of the demographic change and economic as well as employment market policy change. The said workshop pointed out that the share of family nursing care (also called care at home) is very small in comparison with ambulant nursing care. This means, family members do not care for their member requesting for nursing care. One of the main reasons leading to this situation is that the person requesting nursing care at home is living alone. Furthermore, direct family members are requested to participate in care costs. In order to participate, they must work to gain the necessary financial means to face the costs. This situation drives sometimes the family members to employ care staff without or with beginner's care skills to care their parents at home or they send their parents aboard to East-European countries since the nursing care costs are cheaper there though caring at home for a person is not as easy as one can think. Prof. Dr. Eckart Hammer points out in [4] that many dementia patients are subjected to violence by family members who are caring for them at home. By analyzing this book section, one can understand why the German government put effort to solve the care workforce issues faced in order to admit enough nursing care requesting people to the care or nursing homes. Thus, family members who are not able to care for their patients can send them to a nursing/care home. They obviously also want to help the family to decently and lovingly care for their patients and protect the patient against as well as prevent violence. Violence can result from stress faced by the caring person. And the causes of stress are multiple. Violence also occurs in nursing care houses.

People with advanced dementia have complex needs [5]. Schmidt et al. have investigated the needs in a recent study. The study shows the evidence that people with advanced dementia are requesting monitoring round the clock even for a simple activity like "food intake." At nursing care house, monitoring is guaranteed. But what happens if those people are living at their regular residence? This research question is justified by the results carried out by [6], which point out the causes of nursing care workforce shortage and provide recommendations to overcome the issues faced. In [7], the author recommends a series of solutions to fix the workforce shortage. One of these solutions is to use telemedicine to overcome the shortage of issues faced. He writes

Other solutions proposed to reduce the effects of shortages include the use of telemedicine to reach far-away neurologists (though this is unlikely to reduce workloads), the development of artificial intelligence to help in making diagnoses, and expanding neurological care to include non-neurologist physicians and advanced practitioners (specially trained nurses and physicians' assistants)…

The recommended solutions are intended for neurology, though some of them can suite other medical fields.

Using telemedicine to overcome workforce shortage implies to keep a patient at his residence or at the care unit with only primary care services. A further research question rising here is what is the quality of life (QoL) of patients treated at home? Is it worth treating dementia patients at home instead of a nursing care home? Rebecca Palm et al. investigated in [8] the environment as a factor impacting the health-related QoL regarding nursing care for dementia patients. The study reveals that the structural and organizational characteristics of care units may impact the QoL though the study does clearly prove through empirical evidence that the care unit's structure and organization influence the QoL. However, to our best knowledge, no study has investigated the impact of homecare on the health-related QoL based on the QoL measurement metrics pointed out in [8] such as *temperature, noise, lightning, familiarity, adequate space, and opportunities to participate in domestic activities*; it could be subsequently deduced that if the patient's residence place also provides the same environmental criteria as temperature, familiarity, sufficient food, and water, etc., the patient treated at home will undergo the same health-related QoL. In [9], the authors investigated the impact small-scaled nursing care homes have on health outcome-related QoL. They found out that moving from large-scaled to a small-scaled nursing house can improve the aspect of the QoL by reducing the anxiety. This study allows us to conclude that a patient treated at home in his family circle and habituated residence place has less anxiety and better QoL.

It is obvious that patients requesting nursing care can receive nursing care at their residence places with a better health-related QoL. The factors impacting the QoL are well known though caring for dementia, Parkinson's disease, and elderly patients suffering from possible cognitive impairments is a challenging task. The research question raised here is how to assess the factors impacting the QoL for better health outcome?

The literature review on technologies in nursing care or commonly in healthcare reveals that nursing care at home for dementia and elderly patients can take benefit of the technology (cf. section methodology/literature review).

1.1 Study objectives

Homecare is increasingly getting attention among the population for multiple reasons such as the nursing care crisis. This research mainly aims at proposing smart home automation enabled personalized homecare solution for a better quality of life (QoL) for the patient and for assisting the patient's family members to cost-effectively and efficiently care for their patients at home without any impairment of QoL. Furthermore, this study pursues the objectives to assess the impacts of being assisted by home automation system on the QoL of all involving family members.

1.2 Study contribution

This study contributes to the *multidimensionality of the concept of the smart* home where many dimensions of home automation have been considered. The study focuses on many aspects of home automation such as energy saving [10, 11], temperature management, and regulation, security, and safety by managing the entrance, control doors, and windows.

Additionally, the study creates an environment for well-being for people limited in the movement.

1.3 Structure of the chapter

The remainder of the chapter presents in Section 2 some backgrounds and definitions. The research methodology, consisting of a literature review, research data, and system design, is presented in Section 3. Research findings and discussion are presented in Section 4. Section 5 handles a daily personal assistance system, which is designed and implemented to assist patients receiving nursing care at home and who is most of the time alone, and Section 6 concludes the study.

2. Backgrounds and definitions

2.1 Nursing houses and nursing care

According to NIH-UK (National Institute of Health United Kingdom), a nursing home provides hospital-like care services to people (outpatients, elderly, palliative, etc.) that cannot stay in the hospital for any aftercare or for elderly care.

A nursing home is a place for people who don't need to be in a hospital but can't be cared for at home. Most nursing homes have nursing aides and skilled nurses on hand 24 hours a day. (NIH-UK)

It is worth noting the main risk factors of being admitted to nursing and/or care homes (both are similar but are different regarding the qualification of the care-staff—*see care homes vs nursing homes*).

- *Age*: elderly people have more chance of being admitted to a nursing/care home.
- *Low income*: people with low income are vulnerable and have not enough possibilities to hire private care workforce to care for them at home.

Precisely for these reasons, they have a higher chance of being admitted to a nursing home.

- *Poor family support*: especially in cases where the older adult lacks a spouse or children.
- *Low social activity*: isolated people because of cognitive or age-related impairment.
- *Functional or mental difficulties*.

Regarding the risk factors of being admitted to nursing or care homes, it is obvious that a group of people can be excluded from being admitted since they would not meet the conditions.

2.1.1 Nursing homes versus care homes

According to [12], nursing homes have been recommended to employ higher skilled nurse staffing in their homes, with 24-hour registered nursing care.

As the Balcombe Care Homes defines on its website:[1]

[1] https://balcombecarehomes.co.uk/about-us/

A nursing home will provide all the day-to-day care that you would expect from any care home, but the care is supervised by registered nurses who are on duty all day and all night.

while

Care homes are staffed 24 hours a day and a proportion of the staff will be qualified care assistants with NVQs (National Vocational Qualifications) at Level 2 or 3.

2.1.2 What is nursing care?

Segen's Medical Dictionary defines nursing care as

A nonspecific term in medicine; among medically qualified doctors in the UK, nursing care generally refers to procedures or medications which are solely or primarily aimed at providing comfort to a patient or alleviating that person's pain, symptoms or distress, and includes the offer of oral nutrition and hydration

Based on the Segen's Medical Dictionary definition of nursing care, nursing care can be assimilated to palliative as well as elderly care. Most elderly people are requesting nursing care due to health conditions such as cognitive impairments that include dementia, Parkinson, blindness, etc. [13, 14]. Though their chance of being admitted to a nursing home is low, modern technology, as well as methodology such as remote care, can assist to provide them with the needed nursing care at their residence place. The question raised is how will this work?

2.2 Elderly and age-related impairments

The demographic structure of the developed countries (DC) or high-income countries (HIC) contains a large number of older (from 85+ years) and elderly (from 60+ years) people than young people (up to 59 years) and a very small number of teenagers (up to 15 years) in their population. The population of older adults is fastly growing in HIC [15], whereas the population in developing or low- and middle-income countries (LMIC) is remaining younger, although the number of young people is decreasing (see the example of Uganda—**Figure 1**). The median age in LMIC is around 15 years (see **Figure 1**), while the median age in the European Union (EU) is predicted to pass from 36.5 years in 1995 to 47.6 years in 2060 with an increasing tendency [16]. Thus, EU countries are facing an increasingly elderly population with all related needs like nursing and care homes, accommodated elderly healthcare services, etc.

The term "Elderly people" is defined as adults aged 60+ years, while people aged 65+ years are considered as an elder. Orimo, Hajime et al. had reviewed the definition of the term "elderly" in [17] and found out a correlation between elderly and the request or need of medium to severe nursing care.

According to the conventional definition presented by the authors in contrary to the definition above, the elderly is from 65+ years.

Conventionally, "elderly" has been defined as a chronological age of 65 years old or older, while those from 65 through 74 years old are referred to as "early elderly" and those over 75 years old as "late elderly." [17].

Though the World Health Organization (WHO) considers people aged 60+ years as elderly.

At the moment, there is no United Nations standard numerical criterion, but the UN agreed cutoff is 60+ years to refer to the older population [18].

And arguments follow such as why no one can exactly determine the age at which one has to be considered as elderly.

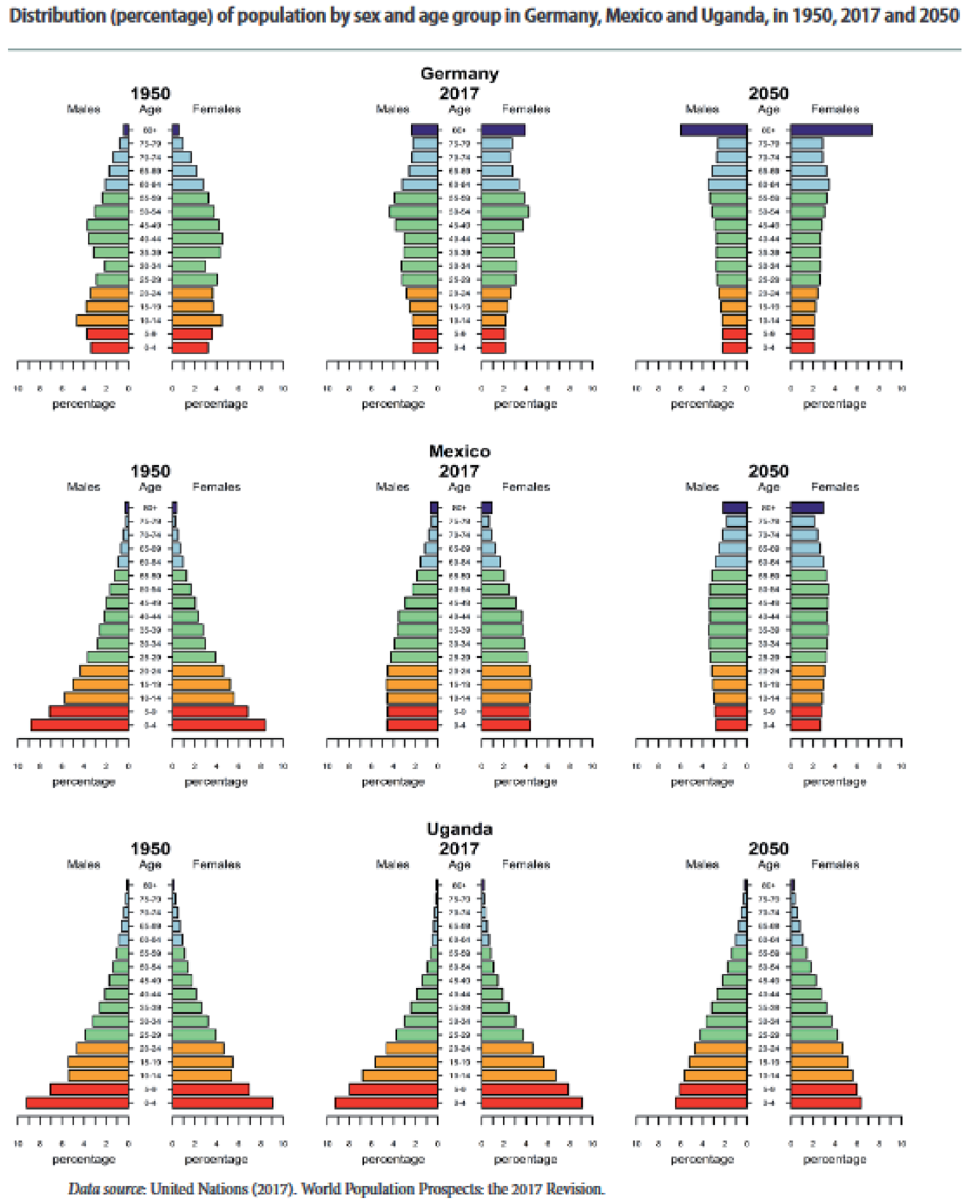

Figure 1.
Projection on demographic change LMIC versus HIC (from 1950 to 2050) [source [19]].

In addition, chronological or "official" definitions of aging can differ widely from traditional or community definitions of when a person is older. We will follow the lead of the developed worlds, for better or worse, and use the pensionable age limit often used by governments to set a standard for the definition [18].

According to the United Nations projection, about 79% of the world elder population aged 60 years or over will live in LMIC by 2050 [19]. Therefore, 20% of them will live in HIC.

Analyzing the population distribution (Figure 6 in [19]) reveals that in countries like Germany, population will count more aging people while an LMIC's population like Uganda's population will remain young.

As a conclusion, it is worth noting that the needs of nursing and care homes are higher in HIC than in LMIC. Therefore, the chapter will more focus on the nursing situation in HIC.

2.2.1 What is age-related impairment

Age-related impairment mostly known as cognitive impairment is a group of diseases, which occurs with advancing age. Cognitive impairment can also occur in young people. Mostly age-related cognitive impairments are dementia, Alzheimer's, Parkinson's, loss of vision, hearing loss, depression, incontinence, etc.

Obviously, cognitive impairment progresses with advancing age. In [17], the authors found out that elderly need from 75+ years severe nursing care. Though nursing care shows the potential to improve the individual's quality of life (QoL), most cognitive impairments cannot be cured. The patient, therefore, needs more attention, for example, reminding him to take food and drink enough water, and bringing him to get socialized again.

In order to better understand why these patients need more nursing care than others, it is worth understanding the symptoms of some cognitive diseases as follows.

2.2.1.1 Dementia

Dementia is a progressive health condition mostly in elderly people. Dementia is a consequence of health conditions like Alzheimer and is characterized by cognitive impairment (loss of cognitive capabilities or abilities).

The Journal of the American Medical Association defines Dementia as

Dementia is diagnosed only when both memory and another cognitive function are each affected severely enough to interfere with a person's ability to carry out routine daily activities.

The free dictionary gives a similar definition as

Loss of cognitive abilities, including memory, concentration, communication, planning, and abstract thinking, resulting from brain injury or from a disease such as Alzheimer's disease or Parkinson's disease. It is sometimes accompanied by emotional disturbance and personality changes.

Regarding the characteristics of dementia, it is highly requested to assist round the clock people suffering from such health condition in order to protect them against any accident that can result from forgetfulness. On one hand, they need assistance, and on the other hand, they can be refused to being admitted to nursing or care home. Furthermore, keeping these people at home remains challenging. Family members caring for these people are mostly by day time at their own job. In this case, the only solution is to employ care/nursing personnel to care for them during the absence of all family members. It is reportedly known that most "care/nursing personnel" hired for homecare are poorly skilled and mostly come from a different cultural background as the patient. The question is can all these factors impact the patient's QoL? Especially, can the cultural differences contribute to QoL loss? Answering this question is out of the scope of the present study.

2.2.1.2 Parkinson's

Parkinson's disease is one of the best-known and most common diseases of the nervous system. It is a cognitive disease and mostly related to advancing age. James Parkinson, the British physician, described the typical symptoms of the disease for the first time in 1817 and gave his name to the disease. Like a most cognitive disease, is a slowly progressive neurological disease that affects certain areas of the brain. The main symptom of Parkinson's disease is the movement disorder.

People suffering from Parkinson's disease are, therefore, dependent on other people since they are limited in their movement. Furthermore, they can lose the sense of smelling and mostly suffer from Dementia, depression, and anxiety.

2.3 Technologies enabling home automation

The main role of home automation is to control and manage devices at the local network(s) in the house. It can enable remote interactions with the network in order to access some information or to set command. For example, one can remotely ask his fridge or the fridge can send him a grocery list. Many technologies are included in home automation. Technologies like wireless sensor networks, videos, and connected devices support smart home automation paradigm. In [20], Toschi et al. reviewed the technologies that enabled a machine-to-machine (M2M)-based house automation. According to the authors, home automation is tending beyond connecting autonomous toward smart process and devices.

In this section, two technologies are briefly presented. In prior, the term automation is defined.

2.3.1 What is smart home automation?

In [21], Vasseur and Dunkels defined home automation as follows:

Home automation is an area of multiple and diverse applications that include lighting control, security and access control, comfort and convenience, energy management, remote home management, and aging independently and assisted living.

In the context of nursing care, home automation (HA) is a network system and application that includes at the first place bio-signal monitoring, well-being control, and other medical means like medication intake, physical exercises, etc. Further, HA includes temperature management, patient-safety, and security by preventing dangerous actions like leaving furnace or gas on, going out without adequate wearing.

Figure 2 (Source Figure 23.1 in [21]) presents a sample of home control devices.

In [22], Pham et al. defined smart home automation as an environment context-related data for precise health monitoring. They write:

A smart home environment provides ample contextual data related to a resident's health, which allows more accurate health monitoring than only using physiological signals.

They further presented cloud-based home automation that collects bio-signals and location information in order to accurately monitor nursing home residents.

2.3.2 Internet of things and the common architecture

The Internet of things is a paradigm for autonomous data gathering and processing. In [23], Luigi Atzori et al. had defined the Internet of things as follows:

"The Internet of Things (IoT) is a novel paradigm that is rapidly gaining ground in the scenario of modern wireless telecommunications. The basic idea of this concept is the pervasive presence around us of a variety of things or objects, such as Radio-Frequency IDentification (RFID) tags, sensors, actuators, mobile phones, etc., which, through

Figure 2.
Sample of home control devices (source: [21]/Figure 23.1).

unique addressing schemes, are able to interact with each other and cooperate with their neighbors to reach common goals."

Internet of health things (IoHT) is designed for medical data gathering and processing. IoHT connects unconnected health means with network connectivity ability. Digital and physical medical objects can thus network with each other in collaborating for data collection, processing, and storage. IoHT is a special case of the Internet of things (IoT) that combines health technologies and IoT and takes full advantage of IoT technology like the ability to initiate actions based on collected and analyzed data [24].

IoT finds its application already in the medical world as Istepanian et al. discussed in [25]. Williams et al. have defined the healthcare Internet of things (also called IoHT—Internet of health things) as

"*…the new embedded sensing capabilities of devices together with the availability of always being connected, to improve patient care whilst reducing costs* [26]."

The common architecture of IoT consists of sensors and actuators called things. Things are located at the data perception level. Behind the things are placed the IoT-gateways and data acquisition systems, followed by the edge IT and the data center (commonly on a remote server) and cloud. There are three (03) layers: (i) perception layer, (ii) gateway layer, and (iii) IoT platform layer.

IoT has the potential to enable home automation in collecting and processing data as well as to autonomously request actuators to execute some tasks for example temperature control by regulating the heater according to the set (for patient comfortable) room temperature.

IoT presents various domain-specific architectures that use various technologies and areas such as RFID, service-oriented architecture, wireless sensor network, supply chain management, industry, healthcare, smart city, logistics, connected living, big data, cloud computing, social computing, and security. **Figure 3** shows an IoT-enabled healthcare data perception system.

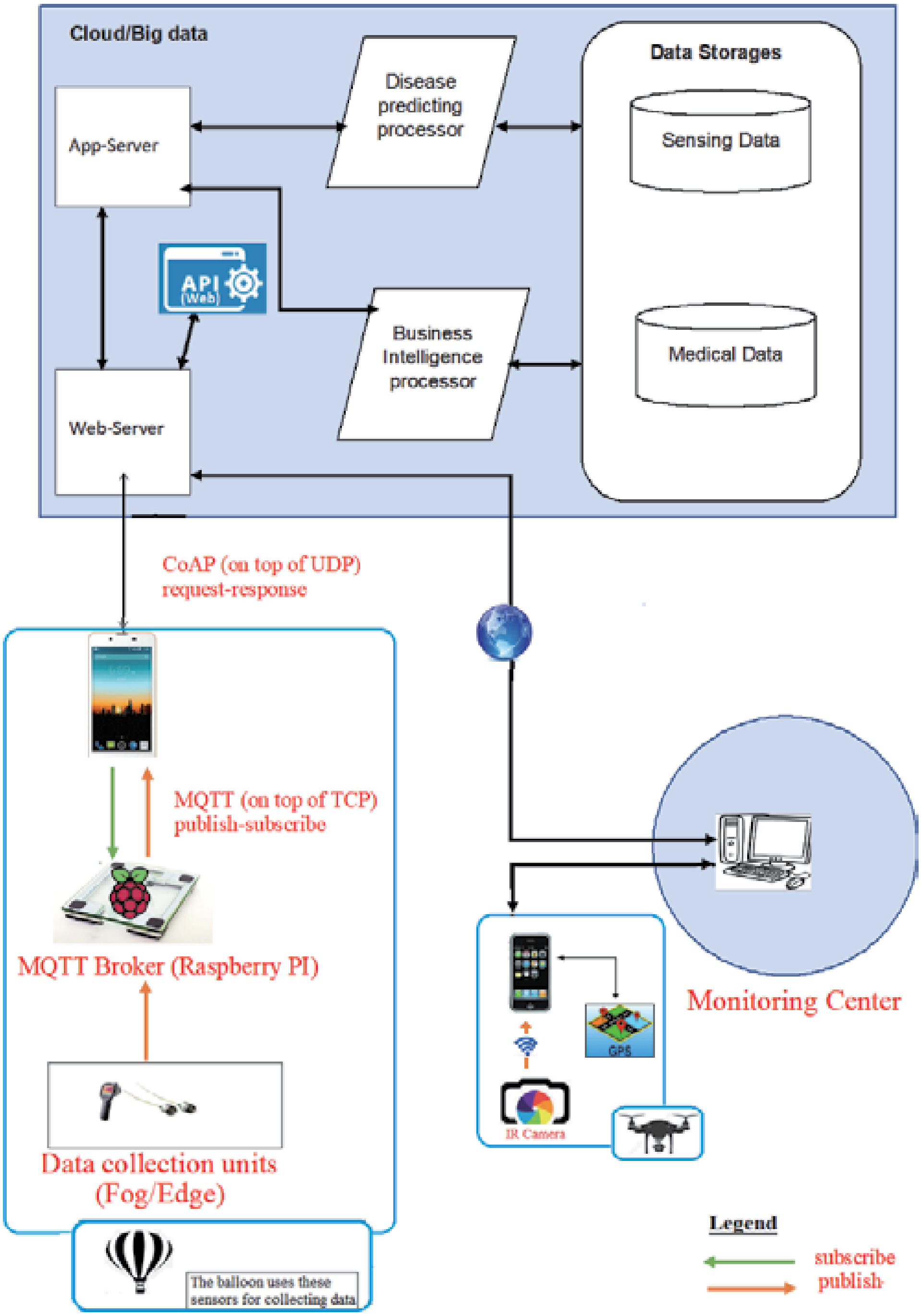

Figure 3.
Healthcare domain specific IoT architecture (source: [27]).

2.3.3 Wireless sensor networks (WSNs) and body area networks (BANs)

Wireless sensor networks (WSNs) find their use in smart home automation application since a while. They are used for medical application and devices to measure the patient's vital parameter. Bio-signals like body temperature, blood pressure, pulse oximetry, ECG, and breathing activity can autonomously and event-based automatically and seamless be measured.

Clinics, hospitals, and care/nursing homes can remotely use end-point devices like video and audio devices to assist family members to care for their sick member at home. Thus, home automation systems can be connected to medical emergency stations at clinics and hospitals close to the patient's residence place and regularly forward the patient's critical data gathered by WSMs and BANs. How this works is presented by Moghadam et al. in [28] where they have designed and implemented a communication system single and multi-antenna in a BAN. They wrote:

"an energy efficient data transmission technique for communication between a single-antenna medical sensor/microrobot inside the body to a multi-antenna receiver on the body surface through non-homogeneous propagation environment."

Transmitting over multiple spatial and temporal scales is challenging in advanced health informatics [29] though advancement achieved in the Internet of things (IoT) protocols like LoRaWAN with platforms like the things network (TTN) [https://www.thethingsnetwork.org/] eases transferring data today.

Wireless body area network (WBAN) is part of wireless sensor networks (WSNs) that can enable monitoring and collecting the patient bio-signal. This has been shown in a previous study [30] where a wireless sensor network system has been used at a cardiologic intensive care unit (CICU) for collecting and monitoring, round the clock, cardiologic activities in-patients. WSNs were connected to the patients and thus bio-signals have been collected in real time. This study has shown the feasibility of using WSNs and WBNs in home automation.

3. Research questions, hypotheses, and scopes

The main objectives behind the research questions are on one hand to investigate the tendency toward homecare regarding the nursing care homes and care workforce shortage and on the other hand to additionally investigate challenges and issues people are facing in homecare. Homecare is when family members care for their sick member at home. The needs in terms of appropriate solutions to overcome challenges and issues faced by caring for patients in homecare are assessed.

3.1 Questions

Q1: What is the tendency for homecare regarding the current nursing care crisis facing HIC?

Three nursing care options are noticed in Germany: (i) nursing care residences with 24 h registered care services and (ii) homecare with the assistance of ambulant nursing staff for a couple of hours per day. Many families hire care personnel from abroad (e.g., Yugoslavia, Budapest, and Ukraine), mostly with beginner's skills or no skills at all to care for their sick parents. Family members also care for the patient following medical instructions, (iii) regarding nursing care homes practiced fees, many families send their sick parents abroad in East European countries.

Q2: What challenges and issues are facing homecare?

Caring for a patient in homecare can be challenging for family members since many patients request round the clock nursing care. This is a full-time job. This study aims at investigating the challenges and issues that can be faced in such a situation.

Q3: Is it worth caring for dementia patients in homecare instead of at nursing care home?

Dementia patients are forgetful. They can forget to take food and drink water. They could forget to turn off a furnace or turn on a heater. Regarding these issues, it is worth assessing how to handle dementia patients.

Q4: What is the quality of life (QoL) of patients treated in homecare?

Many studies investigated the patient's QoL in nursing homes. Measuring or assessing the QoL level of patients in homecare is not achieved. This study aims at assessing it.

Q5: How to assess the factors impacting the health-related QoL for homecare?

There are well-established metrics for assessing the level of QoL in the nursing context though patient in homecare is exposed to additional environmental means. Therefore, it matters to investigate the impact of the QoL of other members on the QoL of the patient. Furthermore, can noise negatively impact the QoL in homecare? A grand-mutter (an elderly) will not be disturbed by a crying grand-child. It is, therefore, important to analyze which criteria are contributing to measuring the QoL in the case of homecare.

Q6: Can the technology assist to overcome homecare-related challenges and issues?

Round the clock care cannot be achieved by one person. It is a challenge. Previous studies have shown evidence for using the technology in healthcare to deliver care at remote, to monitor 24 h a day intensive care patients, etc. Many works have been achieved regarding mental health sensing and assessment, etc. In the present context, this study aims at investigating how home automation supported solution can assist in homecare and overcome challenges and issues faced.

3.2 Hypotheses

H1: The tendency to care for patients in homecare is on increase since the nursing crisis.

The study would like to verify if the nursing crisis has impacted the family member behavior.

H2: Smart automation home technology assists in homecare and impacts the QoL of both family members and the patient.

H3: Smart home automation enables to combine occupation (job) and caring adequately (efficiently and effectively) for a patient at home.

3.3 Scopes

Measuring the quality of services of nursing/care homes is out of the scope of this study, whereas only assessment of the patient's QoL in homecare before and after using the proposed solution constitutes the scope of the present work.

4. Methodology and data

This section presents the conducted literature review on the smart home automation for healthcare purposes. Additionally, data have been collected using semi-structured interview methodology with the objectives to answer the research question and verify the hypotheses.

4.1 Literature review

4.1.1 Paper sampling

In order to conduct a quantitative and qualitative literature review, papers have been sampled using snowball technology. Each found paper provides with numerous other papers through its references. Appropriate papers were thus found and used for the purpose of this study.

Papers were sought on three major bases: (i) home automation for medical applications, energy, security in the smart home, and trends in the smart home at cities. Beyond the technical part, papers dealing with the nursing care home, homecare, quality of life in nursing residences, and user satisfaction toward the nursing care are the main expressions used to find papers in the better academic literature database.

Table 1 summarizes the important papers reviewed.

Pos.	Title	Abstract	Year of publication	Reference
1	Design of an IoT smart home system	This paper basically deals with the design of an IoT smart home system (IoTSHS) which can provide the remote control to smart home through mobile, infrared (IR) remote control as well as with PC/laptop.	2018	[31]
2	A systematic review of the smart home literature: A user perspective	To facilitate the implementation and adoption of smart home technology, it is important to examine the user's perspective and the current state of smart homes. Given the fast pace with which the literature has been developing in this area, there is a strong need to revisit the literature. The aim of this paper is to systematically review the smart home literature and survey the current state of play from the users' perspective.	2019	[11]
3	Implementation of Smart home automation system on FPGA board using IoT	There has been a rapid introduction of network-enabled digital technologies in home automation. These technologies provide a lot of opportunities to improvise the connectivity of devices within the home. Internet helps to bring in with an immediate solution for many problems and also able to connect from any of the remote places which contribute to overall cost reduction and energy consumption. Intelligence based on microprocessors is used by home automation to incorporate electronic structures in the household.	2018	[32]
4	Smart home technologies in everyday life: do they address key energy challenges in households?	This paper interrogates their contribution to the ambitious carbon emission reduction efforts required under the 1.5 _C mitigation pathway set by the Paris Agreement and their suitability for energy poverty alleviation goals. In	2018	[32]

Pos.	Title	Abstract	Year of publication	Reference
		contrast to aspirational claims for a 'smart utopia' of greener, less energy-intensive, and more comfortable homes currently present in market and policy discourses, we argue that SHTs may reinforce unsustainable energy consumption patterns in the residential sector, which are not easily accessible by vulnerable consumers, and do little to help the 'energy poor' secure adequate and affordable access to energy at home.		
5	Environmental impacts and benefits of smart home automation: life cycle assessment of home energy management system	This paper discusses the life-cycle environmental impact of home energy management system (HEMS), in terms of its potential benefits and detrimental impacts. It is the expectation that adapting smart home automation (SHA) would lead to reduced electricity usage in the household and overall environmental advantages.	—	[33]
6	A review of smart homes—present state and future challenges	In the era of information technology, the elderly and disabled can be monitored with numerous intelligent devices. Sensors can be implanted into their home for continuous mobility assistance and nonobtrusive disease prevention. Modern sensor-embedded houses, or smart houses, cannot only assist people with reduced physical functions but help resolve the social isolation they face. They are capable of providing assistance without limiting or disturbing the resident's daily routine, giving him or her greater comfort, pleasure, and well-being. This article presents an international selection of leading smart home projects, as well as the associated technologies of wearable/implantable monitoring systems and assistive robotics. The latter are often designed as components of the larger smart home environment. The paper will conclude by discussing the future challenges of the domain.	2008	[10]
7	Home automation networks: A survey	Home automation networks provide a promising opportunity in designing smart home systems and applications. In this context, machine-to-machine (M2M) networks are emerging as an	2017	[20]

Pos.	Title	Abstract	Year of publication	Reference
		efficient means to provide automated communication among distributed ubiquitous devices in a standardized manner, but none have been adopted universally. In an effort to present the technologies used in the M2M and home integration environment, this paper presents the home area network elements and definitions and reviews the standards, architectures, and initiatives created to enable M2M communication and integration in several different environments, especially at the smart home domain. This paper points out the differences between them and identifies trends for the future.		

Table 1.
Selected literature among the sampling.

4.2 Data gathering and analysis

A semi-structured interview was conducted. Patients living at home as well as at nursing care home, care and nursing staffs, and people on the street were interviewed. The data collection was carried anonymously in accordance with the operative data privacy regulation in the country.

4.2.1 Data collection approach

4.2.1.1 Quantitative data collection approach

The data collection method has included questionnaires with a mixture of closed-ended (yes or no questions) and open-ended questions. Nursing home residents and patients in homecare were interviewed. Data were thus collected about nursing place tendencies and health-related as well as patient's quality of life with regard to the residence place: nursing home or homecare. No data on the quality of services in any nursing were collected.

4.2.1.2 Qualitative data collection approach

Quality of experience (QoE/QoX) or the satisfaction level is commonly based on a subjective appreciation of the quality of services. Patient's quality of life can be subjective somehow. For example, two distinct persons can differently appreciate noise or the presence of other people. Some elderly can feel uncomfortable when the nurse is a foreigner and ignore some elementary cultural rules. Therefore, nursing home residents were especially interviewed about their feeling, about what makes them feel uncomfortable in order to detect the impacts on their quality of life.

An important point was to determine their subjectivity level toward what makes them feel uncomfortable. Furthermore, test participants were asked about any discomfort the system has caused to them as well as if they feel observed or patronized.

4.2.2 Cohort sampling

4.2.2.1 Snowball sampling approach

This approach is the more appropriate method to sample the research cohort since sensible data were (anonymously) collected, and for this reason, precisely, it is difficult to find people willing to provide with their medical data. Participants have been selected on the basis of trust in the person who recruits them.

Table 2 summarizes the nursing home resident's cohort. A total of 33 patients were selected and classified per age range and gender. **Table 3** shows the structure of the patients in homecare. A total of 30 patients were selected. The two cohorts were interviewed for investigating the health-related QoL in nursing homes or in homecare as well as their preference in terms of staying at residence or living at home with their family.

Table 4 presents the cohort for investigating challenges and issues faced by homecare.

Table 5 presents an overview of the structure of the testing cohort. According to [17], elderly people aged 75+ years request severe nursing care. Based on this finding, the testing cohort is split into two groups: (i) < 65 year old participants and (ii) 65+ year old participants. All test participants are living at home. Participants living or having poor family support as well as participants with good family support have been selected. The objective was to verify to what extent the proposed solution can assist the patient even if he has no support. Furthermore, the limitations of the proposed system need to be tested in terms of to what extent the third person is needed so that they can fully assist the patient.

Age range	Total cohort size N = 33			
	N = 17		N = 16	
	Female		Male	
	Number	Health conditions	Number	Health conditions
< 50	2	1 Victim of road accident (outpatient)	4	1 Heart attack
		1 Physically disabled		1 Depression
				2 Schizophrenia
50–64	4	2 Dementia (early stage)	5	2 Depression
		1 Blindness + anxiety		2 Physically disabled
		1 Not diagnosed with a mental disorder		1 Anxiety
65–80	5	3 Alzheimer	4	2 Alzheimer
		2 Anxiety		2 Depression
>80	6	3 Parkinson's disease Advanced dementia	3	2 Alzheimer
		3 Alzheimer		1 Advanced dementia

Table 2.
Nursing home residents (cohort structure and diseases they are suffering from).

Age range	Total cohort size N = 30			
	N = 14		N = 16	
	Female		Male	
	Number	Health conditions	Number	Health conditions
< 50	4	3 Heart attack	7	2 Heart attack
		1 Physically disabled		3 Depression
				2 Blindness
50–64	5	2 Mental disorder (early stage)	5	2 Depression
		2 Anxiety		2 Physically Disabled
		1 Physically disabled		1 Anxiety
65–80	3	2 Alzheimer	3	Depression
		1 Anxiety		
> 80	2	1 Parkinson's disease	1	1 Alzheimer
		1 Alzheimer		

Table 3.
Homecare patients (cohort structure and diseases they are suffering from).

Assessment method	Total cohort size N = 515		
	N = 50	N = 68	N = 397
	Care staff*	Nursing staff`*	Other individuals**
Paper-based questionnaires	45	60	385
1:1 semi-structural interview	5	8	12

***Only people that are caring or have cared for a family member were selected to participate.*
**Only staff involved in homecare.*

Table 4.
Nursing staff and people interviewed on the street.

Age range	Gender	Participants	Family support		Dementia		Other cognitive diseases		NCD/CD
			Good	Poor	Yes	No	Yes	No	
<65	Female	6	5	1	1	5	4	1	Diabetes
	Male	9	4	5	0	9	7	2	Heart diseases diabetes
>65	Female	11	8	3	3	8	8	3	
	Male	7	2	5	1	6	6	1	

**NCD, non-communicable diseases; CD, communicable diseases/infectious diseases. No data collected on CDs.*

Table 5.
The testing cohort.

4.2.3 Questionnaires for semi-structured interviews

This section summarizes the different questionnaires (**Tables 6–8**) used for the different surveys. At nursing homes and at participant's home (case of homecare), the questionnaires were used in 1:1 structured interview followed by a semi-structured interview. Distractor or control questions are inserted into the questionnaire in order to detect discrepancies in the responses and thus filter the biased responses (**Tables 6–8**).

4.2.4 Data analysis

Data analysis was made using IBM SPSS Statistics. Data were cleaned up; biased responses were not included in the analysis. Data dealing with a tendency for care at home as well as at nursing were accordingly classified. An AVG of the scores each category reaches was built. Before building the AVG, the different scores per category (stay at home or living at a nursing residence) obtained were compared with each other. The tendencies were plotted for visual analysis.

4.3 Testing design and methodology

Participants (**Table 5**) were selected using a snowball approach.

The action research methodology was applied for the testing. The system was adjusted according to the results in a phase and re-tested in the next phase. The test lasted one (01) week in the first phase. Data were collected and analyzed. The second phase took one (01) week again and findings from phase 1 were worked into phase 2.

Pos.	Questions	Observations
1	What do you most of all miss here?	Check how many patients prefer staying at home instead of living at the residence
2	Do your relatives visit you?	
3	How often do your parents visit you?	
4	Do you have any close friends here?	Socialization measurement
5	Are you missing your former friends?	Socialization, if he misses his former friends, this means he does not find a one here
6	Do you miss your parents, children, and grandchildren?	If yes, it means he does not receive enough or regular visits
7	Do you like living here?	
8	Do you have enough space for you?	
9	Are you missing your home?	
10	Do you receive enough and regularly food and water?	
11	What did you eat today?	Check if he is forgetful in order to consider or not the responses above
12	How do you feel today?	Assess the quality-of-life related to the patient's health state and care services he is provided with
13	Are the nurses nice to you?	
14	Which nurse is your best friend?	

Table 6.
Questionnaire for patients.

Pos.	Questions	Observations
1	Do you face any challenge during the admission process?	Assess how hard is it to get admitted to a nursing home
2	Would you prefer caring for your parent in homecare? If yes, why? If no, why?	Assess the tendency for homecare And find out why they have a tendency for one or other
3	Are you more confident to let care for your parent in a nursing home? If yes, what gives you that confidence? If no, why? Do you have no trust in nursing?	
4	Do you have a job? If yes, full-time or part-time?	Determine how one can manage both activities
5	If you respond to questions 2 and 4 by yes, then continue here; otherwise, go to the next question. How could you care for your parent in homecare and go to your job or on holidays?	
6	Have you ever experienced caring for a parent at home? If yes, how challenging was this?	Find out the real challenges people who experienced homecare are facing
7	Do you have any idea about which challenges and issues can be faced in homecare? If yes, which ones?	Challenges and issues in homecare. Home automation system should help to overcome these issues
8	Can modern information technology assist in homecare? If yes, how?	Determine the most needed functionality

Table 7.
Questionnaire for no-care staff to check their tendency for homecare or nursing care homes.

Pos.	Questions	Observations
1	Which challenges and issues are you facing daily?	
2	Do you have any technical assistance?	
3	How do you monitor the residents around the clock?	
4	Do you often assess the health-related quality of life of each patient?	
5	How many admissions do you register every year?	Assess the admission tendency
6	What is the admission tendency?	
7	How can you explain the tendency?	

Table 8.
Questionnaire for care-staff to investigate the trend toward the admission application.

At the end of each phase, a quantitative and qualitative analysis was performed. Patient's quality of life (QoL) and satisfaction level were measured in the light of the defined metrics (**Table 9**).

An important point was to involve participants living alone or having poor family support as well as those who have good family support. The objective to do so was to test if the system is well designed to assist people living alone too and how they are comfortable toward using the system (usability).

Quality of life measurement metrics	Description
Food and water intake	This metric verifies how many times the participant failed to take food and water.
Medication intake	Does the participant follow the medical instructions and take the medicine as prescribed?
Physical activities	Does the participant go out for physical activities or perform some at home?
Socialization	How many social contacts the patient has? Does he connect to other people or is he isolated?
Room temperature management	Does the system correctly learn from the participant preferences and set the temperature accordingly?
Noise and lighting control	Noise and light can make the individual feel uncomfortable
Familiarity	How familiar is the place to the individual
Accident rate	Does the system assist and prevent the participant from accident such as injury with a knife, fall down, etc.?
Emergency management	Does the system correctly detect emergency cases and thus manage the emergency?
Bio-signal gathering and data quality	

Table 9.
Quality of life measurement metrics.

4.3.1 Health-related quality of life (QoL) and user satisfaction (quality of experience) measurement metrics

In order to measure and asses the impacts of the proposed solution on the quality of life, a set of quality of life metrics were defined. The results of the experiment were analyzed in light of these metrics.

4.4 Ethical approval

Authorization and written informed participant consents were received from all major participants and their parents. An ad-hoc ethics committee at the involved clinics examined the request to conduct such an interview involving home's residents and approved it. Resident's parents also approved the study.

5. Findings and discussion

This section presents the study findings and discusses the results in light of data analytics.

5.1 Literature review on smart home automation for homecare

The literature review has pointed out that only a few previous types of research consider the *multidimensionality of the concept of the smart home.* Mostly the studies are focused on one aspect of smart home such as energy management [11].

A total of 656 abstracts and 239 full papers (journal and conference papers) were reviewed. Only 41 papers were retained having met the requirement of the present study. Unfortunately, only two papers have discussed many dimensions of smart homes. The rest mostly handle the topic of energy management at home. Smart home for elderly people is well considered in many papers, but the papers have failed to consider the multidimensionality of the concept of "aging at home".

Regarding the results, a novel solution considering the multidimensionality is therefore highly needed.

5.2 Interview findings

5.2.1 Patient's preferences

The interview with nursing home residents has revealed that elderly people prefer staying at home in their familiar and usual social environment (familiarity) and take care of their health by themselves as long as they are able to though only participants with good family support and those who have children, grandchildren, and good social contacts have the wish to stay at home as long as possible. However, alone living people, poor people, and people having no family support feel comfortable at the nursing residence.

Table 10 summarizes the results of the interview. Up to 91% of people living alone prefer residing in nursing homes, while more than 91% of people with good family support prefer staying at home with their family members.

5.2.2 Tendency toward homecare and nursing homes

Beyond the research questions, three (03) hypotheses were set. One hypothesis concerns the tendency for homecare as well as for nursing care home.

H1*: The tendency to care for patients in homecare is on increase since the nursing crisis.*

The study verifies on the light of interview results the hypothesis H1. The survey was carried out to investigate the impact of the nursing crisis on the family member behavior toward the nursing care option for their patients.

The surveys point out the following results:

Category	Social status	Number	Preferences	
			Living at nursing care home	Staying at home
Nursing home residents (33 participants)	Poor family support Poor (financial) Have lived alone	21	17 (85%)	4 (15%)
	Rich Good family support Good social contact	12	01 (8.3%)	11 (91.7%)
Homecare participants (30 participants)	Living alone	23	21 (91.30%)	2 (8.70%)
	Living with family	7	0	7 (100%)

Table 10.
Participant's preferences toward living in nursing homes or staying at home.

There exist two categories of care: (i) stationary and (ii) ambulant nursing care [34].

People traditionally choose nursing residences for many reasons: (i) many people are living alone or have poor family support, (ii) the patient is at the end of life and needs severe intensive and palliative care, (iii) the care level (Ger. Pflegestufe).

A total of 118 healthcare staffs were interviewed. A total of 397 individuals on the street were also interviewed. A total of 56.78% of the interviewed care personnel admitted that the number of applicants for being admitted to a nursing home is

Assessment method	N = 118		
	Application for being admitted in nursing care residence		
	Decreasing	Increasing	Stable
Care personnel	67 (56.78%)	23 (19.50)	28 (23.72)

Table 11.
Tendency viewed by healthcare staff.

Assessment method	N = 397			
	Care experience	Care for sick family members in homecare		
		Prefer	Do not prefer	Prefer going abroad
People on the street	200 experienced with nursing homes	233 (58.69%)	97 (24.43%)	67 (16.87%)
	197 not experienced with nursing homes			

Table 12.
Preference of caring for a patient at home.

Pos.	N = 397			
	Challenges and issues		Number (%)	Comments
1	Nocturnal rest		397 (100%)	The family members have no rest. They can sleep well since assisted by the machine
2	Emergency issues		375 (99.5%)	Patient-centric data are collected.
3	Limited round the clock nursing		397 (100%)	x
4	Inaccurate collected data		40 (10.07%)	x
5	Combining job and care for a family member			The system shows potential to assist people in caring for their in parents aging in place
		Only part-time	317 (80.01%)	
		Stress	397 (100%)	
		Financial issue	298 (74.81%)	
6	Loss of quality of life		397 (100%)	
7	Limited social activities		290 (73.04%)	
8	Depression		15 (3.8%)	

Table 13.
Challenges and issues faced in homecare.

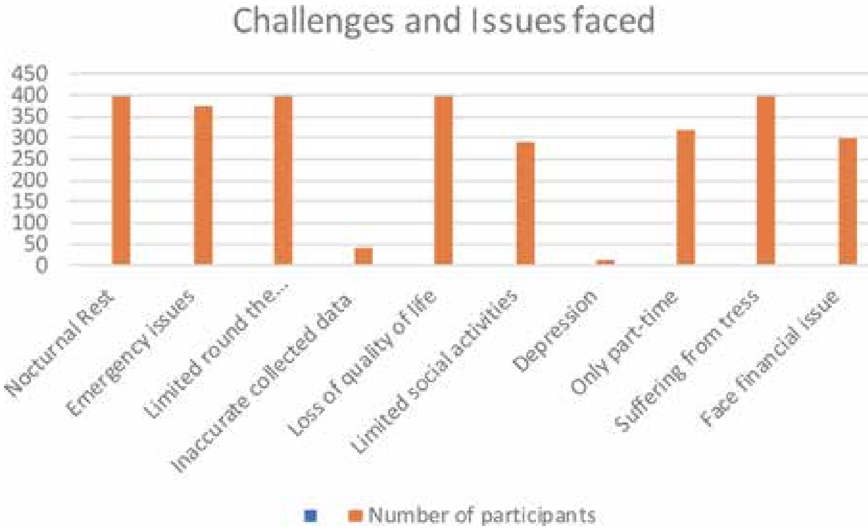

Diagram 1.
Number of participants facing challenges and issues in homecare.

Pos.	Metrics		N= 30 (Test last 2 weeks)			
			Number (%)			
			Before the test (AVG of 5 days observation)		After the test (Data provided by the system)	
			Have met the metrics			
			YES	NO	YES	NO
L1	Food and Water Intake		12 (40%)	18 (60%)	22 (73,33%)	8 (2.66%)
L2	Medication Intake		17 (56.6%)	13 (43,4%)	23 (76,6%)	7 (22,4%)
L3	Physical Activities		4 (13,3%)	26 (86,7%)	11 (36,6%)	19 (63,4%)
L4	Socialization		3 (10%)	27 (90%)	13 (43,33%)	17 (56,6%)
L5	Room Temperature management		3 (10%)	27 (90%)	26 (86,7%)	4 (13,3%)
L6	Noise and Lighting control		2 (6,6%)	28 (97%)	7 (22,4%)	23 (76,6%)
L7	Accident rate		1 (3,3%)	29 (26.7%)	1 (3,3%)	29 (26.7%)
L8	Good Emergency management		5 (16,6%)	25 (23,4%)	15	15
L9	Bio-signal gathering and data quality		1 (3,3%)	29 (26,7%)	18 (60%)	12 (40%)
L10	Results	Quality of life	Mediocre		Good++	
L11		Health outcome	Good-		Good+	

Legend (Comparing before and after test data)

Good++
Bad
Unchanged
AVG

Table 14.
Comparison of patient's quality of life before and after applying the proposed solution.

being slowly decreasing, while 58.69% of people interviewed on the street prefer to care for relatives in homecare.

Tables 11 and **12** show the tendencies of nursing care. The results obtained have confirmed the hypothesis H1.

5.2.3 Challenges and issues faced

The quantitative results regarding challenges and the number of people that reported these challenges and issues by caring for a family member are summarized in **Table 13** (**Diagram 1**). The quantitative data analysis reveals that very few people in home care are faced with data collection issues. This means data are rarely collected in home care. Thus, patients laying at home do not produce patient-centric data. The few data there produce is patient-centered. It is though known that patient-centered data are subjective, incomplete, and sometimes biased [27, 35].

5.3 Testing findings

H2: Smart automation home technology assists in homecare and impact the QoL of both family members and the patient.

The testing has confirmed the hypothesis (H2) regarding the user satisfaction's level and the quality of life (QoL) at both patient side and family side. **Table 14** (**Diagram 2**), **Table 15** (**Diagram 3**), and **Table 16** show detailed results.

H3: Smart home automation enables to combine job outside and adequately (efficiently and effectively) care for the patient in homecare.

The hypothesis is verified. Working family members can partially, full-time, work at home (home office), or go to the job and also care for a member.

5.3.1 Patients

Overall, broad satisfaction is noticed among the participants and their relations.

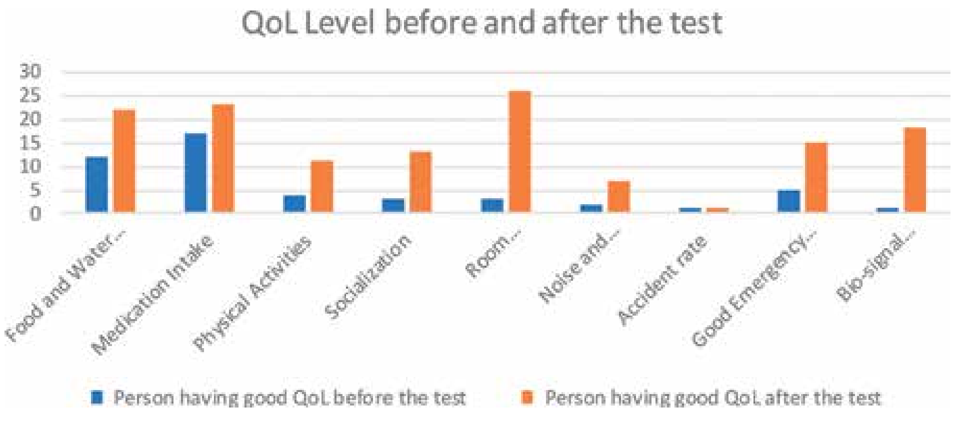

Diagram 2.
QoL level.

Metric [Link to Table 14 (column YES in after test)]	Cohort sampled after the test. It contains people having good metrics.		
	Total participants	Participants with good QoL and the family support level they received during the test	
		Poor	Good
Food and water intake [L1]	N = 22	7	15
Medication intake [L2]	N = 23	5	**18**
Physical activities [L3]	N = 11	2	9
Socialization [L4]	N = 13	3	10
Results	*About **7** have good QoL among 30 Patients after the test* *About **18** have good QoL among 30 Patients after the test*		

Table 15.
Impact of family support level on the patient's QoL.

The solution shows positive impacts on the quality of life (Good++, 36.6% started physical activities and 43.33% re-socialize). Due to the solution, 36.6% reconnect to physical activities, which means an increment of 23.3%. Nevertheless, about 62% remains without physical activities.

5.3.2 Family members

The solution has the pottential to assist people in combining full-time or parttime job with caring for a family member in home care. Since many people

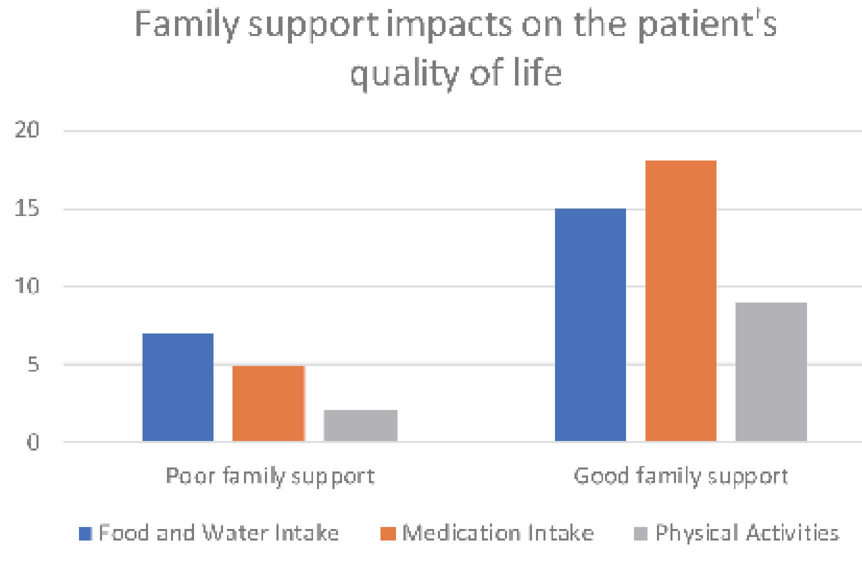

Diagram 3.
Impact of family support on the QoL.

N = 45 (patient's relatives)		
Metrics	**Before the test (Survey + 5 days observation)**	**After the test (Data provided by the system + observation)**
Quality of life	Average	Very good
Socialization	Few	Good
Nocturnal rest	Bad	Very good
Emergency management (quick medical assistance)	Bad	Good
Quality of communication with doctors	Bad	Improved
Bio-signal gathering and data quality	Worst	Improved (good)
Job situation	Worst (no job, part-time job)	Good (mostly full time)
Financial issues	Bad	Improved
Depression	Highly depressive	Less depressive

Table 16.
Comparison of family member's quality of life before and after applying the proposed solution.

aging in place still have the ability and capability to walk and can go out and back home alone, the system assists them and monitor their health condition in order to timely alerte parents and medical doctors in the case of emergency. The results had also shown evidence of improving the quality of life. An upcoming paper will report work conducted on this topic.

6. Health monitoring and daily personal assistance as approach

This section presents the concept of a *multidimensional smart home automation Internet of health things* for assisting dementia patients and elderly to "aging well at home". Additionally, the solution should assist the patient's family members to care for them and go to their occupation as usual.

The section presents the system requirements, features, concept, and architectural view.

6.1 System design

6.1.1 Requirements

The need analysis including the analysis of collected data leads to define the following system requirements and features, which the smart home solution for elderly and dementia patients will provide. As shown above, the health-related quality of life (QoL) is measurable by means of:

1. *The nutrition level (intake of food and water):* elderly and/or dementia patient is the most forgetful and could forget to take food and regularly drink water. This can cause severe health issues.

2. *Medication adherence:* medication adherence level influences patient health outcomes. Dementia patient who adheres to the prescribed medication could have comfortable days.

3. *Physical activities and socialization level:* both influence the patient's QoL.

4. *Family support:* Makes the patient feel more confident, secure, and safe. This is a factor impacting the patient's QoL.

5. *Space and comfort*: More space is a comfort that prevents anxiety in an individual since small space limits activities and movements.

Regarding the QoL measurement metrics, the following system requirements have been defined:

1. Qualitatively and quantitatively assess a patient's QoL level

2. Provide daily living assistance

3. Support patient empowerment and autonomy

4. Positively impact patient's health outcomes

5. Collect patient-centric data and information for accommodated and personalized health care services

6. Further, assist family members to efficiently and effectively care for their sick member at home

The main system-relevant requirement is to provide patients with a cheaper, simple, and better usability by considering their cognitive impairment like eye, hearing, and feeling impairment, restricted movement, etc. Additionally, the proposed solution should work online and offline.

6.1.2 System features

According to the system concept, the following features are provided to meet the requirements above.

6.1.2.1 Food and water intake monitoring

A designed water and food dispenser monitors the patient and can provide him with the food he needs. The system ensures that the patient drinks enough water so as to prevent him from feeling thirsty.

6.1.2.1.1 Food order process

1. Day menu presented.

2. The patient chooses a menu or the system selects 3 favorites based on historical data collected.

3. Food is ordered at the close restaurant and registered for the program.

4. Food is delivered.

6.1.2.1.2 Food dispenser

1. Food is stored in the special fridge (WaFoD).

2. At an appropriate time, the food is warmed.

3. The patient is served.

6.1.2.1.3 Reminder for family member

In case a family member is at home and wants to care for the patient, WaFoD sends an alert to the member.

In the case of ordering food, then food order process will run otherwise the food dispenser will run.

6.1.2.2 Medication intake monitoring

Similar to food intake, a drug dispenser is equipped with a high-resolution camera which logs the drug intake. A future extension will automatically perform anomaly detection on recorded films.

The medication intake is then logged. The logs are sent to the family member and the doctor.

6.1.2.3 Physical activities (in- and outdoor activities)

Special TV programs are displayed at certain times of the day to help the patient to train himself. The patient wears a body-area-networking (BAN) equipped with bio-sensors and accelerometer, which continually controls the position of the patient in order to detect if the patient is falling down or lying on the bed.

For dementia patients, no outdoor program is set.

6.1.2.4 Room temperature monitoring

Temperature control is a well-achieved domain application in smart home automation. Existing devices and systems are added to the network.

6.1.2.5 Noise and lighting control

This feature prevents any noise and controls the lighting.

6.1.2.6 Window and door monitoring

Doors and windows are controlled and closed when too noisy.

6.1.2.7 Reminder and assistance for indoor and outdoor

A smartphone-based application plays the role of a reminder and assistant. It follows the patient everywhere. Based on the patient calendar, this application can autonomously and automatically plan the whole day for the patient.

It can look for an appointment with the treating doctor for the next medical visit. The application is parametrizable.

6.1.3 Concept and architectural view

This section presents the concept of the proposed systems and gives an overview of its architecture.

The system features (i) a data perception unit, (ii) water, food, and medication management unit, and (iii) outside and inside activities.

6.1.3.1 Concept

6.1.3.1.1 Data gathering

IoT-enabled patient-monitoring systems present many advantages for the patient and for treating care personnel. Patient-centric data are collected. Personalized care can be based on these data. Actually, healthcare professionals base their treatment on patient-centered data, which can be biased since they are subjective. Further diagnoses are therefore needed or performed to verify the patient-centered data. Patient-centered data are data provided by the patient through narratives, while patient-centric data are data collected using modern information technologies like (wireless) body area network (W-BAN) or (wireless) sensor networks (WSNs).

Aging persons are often forgetful and thus provide mostly biased information when they are requested to report on their health conditions. Though in a smart home automation enabled healthcare solution for "aging well," collecting patient-centric data in an autonomous way is mandatory. In a previous study [35], various advantages of collecting patient-centric data were discussed. The healthcare personal gets a complete picture of the patient's health condition and can thus pose the right diagnosis.

Based on the requirement above, the proposed concept provides a patient-centric data collector in terms of sensors connected with the patient that fully collects any bio-signal as well as positions data and sends the data to a record system at the remote. A duplicated copy of the data is saved on the local server and serves as training data for a machine learning (ML) routing. Additionally, a set of networking capable video recorders are used to collect the patient's body expressions, behaviors, mimic, and any physical activities. These data are also used by the ML algorithm to predict patient's behaviors, expectations, and physiological needs (like thirst, hunger, going to the toilet, etc.).

Sensors (in a body area network) connect the patient to an IoT-gateway that transfers the collected data, using the MQTT protocol, to the local server. We talk of edge-computing that happens at the edge. Collected data are processed and stored on the local server. Using the CoApp protocol, data are sent to the cloud. Treating care/nursing homes or medical doctor as well as patient's family members can access the data and can send data to the local server, which would use received data to regulate some connected devices.

6.1.3.1.2 Food and water intake and control

For "food and water intake", a smart device is designed. This device combines microwaves and the fridge. The device called water and food dispenser (WaFoD) with networking ability is connected to the patient's smartphone and the local server, which in turn is connected to a remote server at the cloud that connects the home to the outside and can dispatch information and data in the whole network. WaFoD can learn from the individual's behaviors and preferences.

WaFoD is connected to the IoT gateway and can collect data, transfer data, and receive data from a remote unit (system or individual). Registered behaviors build the training data for a machine learning processor (ML) located on the local server, the master in the entire network. The ML processor predicts patient menus, proposes menus to the patient, and can order at the registered restaurant the selected menu. All proposed services to the patient are based on his behaviors and preferences.

WaFoD is designed to remind the patient to regularly drink water. It dispenses water or soft drinks. It can warm food and serve the food to the patient. The system logs each nutrition behavior and sends at the end of the day an activity journal, or in the case of emergency (that means the patient does not drink for a while or refuse to take food), it alerts the nursing home close to the patient's residence.

The patient is provided with a touchscreen that displays TV programs and can display the pictures of menus proposed by WaFoD.

The entire system is designed following the Internet of things (IoT) paradigm: (i) data collection unit(s) and (ii) IoT-gateway place between the local server. The local server is a light copy of the remote server at the cloud, which can perform complex and memory consuming computing activities; (iii) the IoT platform at the cloud.

A copy of data like room temperature, updated patient's preferences, etc. that are needed for any computing action are stored at the local server.

The patient is provided with a set of accelerometers (sensors to determine his position- fall down, laying , staying, seating, etc.). with the objective to detect, predict if the patient is falling down or will. Furthermore, other sensors like "Feuer alrm" have been used to monitor fire harzard.

6.1.3.1.3 Medication intake

A drug dispenser is provided. The dispenser is connected to the IoT-gateway via Bluetooth. It features an alarm and can remind the patient to take his medicine. The medication intake is logged and a protocol is stored on the network. Family members can be informed if the patient does not take the medicine on time, thus, action can be taken to help the patient to take the medicine. Care/nursing homes are also connected to the dispenser via the le cloud and can get alerted when the patient refuses to take the medicine.

6.1.3.1.4 Indoor activities

The local server is connected to a touchscreen TV. It can display physical activity programs, which can let the patient to also do so, for example, activities like a walk in the room, some light movements, etc.

6.1.3.1.5 Outdoor activities

Elderly people need real socialization. They need therefore to go out and meet other people. The solution proposed feature a smartphone-based application that manages and looks for senior-meeting close to residence place. This application integrates Google Maps that drives the patient to the meeting and takes him back home.

Similar is done with medical visit.

6.1.3.2 Architectural view

The architectural view presents 4 layers (**Figure 4**).

6.1.3.2.1 Network things

Bio-signals, behavior, preferences, room temperature, physical activities, food, water, and medication intake data are collected at this stage through sensors.

The data collected data are forwarded to the aggregation stage.

6.1.3.2.2 Data aggregation stage

At this stage, collected data are aggregated, filtered, cleaned up, processed, and pre-stored.

6.1.3.2.3 IT edge stage

Processed data from the prior stage are used here, but also forwarded the cloud.

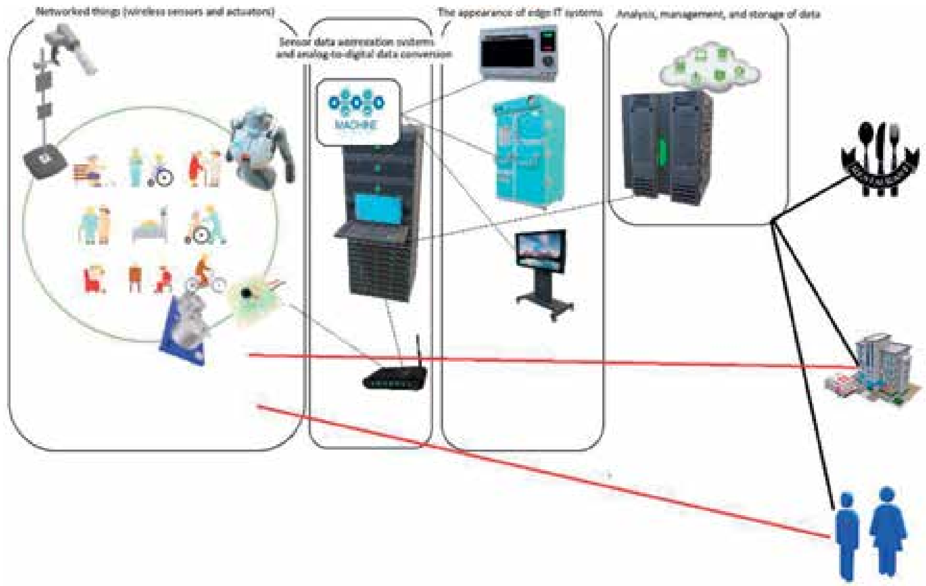

Figure 4.
Architectural view of the proposed system.

6.1.3.2.4 Analysis and other processes at the cloud

Stages A, B, and C happen in the local area (patient residence). In order to enable communication with the remote side, data are forwarded to the cloud. A communication line is, therefore, open between C and D.

Family members, restaurants, nursing homes, and all people authorized to deal with the stored data can access the data through the cloud.

6.1.3.3 Data security

This topic will be discussed in the upcoming paper.

7. Conclusion

This study has investigated the state-of-the-art of "ageing well at home." Many previous studies had archived interesting works on making the "home" comfortable and smarter for elderly and dementia patients. Though most of the previous works have failed in providing a complete solution of smart home automation (*multidimensionality of the concept of the smart home*) for people requesting homecare, this study covers this limitation and shows that smart home automation can impact the patient's and his family member's QoL in a positive way. People staying alone at home as well as those living in nursing care homes would take benefits from such a solution.

8. Upcoming works

The future works aim at launching a human hologram in the program to assist the patient. The patient would though see a family member and can receive from him any instructions or discuss with him. As **Table 15** shows, the presence of a family member has a great impact on the patient's health-related quality of life and thus on his health outcomes.

Setting and remotely regulating the room temperature is well achieved though patient temperature feeling also depends on the treatment he is under. Certain drug or after-physical activities make the patient feel warm or hot. There exists no system that can automatically and autonomously recognize that the patient's room temperature is not more appropriate. Therefore, we plan to design a wearable that can verify if the patient is feeling cold or hot and thus regulate the heater.

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Section 4

Artificial Intelligence and Other Applications

Chapter 6

Optimizing a Centralized Control Topology of an IoT Network Based on Hilbert Space

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Abstract

An Internet of Things network (IoTN) is composed of many small devices or nodes located in homes and/or offices, to be operated through the Internet from anywhere, making these devices smarter and more efficient. For improving the efficiency of an IoTN, in this chapter an optimized fractal algorithm (OFA) was proposed for designing a centralized control topology of an IoTN, whose nodes are distributed according to the Hilbert space-filling fractal. We developed the OFA to find the best nodes where a smart home device can find the highly reliable link between its neighbors by a software-defined network (SDN) with a target coverage since OFA only considers reliable links among devices. Finally, through laboratory tests and computer simulations, we demonstrated the effectiveness of this proposal by using a large amount of IoT devices making them more efficient operating systems. The quality of service (QoS) is a challenge that guaranteed the level of service delivery to an IoTN, so that OFA takes less time to reach its destination after it is generated by its source, increasing the probability that the target node can recover the original packet before the lifetime expires.

Keywords: smart home, IoTN, centralized control topology, optimization, Hilbert fractal algorithm, quality of service

1. Introduction

In the coming fourth industrial revolution, several technological fields are impacting all disciplines, economies, and industries, such as artificial intelligence (AI) and the Internet of Things (IoT). Artificial intelligence permits machines to learn and adapt to different situations and problems. Due to its great versatility, AI can work in conjunction with the Internet of Things, allowing smart home devices or microcontroller units (MCUs) to create many Internet of Things networks (IoTNs) to be able to collect, process, and share data of different nature that flows through the network. It is expected that by 2025 26–30 million MCUs in homes and offices will be connected as networks to the Internet and equipped with sensors, processors, and embedded software.

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As a network, IoTN behaves as a collective entity which does not depend on a central control or hub. Therefore, it is necessary to design IoTN topologies that are not subject to the performance of a single MCU or node for guarantying the quality of service (QoS) requirements due to an efficient connectivity based on a bandwidth that links each of MCUs with their immediate neighbors at 300 Mbps, in order to ensure that all of them really share their parameters when they are operating. This implies to design networks with shared parameters between their nodes and where the locality is preserved and limited the maximum average distance between the MCUs by using alternative tools, such as space-filling curves. The Hilbert fractal is a continuous space-filling curve whose locality-preserving behavior is better than that of Z-order curves, because the distance between each node in a Hilbert curve does not fluctuate, whereas that distance in a Z-order curve does fluctuate.

Accordingly, in this chapter an effective and a reliable optimized fractal algorithm (OFA) for extending the range of transmission of a given IoTN in an intelligent, adaptive, and dynamic way is proposed. The OFA finds a path from a source to a target to optimize the links by considering the quality of service constraints such as end-to-end reliability and delay. In this way, with OFA we pretend to achieve the best two MCUs where each smart home of the IoTN can transfer or share its parameters. Finally, through laboratory tests and computer simulations, we demonstrate the effectiveness of our approach by means of a fractal routing in IoTN, using from 16 to 64 smart home devices for real-time monitoring of different parameters, in order to make more efficient the Smart Home Automation by reducing the IoTN energy consumption.

The further sections of this chapter are organized as follows. First, in Section 2 we explain the relation between smart home devices distributed in networks and the energy efficiency. In Section 3 an explanation of the theoretical definition of the Hilbert space-filling fractal is given. OFA scheme is defined in Section 4, while in Section 5, the simulation and the comparison of the performances are announced, in order to verify the correction and feasibility of the proposal. Finally, the arguments and discussion of this chapter are analyzed in Section 6.

2. Merging smart home and software-defined networks

A house is smart when it has installed a series of electronic systems, sensors, and devices, so that any person can easily control it, even from a distance, and the house performs certain actions on their own.

An example of this would be the management of heating and air conditioning, so that our home always has a comfortable temperature, whatever the time of year.

This can be achieved by installing temperature sensors and connecting them to a computer or a dedicated device, which once we have programmed it, deciding which temperature is the best for the residents, sends orders to the heating or air-conditioning control devices. This automation is what is called home automation.

In this way, home automation has been around for a long time, as we can link various automations through domestic wiring, sometimes with cable inside the walls. The technological advance has given us wireless connectivity and miniaturization, which have allowed the extension of the concept of home automation to many other aspects, even outside the home.

Currently, and under the definition of the smart home, there are devices that allow to control almost everything imaginable, either automatically or facilitating human control.

In this sense, we can say that the smart home is the result of the intersection between architecture, interior design, and the most advanced technology, which allows the automation in an unattended way of certain domestic tasks, but also with the condition that there can be supervision or fixed objectives on the part of the residents.

Thus, a smart home seeks to:

- Increase our security cameras or motion sensors which are elements that warn us of intrusions and suspicious movements even when we are absent.

- Provide us more time. By automating certain tasks, we stop thinking about them. If we wake up every morning at a certain time, the same home (through its artificial intelligence) can raise the blinds and start to heat the coffee, so we can save this time to get to work a little earlier or simply to sleep 5 more minutes.

- Allow us remote control. Turning on the air-conditioning unit 10 min before we get home so that when we enter it.

- The energy saving with multiple sensors scattered around the home are more reliable than the human sensation, where exactly the energy needed to heat or cool the house is used.

The latter statement guides us to consider as one of the most important issues the way to save energy among sensors, namely, how efficient is the energy consumption. In this way we identify energy efficiency as the most critical challenges in IoTNs because the nodes or smart home devices in such networks have limited resources. In this way, software-defined networks (SDNs) are a way to approach the creation of networks in which control is detached from the hardware and given to a software application called a controller. So, SDNs, also known as programmable and automated networks, are presented as a proposal that provides greater speed, agile infrastructure, and better costs in cloud IT platforms; it is urgent to respond to the dynamism of the applications required by the user.

When a packet arrives at a switch in a conventional home network, the rules built into the proprietary firmware of the switch tell the switch where to transfer the packet. The switch or router sends each packet to the same destination on the same path and treats all packets in the exact same way. In this proposal, intelligent routers designed with specific MCUs are sophisticated enough to recognize different types of packages and treat them differently, but these router can be only the seed or the begging of the home network. Furthermore, in an SDN, a home network administrator can shape traffic from a centralized control console without having to touch individual smart devices, in this case sensors. The administrator can modify any rule of network switches when necessary—giving or removing priority or even blocking specific types of packets with a very detailed level of control.

This is especially useful in a multi-tenant architecture for cloud computing because it allows the administrator to handle traffic loads flexibly and more efficiently. Essentially, this allows the administrator to use fewer and more *intelligent routers* and have more control than ever over the flow of all the smart devices of the network traffic. Nowadays, the most popular specification for creating a software-defined network is an open standard called OpenFlow. OpenFlow allows network administrators to control routing tables remotely.

In addition, home networks have not changed about 20 years ago; unlike programs, we are facing a paradigm shift to which we must adapt. The development of

SDNs began in 1990, where programmable functions are included in the network; in 2001–2007, the control and data planes were improved, improving with this innovation. From 2007 to 2010, it was implemented. The OpenFlow API, is presented as an open interface, presents various ways the separation of the control plane and data to be scalable, practice where virtualization played an important role in this SDN evolution.

The progress and evolution of SDNs underlies because traditional home routers cannot respond to unpredictable traffic patterns much less to peak demand. In addition, there would be two alternatives to climb to a more expensive home network by spending more time in configuration or adapting to a dynamic home network. SDNs are suitable for people that require rapid changes in the short term, which happens in a conventional home where mobile devices are added and disappear arbitrarily over time. Currently a conventional home user uses social networks in many devices, which are in high demand or require sudden changes, for example, not only working on geographic traffic but environmental variables such as temperature or humidity, development of mobile devices, virtualization of network devices and sensors, and cloud services.

In this way it is important to point out that SDN is an architecture approach, not a specific product, which has traditionally been thought of as the virtualization of data center networks.

This means separating the management of the control plane from the home network devices from the underlying data plane that forwards the home network traffic. The use of a software-defined system to control this disaggregation provides many benefits, including greater network management flexibility and the ability to more easily implement high-precision security policies.

However, Kindness points out that smart home network operators think of SDN with a too narrow focus, although there has been an evolution in the SDN market in recent years, driven by the increase in demands on the network.

To meet these new challenges, the underlying technology that drives SDN has also been applied to other network areas such as the homes with a lot of sensor or smart devices.

SDNs emerged in early 2010 out of mere necessity. Many networks today were designed for client–server applications that run on a non-virtualized infrastructure. The purchase of Nicira by VMware in 2013 was considered a turning point for the SDN industry, as it turned the virtualization giant into a network provider. Today, VMware's NSX SDN product is based on that technology. Cisco Application Centric Infrastructure is the basis of its SDN offer. Many other companies, such as Juniper and Arista, also offer their solutions. IDC estimates that the SDN market has grown from an industry of 406 million dollars in 2013 to over 6600 million dollars in 2017. The consulting firm anticipates that the SDN market will continue to do so at a compound annual growth rate of 25.4%, reaching about 13,800 million dollars in 2021.

A survey conducted in 2017 by the Network World publication among 294 network professionals found that 49% of them are considering or actively piloting an SDN implementation; 18% already have an SDN installed.

Furthermore, IDC has identified a handful of major use cases for SDN today:

- To maximize investments in server virtualization and private cloud
- To enable network programming

Although so far many SDN deployments have focused on the data center network, Kindness, the Forrester analyst, states that the future of SDN will be defined by how this technology is used outside of the data center.

There are a variety of factors that will continue to pressure network operators, including the increasing use of public cloud computing, the attack of network traffic created by the Internet of Things, the proliferation of a mobile workforce, and an increasing number of distributed branches. Given this, SDN will play a role in configuring the next generation of networks for each of these use cases.

And there is already evidence of this in actual use: Software-Defined Wide Area Network (SD-WAN) is a software management platform to control access to the remote offices or branches of an organization.

In the past, home customers had only one connection to their branches; today SD-WAN allows companies to add several types of network connections to a branch and have a software management platform that allows high availability and automatically prioritize traffic.

SD-WANs can save a home customer's expense by installing expensive custom WAN acceleration hardware allowing them to run a software overlay on less expensive hardware.

Expects highlight that the SD-WAN will become a market of 6 billion by the year 2020.

In addition, software-defined IoTNs (SD-IoTNs) can be technically sorted in nine classifications:

1. Security: identifying the malicious user and their activities, namely, global overview of a device's status in the home network.

2. Routing: the network data and information is efficiently transferred.

3. Mobility: due to external forces, any node of the home network can be physically moved.

4. Reliability: the ability to be, almost always, in an operational state under adverse circumstances, usually after failures. Operating state is understood to be that in which the SDNs are capable of performing a specific operation.

5. Management: maintenance, network configuration, and provisioning.

6. Quality of service: it is a set of service requirements that SDN must accomplish when routing a data flow. It can be implemented in different situations, to manage congestion or to avoid it. It allows to control some significant characteristics of packet transmission. These characteristics can be specified in quantitative or statistical terms such as bandwidth, latency, jitter, and packet loss in the network, ensuring a pre-established degree of reliability that meets the traffic requirements, depending on the profile and bandwidth for a given data flow.

7. Wireless power transfer: energy sensor node can be transmitted to other nodes through an appropriate transmitter.

8. Localization: many applications of IoTNs need the information of each node.

9. Energy efficiency: sleep scheduling approaches are designed for switching the nodes into idle state if their functionality is not required.

In addition, this classification can be rewritten as follows:

- Coverage control: control activates or deactivates the sensor nodes to cover a network region.

- Clustering: nodes into clusters and a head node for each.
- Lifetime: possibility to utilize the node capabilities for a longer period of time.

Accordingly to SD-IoTN paradigm, no matter the sort of topology, any sensors inside a smart home network are connected individually to a central router, and they were almost never interconnected among them. Thus, the devices furthest from the router spend more energy than those that are closest to it. In addition, any communication between sensors must necessarily go through a centralized router, even if they are a foot away from each other.

In this sense, the main proposal of this chapter is to communicate with the nearest sensor using a non-centralized, rather a distributed and dynamic, topology that is reorganized according to a fractal function based on the Hilbert scanning.

3. Hilbert space-filling fractal

Mathematician B. Mandelbrot coined the fractal term in his pioneer work *The Fractal Geometry of Nature* [1], describing a fractal as an irregular or fragmented geometric structure that can be divided into parts: each of which is (or approximately) a smaller-size copy of the whole. He also pointed out that many fractals are found in the nature forming irregularly shaped objects or spatially nonstandardized phenomena in nature that cannot be attributed to Euclidean geometry, such as mountains or blood vessels, with fractional or non-integer dimension. From a mathematical point of view, fractals are a kind of composite geometric shapes which regularly display the property of self-similarity, such that a small segment of it can be reduced as a fractional scale replica of the whole [1].

All obtainable fractal objects in nature are generated from non-determined or random steps. Fractals generated by an iterative procedure, produced by consecutive dilations and conversions of a primary set, are deterministic. There are two properties attributed to fractals: self-similarity and space-filling. Self-similarity stands for a piece of the fractal geometry which seems to be like that of the total structure for all time, while the space-filling property means that a fractal outline can be packed in a limited region as the iteration increases without increasing the whole area.

Concerning the space-filling property, there are fractal curves that fill the plane that contains them in a specific order by continually changing direction or passing through each point that is in the defined space [2], such as the Hilbert fractal curve. The Hilbert space-filling curves are in a single layer that do not intersect; each point of them is at a constant distance unique to any other point, and these curves contain only one starting point and one stopping point in a single layer.

In 1878, mathematician G. Cantor demonstrated that there was a one-to-one correspondence between the unit interval $[0, 1]$ and the unit square (plane) curve. In 1879, Netto showed that any such mapping could not be continuous. In 1887, Jordan defined a (plane) curve as the set of points $(\phi(t), \psi(t))$ where ϕ and ψ are continuous functions on a closed interval $[0, 1]$, t is the time, and the curve is the path of a particle starting at $t = 0$ and ending at $t = 1$. In 1890, Peano discovered a space-filling curve. Thus the Peano curve must have multiple points, that is, points which are the images of two or more distinct values of t [3].

In 1891 Hilbert discovered another space-filling curve. Whereas Peano's curve was defined purely analytically, Hilbert's approach was geometric [2].

To construct Hilbert-type space-filling curves, lets denote the unit interval $[0, 1]$ as $I = \{t|0\} \leq t \leq 1$ and the unit square as $Q = \{(x;y)|0 \leq x \leq 1; 0 \leq y \leq 1\}$. For each positive integer n, the interval I is partitioned into 4^n subintervals of length 4^{-n} and the square Q into 4^n subsquares of side 2^{-n}. A one-to-one correspondence between the subintervals of I and the subsquares of Q subject to two conditions is constructed: (i) adjacent subintervals correspond to adjacent subsquares with an edge in common, *adjacency condition*, and (ii) if at the $n - th$ partition, the subinterval I_{nk} corresponds to a subsquare Q_{nk}, and then at the $(n + 1) - st$ partition, the four subintervals of I_{nk} must correspond to the four subsquares of Q_{nk}, *nesting condition*.

For each n the 4^n subintervals are labeled in their natural order from left to right. The correspondence between the intervals and the squares amounts to numbering the squares so that the adjacency and nesting conditions are satisfied. Hilbert's enumeration of the squares is shown in **Figure 1** for $n = 1, 2, 3$. The first square is always in the lower left corner, and the last square is always in the lower right corner. This means that the Hilbert space-filling curve starts at $(\phi(0), \psi(0))$ at $t = 0$ and ends at $(\phi(1), \psi(1))$ at $t = 1$. With the first and last squares of each partition determined, there is only one enumeration of the squares that satisfies the adjacency and nesting conditions.

The construction of a Hilbert space-filling curve is presented in **Figure 1**, in which the dotted square shows the area to be filled by the curve. This square is divided into four squares.

On the other hand, many space-filling curves can be produced as the limit of a sequence of polygonal curves, where the curves are generated via an iterative process, for example, a Lindenmayer system (L-system), in order to visualize such sequences of curves. A small part of the curve at one step of the iteration is close to a corresponding part of the curve at the previous step, and so it is natural to add frames that continuously interpolate between the curves of the iteration.

The Hilbert fractal can be generated by using specific rewriting rules of the Lindenmayer systems [5].

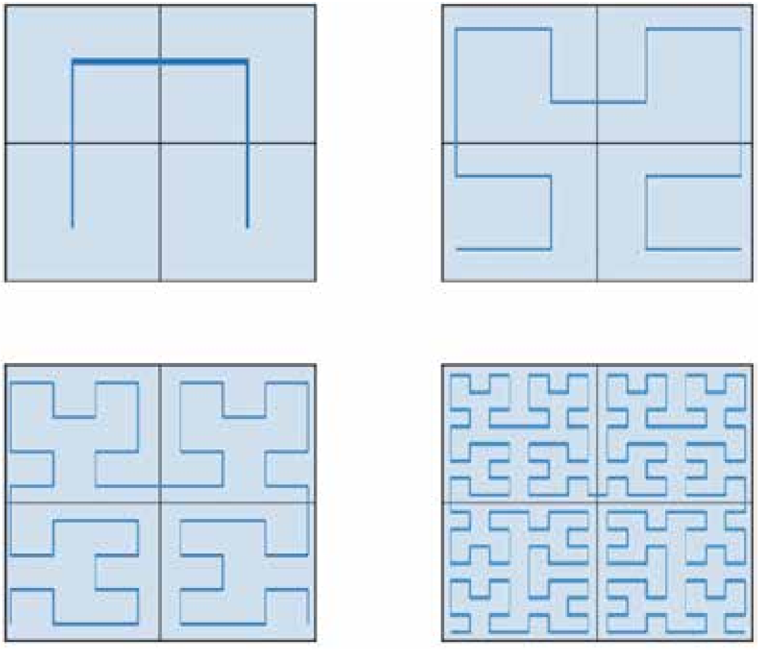

Figure 1.
First four stages in the generation of Hilbert's space-filling curve, axiom = R (see Section 4.3) employed by Hilbert in [4].

The L-systems, developed by Lindenmayer in 1968, emerged as a way to discreetly describe the development and growth of multicellular organisms [6]. An L-system is a string rewriting system. We have an alphabet of symbols V; a string of symbols ω defining the start of the system, or *axiom*; and a set of production rules P determining how we produce a new string from an old string. The *L-system* grammar is the collection of these three parts, $G = (V, \omega, P)$. This generates a sequence of strings by repeatedly applying the rules P, starting with the axiom ω.

To construct the Hilbert space-filling curve, we proposed the following L-system grammar:

$$G_{Hilbert=}(\{F, -, +\}, R, \{R \rightarrow +RF - LFL - FR+\})$$

Then the output of the L-system is the following sequence of strings for the first three steps:

Step 1:	$-LF + RFR + FL-$
Step 2:	$- + RF - LFL - FR + F + -LF+$
	$RFR + FL - F - LF + RFR + FL$
	$- + F + RF - LFL - FR + -$
Step 3:	$- + -LF + RFR + FL - F - +RF - LFL - FR + F + RF - LFL-$
	$FR + -F - LF + RFR + FL - +F$ + - + RF-LFL-FR + F + -
	$LF + RFR + FL - F - LF + RFR + FL - +F + RF - LFL - FR$
	$+ - F - +RF - LFL - FR + F + -LF + RFR + FL - F - LF+$
	$RFR + FL - +F + RF - LFL - FR + -F + -RL + RFR + FL-$
	$F - +FR - LFL - FR + F + RF - LFL - FR + -F - LF + RFR + FL - +-$

Given the L-system for the Hilbert space-filling curve, it is possible to view the produced strings as instructions for building these curves in a turtle graphic fashion [7]. That is, we start somewhere on the plane, with a specified forward-facing direction. We read the input string from left to right and interpret the symbols as actions to be performed. For the L-system for the Hilbert space-filling curve, we make the following interpretations:

1. F, move forward one unit

2. +, turn left (counterclockwise) 90°

3. −, turn right (clockwise) 90°

In this chapter it is proposed to use the symbols L and R to represent a kind of small deviation from a forward step (starts with a left turn) and to represent a small detour in the other direction (starts with a right turn), respectively.

4. Methodology

The proposed methodology in this chapter is defined by the following passes:

- Hub MCU

- $LRN_i(t)$ and $LSN_i(t)$

- Hilbert fractal scanning
- Initial topology

It is also important to consider the general parts of the environment of the proposal, so any configuration of IoTNs consists of a wireless access point (WAP) and a β number of IoTN nodes which can be increased or decreased in its amount. In this case β embedded systems or MCUs that composed the IoTN, which shares parameters among sensors inside a given room or floor plan; β ranges dynamically are $1 \geq \beta > 4^n$. In this way, we also define $IoTN_N(t) = \sum_{i \geq 1}^{\beta} MCU_i(t)$, where $t = \{t_0, t_1, t_2, \dots t_j\}$, i.e., a specific period of time (t) when the IoTN is defined as a set of MCU_i with at least one member up to 4^n members. Whereas n is the Hilbert fractal level needed to go from the first to the last MCU_i and it is expressed by $n = \lceil \log_4(\beta) \rceil$, here i represents the index inside the IoTN (t) of a given MCU, namely, MCU_1 is the first MCU, MCU_2 the second one, and so on.

It is important to emphasize that the IoTN has β MCUs in the time frame (t_j), but it can have up to $4^n - 1$ devices. If $\beta \geq 4^n$, the value of n is recalculated, and a new topology is reconfigured; otherwise the algorithm just adds a new node in the network, with the purpose that each node of the same network is linked or indexed by the curves that make up the Hilbert fractal. Subsequently, the effectiveness of the methodology exchange parameter throughout the network is measured. Finally, the point-to-point algorithms of Wi-Fi (P2P) and SoftAP are configured.

4.1 Hub MCU

It is important to establish that $\beta(t_j)$ IoTN devices are randomly distributed along a certain floor plan which forms a matrix γ with $2^n \times 2^n$ dimension. Namely, our proposal estimates a certain topology according to the β devices in the room in a certain period of time t_j. Then, the main WAP or hub is placed in the center of the main room, although it can be placed anywhere within the room, to have connections at any direction. That is, every connection to the WAP will be the mainstream star topology. In this first generation of MNIs, a consecutive number will be assigned according to the speed of its link with the WAP. Thus, certain MCU_i has the best link so this device is labeled as $i = 1$ or MCU_1. Any floor plan had some walls, which attenuate the signal; that is why certain devices with shorter linear distance have a slower maximum speed than others that are further away from the WAP.

4.2 $LRN_i(t)$ and $LSN_i(t)$

$MCU_{i=1}(t)$ is identified as the main node in the IoTN. In this way, all the embedded systems both $IoTNe(t)$ and $MCU_1(t)$, enable Wi-Fi Direct mode and a full table with the bandwidth of the nodes are next to them, in order to generate a list of reliable nodes in a certain period of time t $(LRN_i(t))$. Every MCU generates a particular $LRN_i(t)$; then the proposed IoTN can generate 4^n LNRs at the instant t. In addition, every $LRN_i(t)$ contains the bandwidth of all $MCU_i(t)$ with which it establishes connection. In order to belong to the wireless sensor network, every $MCU_i(t)$ must connect to at least one link to another $MCU_i(t)$. All LRNs are shared, and $\sum_{i=1}^{4^n} MCU_i(t)$ knows the way to any node in the network, namely, everyone knows the topology of the network. In this way it is important to estimate the $LRN_i(t)$, but not all of these nodes are significant to be considered as the best option to establish a link, in which manner we define $LSN_i(t)$ as the list of significant nodes

(LSN) which is a vector that contains the best bandwidths of a certain $MCU_i(t)$. Algorithm 1 shows the methodology to estimate the $LSN_i(t)$ that needs i^{th} MCU and its $LRN_i(t)$. At this moment the IoTN can be considered as a scarce network, since only the $\frac{\rho_i(t)}{\beta}$ percent of the reliable links is connected.

Algorithm 1: Generator function to estimate the list of significant nodes (LSN) and the number of significant nodes ($\rho_i(t)$).

```
Input: i, LNR_i(t)
Output: ρ_i(t), LSN_i(t)
j ⟸ size of the LNR_i(t) for the MCU_i(t)
Sort all LNR_i(t) regarding their bandwidth in S_LNR_i(t)
Estimate B_thr = μ_i(t) − σ_i(t)
Initialize the counter label = 1 and LSN = {0, 0, 0}
for label ← 1 to j do
    Calculate B_LNR_k(t): the bandwidth in Mbps of the k element in the
      SLR_LNR_k(t)
    if B_LNR_k(t) ≥ B_thr AND k ≤ 3 then
    |   LSN(k) = MCU_label(t)
    |   k ⟸ k + 1
    LSN(k) = { the three best links according B_thr, if possible }
    ρ_i(t) is the number of elements ≠ 0
```

4.3 Hilbert fractal scanning

The construction of the Hilbert space-filling fractal, under the paper's graphic interpretation framework, was reduced to the replacements of the smallest elements (symbols) or interior replacements. This path can be optimized by means of the correlation of the strength of the signal or the bandwidth of the link by Eq. (1):

$$\phi_{xy} = \frac{\sum_{i=1}^{n}(x_i - \overline{x})(y_i - \overline{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \overline{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \overline{y})^2}} \tag{1}$$

where ϕ_{xy} is the sample correlation coefficient, n is the stage 0 level of Hilbert curve (**Figure 2a**), and x_i and y_i are, respectively, the best and the second best individual bandwidths in a certain MCU_i indexed inside the IoTN as the ith element, while $\overline{x}$ and $\overline{y}$ are, respectively, the sample mean of the best and the second best individual bandwidths in a certain MCU_i. Thus, we can estimate the best link to a particular MCU_i.

All $\sum_{i=1}^{4^n} MCU_i(t)$ are distributed randomly giving as a result a shape as shown in **Figure 2b**. When γ is reordered as vector, it gives as a result the Hilbert curve indexing $\overrightarrow{\gamma}$ which contains the order of the $MCU_i(t)$ (see **Figure 2c**).

4.4 Initial topology

Once the Hilbert curve is defined as L-system, we adapt the production rules of the original work by Hilbert [4], who proposed an axiom with a $\mathcal{D}$ trajectory, while we propose to start with an $\mathcal{U}$ trajectory. Our proposal is based on the fact that most of the energy is concentrated in the nearest MCU, namely, at the right or left. In this way the production rules of the Hilbert curve are defined by:

- $\mathcal{U}$ is changed by $\mathcal{LUUR}$
- $\mathcal{L}$ by $\mathcal{ULLD}$

1	4	5	6	59	60	61	64
2	3	8	7	58	57	62	63
15	14	9	10	55	56	51	50
16	13	12	11	54	53	52	49
17	18	31	32	33	34	47	48
20	19	30	29	36	35	46	45
21	24	25	28	37	40	41	44
22	23	26	27	38	39	42	43

(a)

64	2	3	61	60	6	7	57
9	55	54	12	13	51	50	16
17	47	46	20	21	43	42	24
40	26	27	37	36	30	31	33
32	34	35	29	28	38	39	25
41	23	22	44	45	19	18	48
49	15	14	52	53	11	10	56
8	58	59	5	4	62	63	1

(b)

64	9	55	2	3	61	12	54	....	51	13	60	6	7	50	16	57
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	....	*57*	*58*	*59*	*60*	*61*	*62*	*63*	*64*

(c)

Figure 2.
(a) First three stages of the Hilbert curve, (b) matrix of dispersion or γ *of* $\sum_{i=1}^{4^n} MCU_i(t)$ *inside a convectional room, and (c) matrix* $\vec{\gamma}$ *ordered as a vector.*

- $\mathcal{R}$ by $\mathcal{DRRU}$
- $\mathcal{D}$ by $\mathcal{RDDL}$

The Hilbert curve has the property of remaining in an area as long as possible before moving to a neighboring spatial region. Hence, the correlation between neighbors $MCU_i(t)$ is maximized, which is an important property in the optimization of any system. The higher the correlation for estimating the final topology, the more efficient the data parameter sharing.

5. Experimental results

In this section, first we approach the basic concepts of the network simulator (NS) and then use it to compare the most current SDN topologies, which helps us to identify the effectiveness of the proposed algorithm.

5.1 Network simulator

Network simulator is a software to simulate discrete events, and it was designed to aid in the research of telematic networks. NS provides support for the simulation of a multitude of protocols of the application layers (http, ftp, cbr, etc.), transport (TCP, UDP, RTP, SRM), unicast and multicast routing protocols, etc., both for networks wired as local or satellite non-wired and with complex topologies with a large number of traffic generators. NS began in 1989 as a variant to the existing REAL Network Simulator and has evolved substantially in recent years, having been developed by DARPA with the help of several network research institutions, such as LBL, Xerox PARC, UCB, USC/ISI, etc.

NS is basically an object-oriented simulator, written in C++, whose user interface is presented as an object-oriented Tcl language interpreter or, in other words, OTcl language. The simulator supports a hierarchy of classes written in C++, also

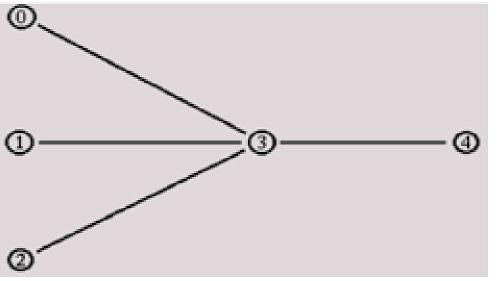

Figure 3.
Example of network topology.

called a compiled hierarchy, and another hierarchy of classes similar to the previous one but within the interpreter that is presented to the programmer in OTcl, and which is also known as an interpreted hierarchy. These two hierarchies are closely related to each other, so that, from the user's perspective, there is a one-to-one correspondence between one class in the interpreted hierarchy and one in the compiled hierarchy. The root of this hierarchy is a class called TclObject. When the user creates a simulator object from the interpreter, which usually starts a script, this object is created within the interpreter, and a close relationship is created with another identical object but within the compiled hierarchy. The interpreted class hierarchy is established automatically through methods defined within the class called TclClass. In addition, we can create other hierarchies to our liking in the scripts, written in OTcl, that are not split in the compiled hierarchy.

To create the topology, we just show a simple example for purposes of understanding the use of this simulator. For this example we use the connection depicted by **Figure 3**.

Then the nodes are created in the same way as in **Figure 3**, as follows:

```
set n0 [$ns node]
set n1 [$ns node]
set n2 [$ns node]
set n3 [$ns node]
set n4 [$ns node]

$ns duplex-link $n0 $n3 1Mb 100ms DropTail
$ns duplex-link $n1 $n3 1Mb 100ms DropTail
$ns duplex-link $n2 $n3 1Mb 100ms DropTail
$ns duplex-link $n3 $n4 1Mb 100ms DropTail
```

Then, traffic sources are attached to nodes n0, n1, and n2:

```
proc attach-expoo-traffic { node sink size burst idle rate } {
  #Get an instance of the simulator
  set ns [Simulator instance]

  #Create a UDP agent and attach it to the node
  set source [new Agent/UDP]
  $ns attach-agent $node $source

  #Create an Expoo traffic agent and set its configuration parameters
  set traffic [new Application/Traffic/Exponential]
  $traffic set packet-size $size
  $traffic set burst-time $burst
```

```
$traffic set idle-time $idle
$traffic set rate $rate
# Attach traffic source to the traffic generator
$traffic attach-agent $source
#Connect the source and the sink
$ns connect $source $sink
return $traffic
```

First, the procedure creates a traffic source and attaches it to the node. Then, it creates a Traffic/Expo object, sets its configuration parameters, and attaches it to the traffic source. Before, the source and sink have been connected. Now, the traffic sources (with different peak rates) are attached to n0, n1, and n2, and then they are connected to the three traffic sinks in node n4, which has been previously created:

```
set sink0 [new Agent/LossMonitor]
set sink1 [new Agent/LossMonitor]
set sink2 [new Agent/LossMonitor]
$ns attach-agent $n4 $sink0
$ns attach-agent $n4 $sink1
$ns attach-agent $n4 $sink2

set source0 [attach-expoo-traffic $n0 $sink0 200 2s 1s 100k]
set source1 [attach-expoo-traffic $n1 $sink1 200 2s 1s 200k]
set source2 [attach-expoo-traffic $n2 $sink2 200 2s 1s 300k]
```

In this example, Agent/Loss Monitor objects are used as traffic sinks, since they store the amount of data received, which can be used to calculate the bandwidth. In the same way, we construct all the nodes and interconnections for the simulation of the next section.

5.2 Comparing SDN performance

Once NS is defined, we estimate the performance of this chapter by the simulation of the effectiveness of the project node and the quality of service. Moreover, the duration of the OFA was evaluated by the end of the delay (E2ED) and the packet delivery ratio (PDR). So we compared the performance of OFA to newer algorithms similar to the latest technology:

1. Reliable and energy-efficient routing (REER) proposed by Li et al. in [8]

2. Delay-energy trade-off in wireless sensor networks with reliable communication (DETR) proposed by Liu et al. in [9]

3. Reliable routing with distributed learning automaton (RRDLA) proposed by Mostafaei in [10]

We use the network parameters recommended by Zorzi and Rao in [11] and Karp and Kung in our experiments [12].

In this way, it is important to define E2ED as the time it takes a packet to reach its destination after it is generated by its source, it is important to set the time for the packet to be reached because its next delay and delivery delays will be targeted at PDR probability of a total of [13] knot; the life span may be reset to original packages before the expiration of [14]. According to this definition, the correlation between the maximal and minimal end-to-delinquency values of the η is determined by the change between maximal and minimal packet delivery ratios. If the delay ends are stable, η will be equal to 0, and if the packet delivery rate is constant $\eta = \infty$, a delay will appear:

$$\eta(\varphi) = \frac{E2ED(\varphi)_{\max} - E2ED(\varphi)_{\min}}{PDR(\varphi)_{\max} - PDR(\varphi)_{\min}} \tag{2}$$

where φ is the effect of node density or the requirements for reliability of QoS. According to the models proposed by Niu et al. [15], it is based on the experience described for Mostafaei in [10] and Zeng et al. in [16].

In this way, **Figure 4a** and **b** show the comparison between PDR and E2ED, respectively, in terms of node intensity and reliability. We can say that better algorithms are reached with the higher E2ED and the lower PDR. Thus, both algorithms get the best results and try to minimize delays when sending target data which can restore original packages. OFA is slightly better in both cases, but the differences are not higher than 1.97%. Additionally, the delay in RRDLA and OFA is noticeably changed by increasing the intensity of the network or QoS node. DETR and REER also have worst results than the two best algorithms.

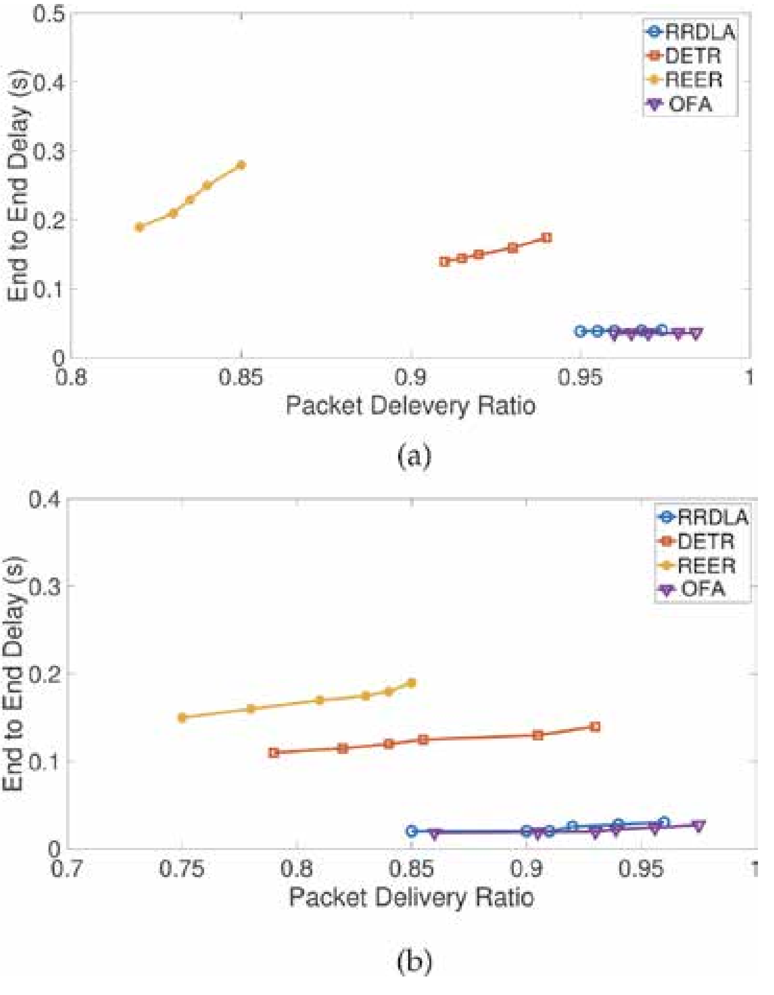

Figure 4.
The simulation of the impact of the node density and quality of service, case end-to-end delay vs. packet delivery ratio. (a) Node Density, and (b) Reliability Requirements.

Algorithm	η (node density)	η (quality of service)
RRDLA	*0.0833*	*0.0909*
DETR	1.1667	0.2143
REER	3.000	0.4000
OFA	**0.0386**	**0.0705**

Table 1.
$\eta(\varphi)$ for the impact of node density and quality of service.

Table 1 shows $\eta(\varphi)$ for node intensity and service quality, both in the OFA or best results (bold) to 0 and RDDLA will have the second (emphasized).

If **Table 1** is analyzed, we can realize that OFA obtains the better result when node density and quality of service are compared. It is important to mention that using the regression techniques of a variable of E2ED on a PDR variable, we look for a function that is a good approximation of a point cloud (x_i, y_i); this regression algorithm reduces in an important way the time of processing. The simple linear regression model has the following expression:

$$E2ED = \alpha + \beta PDR + \varepsilon \tag{3}$$

where α is the ordinate at the origin (the value that E2ED takes when PDR is 0), β is the slope of the line (and indicates how E2ED changes when increasing PDR in a unit), and ε is a variable that includes a large set of factors, each of which influences the response only in small magnitude, which we will call error. PDR and E2ED are random variables, so you cannot establish an exact linear relationship between them.

As a result, a package sent by OFA will spend less time to achieve its target, because the target node will increase the chance of recovering the original packet before its expiration.

6. Conclusions

Smart home technology, as part of IoT, is the future of residential-related technology which is designed to deliver and distribute services inside/outside the house via networked smart devices sharing information by means of a broadband Internet connection. In this chapter we developed an OFA for optimizing a central IoTN topology, increasing the range transmission of a given Wi-Fi network in an adaptive and dynamic way when sharing parameters, in order to achieve an energy-efficient IoT-based smart home.

With the IoTN topology proposed in this chapter, based on the L-system for the Hilbert space-filling fractal and focused on the efficient connection of the smart home devices or MCUs, the energy consumption of the connected devices is reduced. Most of this energy consumed by MCUs can be saved through inclusion of new nodes or devices connected in the same IoTN, since most of the information detected throughout the network is redundant due to geographically placed sensors.

Thus, our proposal optimizes the links among MCUs or smart home devices, since in a dense network we have 2016 possible links but with only 64 links we can share parameters of sensor, namely with only the 3.05% or we are reducing the 96.95% the number of links in the presented IoTN. In addition, we can manage scarce IoTNs in order to obtain more dense networks, since by means of a backbone, many WAPs can be interconnected to form more complex or dense topologies, which can grow using higher levels of Hilbert fractal.

Finally, we propose a software-defined network (SDN) with strong mobility since it can be reconfigured depending on the amount of nodes; also we employ a target coverage because OFA only considers reliable links among smart home devices. In terms of reliability, our proposal can share parameters such as battery, radio, hardware, or operating systems. By itself, the quality of service is a challenge that guaranteed the level of service delivery to an IoTN; OFA takes less time to reach its destination after it is generated by its source increasing the probability that the destination smart home device can recover the original packet before the lifetime expires.

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Chapter 7

Living Function-Resilient Society in the Centenarian Era: Living Safety Technology Based on Connective, Artificial Intelligence

Yoshifumi Nishida and Koji Kitamura

Abstract

In the centenarian era, it has become even more imperative to address the physical and cognitive changes faced by children, the elderly, and disabled persons. We need a "living function resilient society," which ensures they enjoy safe living environments in ways that allow them to maintain active social participation levels despite the changes. To build such a society, more attention should be paid to problems: diversity in life function and intervention needs, gap between efficacy and effectiveness, fragmentation of living data and support service and variety in privacy exposure. To deal with these issues, this chapter describes a new approach referred to as "connective AI" that allows individual lives to be connected with each other and efficacy to be scaled to effectiveness by computerizing places of living in accordance with the private policy of individual facilities and connecting them with each other through a network. As a concrete example of connective AI, this chapter introduces smart living labs that are developed by the National Institute of Advanced Industrial Science and Technology (AIST) in cooperation with children's hospitals, rehabilitation hospitals, intensive care homes for the elderly, and private homes.

Keywords: living function, health monitoring, living laboratory, handrail, wearable device, RGBD camera, social participation, nursing care support

1. Introduction

A society that fosters resilience to changes in living function (a "living function-resilient society") is required now. We need social and industrial systems that ensure safety and high-level community involvement when we experience changes in cognitive function, physical function, or family function as we move toward an aging society (a dementia society). **Figure 1** shows the current age distribution of the Japanese population and that of accident rates, birth, and caregiving. Rapid, mental, and physical developments occur during infancy. Women experience significant changes during pregnancy and around birth. There are times when they or their child or parent needs nursing care. Changes in their physical and mental functions or in being able to care for someone in

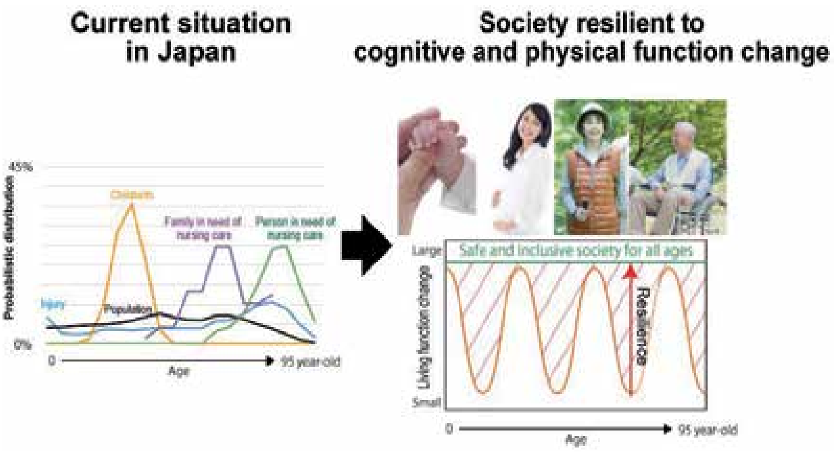

Figure 1.
Changes in living function and a living function-resilient society.

the family occur rather frequently in the family context. When viewed in terms of changes in living function, this means that a society will emerge in which we have to address changes in living function over generations, from a parenting generation that deals with development in children to a caregiver generation that deals with the declining living function of the elderly. The UN's 2030 Agenda for Sustainable Development, adopted in 2015, indicates the need to ensure the safety of people of all ages and the physically and intellectually challenged, ensure access to services, and implement urban design with consideration of safety and accessibility [1].

Figure 1 shows a snapshot of the current Japanese society. Significant changes will occur in a short period of 10 years or so: Japan's aging population will continue to grow until 2025 as the baby boomer generation grows old. As a result, our society will have a rapidly growing population that will need support in daily living. Compared to 2015, the elderly people aged 75 or over will increase by 5,000,000, and the number of dementia patients will increase by 2,000,000. China, as a driving force in the global economy, is also faced with an aging population: the proportion of its population aged 65 and over will be 16% by 2030. So China is likely to have the same issues as Japan, incurring enormous social costs. Today, Japan's social costs associated with dementia are huge, at US$ 127 billion. The costs are projected to reach US$ 181 billion in 2025 in Japan and US$ 2 trillion in 2030 globally. Thus, the issue of how society can develop adaptability to changes in living function will be increasingly important and is a key issue leading to a new growth strategy to develop adaptability (resilience) to changes in living function as a social mechanism separate from the issue of individual efforts.

In recent years, low-cost sensors, storage devices, and cloud computing services have become widely available. Artificial intelligence (AI) based on big data is rapidly advancing. These developments will make it possible to build a society that fosters resilience to changes in living function (a "living function-resilient society") that can adapt flexibly to changes in diverse physical and cognitive functions of children, women, the elderly, and the physically and intellectually challenged and allow people to exploit their potential to the fullest. There is an expectation that in the next 10 years, a new industry that helps translate the need for living function resilience into innovation will grow significantly.

This report identifies issues in building living function resilience and discusses, on the basis of our research, the potential for AI and the Internet of things (IoT) in building a living function-resilient society.

2. Issues in building a living function-resilient society

2.1 Variety in living function and intervention needs (one-size-fits-all issue)

The variety in living function needs to be acknowledged. A one-size-fits-all or universal intervention strategy is not necessarily effective: we need a mixed strategy combining universal, selective, and individual strategies [2]. We must have a basic understanding of what issues are involved in designing interventions based on a mixed strategy and where they arise. However, we do not fully understand them. We need to reveal the whole picture of issues associated with changes in the living function of the elderly and to base intervention design (precision intervention [2]) on that picture. To this end, we must have a system that collects data on changes of living functions and issues stemmed from the changes.

In the area of nursing care, providing one-to-one care services using human labor is considered ideal. In reality, it is difficult to provide services in terms of social costs. On the other hand, a universal strategy does not allow the variety in living function to be addressed. Precision care, which is defined as intermediate between universal and one-to-one strategies, is important. The use of AI technology may make it possible to align the variety in living function with individual adaptability by properly dividing the variety in living function into segments and selecting services that match each segment.

2.2 Gap between efficacy and effectiveness

Various intervention approaches have been proposed. An approach that is shown to have efficacy under laboratory conditions or under specific circumstances may have no effectiveness in other situations, such as the local community or society more broadly [3]. This is an issue of a lack of understanding of a local community or an individual life as a complex system and of error arising from the incorporation of a simplified model used in laboratory research into a complex system [4]. It is suggested that researchers act to hear user requests with a serious mind, for example, by conducting a complete interview survey. The issue is often discussed in terms of attitude or mindset in conducting research. However, we think that this discussion misses the point and that it is not a matter of mindset and effort but is a scientific issue arising from lack of science and technology and methodology for dealing with complex systems in field settings. Recently, it has been pointed out that the incremental approach (incrementalism) has a limit and design should be implemented in a manner that allows scaling (big change). We need to put in place in individual lives and facilities a system to evaluate the effectiveness of interventions and make continuous improvements. We need a method of designing and evaluating effective interventions in complex life systems that are present in individual lives and in facilities and in communities.

2.3 Fragmented living data and support services

Data on life are fragmented by facility and life situations. For example, data on illness, data on living function change, data on daily activities, and data on accidents/incidents exist in different facilities. It is necessary to use the data in an integrated manner and thereby to evaluate the variety in living function among children and elderly people, identify issues associated with the variety, and evaluate potential solutions. More importantly, we need a method of detecting their changes in daily life.

In addition to data fragmentation, services as solutions are fragmented. A collective impact model has been proposed to achieve effectiveness by collectively using stakeholders and social resources with a common purpose [5]. There is a need for a system for implementing the collective impact model based on the data.

2.4 Variety in privacy exposure

The definition of personal information has been changing. Besides that, there are a variety of ideas about privacy exposure. This means that there is a "one-size-fits-all" issue also in privacy policy; we need a system and technology to control information according to the variety of ideas of individuals and facilities about privacy, instead of developing a privacy policy common to all people and facilities. For example, there are facilities that are positive about installing cameras to prevent abuse of the elderly.

3. Problem solving by connective AI

3.1 Description of connective AI

To address issues in the variety in living function, intervention needs, data fragmentation, and variety in privacy exposure, we believe in the importance of an approach referred to as "connective AI" that allows individual lives to be connected with each other and efficacy to be scaled to effectiveness by computerizing places of living in accordance with the private policy of individual facilities and connecting them with each other through a network. We believe that connective AI is essential to building a living function-resilient society.

While our lives and living environments have individuality and are different from each other, there are many similar phenomena and environments. Skillful processing of information should make it possible to share information and convert it into knowledge. As pointed out by Herbert Simon, a physical phenomenon is essentially nonlinear when viewed hierarchically. We can develop a science based on the assumption that a physical phenomenon in the target layer can be modeled by associating it with feature quantities in the sublayers.

3.2 Smart living lab coevolving with connective AI

As **Figure 2** shows, to work with connective AI in concrete terms, we at the National Institute of Advanced Industrial Science and Technology (AIST) have developed a smart living lab in cooperation with children's hospitals, rehabilitation hospitals, intensive care homes for the elderly, and private homes. The term "smart living lab" here means (1) a place where we identify needs in field settings with user participation and adaptively explore whether new proposals to meet the needs are acceptable to the users in these "living labs" and (2) a place where we collect data, using AI and sensors, on activities of daily living of users (including children as non-main users) with a variety in living function (a smart field).

A system that allows daily life data fragmented in these places to be shared is essential to understanding the variety in living function. We need a new approach for information processing (AI for reality) to clarify real conditions. A system to

Figure 2.
Smart living lab developed by AIST.

link the verification of efficacy at the laboratory level to verification of effectiveness in facilities and communities is essential to developing solutions to support daily life. There is a strong need for a direction (reality for AI) for support technology to be put in place. We need to develop a living ecosystem suitable for individuals by combining stakeholders involved and social resources. We need to understand a field system as a complex system from a system science perspective and develop solutions that scale to different field settings. The next section describes connective AI technology being developed at AIST to build a living function-resilient society and smart living lab activities using the technology.

4. Attempt to demonstrate safety in daily life using AI and IoT technology

4.1 Raising awareness using data scattered across multiple organizations in an integrated manner (issue identification)

A recent text mining technique allows us to process quantities of data that are too big for humans to process. It has the potential for social function, which can be referred to as awareness (issue identification). Using data on medical treatment costs and situations resulting in injury from the Japan Sport Council, we at AIST are developing a technique that automatically analyzes situations that may result in severe injury. This technique identifies phrases unique to situations resulting in severe injury from free descriptive text, based on the assumption that treatment costs increase with increasing severity of injury. It is called "severity cliff analysis [6]." As shown in **Figure 3**, when similar situations are plotted in descending order of treatment costs, a cliff appears where the treatment costs change sharply. The technique allows us to identify the inflection point of the cliff and analyze what causes the severity of injury to increase.

Using this new technique, we analyzed injuries in school environments. Among injuries that involve running and tripping, the severity of injury is higher for hurdle running than for rope jumping and running on flat ground, because it involves hurdles. We investigated measures to prevent hurdle injury and found a hurdle with a top bar that opens like a double door when struck by the foot, which is in use at high schools in Miyagi Prefecture. Thus, severe injuries can be significantly reduced by taking effective preventive measures like this.

The technique allows us to understand in detail situations that result in severe injury by compiling incident data scattered across multiple organizations into big data for analysis by AI. Consequently, we can develop new prevention measures and associate them with existing measures. With data available only at some organizations (some schools, care facilities, etc.), we cannot know the overall occurrence and extent of severe injuries. As a result, known preventive measures remain isolated, and their widespread introduction is delayed. A new approach to improving situations in real-life settings by identifying problems and connecting them with solutions will be increasingly important in the future.

4.2 Monitoring changes in living function using IoT technology

Elderly people typically lose cognitive and motor functions with age and experience increasing challenges in daily life. There is a need for IoT sensors to detect changes in the living function of individual elderly people as they occur and to call for appropriate interventions. A recent projection for the next 10 years holds that smart homes will provide a market for sensors to support not only home security but also healthcare and safety in the home.

We developed a sensor to make it possible to measure how fast the elderly can walk and how well they can walk unaided. The sensor is designed to be built into an object used in daily life, in this case a handrail [7]. It collects only relevant data (maintaining privacy) and does not need to be attached and detached. We verified the basic functions of the sensor in the living lab at AIST and then installed it in the home of an 88-year-old woman who lives alone. Our study will verify the efficacy of the sensor through long-term monitoring.

Figure 4 shows how the sensor works and its installation. The sensor comprises two strain gauges fixed above and below a steel bracket secured to the wall. When the subject puts her hand on the handrail, the downward load is detected by the strain gauges.

We conducted a verification test of the sensor in a real-world setting. We installed several sensors on a handrail in the hallway in the subject's house (**Figure 4**, right). **Figure 5** (left) shows a sequence of images of the subject walking while holding the handrail. We collected data continuously for 24 months and plotted the subject's walking speed by using the installation's position-estimation capability (**Figure 5**, right).

We plotted the monthly median walking speed to reveal any changes in the walking pace from January 2016 to December 2017. As **Figure 6** shows, it changed substantially over the period: it decreased from February to August as physical strength declined, increased again from September to November, but declined again from January to March. The subject told us that she initially lost physical strength but regained it from September, but knee pain caused increasing difficulty in walking from January 2017. In May 2017, she broke her thighbone and was admitted to a hospital. In August 2017, she discharged from the hospital. Our results show that the sensor can detect some problems in daily life, although not the cause.

The walking pace of the elderly decreases with advancing age, along with walking patterns such as stride length, walking pace, and lower limb muscle strength.

Such declines increase the need for in-home support services for people who retain a strong need to remain in their own home. Low-cost monitoring of health and mobility would allow quick identification of risks to safety such as by falls. Such monitoring of individual elderly people would allow the timely implementation of appropriate interventions as a form of precision care or individualized care. Continued advances in AI and IoT will support this.

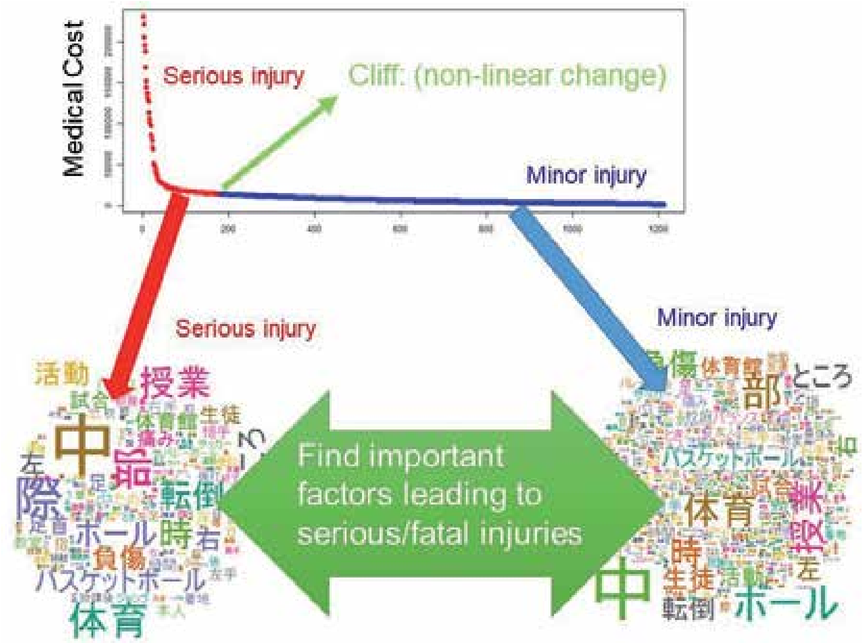

Figure 3.
Severity cliff analysis, using big data, to identify factors involved in situations resulting in severe injury.

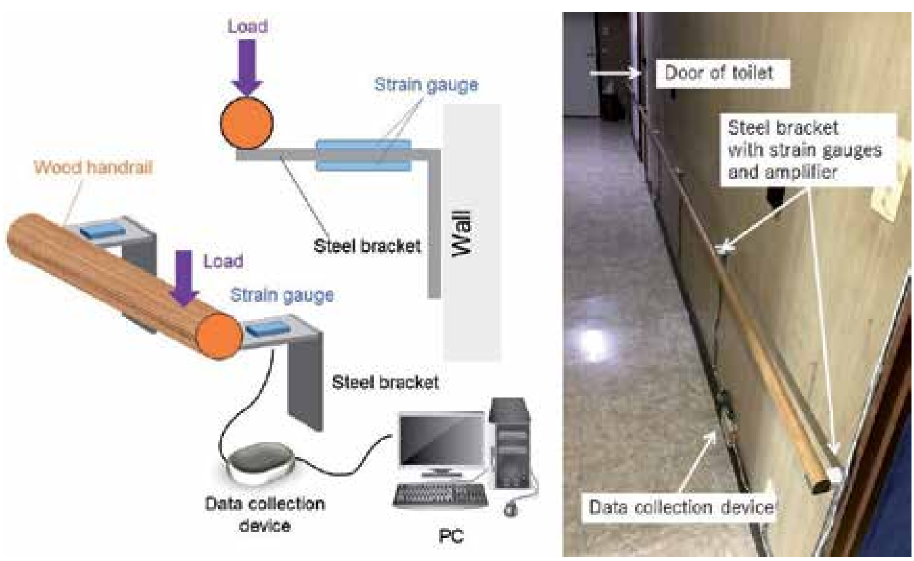

Figure 4.
Handrail-type IoT sensor (left, configuration; right, picture).

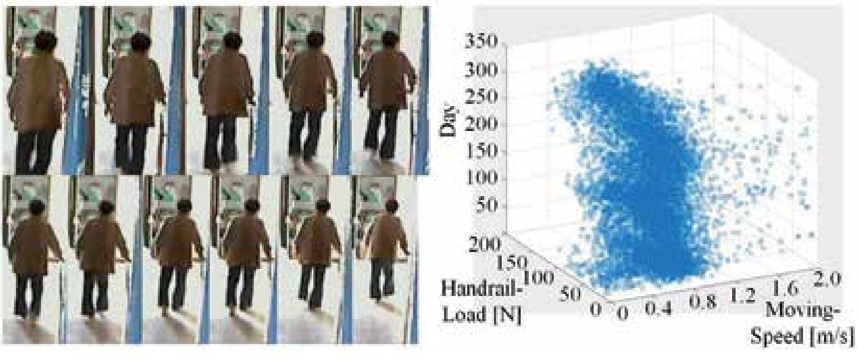

Figure 5.
The subject using the handrail (left) and motion data obtained (right).

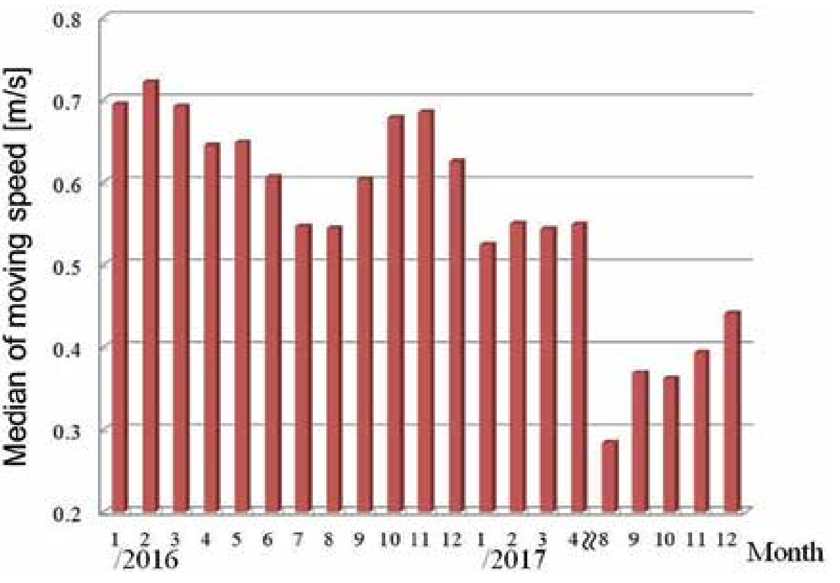

Figure 6.
Results of 15-month monitoring of walking pace as a health indicator.

4.3 Supporting community involvement of people with different living functions by using a daily life database

If we can detect changes in walking pace and other changes in daily life, what is the best way to use this information? One way is to provide services that support community involvement according to changes in living function.

To understand the living conditions and living function of the elderly, we interviewed elderly participants at home and collected data on their living conditions as a technological element for providing tailored support for community involvement. We developed a system to describe daily life data in terms of relationships between elements such as community involvement, experience, emotions, people, things, and activities related to community involvement [8]. We included elements and experiences used to describe daily life in the International Classification of Functioning, Disability and Health. **Figure 7** shows an example of graphically represented life data of an elderly person at one time point. The plot represents the overall life structure. Such graphic representation allows an understanding of the entire life structure, including the relationships between individual elements, the use of graphic structure analysis, and numerical representation of the degree of similarity between individual graphic structures and searching on life data. Using this method, we have developed a life database of more than 70 elderly people.

The use of graphic representation of daily life allows calculation of the degree of similarity between individual graph structures and identification of those who have a similar life structure. **Figure 8** shows the life structures of 20 elderly people and plots the degree of similarity between them. It reveals groups concentrated at the top left corner of the graph, where the life structures have a degree of similarity, along with one person at the right edge (G15) and one at the bottom edge (G10), both substantially different from the others. The placement of G15 indicates that that person mostly feels happy about community involvement but sometimes feels sad, angry, or worried about it. The placement of G10 indicates that the person has mostly negative feelings such as loneliness, sadness, and anger. Such graphical representation allows us to identify elderly people with a different life structure from the majority who might therefore require interventions to support them in changing their living conditions.

For example, when we design an intervention to improve living conditions, by using a life structure distance space (or life structure manifold), we can identify people with similar life structures and encourage them to become involved in community activities, instead of putting together people with very different life structures. If a person's life structure later changes, we can again encourage community involvement with people with more similar life structures. This is a scientific approach to changing people's life structure step-by-step to bring it closer to what they want or by revising goals. We think that this approach will lead to a data-based scientific approach (life design methodology) to process design to achieve a desirable life structure.

Figure 9 shows the output of software that has read the life structure data of an 80-year-old woman and has searched for elderly persons with similar life structures

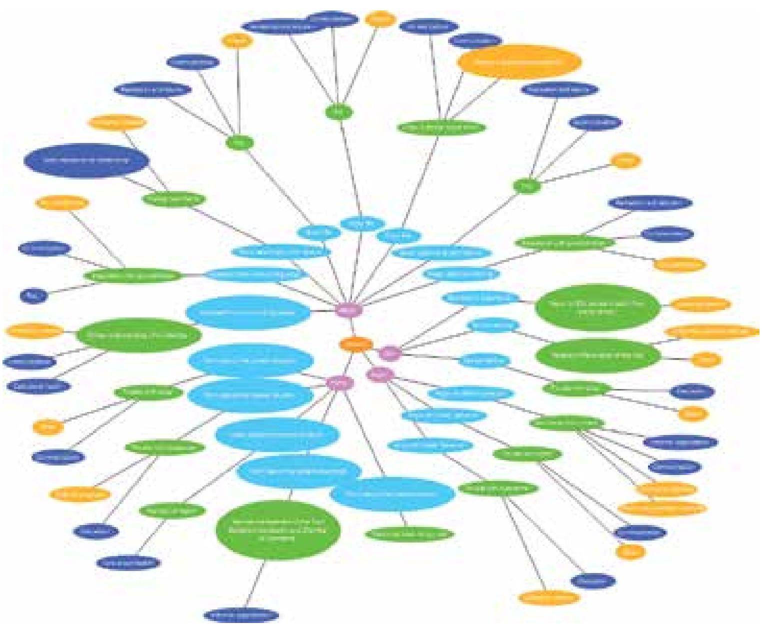

Figure 7.
Example of graphical representation of life structure data.

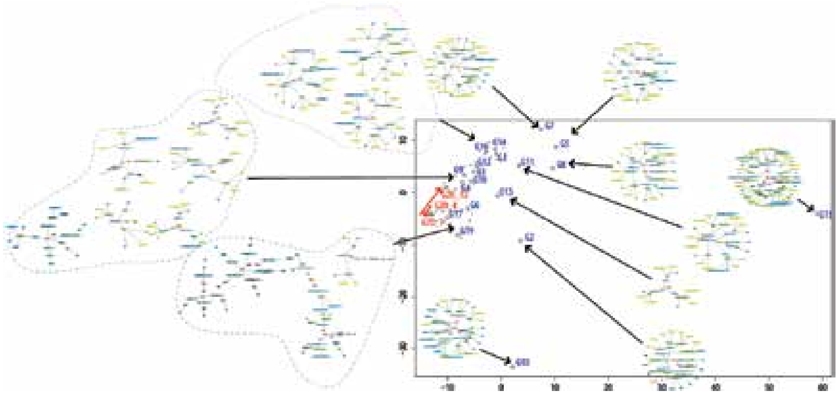

Figure 8.
Visualization of life structure patterns (life structure distance space or life structure manifold).

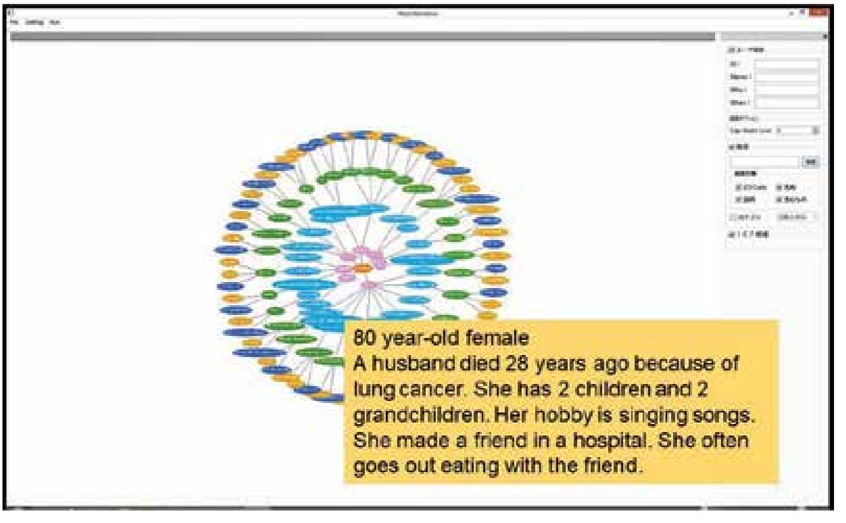

Figure 9.
Software to support life design based on an enormous amount of life data and life geometric operations (digital crystal ball).

and for things that make her happy. **Figure 10** shows a group of elderly people mapping the locations of little-known community involvement events. Currently, we are working with a community association and a local elderly care management center to provide the participants with advanced support, tailored to their individual living conditions, in community involvement, by combining life design support technology and local maps and making good use of resources available in the local community.

4.4 Trial of precision care at IoT-based care facilities

In collaboration with care homes, we are undertaking a project to develop monitoring technology, tailored to individual elderly persons, to prevent accidents and detect early changes in behavior in anticipation of the time when an elderly person with declining living function needs care or support. **Figure 11** shows a system to measure the location of an elderly person with dementia and monitor his

Figure 10.
Working with a local elderly care management center and a community association to create a map to support community involvement.

or her behavior, using a beacon embedded in the sole of the person's shoe [9]. Using sensors like this, we can monitor changes in walking patterns. **Figure 12** shows a case in which monitoring over 45 days revealed a change in the walking pattern of an elderly person with dementia: the distance walked decreased greatly about halfway through the monitoring period. Later, we found that the decrease was due to a broken bone caused by a fall. This case shows how the use of sensors allows us to quantify changes in individual persons' behaviors and to accurately detect changes that can be missed.

Both wearable sensors and smartphones can collect information on individuals, but they use battery power. This is a major hindrance, because devices that require frequent battery changes are not acceptable in real-life settings. At the same time, the use of AI technology not just to find people but also to identify them has made tremendous improvements. Such "non-wearable" has begun to appear. The combination of mounted RGBD cameras and face identification software can allow unintrusive long-term monitoring of individuals, as the monitors are not worn [10]. Some facilities have started to use it. **Figures 13** and **14** show a RGBD camera and a plot of a person's walking posture captured by RGBD camera. This person's walking pace tended to be slow in the morning and to vary greatly.

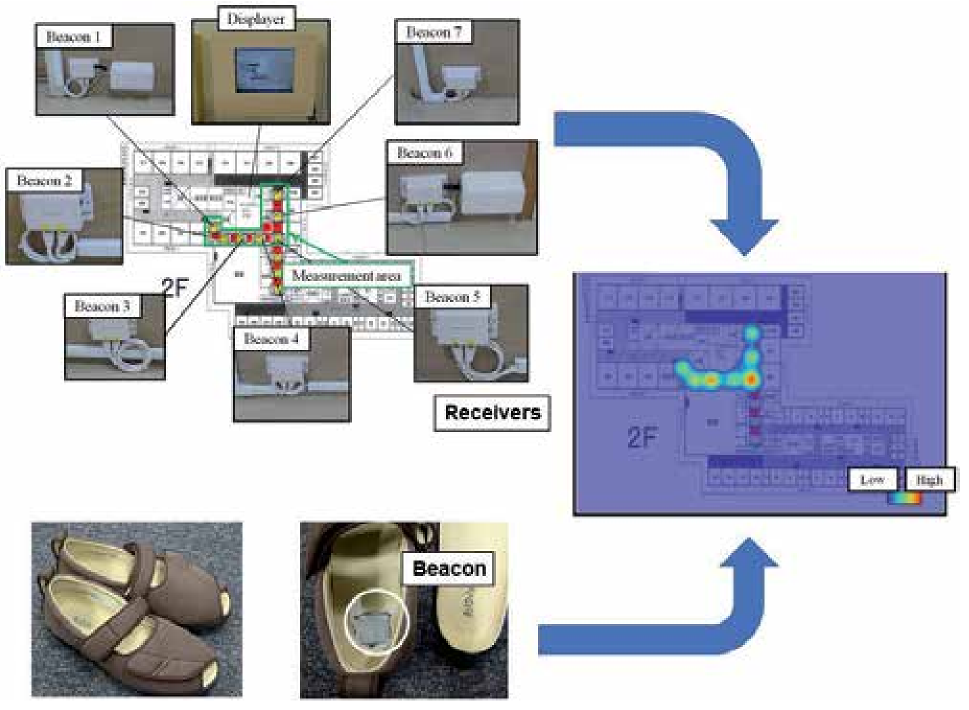

Figure 11.
Shoe-embedded location sensor for monitoring of the elderly.

The facility staff made the following comments on individualized monitoring:

1. The video of events that may not be accurately communicated by humans is recorded. This allows information on events to be shared accurately (video can be used, e.g., when passing information onto another staff member).

2. By watching the video of actual positioning of things and people at a care facility, instead of reading textbooks, staff awareness is raised, and crisis management training can be improved.

3. By watching the video, staff can know what happens when they are not on hand and can take action immediately.

4. Staff can monitor daily changes in the walking pace of elderly people and can associate the changes with medications, mental state (dementia), excretion, and pain. Many medications, notably sleeping pills, can cause falls. However, support tools for personal health management have not been available.

5. By associating the profile of an elderly person with risks, staff can know at a glance what risks the person faces, group people with similar needs for better management, and provide better care.

6. Being able to identify daily changes in individuals and their long-term trend, staff can determine the need for intervention and evaluate the effectiveness of intervention. The monitoring function can also be used as tool for nursing care.

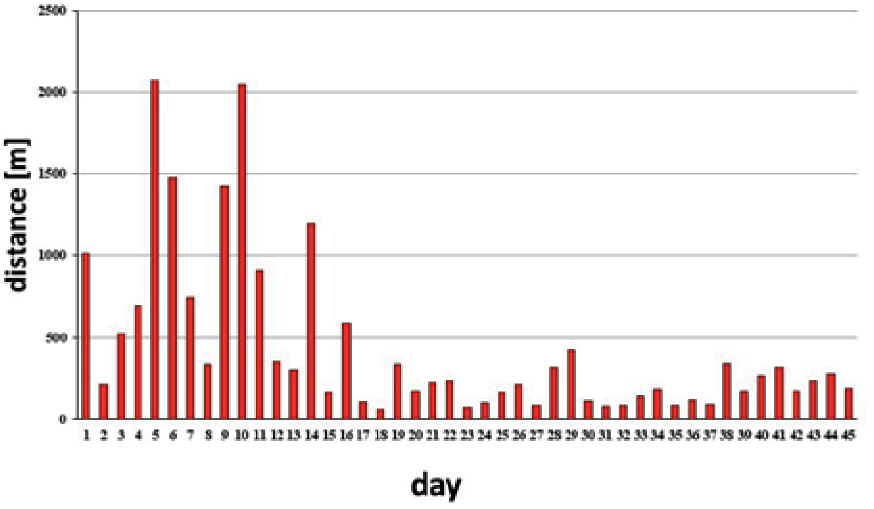

Figure 12.
Results of long-term monitoring with a shoe-embedded location sensor.

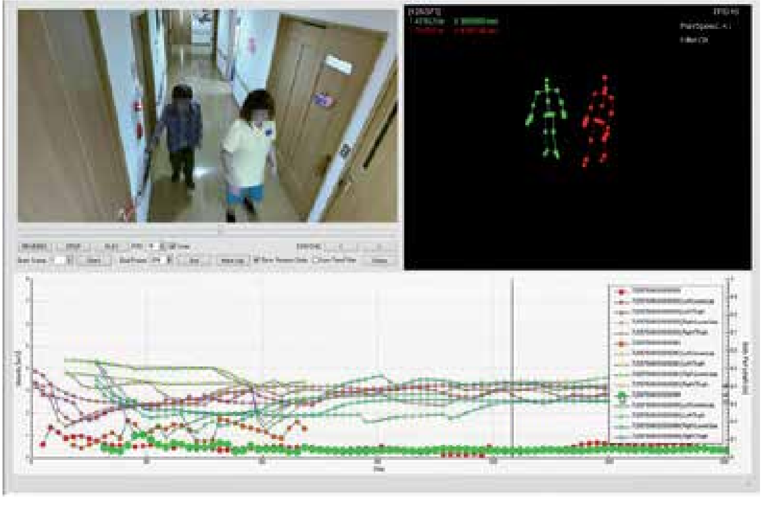

Figure 13.
Camera image (left) and measurement of walking posture (right).

Amid increasing reports of elder abuse, more facilities and users favor the use of sensors. Staff alone will not be able to monitor residents in the level of detail that this will entail. While acknowledging the need for privacy, we need to identify what services can be made possible by what sensing technology (with attendant risks to privacy). It is important to provide levels of services that suit users' needs best by preparing a variety of options for such services.

4.5 Elderly behavior library for searching for product usage by those with changing living function

Changes in living function vary among the elderly. Unlike in the case of children, this makes it difficult to classify events by age, because living function varies significantly among people of the same age. We can specify "a bed for babies up to

Figure 14.
Plot of walking pace monitored by mounted camera in a home.

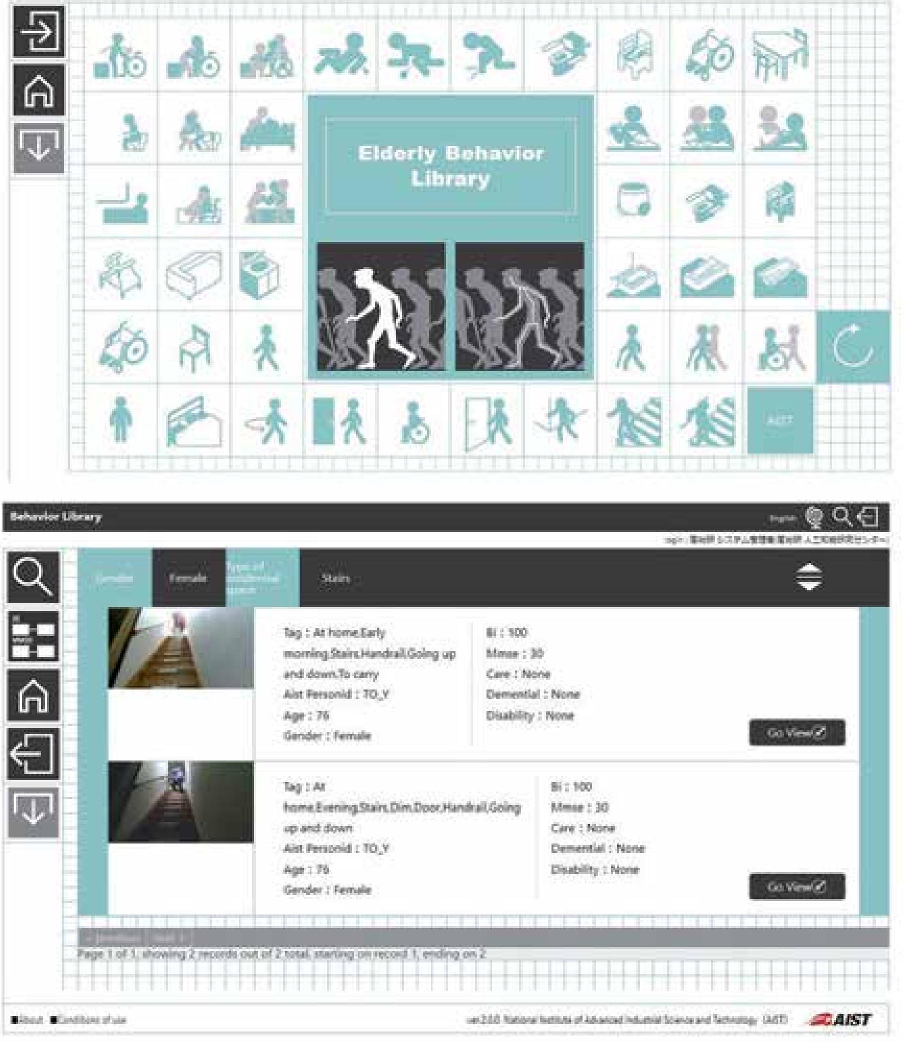

Figure 15.
Searchable library of elderly behaviors for identifying changes in living function.

24 month old," but not "a chair for persons 75 years old and older". As a means to understanding life dimensions in the elderly, we created a library of videos showing how different products (beds, chairs, wheelchairs, canes, doors, kitchen tools, handrails) are used by the elderly, depending not only on age but also on cognitive ability, physical ability, and level of care needed [11]. **Figure 15** shows snapshots of the developed library. The library was launched in March 2018. Its use requires registration. The library is a pioneering attempt to show how elderly use items, such as to identify handrails that are easy to use. We intend that it will be used to identify problems and develop solutions. If you are interested, please contact us at the address provided on the website [12].

5. Conclusions

In this report, based on our research, we describe "a living function-resilient society" as a desirable society and show the potential of AI and IoT technology to identify problems and resolve them. In terms of intelligence, to resolve issues associated with the variety in living function, we need to find innovative solutions using the variety in intelligence. Today, a society is emerging in which problems, data, and intelligence are ubiquitous. Sensing and recording technology is advancing and spreading throughout the society. Various organizations now store big data. In recent years, AI, such as data analysis technology, has been advancing. Human resources spread among universities, administrative organizations, care homes, regions, and companies can be linked to create an intelligence-ubiquitous society. New social issues emerge constantly. The type of innovation required today is the transformation of the society into an advanced interconnected society by using the ubiquity of data and intelligence in modern society to address newly emerging issues.

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Edited by Yasser Ismail

Internet of Things (IoT) is a recent technology paradigm that creates a global network of machines and devices that are capable of communicating with each other. Security cameras, sensors, vehicles, buildings, and software are examples of devices that can exchange data between each other. IoT is recognized as one of the most important areas of future technologies and is gaining vast recognition in a wide range of applications and fields related to smart homes and cities, military, education, hospitals, homeland security systems, transportation and autonomous connected cars, agriculture, intelligent shopping systems, and other modern technologies. This book explores the most important IoT automated and smart applications to help the reader understand the principle of using IoT in such applications.

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