How IoT Applications with Wireless Technology improving security of people with Dementia and reduced the loading of care takers

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
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Vienna, 09.04.2020

Affidavit

I, **FANGYIN, FRANNIE, LIU**, hereby declare

1. that I am the sole author of the present Master's Thesis, "HOW IOT APPLICATIONS WITH WIRELESS TECHNOLOGY IMPROVING SECURITY OF PEOPLE WITH DEMENTIA AND REDUCED THE LOADING OF CARE TAKERS", 64 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted the topic of this Master's Thesis or parts of it in any form for assessment as an examination paper, either in Austria or abroad.

Vienna, 09.04.2020

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Signature

Abstract

The purpose of this thesis is to find Wireless IoT Applications to help the Dementia patients to be more independent and improving the quality of life. Also, reduce the loading of the care taker. This research is based on 3 research questions:

RQ1: I like to find out what kind of safety related issues that a person who suffers from Dementia will encounter in their daily life.

RQ2: I like to explore what are the existing wireless technologies that applied in Health Care IoT Applications nowadays.

RQ3: I like to map the IoT Applications that can be applied to help the elderly who suffer from Dementia. The Applications that can help them to be more independent, safer in their daily life, and keep them in connect with the people who care for them.

The research result is Dementia suffers' daily security issues were identified from interviews. The possible Wireless IoT Applications were found from literature review. The finding were mapped out in between the daily security issues with Wireless IoT Application.

Keyword: Dementia suffers, Daily security, IoT Applications, Elderly Care, and Dementia Care.

1.Contents

1. Introduction

1.1 Motivation

I worked for a Taiwanese ODM (original design manufacturer) Sercomm Cooperation in Taipei from year 2006 to 2017. Sercomm Cooperation has many Tier 1 Telco customers in China, Europe and US. These Telco customers requested IoT devices to be designed and manufactured for different purposes with different specific technical requirements with different wireless technologies. Because of that I was exposed in different wireless technologies that were used in different IoT Applications. Back in 2016, I had the chance to work on several IoT products for a Tier 1 Telco in Europe and those product were launch in the retail market in 2018. These products are: Door Window Sensor, Alarm Sensor, Smart Plug, Smoke Detector, Motion Sensor, and Smart Speaker.

I was working with a group of engineers from starting the technical design specification discussion, development of the products, introduced the products into mass production, and deployment to the consumer market. The whole experiences were very interesting for me and I was wondering how IoT devices can evolved in the future with so much possibilities to make human life easier, better and safer.

Few months ago I was reading an article on a magazine regarding the world old-age population is growing from 901 million now and expecting 2092 million in year 2050. (Nation, 2019) That means the people who needs assistance living will grow much more as well. However, from the current social trend that the number of care taker might not be enough in the future for people who needs full time or part time care. Thus, I was thinking there must be IoT Applications that can help those people who needs assistance living and technologies that can promote independence.

Thus I like to explore this area further. Since I am working in the industry that specialized in Wireless technologies for years so I have a good level of knowledge in the industry and know the differences among those different wireless technologies. Hence, I have a very good childhood friend, whose father suffers from Dementia for more than a decade. Not only my friend's father suffer, my friend and her family also suffer from all kind of problems occur with her father's Dementia in daily life. I like to explore in this area and find out what kind of wireless IoT Applications that will help the people who suffer from Dementia in their daily life in the future as I like to help people. This thesis is to find Applications that will make their and their family's life better, easier and more secure.

1.2   Problem Statement

As mentioned earlier, the old-age population in the world is growing from 901 million now and expecting 2092 million in year 2050. (Nash, 2019) The old-age population will be more than double. The trend can be seen from the chart and graphic below:

Figure 1

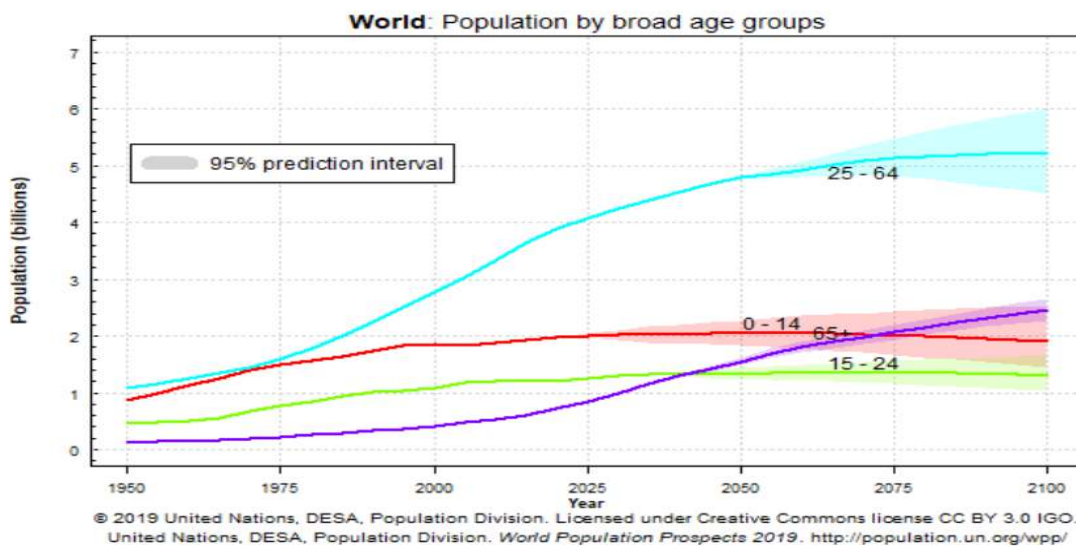**World**: Population by broad age groups

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United Nations, DESA, Population Division. *World Population Prospects 2019*. http://population.un.org/wpp/

Figure 2

World

	1950	1970	1990	2000	2005	2010	2015	2020	2030	2050	2075	2100
Population												
Total population (thousands)	2 536 431	3 700 437	5 327 231	6 143 494	6 541 907	6 956 824	7 379 797	7 794 799	8 548 487	9 735 034	10 577 288	10 875 394
Median age (years) (a)	23.6	21.5	24.1	26.3	27.4	28.5	29.6	30.9	33.0	36.2	39.2	41.9
Population under age 15 (thousands)	869 608	1 389 143	1 748 101	1 851 319	1 841 053	1 876 541	1 931 326	1 983 649	2 019 462	2 055 659	2 014 256	1 897 705
Population aged 15-24 (thousands)	462 384	669 320	1 009 043	1 085 432	1 182 711	1 215 717	1 199 207	1 209 584	1 293 877	1 338 497	1 357 401	1 305 863
Population aged 25-64 (thousands)	1 075 729	1 445 760	2 241 877	2 784 535	3 043 271	3 337 877	3 641 717	3 873 960	4 237 660	4 792 026	5 140 708	5 215 163
Population aged 65+ (thousands)	128 709	196 215	328 211	422 209	474 872	526 688	607 548	727 606	997 488	1 548 852	2 064 923	2 456 663
Percentage of population under age 15	34.3	37.5	32.8	30.1	28.1	27.0	26.2	25.5	23.6	21.1	19.0	17.5
Percentage of population aged 15-24	18.2	18.1	18.9	17.7	18.1	17.5	16.3	15.5	15.1	13.8	12.8	12.0
Percentage of population aged 25-64	42.4	39.1	42.1	45.3	46.5	48.0	49.4	49.7	49.6	49.2	48.6	48.0
Percentage of population aged 65+	5.1	5.3	6.2	6.9	7.3	7.6	8.2	9.3	11.7	15.9	19.5	22.6

World Population Prospects 2019, Volume II: Demographic Profiles(Nation, 2019)

United Nations, Department of Economic and Social Affairs, Population Division

The growth of old-age population is leading to many issues and problems that need to be addressed and look for solutions especially in the area for elderly care. For example, if an elderly person is alone at home without a care taker aside, it is maybe she or he cannot afford a care taker, or there is a labor shortage in the market for care taker, or the elderly person simply does not like to have stranger at home. If the elderly people suffer from Dementia as most of the Dementia patients are elderly, the difficulties that they are facing will be even more severe. There are many problems will occur but I believe there are possible solutions now with the advance of technologies. This bring to the questions that I want to research in this paper.

RQ1: I like to find out what kind of safety related issues that a person who suffers from Dementia will encounter in their daily life.

RQ2: I like to explore what are the existing wireless technologies that applied in Health Care IoT Applications nowadays.

RQ3: I like to map the IoT Applications that can be applied to help the elderly who suffer from Dementia. The Applications that can help them to be more independent, safer in their daily life, and keep them in connect with the people who care for them.

The cost of Dementia of society is projected to be 2 trillion in US dollar in 2030. (Organizaiton, 2017) From below Figure you can see the estimate cost.

Figure 3
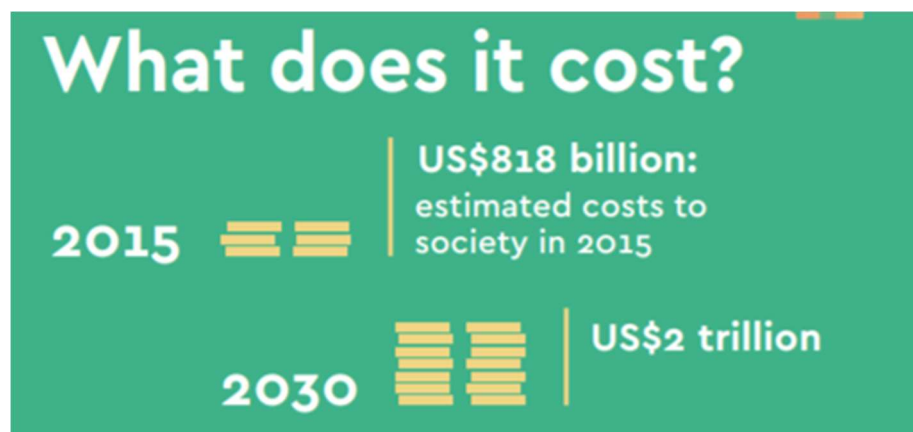
The cost of society for Dementia; Source: World Health Organization

Worldwide, around 47 million people have Dementia with nearly 60% in low- and middle-income countries. (Organization, 2019) If we can reduce the cost and resources of Dementia care, it will be highly beneficial for the Dementia patients, their family, and their care takers.

Figure 4
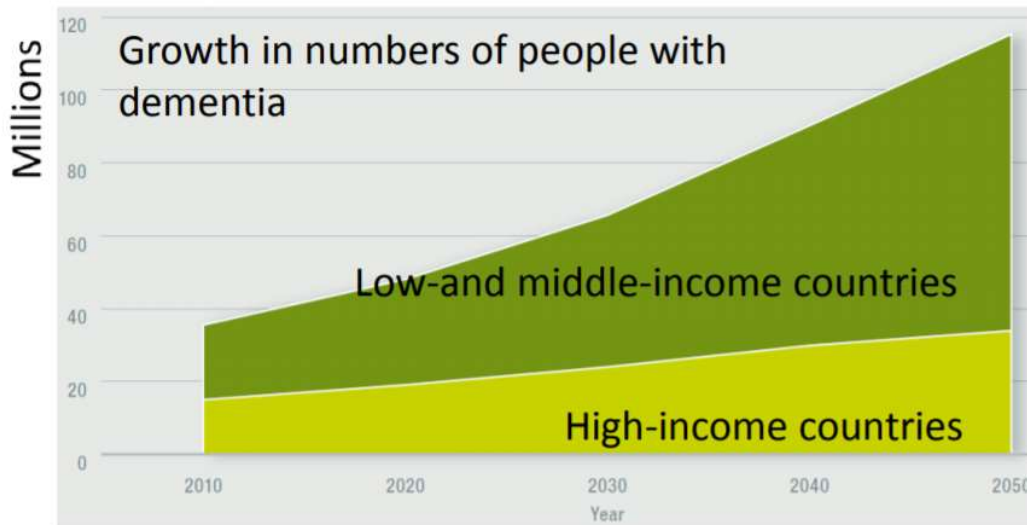
By 2030 it is projected to be 75 million people with Dementia and 132 million by 2050.

Every year there are 9.9 million new cases. (Organization, 2019)

Figure 5
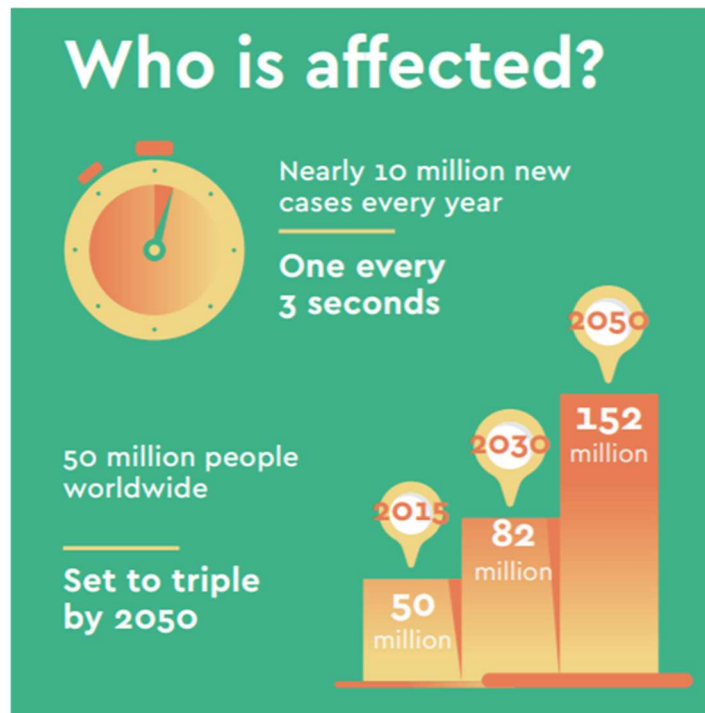
Source: Global Dementia Observatory (GDO) (2020)

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If we can leverage IoT technologies and reduce the overall cost, it will be extremely beneficial financially for the whole society to save cost and labor resources. It is also our social responsibility to see what can be done to help the one that are in need.

2. Literature Review

2.1 Introduction

This chapter is the search and review of academic papers, books, and official reports with related information that can be used in this thesis and relevant to the topics of Dementia disabilities, Wireless Technology, and IoT Applications that have the potential for helping people with Dementia and their care takers by using Wireless Technology.

2.2 Literature Mining

The literature search was conducted using the online libraries at TÜ Wien, ScienceDirect, IEEE Association, PubMed, and Google Scholar. The primary keywords and key phases for this study included: *Wireless Technology, IoT Application, Age Demographic, Dementia disease, cognitively impaired elderly, independent living, and Assistance Living, Smart Home, IoT devices.* In result, I found many interesting and useful literature that can be used in this thesis. However, they are also many literature that I obtained that are not applicable in this thesis.

2.3 Literature on Dementia

2.3.1 Introduction

This section is to review the literature and look into why people have Dementia and what are the possible causes. What kind of characteristic Dementia patient will have? I will also explore the demographic information and see if the trend is growing or decreasing

in order to see the demand of care taker that is needed. This will give me more understanding in Dementia and prepare myself for questions design for the interviews.

2.3.2 What is Dementia

Dementia is an overall term for diseases and conditions characterized by a decline in memory, language, problem-solving and other thinking skills that affect a person's ability to perform everyday activities. (Organization, 2019) Dementia may be defined as a clinical syndrome of mental capacity characterized by a substantial global decline in cognitive function that is not attributable to altered consciousness; it consists of a combination of symptoms attributable to various causes or pathological events. (Palm et al., 2016) Dementia is a general term for disorders grouped caused by abnormal brain changes. These changes trigger a decline in thinking skills, also known as cognitive abilities, severe enough to impair daily life and independent function. They also affect behavior, feelings and relationships. (Association, 2020b)

Dementia results from a variety factors. It can be results from drug or alcohol abuse in early age, diseases such as Alzheimer, stroke, or injuries that primarily or secondarily affect the brain. (MacGill, 2017) Not only is it overwhelming for the people who have it, also for the patient's families. There are lack of awareness and understanding still nowadays of Dementia, resulting in stigmatization and barriers to diagnosis and care. The impact of Dementia on cares, family and society at large can be physical, psychological, social and economic.

2.3.3 Age Demographic Information

It is important to understand how the age population growth and how quickly the problem of not enough care taker will hit us. There is a good Age Demographic information on United Nations database online. It shows that the ageing population around the world has been rapidly growing. As a result, the life span of human being is increasing. This is mainly attributable to the substantial improvement in the nourishment, medicine and public health. In the United Kingdom alone, the population over the age of 85 is predicted to nearly triple by 2035. (Nash, 2019) For example, from below Figure you can see the demographic trend in UK.

Figure 6:

(Population: Thousands)
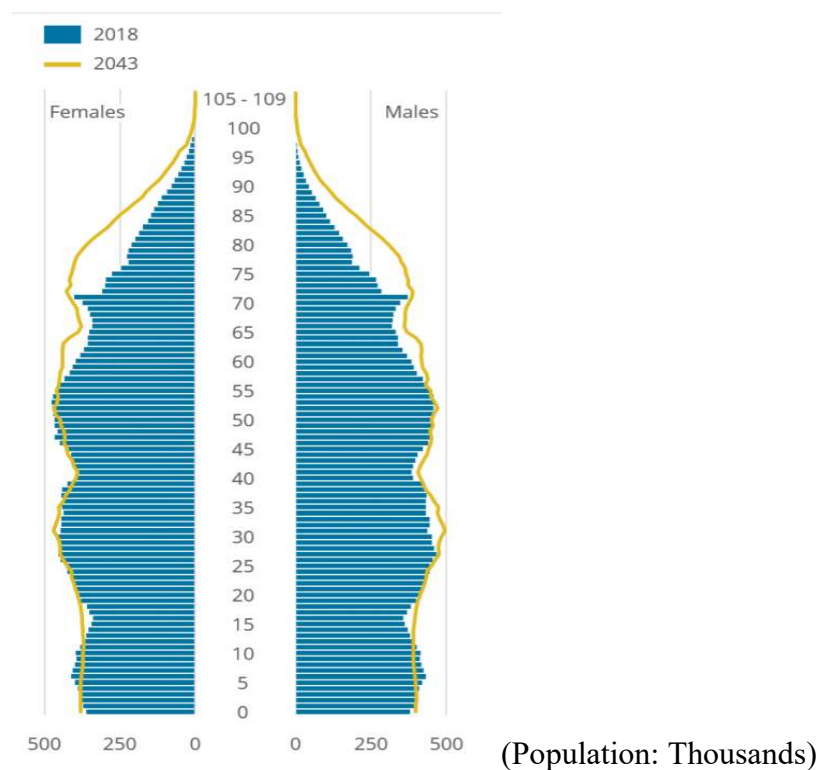
UK Age structure of the UK population, mid 2018 and mid 2043(Nash, 2019)

Source: Office for National Statistics – National population projections

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The global population aged 60 years or over numbered 962 million in 2017, more than twice as large as in 1980 when there were 382 million older persons worldwide. The number of older persons is expected to double again by 2050, when it is projected to reach nearly 2.1 billion. (Nation, 2019)

It is estimated that today, more than 47 million people around the world are living with Dementia. Dementia affects mostly people older than 60, but may be sometimes affect younger people as well. It was projected in 2030, there will be 80 million people will live with Dementia. In 2050, there will be 152 million people suffer from Dementia. (Organizaiton, 2017)

2.3.4 Cause of Dementia

Dementia is mainly caused by damage to brain cells or brain cell death from head injury, a stroke, or a brain tumor. For example: Post-traumatic Dementia is directly related to brain cell death caused by injury in particularly if repetitive, such as those received by sports players. It have been linked to certain Dementias appearing later in life. (Timothy J. Legg, 2017) Dementia is also caused by neurodegenerative disease that progressive brain cell death that happens over time. The brain damage interferes with the ability of brain cells to communicate with each other. When brain cells cannot communicate normally, thinking, behavior and feelings will be affected. The brain has many distinct regions, each of which is responsible for different functions (for example, memory, judgment and movement). When cells in a particular region are damaged, that region cannot carry out its functions normally. (Association, 2020a)

Some other diseases that connected to the cause of Dementia are:
Prion diseases – for instance, CJD (Creutzfeldt-Jakob disease).

HIV infection – how the virus damages brain cells is not certain, but it is known to occur.

Reversible factors – some Dementias can be treated by reversing the effects of underlying causes, including medication interactions, depression, vitamin deficiencies, and thyroid abnormalities. (MacGill, 2017)

2.3.5   Dementia Symptoms

There are over 100 forms of Dementia with different symptoms.   The most well-known form of Dementia is Alzheimer's disease, which accounts for 50-60% of all cases. Other forms of Dementia include vascular Dementia, Dementia with Lewy bodies and fronto-temporal Dementia. (Organization, 2019)

2.3.5.1 Early symptoms

Every person is unique and Dementia affects people differently. There is no two people will have symptoms that develop in exactly the same way. An individual's personality, general health and social situation are all important factors in determining the impact of Dementia on him or her.

Symptoms vary between Alzheimer's disease and other types of Dementia, but there are broad similarities between them all. The most common signs are memory loss and the loss of practical abilities.   The most common early symptoms of Dementia are:

a) *Memory loss*

Declining memory, especially short-term memory, is the most common early symptom of Dementia. People with ordinary forgetfulness can still remember other facts associated with the thing they have forgotten. For example, they may briefly forget their next-door neighbor's name but they still know the person

they are talking to is their next-door neighbor. A person with Dementia will not only forget their neighbor's name but also the context.

b) *Difficulty performing familiar tasks*

People with Dementia often find it hard to complete everyday tasks that are so familiar and simple that we usually do not think about how to do the tasks. A person with Dementia may not know in what order to brush their teeth, put clothes on, or the steps for preparing a meal.

c) *Problems with language*

Occasionally everyone has trouble finding the right word. However, a person with Dementia often forgets simple words or substitute's unusual words, making speech or writing hard to understand and this lead to communication difficulties.

d) *Disorientation to time and place*

We sometimes forget the day of the week or where we are going. However, people with Dementia can become lost in familiar places such as the road they live in. They can forget where they are or how they got there, and not know how to get back home. A person with Dementia may also confuse night and day.

e) *Poor or decreased judgement*

People with Dementia may dress inappropriately. For examples: They might wear several layers of clothes on a warm day or very few on a cold day. They might forget to wear shoes or glasses when they go out.

f) *Problems with keeping track of things*

A person with Dementia may find it difficult to follow a conversation, forget they are cooking lunch, or keep up with paying their bills.

g) *Misplacing things*

Anyone can temporarily misplace his or her wallet or keys. However, a person with Dementia may put things in unusual places such as a hairdryer in the fridge or a wristwatch in the sugar bowl.

h) *Changes in mood or behavior*

Everyone can become sad or moody from time to time. A person with Dementia may become unusually emotional and experience rapid mood swings for no apparent reason. Alternatively a person with Dementia may show less emotion than was usual previously.

i) *Trouble with images and spatial relationships*

Image problems are different from typical age-related issues, such as cataracts. People with Dementia can have difficulty in reading, judging distances, and in determining color or contrast.

j) *Withdrawal from work or social activities*

At times everyone can become tired of housework, business activities, or social obligations. However a person with Dementia may become very passive, sitting in front of the television for hours, sleeping more than usual, or appear to lose interest in hobbies. (INTERNATIONAL, 2017)

Another research from caregiver's point of view shown: Caregivers reported that memory impairment was the most common presenting symptom (57%), followed by visual hallucinations (44%), depression (34%), problem solving difficulties (33%), gait problems (28%), and tremor/stiffness (25%). (Auning et al., 2011)

I exam the Dementia related literature and found out the possible cause and symptoms. This will help me to have better understanding when I conduct my interview and design my interview questions and find out the issues that might have in patient's daily living.

2.4 Literature on Wireless Technologies

2.4.1 Introduction

There are many different kinds of Wireless Technologies nowadays and the literature review is focusing on finding the ones that are used in IoT Applications, the ones that can transmit certain amount of data to Smart Phone and Wi-Fi Router and for these data to be collected in a Database for information processing. Then I will map these Wireless Technologies with IoT Applications once I identified the IoT Applications that are able to help the Dementia sufferer and care taker. Some of the literature review results are not listed here but in the Chapter for Finding in order to support the findings.

2.4.2 Existing Wireless Technologies

Wireless is a term used to describe telecommunications in which electromagnetic waves (rather than some form of wire) carry the signal over part or all the communication path. In simplest terms, wireless technology is exactly that, wire-less. It is technology that allows us to complete the same tasks that we would usually have to accomplish with the use of a cable or wire. Some monitoring devices, such as intrusion alarms, employ acoustic waves at frequencies above the range of human hearing; these are also sometimes classified as wireless. For example, the internet could only be accessed if a computer was connected to a telephone cable. However, wireless technology makes the same action possible without the wires. (R.Yamuna, 2011)

The existing Wireless Technologies out there can be categories into three types:

1) Fixed Wireless The operation of wireless devices or systems in homes and offices, and, equipment connected to the Internet via specialized modems.

2) Mobile Wireless The use of wireless devices or systems aboard motorized, moving vehicles. Mobile technology such as GSM and CDMA made a revolution on communication and it uses time division, frequency division and code division multiplexing. These are the latest and hottest example of wireless technologies. Examples include the automotive cell phone and mobile.

3) Portable Wireless The operation of autonomous, battery-powered wireless devices or systems outside the office, home, or vehicle. Examples include handheld cell phones and PCS units D. IR Wireless The use of devices that convey data via IR (infrared) radiation; employed in certain limited-range communications and control systems. Examples: Bluetooth, Wi-Fi, infrared, etc. (R.Yamuna, 2011)

2.4.3 Wireless Technology that used in IoT Applications

There are many wireless applications in IoT. However, there are 6 leading types of IoT wireless technologies:

1) LPWANs

Low Power Wide Area Networks (LPWANs) are the new phenomenon in IoT. By providing long-range communication on small, inexpensive batteries that last for years, this family of technologies is purpose-built to support large-scale IoT networks sprawling over vast industrial and commercial campuses.
LPWANs can literally connect all types of IoT sensors – facilitating numerous Applications from remote monitoring, smart metering and worker safety to building

controls and facility management. Nevertheless, LPWANs can only send small blocks of data at a low rate, and therefore are better suited for use cases that don't require high bandwidth and are not time-sensitive.

Also, not all LPWANs are created equal. Today, there exist technologies operating in both the licensed (NB-IoT, LTE-M) and unlicensed (e.g. MIOTY, LoRa, Sigfox etc.) spectrum with varying degrees of performance in key network factors. For example, while power consumption is a major issue for cellular-based, licensed LPWANs; Quality-of-Service and scalability are main considerations when adopting unlicensed technologies. Standardization is another important factor to think of if you want to ensure reliability, security, and interoperability in the long run.

2) *Cellular (3G/4G/5G)*

Well-established in the consumer mobile market, cellular networks offer reliable broadband communication supporting various voice calls and video streaming Applications. On the downside, they impose very high operational costs and power requirements.

While cellular networks are not viable for the majority of IoT Applications powered by battery-operated sensor networks, they fit well in specific use cases such as connected cars or fleet management in transportation and logistics. For example, in-car infotainment, traffic routing, advanced driver assistance systems (ADAS) alongside fleet telematics and tracking services can all rely on the ubiquitous and high bandwidth cellular connectivity.

Cellular next-gen 5G with high-speed mobility support and ultra-low latency is positioned to be the future of autonomous vehicles and augmented reality. 5G is also expected to enable real-time video surveillance for public safety, real-time

mobile delivery of medical data sets for connected health, and several time-sensitive industrial automation Applications in the future.

3) *Zigbee and Other Mesh Protocols*

Zigbee is a short-range, low-power, wireless standard (IEEE 802.15.4), commonly deployed in mesh topology to extend coverage by relaying sensor data over multiple sensor nodes. Compared to LPWAN, Zigbee provides higher data rates, but at the same time, much less power-efficiency due to mesh configuration. Because of their physical short-range (< 100m), Zigbee and similar mesh protocols (e.g. Z-Wave, Thread etc.) are best-suited for medium-range IoT Applications with an even distribution of nodes in close proximity. Typically, Zigbee is a perfect complement to Wi-Fi for various home automation use cases like smart lighting, HVAC controls, security and energy management, etc. – leveraging home sensor networks.

Until the emergence of LPWAN, mesh networks have also been implemented in industrial contexts, supporting several remote monitoring solutions. Nevertheless, they are far from ideal for many industrial facilities that are geographically dispersed, and their theoretical scalability is often inhibited by increasingly complex network setup and management.

4) *Bluetooth and BLE*

Defined in the category of Wireless Personal Area Networks, Bluetooth is a short-range communication well-positioned in the consumer marketplace. The new Bluetooth Low-Energy, also known as Bluetooth Smart is further optimized for Consumer IoT Applications thanks to low power consumption.

BLE-enabled devices are mostly used in conjunction with electronic devices – often smartphones – that serve as a hub for transferring data to the cloud. Nowadays,

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BLE is widely integrated in fitness and medical wearables (e.g. smartwatches, glucose meters, pulse oximeters etc.) as well as Smart Home devices (e.g. door locks) – whereby data is conveniently communicated to and visualized on smartphones. In retail contexts, BLE can be coupled with beacon technology for enhanced customer services like in-store navigation, personalized promotions, and content delivery.

5) *Wi-Fi / Wi-Fi HaLow*

There is virtually no need to explain Wi-Fi (IEEE 802.11a/b/g/n), given its pervasiveness in both enterprise and home environments. However, in the IoT world, Wi-Fi plays a less significant role.

Except for few Applications like digital signages and indoor security cameras, Wi-Fi is not often a feasible solution for connecting IoT end devices because of its major limitations in coverage, scalability and power consumption. Instead, the technology can perform as a back-end network for offloading aggregated data from a central IoT hub to the cloud, especially in the Smart Homes. Critical security issues often hinder its adoption in industrial and commercial use cases.

A new, less known derivative of Wi-Fi – Wi-Fi HaLow (IEEE 802.11ah) – introduces noticeable improvements in range and energy efficiency that cater to a wider array of IoT use cases. Nonetheless, the protocol has received little traction and industry support so far, partly because of its low security. HaLow also operates in the 900 MHz frequency band only available in the USA, making it far from a global solution.

6) *RFID*

Radio Frequency Identification (RFID) uses radio waves to transmit small amounts of data from an RFID tag to a reader within a very short distance. Till now, the technology has facilitated a major revolution in retail and logistics.

By attaching an RFID tag to all sorts of products and equipment, businesses can track their inventory and assets in real-time – allowing for better stock and production planning as well as optimized supply chain management. Alongside increasing IoT adoption, RFID continues to be entrenched in the retail sector, enabling new IoT Applications like smart shelves, self-checkout, and smart mirrors. Each solution has its strengths and weaknesses in various network criteria and is therefore best-suited for different IoT use cases. (Inc, 2018)

Below is an illustration on how these wireless technology interop with each other at the moment.

Figure 7
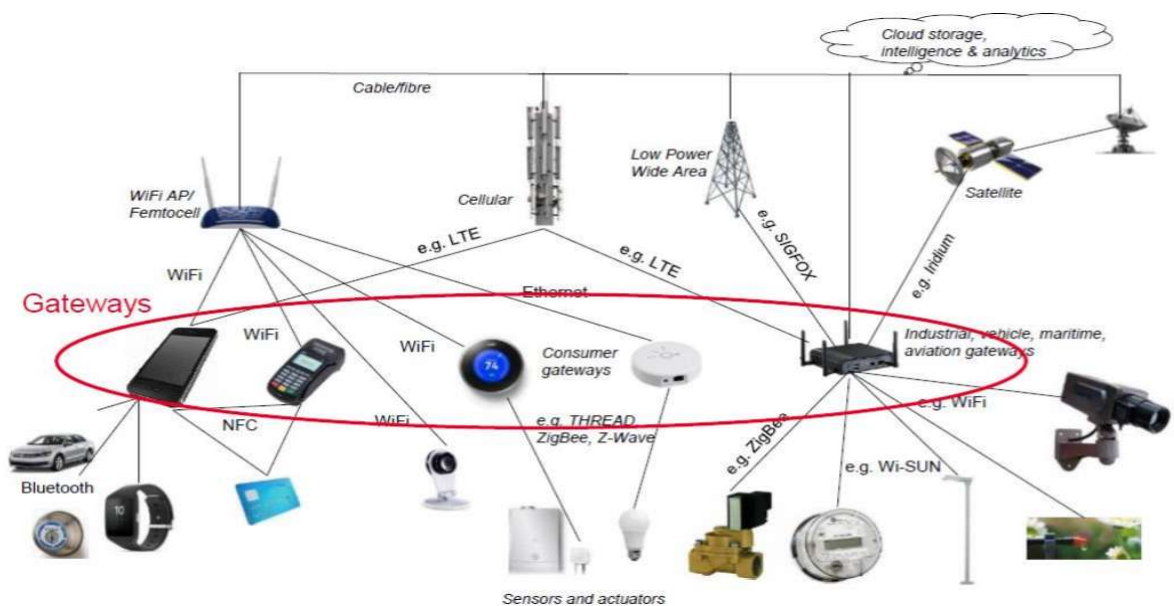
Connecting "Things" to the Cloud, How the mesh network looks like (Kumar et al., 2017)

There is wireless mesh technology in development for the goal that all the wireless devices are able to communicate with each other and the information does not always have to go through a router or gateway. A new wireless networking technology named the wireless mesh network (WMN) overcomes some of the limitations of the WLAN. A WMN combines the characteristics of both a WLAN and ad hoc networks, thus forming an intelligent, large scale and broadband wireless network. These features are attractive for telemedicine and telecare because of the ability to provide data, voice and video communications over a large area. (Wang, 2008)

From this section of literature review, the Wireless Technogym that were used on IoT Applications were identified. In later Chapter, I will conduct mapping with the IoT Applications that are able to improve the life of Dementia suffers.

2.5 Literature Review on IoT (Internet of Things) and Applications

2.5.1 Introduction

IoT is not something new and there are many research paper out there with IoT topics as it does have wide range of IoT Applications in a mix of old and new technologies. This section we will review literature in general in regards to IoT. After I conducted my interviews and identified the daily security issues that Dementia patients have, I will deep dive again into the IoT Applications and illustrate my findings for Research Question at following chapter.

2.5.2 What is IoT

The Internet of things refers to a type of network to connect anything with the Internet based on stipulated protocols through information sensing equipment to conduct

information exchange and communications in order to achieve smart recognitions, positioning, tracing, monitoring, and administration. (Patel and Patel, 2016)

According to Gartner, a research and advisory company, that by 2020 there will be over 26 billion connected devices. (Hung, 2017) By 2020, the Federal Trade Commission predicts that there will be 50 billion internet-connected devices ranging from cars to toasters to pet monitors, cameras and many many others. According to Tractica, a research company, that by 2021 the numbers of wearable devices will surpass 97.6 million. The IoT's prominence in our society is only going to increase. (Landau, 2019) IoT is a giant network not only connected things but also people. The relationship will be between people-people, people-things, and things-things. Recent advances in software, falling hardware prices, and more receptive attitudes towards emerging technology are fueling demand for IoT solutions. The latest advancements in IoT are bringing significant changes to the creation and consumption of products and services. (Morgan, 2014)

2.5.3 IoT Market General Trend

According to a Gartner Report that by 2020 there will be over 20 billion connected devices. (Hung, 2017) That's a lot of connections. Some other reports even estimate this number to be much higher, over 100 billion. IoT has become one of the most important goal for technologies development of the 21st century.

Below is the forecast number of how many IoT devices we will have in billions. It is certainly a huge market.

Figure 8:

Number of Installed IoT Devices from 2015 - 2025

Source: Statista

Designed by FinancesOnline
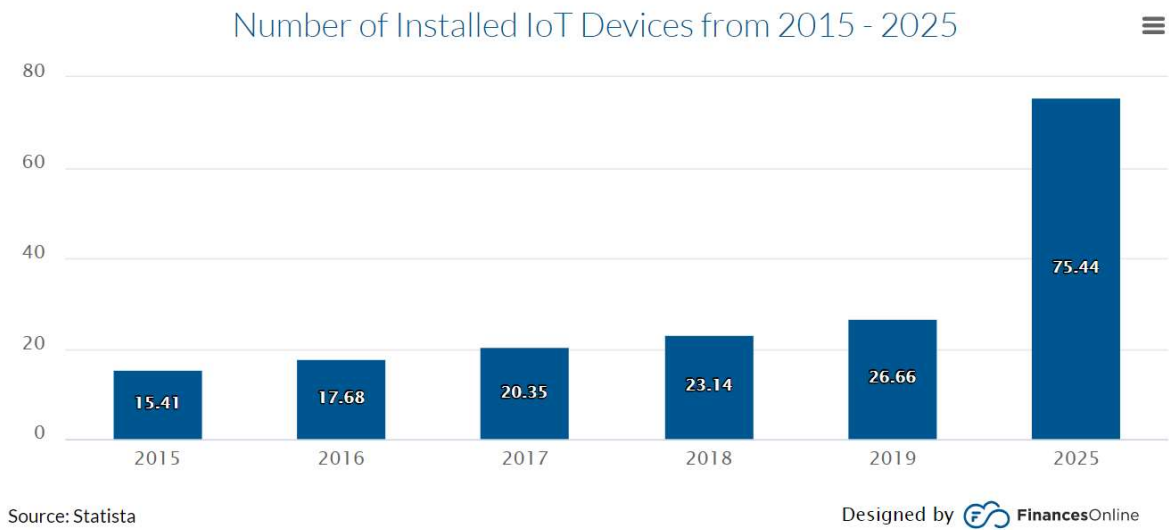
Numbers of Installed IoT devices around the world   (Department, 2016)

According to Finance Online, these are the top 10 trend in IoT for 2020:

1) Focus on Security

2) IoT in Manufacturing

3) Big Data, Analytics, and Machine Learning

4) Healthcare Spearheads IoT Adoption

5) Better Workforce Management

6) The Emergence of Smart Cities

7) Cloud Vendors to Zero In on IoT

8) IoT in Customer Service

9) Developers to Come Up with IoT Milestones

10) Powering Smart Stores

(Chang, 2019)

Health Care is one of the top 10 trend and it is important that there is money and resources investing in this area so the Dementia patients can be benefit from this trend.

2.5.4 IoT Applications

In general, the IoT application covers "smart" environments/spaces in domains such as: Transportation, Building, City, Lifestyle, Retail, Agriculture, Factory, Supply chain, Emergency,

Healthcare, User interaction, Culture and tourism, Environment and Energy. (Patel and Patel, 2016)

There are tons of IoT Applications nowadays in above domains and during the process of literature view I found so many.   It is difficult to list all of them here as there are thousands of IoT Applications out there.   In this thesis I am focusing the IoT Applications that are related to Health Care and are able to promote independent living of the Dementia patients and reduced the loading of care taker.   In the Finding Chapter I will list the ones that I believe that are relevant to my research questions and will map them with the daily security issues that I identified from my interviews and from literature.

3. Research Design

3.1 Introduction

The research method that to be used in this paper and the logic and reasons behind the research design to be explained in this chapter.

3.2 Research Method

The research method that I am using for this paper is interview. The reason that I choice this topic was because one of my very close childhood friend at Taiwan, Zhi-Ping K., her father suffered from Dementia over 15 years now. In the beginning, it is very difficult for her and her family to accept that her father had Dementia. It is also a financial burden for them as they need to hire a care taker to look after her father 24/7 now. The family tried to take turns to look after her father but it was just too much work. I personally known her father since I was very young and he was always very kind to me when I visited Zhi-Ping K. at her home. I felt sad that he had Dementia and if there is ways for technology to come in help, it will be beneficial for future Dementia patients and the care takers. Thus I choice interview as research method as Zhi-Ping K. will be one of my candidate that I can interview. Interviews will provide me the view from the care takers and collect in-depth information on people's opinions, thoughts, experiences, and feelings. Furthermore, it will help me to understand in regards to what is going on with Dementia suffers, what are the issues, and how their family cope with the situations from interviewee's personal experiences.

Thus I choice interview as my research method as I know people who has personal experiences with family members who suffer from the disease and it is the most efficient way to conduct this research with limited time and resources.

3.3 The interviews

3.3.1   How the interview was set up

The interviews were conducted by LINE and WeChat calls sessions and texts for Q&A in the process of writing this paper.   LINE is a popular massager App in Asia and WeChat is a popular messenger App in China.   The interview transcripts are in section *3.3.4* of this chapter.   The interviews were conducted in several sections as there are new thoughts and ideas in the process of writing this thesis.

3.3.2   Number of Interviews and Interviewee profile

Interviewee No. 1

Name: Zhi-Ping K.

Location: Kaohsiung, Taiwan

Organization: Cleanaway Co Ltd, Taiwan

Profession: Chemical Researcher

Age: 48

Gender: Female

Other details related to the research topic: Zhi-Ping K.'s father had Dementia for 15 years and he needs a care taker with him 24/7 as he is having trouble standing up by himself.   Her mother, brother, sister-in-law, and herself are taking parts of the care taking of her father.   There are much information to share from Zhi-Ping's personal experiences.   She also take part of the care taker whenever she visited his father, thus her input from the perspective of care taker is valuable.

Interviewee No. 2

Name: Yen-Feng L.

Location: Shanghai, China

Organization: None

Profession: House Wife

Age: 52

Gender: Female

Other details related to the research topic: Yen-Feng, L's father suffered from stomach cancer and Dementia disease 18 years ago and her father past away not long after that.   It was a very painful experience for her and I've heard much from her regarding her father's illness.   Yen-Feng also shared part of the task as a care taker whenever she visited her father.

Zhi-Ping K. and Yen-Feng L. provided their consent over the phone to publish the above information in this paper.

3.3.3   Interview Questions

In order to achieve my research goals, the questions that I ask my interviewee are:

1) <u>When did your father started to have early symptoms</u>

2) <u>What kind of symptoms that you can recall?</u>

3) <u>How did you feel when you first learn that your father has Dementia?</u>

4) <u>What kind of safety issues that occurred in his daily life after he was diagnose with Dementia?</u>

5) <u>Did you or your family take care of your father sometimes?</u>

6) <u>Do you or your family hire a care taker?</u>

3.3.4 Interview Transcripts

➢ Interviewee No. 1

1) <u>When did your father started to have early symptoms?</u>

She could not remember exactly which year that her father started to have early symptom during phone interview. So she ask her mother after the 1st phone interview session and got back to me with the correct information. It started around 15 years ago.

2) <u>What kind of symptoms that you can recall?</u>

Her father did not have the best memory in the past. However, her family and she started to notice that her father could not remember what happened yesterday or what happened this morning. This is the first sign as far as she can recall.

3) <u>How did you feel when you first learn that your father has Dementia?</u>

She was shock and could not believe this happen to her father. What upset her the most was when her father could not recognized her and her brother. She try many ways and show him old photos and hope her father can regain his memory but with limited of success.

4) <u>What kind of safety issues that occurred in his daily life after he was diagnose with Dementia?</u>

There are many security related episodes happened after her father was diagnosed and her father's wellbeing just getting worse and worse. The daily issues regarding safety for her father that she can think off are:

i. Forgot to take medication. - Her father often did not know that he should take medication and he has high blood pressure that required taking medication daily.

ii. Forgot to turn off the stove. - Her father sometimes would turn on the stove and try to cook. However, sometimes he forgot he was cooking so the stove was still on. It is very dangerous because the stove in Taiwan is using gas and there is no safety measure. The apartment might catch on fire or explosion with the combination of fire and gas. Also, the building that her father live does not have smoke detector of any kind.

iii. Ate some wrong things - Her father will mistake colourful vitamins as candies and ate a bunch of those. He once ate chewing gum from his granddaughter and swallowed it and the gum was stock in his throat. This also led to the risk of chocking.

iv. Go out without caretaker accompany him – Her father liked to go out at the early stage as he was often agitated at home during that period of time. However, the following situation happened on her father that might lead to security issue such as: he forgot the home key, he could not remember where he was going, could not remember where is home. He would forget to bring money with

him when he went out so there is no way he can make phone call and he forget to bring mobile phone with him. Go out in the middle of the night can be dangerous too as he might fall on the street in the dark.

v. Fall in the bathroom – her father fall in the bathroom once and broke his elbow. She thought this is a big security risk if her father's head hit the ground.

vi. Physically attacking other people - My friend told me that her father sometimes got angry with the care taker because the care taker wanted him to take medicines. Her father questioned why he need to take those medication and got angry and started to attack the people who try to get him to take medicine. It was under control after my friends' mother got involved. However, this is still a potential security risk to the patient and people around him if this turn into a serious physical fighting situation.

5) <u>Did you or your family take care of your father sometimes?</u>

She told me in the beginning her mother is the main care taker. She and her brother will also help from time to time when they went home. However, after a while her mother is tired of it as it is a stressful work. Also, her mother is getting old and there are tasks that she was not able to perform such as lifting her father up from the wheelchair as her father now lost the capability of walk and need wheelchair.

6) <u>Do you or your family hire a care taker?</u>

Yes, eventually the family hire a full time care taker to help. Her brother pays most of the money. She and her mother also chip in some money to

hire a care taker to stay in the apartment 24/7. The care taker also help with house chores. In the beginning her mother did not like a stranger live in the apartment but later she got used to it. The 1st care taker is originally from Philippine so the communication was hard as her mother does not speak English and the 1st care taker only speak a little bit of Mandarin. The 2nd care taker is from Vietnam and the care taker speak simple Mandarin so it is much easier to communicate.

➢ Interviewee No. 2

1) <u>When did your father started to have early symptoms?</u>

Yen-Feng also could not remember exactly which year that her father started to have early symptom during phone interview. However, she remembered it was after her father had stomach surgery to remove cancel cell as her father had stomach cancer back then. It was in Taipei. After the 1st phone interview, she further checked the exact time frame with her younger sister and they found out it was around 18 years ago.

2) <u>What kind of symptoms that you can recall?</u>

She remembered it because her father pee in his pants. He did not know he needs to go to the bathroom. The symptoms started to show after her father's stomach surgery.

3) <u>How did you feel when you first learn that your father has Dementia?</u>

She was very sad and could not stop crying when she first learned that her father has Dementia. She knew this is really bad news because not only her father had stomach cancer but also Dementia. What her worried the most was that her parent's relationship was not very good so she was afraid that no

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one will take care of her father. Her brothers who live in the same house were not very caring people either. She went to the temples many times to pray for her father. When she went back to Taipei, she will take care of her father as possible as she can. However, she could not go back to Taipei often as she lives in China with her husband and children.

4) <u>What kind of safety issues that occurred in his daily life after he was diagnose with Dementia?</u>

Her father was diagnosed with Dementia after his stomach operation. Her father's physical condition was not well and it was worsen every day. As far as she can remember, the daily safety issue in regards to her father's daily life are:

i. Falling at home: The apartment was a 4 stores apartment and her parents used to sleep on the 1st floor. Her father had difficulty to climb up the stairs and fall from the stairs for a few times and once hit the forehead. Later her father moved to the ground floor and his activities was limited at ground level after that.

ii. Take too much medication. - Her father often forgot if he took the medication or not. Sometimes her father took too much medication because he was worried that he did not take medication and would die.

iii. Poor food and nutrition intake – her father did not cook as usually her mother who cooked for the whole family. After his father had stomach surgery and Dementia, he could not work so my friend's mother needed to go out and work. Thus there was no one at home who cooked. Most of the time her mother will bring dinner back home but at lunch time her mother could not be around and cook for

her father. Her father did not know how to make food and he lost appetite anyway most of the time and did not eat much of food in order to gain some physical strength and obtain good nutrition.

iv. Delusional – her father suspect that someone would hurt him or kill him. He was into a paranoia mode. He often suspected that people try to poison him and this might be dangerous if he gets defensive physically.

v. Go out without caretaker accompany him – Her father also liked to go out at the early stage as he felt depressed at home. However, her father would forget the home key or he could not remember where he was going, and could not remember where was home. He would forget his glasses and could not see things clearly. He often left his wallet at home when he went out or did not ware warm clothes in the winter.

vi. Financial risk – at the area that her father lives, there were people who try to scam her father's money. Once there was a guy who ask her father to go to the ATM and withdraw money. Luckily her father did not remember the pin and he mentioned this when he got home without realizing that it was someone who try to scam him.

5) <u>Did you or your family take care of your father sometimes?</u>

She told me there was no one who was looking after her father in the beginning during the days since her mother and brothers needed to work. Her mother and brothers would take care of her father in the evening. It was not so bad in the beginning because her father still had some limited senses. However, it got harder and harder for her mother and brothers to take care of her father as the symptoms were getting server over time. One time her

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mother almost fall while helping her father to take a bath. Her brother took over the task after the incident happened. She also helped whenever she was at home.

6) <u>Do you or your family hire a care taker?</u>

Yes, eventually her family hire a care taker. After a while her father got really weak and could not stand and could not get out of the bed, by then they hire a care taker to come to the house during the day to help and take care of her father.

3.4 General limitation of the approach

Due to the limited of time and resources, I could not conduct a wide range of survey with a significant number of people. Thus I choice interview as my research method. Although interview can provide in-depth information with personal experiences, it has limitation. A limited number of interview can cause biases as the result can be affected by interviewee's culture background, race, education level, class, or age. My interviewee are all Taiwanese so the result is limited from Taiwanese perspective. Also, interview studies provide less anonymity, which is a big concern for many respondents. In my case my friends did not mind that I published part of their information.

In order to compensate the limitation of my research method, I decided to cooperate the information that I gather from literature reviews that are similar to the issues that I found from the interviews. This will create more accurate and holistic insights.

4. Findings

4.1 Introduction

This chapter is to list down the daily security issues that were identified from the interviews and also from literature review to support the findings. In this chapter the IoT Applications that might be able to solve the issues or improve the situation for both dementia sufferer and the care takers are listed down.

4.2 The security identified from the interviews and literature reviews

The issues that were identified from the interviews and literature reviews that related to Dementia suffers daily security are:

1) Forgot to take medication or take too much medicine. This result was shown by both of my interviews. The medication is not necessary for Dementia but for other diseases that came with old age. Diseases such as diabetic, high blood pressure, or heart related conditions. It can be problematic if the patient forgets to take medication, take too much medicine, or take the wrong medicine.

2) Cook at home: One of my interview result showed that there is a risk when the Dementia sufferer cooked at home. When the Dementia patient cooked or try to cook at home, the following scenarios might happens with security risks.

  - Forgot to turn off the stove and it will lead to possible fire or explosive incident.
  - Accidently cut themselves and do not know how to deal with wound

- Ate some wrong things such as expired food and got food poison or confused rat poison as food.

3) Go out without care taker's accompany

   Both of my interviews indicated that this is a risk. Dementia patient in general like to go out and going out actually help them promoting better health physically and mentally. (Adekoya and Guse, 2019) However, if they go out without a person who accompany them, the following scenarios will lead to security problems. This security issue were identified by both my interviewee. Here are the details of the issues:

   a. Forgot to bring key and cannot return back to the house

   b. Forgot to bring money and no way to come back home

   c. Forgot where are their homes

   d. Forgot who they are

   e. Forgot to wear glasses and get into traffic accident

   f. Did not know to ware warm clothes in a cold weather, this will lead to problem such as hypothermia

   g. Going out in the middle of the night, fall into an unsafe place such as river or ditch

4) Fall at home especially in the bathroom: One of my friend's father who has Dementia once fall in the bathroom and she think this is a big security risk if her father's head hit the ground. Through the literature reviews, there are research indicated that in most cases Dementia comes with old age and falls are a common and often overlooked cause of injury in the elderly. The age-related loss of muscle strength as well as muscle mass and muscle function is risk factors for falling. (Schoene et al., 2019) There is a research in 2014 related to this. In this study, the research team examined the circumstances and outcomes of falls experienced by 328 participants in the Dane County Wisconsin with randomized controlled trial of a community-based multifactorial falls intervention for older adults at high risk for

falls, conducted from October 2002 to December 2007. Participants were adults aged equal or order then 65 years who reported at least one fall during the year. Falls incident information were collected and everyone who reported a fall was contacted by telephone to determine the circumstances surrounding the event. The results of the research are: Totally 1,172 falls and research showed that being aged ≥85, female, falling backward and landing flat or sideways and forward were significantly associated with the likelihood of injury. Of 783 falls inside the home, falls in the bathroom were more than twice as likely to result in an injury compared to falls in the living room. (Stevens et al., 2014)

5) Physically attacking other people due to emotional instability: From one of my interview, the interviewee told me that her father sometimes got angry with the care taker because the care taker wanted him to take medicine. Her father questioned why he need to take those medication and got angry and started to attack the people who try to get him to take medicine. It was under control after my friends' mother got involved. However, this is still a potential security risk to the patient and people around him. I look into the resources that I have and found some research that confirmed this risk. In a research report from Trolle-Wachtmeister Foundation for Medical Research, the result indicate that there are physical aggression among patients with Dementia. The research included 281 cases with a neuropathological Dementia diagnosis from the brain bank at the Department of Pathology, Lund University, for this retrospective medical records review. The study covers cases with a post-mortem examination performed between 1967 and 2013. And the research result of these 281 patients studied, 97 (35%) patients had a history of exerting physical aggression during the course of their disease. (Liljegren et al., 2017) Another research showed that there are 6 types of common causes of aggression from Dementia patients. There are many reasons why people with Dementia may experience and express anger, some of which are related to

the disease and others of which are associated with the emotional impact of Dementia. The 6 types of common causes are:

a. Loss of Recognition - People with Dementia might not recognize their family members or friends, and this can cause fear, anxiety, and aggressive behavior. For example, a wife with Dementia may try to attack her husband because she is afraid of the "strange man" in their house.

b. Paranoia, Delusion, and Hallucinations - Distortions of reality, such as paranoia, delusions, and hallucinations, can be another result of the disease process in Dementia. Not everyone with Dementia develops these symptoms, but they can make Dementia much more difficult to handle.

c. Progressive Brain Injury - Dementia affects the brain, and the brain is responsible for more than just our memory and thought process. The brain also controls our emotions and behaviors. So, depending on where the damage in the brain is, emotions may be affected as well. The frontal parts of the brain are where the capacity for empathy, impulse control, personality, and judgment reside. The loss of these functions can lead to impulsive and unconstrained behaviors.

d. Poor Food Intake - Studies have shown an association between poor food intake, weight loss, and problematic behaviors in persons with Dementia. Poor nutrition can affect mood, energy, and cognitive function in people without Dementia. In people with Dementia, the same deficiencies can fuel sudden outbursts and aggressive impulses. Improving nutrition and ensuring that the dining space is calm can go a long way toward reducing angry outbursts. This was shown in one of my interview.

    e.   Misunderstandings - Because Dementia affects communication, the ability to understand what someone else is saying or doing is reduced. As a caregiver, you may mean only to be helpful, but the person with Dementia might not understand why you're trying to help her or feel that you're trying to boss her around.

    f.   Caregiver Overload - If you as a caregiver are more frustrated, impatient, and angry, even if these feelings aren't verbalized, there's a good chance that the person with Dementia will reflect these feelings back to you in their own behaviors. Both your verbal and non-verbal communications can be picked up by the individual with Dementia, and sometimes, like a mirror, projected back at you. (Heerema, 2019)

From the interview and literature review   , the risk of physical aggression is another security risk for the Dementia patients and also a risk for the caretakers.

6) Financial risk: One of my interviewee told me one time there is stranger try to lure his father to get money from the ATM machine. Dementia patients were often targeted by con man to lure them giving out the money from the bank as the patients cannot make rational decisions. This might lead to financial risk of the Dementia suffers. Financial exploitation of older adults is a common and serious problem. Elders from groups traditionally considered to be economically, medically, and sociodemographic vulnerable are more likely to self-report financial exploitation. (Hsu and Willis, 2014)

From the table below we can have a clear view on the safety issues that were identified from the interview and literature review. This Table address to my RQ1: I like to find out what kind of safety related issues that a person who suffers from Dementia will encounter in their daily life.

Table 1.

Main Security Issue	Description
Forgot to take medication or take too much medicine	Forgot to take medicine on time or take the wrong medicine
Cook at home	Forgot to turn off the stove and possibility of leading to fire
	Accidently cut themselves and do not know to deal with wound
	Ate some wrong things such as expired food and got food poison or confused rat poison as food
Go out without care taker's accompany	Forgot to bring key and cannot return home
	Forgot to bring money
	Forgot where are their homes
	Forgot who they are
	Forgot to wear glasses and might get into accident
	Did not ware warm clothes in a cold weather and will lead to problems such as hypothermia
	Go out in the middle of the night and fall into an unsafe place such as river or ditch
Fall at home	Fall in the bathroom or anywhere in the home

Physically attacking other people due to emotional instability	Get aggressive with people around and this might hurt themselves or people around them
Financial risk from con man	Con man that trying to get people with dementia to transfer money or withdraw money from the bank

4.3 IoT Applications which help Dementia patient and the care taker

After going through a lot of literature, I found certain Applications that are useful and can benefit Dementia health care especially home centric health care environment Applications instead of hospital visit for regular checkup. The patients can stay in a comfortable environment which reduces the mental stress in comparison to the crowded medical institutions. This will definitely benefit the emotional stability of the Dementia patient. Not only that, the care taker will not need to accompany patient to the hospital regularly so time, energy, and resources are saved. The home centric health environment Applications will ease care takers' loading and will also reduce Dementia patients' risk of getting lost when they go out. Not being in the crowded medical institution will also reduce some of patients' physical aggression as indicated from previous findings. The patients can have their diagnoses from the daily monitoring service through IoT Applications at home instead of from hospital visits. This can also reduce the cost of medical equipment by monitoring the current condition of each patient remotely. Hospital authorities will know when they have to replace out of date equipment when IoT sensors would send notifications. Doctors will be able to know the

current location of the required equipment and when the patients need their attention. This can be time effective.

For the data that IoT sensors collected, a Data Center is needed in combination of different wireless IoT sensors

Below is the architectures of how everything connected to Data Center

Figure 9

(M.Rahmaniab and Nguyen, 2018)

By connecting different wireless sensors this database will be able to collect tons of information that transferring into useful data to the Data Center for doctors and care takers to work more efficiently. These data can be analyzed, designed, implemented, and evaluated. Doctors can use the analyzed data outcomes to improve patient care, and strengthen the clinician-patient relationship. Furthermore, with these data doctors can diagnose disease early by monitoring patient's vital body parameters. Also, in case of emergency, patients can locate the nearest medical service center in case they need urgent assistance. The database can collect the medicine that a patient uses and remind patient to take medicine and it can alarm the system and patient if the medicine was not taken on time.

After going through many literatures, the following Wireless IoT Applications devices can be used and feed data into this Data Center:

1) Wearable devices such as Fitbit and smartwatch using Bluetooth wireless technology - Fitbit is an American company headquartered in San Francisco, California. Its products are activity trackers, wireless-enabled wearable technology devices that measure data such as the number of steps walked, heart rate, quality of sleep, steps climbed, and other personal metrics involved in fitness. (Wikipedia®, 2020) The most iconic devices is the Fitbit wristband. It can be worn on the patient's wrist, neck as necklace, or cloth as a clip on device and track vital body parameters such as heartbeats, temperature, and steps that the patient take daily. It can help to provide continuous data to be feed into the Data Center. Smart Watch such as Apple Watch, It is a device that you ware on your wrist with application for monitoring and tracking fitness-related metrics such as distance walked or run, calorie consumption, and in some cases heartbeat. It is a type of wearable computer. It can feed the above data into your smartphone and transfer useful information. There are many similar devices in the market now.

2) IoT weight scale that use Bluetooth wireless technology - It is a weigh scale with wireless connection that can feed measured data to your smartphone for tracking your weight. And the record data can also be feed into Data Center for doctors to analysis and monitor patient's health status.

3) Bed and Chair Sensor by using infrared or microwave wireless technologies - There is an Israeli company call EarySense that develop contact-free sensor using passive infrared or microwave. The sensors can captures a patient's heart-rate-related parameter, tremor-related parameter, and identifying shallow breathing. The sensor is discreetly placed underneath the patient's mattress or chair cushion to monitor patient's level of motion, heart rate and

respiratory rate. The sensors can deliver real-time actionable data, combined with data management tools, it can empower clinical staff to identify potentially critical situations early, before they become high risk. (EarlySense, 2020)

4) Smart Contact Lens using RFID wireless technology - A number of companies have already announced they're researching smart contact lens technology that could accelerate vision beyond natural human capabilities. The smart contact lenses that reach market are likely to contain micro-versions of the following technologies: Auto-focusing lens, Battery, CPU, wireless chip, Data Storage, Antenna, Task-specific sensors, RFID, Bluetooth, Display, and Radio you can wear basic smart contact lenses like a normal contact lens; they don't require surgery and can be inserted or removed by the user. They sit on the eyeball and contain micro versions of existing technology.

The advanced smart lens involves a surgical replacement of your existing lens with an electronic one. (Chiou et al., 2017) Fluid is injected into the eye, fusing with the lens capsule as it solidifies. This has the same technological features but is more robust and permanent. The artificial lens takes over the job of focusing light on the retina, improving vision in a flexible way. However, they're likely to be just as comfortable as normal lenses. Smart lenses are designed to harvest energy. The two methods being discussed are solar power sensors, to convert light to electrical power, and piezoelectric sensors, to convert the mechanical eye movement of blinking into electrical power. (Nasreldin et al., 2019) Smart contact lenses don't just stop at sharpening vision, they are being designed to help with a number of other medical conditions. They can carry a wireless chip and miniaturized sensor for monitoring physiological parameters such as the glucose levels in the tears of a diabetic patient or intraocular pressure in glaucoma patients. (Direct, 2019)

5) Ingestible Sensors

According to an article on The New York Times, half or more of prescribed medication is never taken. (Frakt, 2017) This practice leads to the severe conditions of the patient. Ingestible sensors with magnesium and copper coating can trigger a signal if medication is not taken at the exact time. This means you can monitor your family members if they take the necessary medicine on schedule and your smartphone will got a message that your family member did take or did not take medication at the proper time. This can also work with Applications and record patient's medicine intake record.

Below photos showed hot the digestible sensors look like, it can be attached in the pill and medicine.

The wireless technology that was used on Ingestible sensors is called Body Sensor Network and often use ZigBee or other IEEE 802.15.4 based on 433 MHz Band. Body Sensor Networks (BSNs) have been investigated for more than a decade and an increasing number of groups are exploring new Applications for BSNs. From their initial application in military scenarios, BSNs are now a focus in biomedical engineering. Below graphic shows how it works, Star-shaped network with three sensor slaves and one master module. Data are relayed to a PDA that can send the data over a Wi-Fi or UMTS connection to a back-end server. (Kim et al., 2013)

Insights that we can get of ingestible sensor applications:

➢ Monitors if patients are taking the medication at the wrong time, which can cause side-effects.

➢ Research is going on if it is possible to track chronic disease.

➢ In the area of mental health, this application can play a vital role in cure as you know psychiatric patients hardly take medications.

➢ This application is very cost-effective as it ensures the consumption of medication.

➢ IoT healthcare solutions like this example can reduce the daily life pressure of the caring patient. (CHOWDHURY, 2019)

One unique feature of such ingestible sensors is that their passage through the gut lumen gives them access to each individual organ of the gastrointestinal tract. Therefore, ingestible sensors offer the ability to gather images and monitor luminal fluid and the contents of each gut segment including electrolytes, enzymes, metabolites, hormones, and the microbial communities. (Kalantar-zadeh et al., 2017) The amount of data that can be collected from ingestible sensors are amazing.

6) GPS tracking devices that use cellular Wireless Technology - There are many GPS tracking devices in the market right now.   However, as Dementia patient often not remember to take the devices with them when they go out, they usually remember to wear shoes. Thus there are companies that developed GPS tracking device that is hidden and sealed within a water-resistant, trimmable shoe insert. It uses GPS and 2G cellular wireless technologies and sending information to smartphone and automatically update its location. A company named Smart Sole has leading position in this area.

Here's how it works:

- Wireless charging

- The ergonomic GPS SmartSoles* is placed inside a shoe.

- Family or caregivers can track movement of the people with dementia unobtrusively, leaving them free from the stigma of "lock on" bracelets.

- Completely waterproof. These have got military grade tracking technology from the USA. In an unlikely event if Dementia patient fall in a lake or river and perhaps become completely submerged, these tracking devices should still be able to locate them.

- SmartSoles also give you alert when they're low on battery. When the charge goes below 20%, it will send out alert so you can get them charged before they go dead.

(Draper, 2018)

7) Medical Wristband Wireless Sensor to Measure the Stress Level for People with Dementia

Sensor technologies have potential Applications in early detection of cognitive impairment to aid in the management of behavioral and psychological symptoms in Dementia. (Husebo et al., 2020) There is a research paper provided such evidence. According to this research, 90% of people who suffer from Dementia have symptoms of agitation, delusions, euphoria, hallucinations, apathy, depression, aberrant motor behavior, irritability, eating problems and sleep problems. (Kikhia et al., 2016) Many studies suggested the use of physiological signals to detect stress and measure emotions of people.   In this research they use a medical wristband device to collect a number of different parameters, such as skin conductance, motion accelerometers, skin temperature, environment temperature and environment light. The collected data can be analyzed and translated into the aggression level of the patient.

8) Smart Home Applications that use Bluetooth, Cellular, infrared, Wi-Fi, Zigbee, or Zigwave wireless technologies - There are so many Smart home Applications and devices in the market now and the technologies are well developed. Devices such as IP camera, smoke & gas sensors, smart door lock, smart plug that able to switch on and off of devices, thermal sensors, passive infrared motion sensor, light sensor, smart speaker, pressure sensor, and door & window alarm for home security, etc. These Applications can measure different physical, motion, contact, and presence properties within a home.   The data collected from these smart home devices can be feed into a health care data base for clinical usage. (Norell Pejner et al., 2019)

9) Wi-Fi Sensing

Wi-Fi Sensing is a new technology which enables motion detection, gesture recognition as well as biometric measurement by using existing Wi-Fi signals. Wi-Fi Sensing operates similarly to a radar system, detecting motion and providing information that can be enable in Wi-Fi based services.   It builds upon the existing standards, hardware, infrastructure, and

deployments of Wi-Fi. Wi-Fi Sensing creates opportunities within the home security, health care, enterprise, and building automation/management markets, among many others, and creates a bridge for Wi-Fi service providers to enter these markets. (Lopez-Perez, 2019) With the combination of Infrared Tracking Module, IR Thermal Sensors, and Wi-Fi sensing, it can even achieve possible face detection. (Tan et al., 2019) Another research showed that human pulse detection is also possible. (Zheng et al., 2019)

Lately the famous Router producer Linksys accounted their new Wi-Fi Mesh Router product with Wi-Fi Sensing capability: Linksys Aware detects activity via Wi-Fi signals and sends "motion alerts" to the user through the Linksys App when activity has occurred. Users can turn on, off or snooze "motion alerts," controlling the frequency of notifications from the palm of their hands, and even customize the motion sensitivity level in the home, ensuring an extra layer of protection and avoiding any false alarms. The software also senses movement throughout the house, which may aid in remote care for the elderly, while providing the user with great peace of mind. Linksys Aware provides historical data for up to 60 days and can be viewed hourly, daily and weekly for actionable insights. (Warren, 2019) The technology is now out there and ready to be used.

There is a research showed how the sensing work image looks like on computer in comparison to real photos.
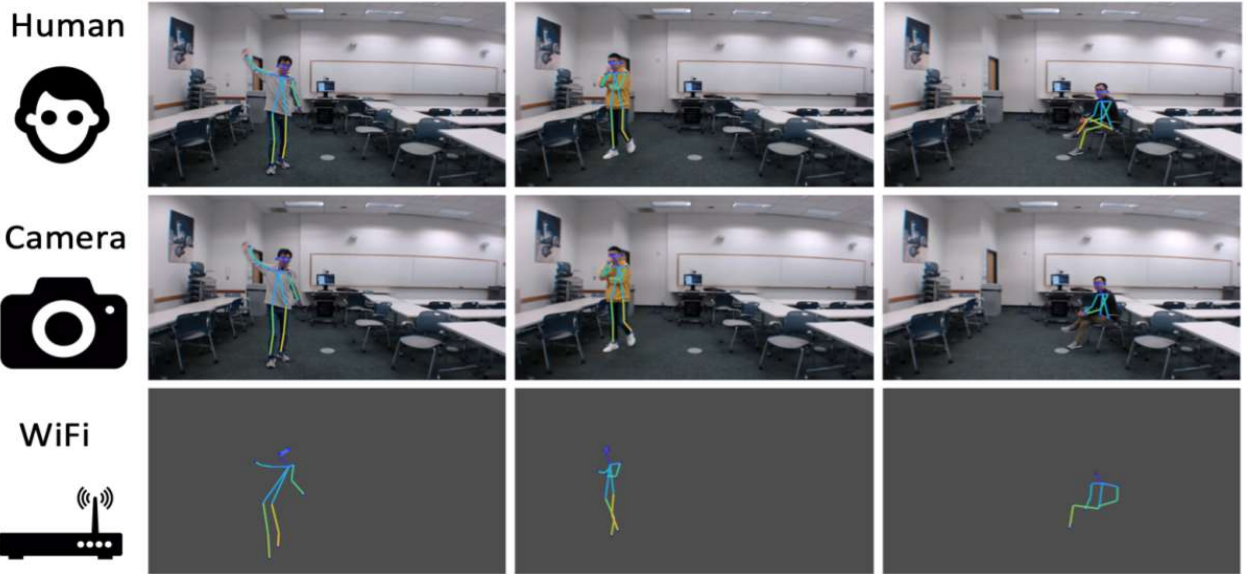
(Wang et al., 2019)

10) Smart Phone using Bluetooth, Cellular, GPS, and Wi-Fi wireless technologies - Smart phone consider to be a powerful IoT devices as it works as a computer and be able to process complicated data. It works with RFID, Bluetooth, 3G, 4G, 5G, wireless sensor networks, etc., along with long-lasting batteries, all bundled in one inexpensive, small, light, and portable device, which is the smartphone. (Khaddar and Boulmalf, 2017) It also serve as a hub that is able to collect and feed data into a data base or data center. Not only that, it also equipped the capability to process the data into useful information.

Below Table showed that the above IoT Application mapping with Wireless Technologies. Which address to my RQ2: I like to explore what are the existing wireless technologies that applied in Health Care IoT Applications that exist nowadays. We can see the findings at Table 2 below.

Table 2:

IoT Applications	Wirless Technology
Wareable Sensors to keep track on patient's health related peremeters	Bluetooth
IoT Weight Scale	Bluetooth
Bed and Chair Sensor	Infrared or Microwave
Smart Contact Lens	RFID
Ingestible Sensors	Zigbee or IEEE 802.15.4 base on 433 MHz band
GPS Tracking devices	Cellular
Medical Wiresband	Bluetooth
Smart Home Devices: *Thermal Sensor *smart plug for power on and off *Smoke Detector *IP Camera *Smart Speaker *Smart Door Bell with Camera *Smart Door lock	Wi-Fi, Zigbee, Zigwave, Bluetooth
WiFi Sensing	Wi-Fi
Smart Phone	Cellular, Bluetooth, RF for GPS, Wi-Fi

5.Conclusion

5.1 Mapping of IoT Applications to Dementia Care Needs

My last research question is RQ3: I like to map the Wireless IoT Applications that can be applied to help the elderly who suffer from Dementia. The Applications that can help them to be more independent, safer in their daily life, reduce care taker's loading, keep them in connect with the people who care for them.

In order to clearly relating my research questions to the research findings, below table will show you the Wireless IoT Applications were identified in this research that are able to address the security issues that were found in this thesis.

Table 3:

Main Security Issue	Description	Applications that are able to help	Wireless Technology
Forgot to take medication or take too much medicine	Forgot to take medicine on time or take the wrong medicine	*Ingestible Sensors that are able to monitor patient's medicine intake and also monitor other health related perimeters * Wearable Sensors to keep track on patient's health related perimeters * Bed and Chair sensors to monitor patient's daily activities and record health related perimeters * IoT weight scale to record patient's weight as it can be a health indicator	ZigBee, devices base on 433 MHz Band, Bluetooth, Infrared, Microwave

|			
Cook at home	Forgot to turn off the stove and possibility of leading to fire	*Thermal Sensor to detect the rising temperature at home *smart plug that able to shut down the stove remotely and other electronic devices remotely *Smoke Detector to detect smoke *IP Camera for care taker to see what happened remotely *Smart Speaker for care taker to talk to the patient remotely and guide them what to do	Wi-Fi, Zigbee, Zigwave, Bluetooth
	Accidently cut themselves and do not know to deal with wound	*Wearable Sensor to detect heart rate rising or falling *IP Camera for care taker to see what happened *Smart Speaker for care taker to talk to the patient remotely and guide them what to do *Smart door lock to open the door for neighbor to come to the home and help	Wi-Fi, Zigbee, Zigwave, Bluetooth
	Ate some wrong things such as expired food and got food poison or confused rat poison as food	*Wearable Sensor to detect heart rate rising or falling *IP Camera for care taker to see what happened *Smart Speaker for care taker to talk to the patient remotely and guide them what to do	Wi-Fi, Zigbee, Zigwave, Bluetooth
Go out without care taker's accompany	Forgot to bring key and cannot return home	*Motion Sensor to send alarm when patient goes out the door *Wi-Fi Sensing to send alarm when there is no movement in home *IP Door Camera that can open the door remotely by care taker *Smart Phone that are able to open the door remotely with Mobile App *Smart door lock to lock the home so they cannot go out	Wi-Fi, Zigbee, Zigwave, Bluetooth, Cellular
	Forgot to bring money	*Motion Sensor to send alarm to care taker when patient goes out the door *Wi-Fi Sensing to send alarm to care taker when there is no movement in home *Smart Phone that is able to pay with APP or call for help *GPS Tracking to find out where the patient is and send someone to help *Smart door lock to lock the home so they cannot go out	Cellular, Bluetooth, Infrared, RF for GPS, Wi-Fi
	Forgot where are their homes	*Motion Sensor to send alarm when patient goes out the door *Wii Sensing to send alarm when there is no movement in home *Smart Phone for them to call for help *GPS Tracking to find out where the patient is and send someone to help	Cellular, Bluetooth, RF for GPS, Wi-Fi

	Forgot who they are	*Motion Sensor to send alarm when patient goes out the door *Wi-Fi Sensing to send alarm when there is no movement in home *Smart Phone for them to call for help *GPS Tracking to find out where the patient is and send someone to help *Smart door lock to lock the home so they cannot go out	Cellular, Bluetooth, RF for GPS, Wi-Fi
	Forgot to wear glasses and might get into accident	*Motion Sensor to send alarm when patient goes out the door *Wi-Fi Sensing to send alarm when there is no movement in home *Smart Phone for them to call for help *GPS Tracking to find out where the patient is and send someone to help *Smart Contact Lens to improve eyesight *Smart door lock to lock the home so they cannot go out	Cellular, Bluetooth, RF for GPS, Wi-Fi, RFID
	Did not ware warm clothes in a cold weather and will lead to problems such as hypothermia	*Motion Sensor to send alarm when patient goes out the door *Wi-Fi Sensing to send alarm when there is no movement in home *Wearable Sensor to send alarm when body temperature is too low *GPS Tracking to find out where the patient is and send someone to help *Smart door lock to lock the home so they cannot go out	Cellular, Bluetooth, RF for GPS, Wi-Fi
	Fall into an unsafe place such as river or ditch	*Motion Sensor to send alarm when patient goes out the door *Wi-Fi Sensing to send alarm when there is no movement in home *Wearable Sensor to send alarm when body temperature is too low or too high *GPS Tracking to find out where the patient is and send someone to help *Smart door lock to lock the home so they cannot go out	Cellular, Bluetooth, RF for GPS, Wi-Fi
Fall at home	Fall in the bathroom or anywhere in the home	*Wi-Fi Sensing to detect falls *IP Camera for care taker to see what happened *Wearable Sensors to detect fall *Smart speaker for them to talk to care taker and ask help	Bluetooth, Zigbee, Zigwave, Wi-Fi
Physically attacking other people due to emotional instability	Get aggressive with people around and this might hurt themselves or people around them	*Medical Wristband to track emotional related parameter * Wearable Sensors to keep track on patient's health related perimeters * Bed and Chair sensors to monitor patient's daily activities and record health related perimeters * IoT weight scale to record patient's weight as it can be a health indicator	Bluetooth, Zigbee, Zigwave, Wi-Fi, Infrared, Microwave
Financial risk from con man	Con man that trying to get people with dementia to transfer money or withdraw money from the bank	*Motion Sensor to send alarm when patient goes out the door *Wi-Fi Sensing to send alarm when there is no movement in home *Smart Phone with App with dual authentication which involved a close family member to authorized money withdraw or transfer	Cellular, Bluetooth, Zigbee, Zigwave, Wi-Fi

Table 3 summaries the Wireless IoT Application that can be used to alarm the care taker when Dementia patients need help or in a condition that need extra medical attention. Also, these Wireless IoT Applications help the Dementia suffer to be able to live more independently. However, these Wireless IoT Applications are not widely used yet as many people do not know about these Applications. I talked to my interviewee again to discuss the findings. They are very surprised to learn that there are so many IoT Applications that have the possibilities to make their father's and their life easier. However, both of them told me that some of these IoT Applications cannot be found in Taiwan still. According to one of my interviewee, she said the Smart Home devices such as IP Camera, Motion sensors, Thermal sensor, and smoke detector are available in the market. She can also find Smart weight scale and wearable devices. However, the data that were collected dose not feed into medical related Data Center thus there is no link to the Health Care system. Furthermore, some of the Wireless IoT Applications that were identified in this research cannot be found in Taiwan due to no infrastructure or business model. How to make these Wireless IoT Applications to be able to deploy in mess market so most people can enjoy the benefit is another important topic that the society needs to address.

In the future there are much more technology can bring into Health Care field and benefit Dementia patient, medical workers, and care taker. For example, with smart city infrastructure building up, there will be billions of the connectivity devices in the city and when all these devices communicate with each other and feed data into the central data center, these data can be transferred into useful information and help Dementia sufferer and the care taker even further. When all the devices are connected, people around the Dementia patient can receive real time alerts and instructions on their smart phones in order to help the Dementia patient that is nearby. The neighbors, people who walk on the street, and people who drive by can all give their helping hands.

Below architecture showed how these can be possible in the future.

Figure 10
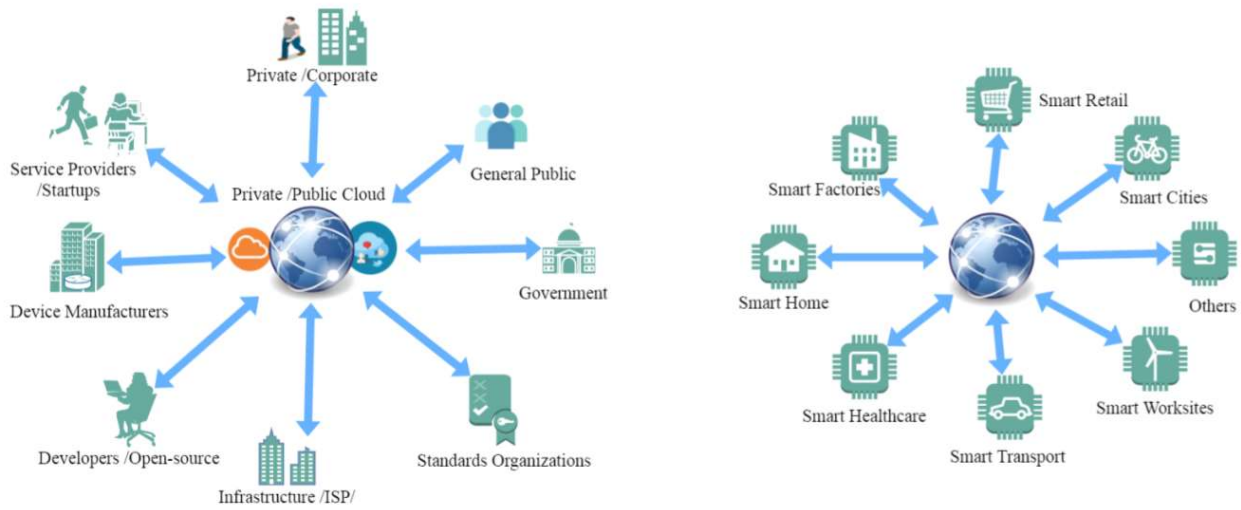
On the left side, stakeholders in an interoperable IoT scenario and on the right side are the different use cases or domains. The illustration is simplified as a star assuming IoT as a central system rather than a mesh. (Negash et al., 2018)   With all these Wireless IoT Devices and Application connected, there are so much data that can be turn into useful information to benefit future Health Care systems.

5.2 Social Responsibility

Global population growth and age demographic continue to lean to older age, it is everyone's social responsibility to contribute the support of Dementia care and other illness care that in need when it comes with old age.   Long-term care cannot be viewed solely as an individual or family responsibility anymore. It requires the support of the community. In Taiwan, there are Long-term care insurance that you can purchase in order to contribute and reduce future financial risk. Also, there are charity organizations and private cooperates, who devote men power and financial resources to help the ones that in need. Hopefully, people can be influenced by the good deed and pay it forward for the needed to receive help.   It is our social responsibility to do so and it will make the community better.

"The purpose of life is not to be happy. It is to be useful, to be honorable, to be compassionate, and to have it make some difference that you have lived and lived well."

— Ralph Waldo Emerson

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