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Mathematics & Computer Science

Edge computing :
A business model for tele monitoring IoT applications for diabetic remote care

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Preface

Hello, and thank you for taking the time to read my Masters thesis. This Masters thesis is the final requirement which must be achieved in order for me to graduate from the University of Twente and obtain my Business Information Technology's Masters degree. In the past two years, in which I attended my courses, I gained an abundance of information and knowledge from this program.During this final part of my studies I am in good company because I am allowed to carry out my graduation assignment at BDO. Here, in collaboration with BDO and a hospital within the BDO clientele, I am allowed to do research on Cloud computing innovations and the use of IoT in healthcare. In which I want to focus primarily on IoT systems that enable more high-quality home care and support patients in performing medical procedures on their own and how this can be implemented.

This topic appeals to me personally because I am a diabetic patient. And by using very small sensors, which are possible through the use of IoT, many steps within the care process can be automated, which ensures that the quality of life is greatly improved. An obstacle in the development of these types of systems is formed by various privacy issues, so that in my opinion not enough is yet achieved from the possibilities that cloud computing and IoT can offer.

In the first place I would like to thank my family for always supporting my, mentally as well as financially. Without their support this all would have not been possible and I would have not been able to successfully complete this study. I also want to express my gratitude to my professors, Maria Iacob and Marten van Sinderen, who have always supported me well and helped me conduct my research. Finally, I want to thank BDO and the technology team for the opportunity I have had to carry out my research. And in particular Kees Plas, who has always assisted and supported me in my work during my graduation period. Chestver van den Bogaard who first introduced me at BDO and last but not least Ed de Myttenaere and his colleagues at Noordwest Ziekenhuis Groep who have given me the opportunity to delve into the IT architecture of a hospital.

Last, but definitely not least, I want to thank everyone who contributed to this thesis. Whether it was via feedback, brainstorm sessions or just plain conversations with my roommates. Without the inspiration of all you guys I would not have been able to fulfill this Masters project. Also my colleagues at Cofano Software Solutions in Enschede have been an inspiration, guide and motivator to me, as well as my BDO Technology colleagues. My thanks go out to you guys.

To conclude, I want to end with a quote that is very typical for me as a person and as a professional, for I have made numerous mistakes during my time in academia, though have taken these mistakes as learning modules improving my knowledge and capabilities every step of the way.

"An expert is a person who has made all the mistakes that can be made in a very narrow field"
- Niels Bohr

Willem J. van der Plas
Utrecht, 4 July 2020

Summary

The Dutch healthcare sector is an ever growing environment where BDO as audit and assurance, but also as trusted advisor plays an important role in compliance but also with respect to digital transformation. More and more (technical) innovative projects are created within the healthcare sector to improve patient care and quality of life as well as increased efficiency and lower costs and pressure on healthcare professionals. More and more technology is being applied to healthcare processes globally and IT innovation can, not only help with better care for patients but also help to increase patient privacy by adopting certain techniques.

To create a better (business) understanding of the possibilities of new technologies in the healthcare sector and to improve patient control of medical data, a new technique researched in this thesis is Edge computing. Edge computing has the potential to increase remote monitoring solution as well as improve on privacy matters with respect to patient data. To do this, a business model for edge computing will be designed and validated with the goal to support remote monitoring solutions created by the use of IoT. The main research question answered in this thesis is the following:

"What is the business model for an IoT supported mobile edge computing system to support remote tele-healthcare and what are the (IT) implications for current hospitals?"

Some work with respect to edge computing, as well as fog computing, mobile edge computing and other cloud computing expansions are being intensively researched at the moment. Many of these techniques propagate more interoperability, more extensibility and also the potential for more control on privacy and patient data. Eventually, by using the business model canvas, a business model is defined for edge computing adopted in a remote monitoring IoT setting. Within this business model, several important stakeholders and their requirements are included in the design process of the business model.

In order for the business model to be usable for hospitals and other Dutch healthcare organizations, IT implications and required conditions for the use and adoption of edge computing will be gathered, sorted and previewed for a smooth transition towards a pilot study phase. Several potential techniques and conditional values and setups will be discussed in order to make the design of a pilot study as effortless as possible.

Finally, the designed business model will be validated by several experts in the field of Finance, Digital Transformation, Audit & Assurance and healthcare to make the business model more relevant, and to remove common mistakes and omissions from the business model. The validation session has been designed more or less as a panel discussion of several experts in the above described fields. Concluding the results of the validation, the focus points where on creating value for the patient as the most important aspect of the business model and to make hospitals more interested in the business model. One final remark is the current tendency of storing patient data as close as possible to the patient, the edge computing technology therefore shows great promise of delivering this to patients and hospitals alike.

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List of acronyms

UWB ultra-wideband

DSRM Design Science Research Methodology

WWAN Wireless Wide Area Networks

WLAN Wireless Local Area Networks

WPAN Wireless Personal Area Networks

UID Unique Identifier

DCE Distributed Computing Environment

LPWAN Low-Power Wide Area Networks

IrDA Infrared Data Association

UWB Ultra-Wide Band

NFC Near Field Communication

ICD Implantable Cardioverter Defibrillator

FPGA Field Programmable Gate Array's

BMC Business Model Canvas

ZiRA Ziekenhuis Referentie Architectuur

QoS Quality of Service

UML Unified Modelling Language

ECC Edge Computing Consortium

AII Alliance of Industrial Internet

Chapter 1

Introduction

This point is the beginning of my Master thesis and will provide an introduction to the problem and the related research domain. The research towards a positive business model for edge computing adoption within the health care sector to support adoption of and provide patients with a system for remote monitoring while being in full control of their own medical data. Nowadays more and more criticism on the privacy picture of medical applications is being voiced. This criticism can counteract the use of innovative IT solutions in healthcare. This is a bad development because IT innovations can provide higher-quality care, a reduction in costs and workload within care and the reduction of queues, so that patients can be helped faster. It is also becoming increasingly clear that remote care will become an increasingly important aspect of care, it is of course important that users and interested parties do support this and actively support this type of movement. If this is not the case, the adoption will be delayed. Within this thesis, work has therefore been carried out on a business model for the use of the new technology 'edge computing' for remote monitoring of vital signals from diabetes patients. As well as potentially providing patients with more control over their own generated medical data. This in the hope that IT innovations encounter less resistance because patients gain more control over privacy sensitive data.

The first section will elaborate the context of the current research on the concept of edge computing within the medical IoT domain and an insight onto the Dutch healthcare sector, and also present the organization where the research has been executed. In the subsequent sections the main goal of this research, the problem statement of this research and the formulated research objectives will be covered. At the end of the first chapter the research methodology which has been applied during this research will be formulated.

In the remainder of this thesis state of the art research with respect to relevant research areas like medical IoT, edge computing and business model frameworks is being presented. Subsequently a problem analysis is being conducted including a complete stakeholder analysis. When the stakeholders have been identified through the stakeholder analysis, the business model is presented and IT implications of the system are elaborated on. This thesis concludes with a validation of the business model and a conclusion and recommendations for future research.

1.1 Background

This background section will provide more context for this research. An introduction is made of BDO, the organization where the research is being conducted. Also, the Dutch healthcare will be introduced, and will show BDO's connection to the Dutch healthcare sector. This section will finalize with contemporary and potential technical solutions to current issues within the Dutch healthcare landscape.

1.1.1 Organization

This research is being conducted at BDO Nederland (hereinafter referred to as 'BDO') in coordination with BDO and some of the clients of BDO within the Dutch healthcare sector. BDO is an international organization with an international network. This network consists of so called 'members'. Every country where BDO is active will be a member to this international network. The activities carried out by BDO include accountancy, tax, consultancy and business advisory. Currently, BDO as an organization is shifting more to the digitization trend. The BDO firm in the Netherlands has been founded in the year 2000 from a fusion between the accountancy firms Walgemoed and Camps Obers. The international network of BDO has been founded in the year 1963. BDO has approximately 2000 employees, of which currently 30 are dedicated towards technology and innovations. Also a dedicated group of employees focusses on the Dutch healthcare clients.

1.1.2 Dutch healthcare

The Dutch Healthcare sector has been growing on a yearly base. Within the Dutch care sector you will find three central parties, the Dutch citizens, the Healthcare providers and the insurance companies. According to [26] the Dutch healthcare system is the best healthcare system in Europe but also one of the more expensive systems in Europe. Where the Netherlands healthcare system is only trumped by Denmark, Luxembourg, Monaco, Norway and Switzerland on average costs per citizen. Also, looking at the total costs of the healthcare system, the Dutch healthcare system might be the most expensive of Europe.

The healthcare system can be subdivided by four areas, this is done via four different laws:

Applicable law	**Target audience**
1. De zorgverzekeringswet	All citizens
2. De wet langdurige zorg	Chronically ill or care needed for more then 6 months
3. De wet maatschappelijke ondersteuning	People with disabilities
4. De jeugdwet	Children and young people below the age of 18

Table 1.1: The division of the Dutch healthcare sector by law

The different actors which are apparent in the Dutch healthcare sector are being displayed in the below image from the Health systems review from European Observatory on Health Systems and Policies.

The different types of care present in the Dutch healthcare system is being summarized in the Ziekenhuis Referentie Architectuur (ZiRA). The following types are mentioned within the ZiRA and on the ZiRA website within the '*diensten model*' [27]:

1. Palliative care
   Palliative care does not aim at the healing of a patient, but rather at promoting the highest

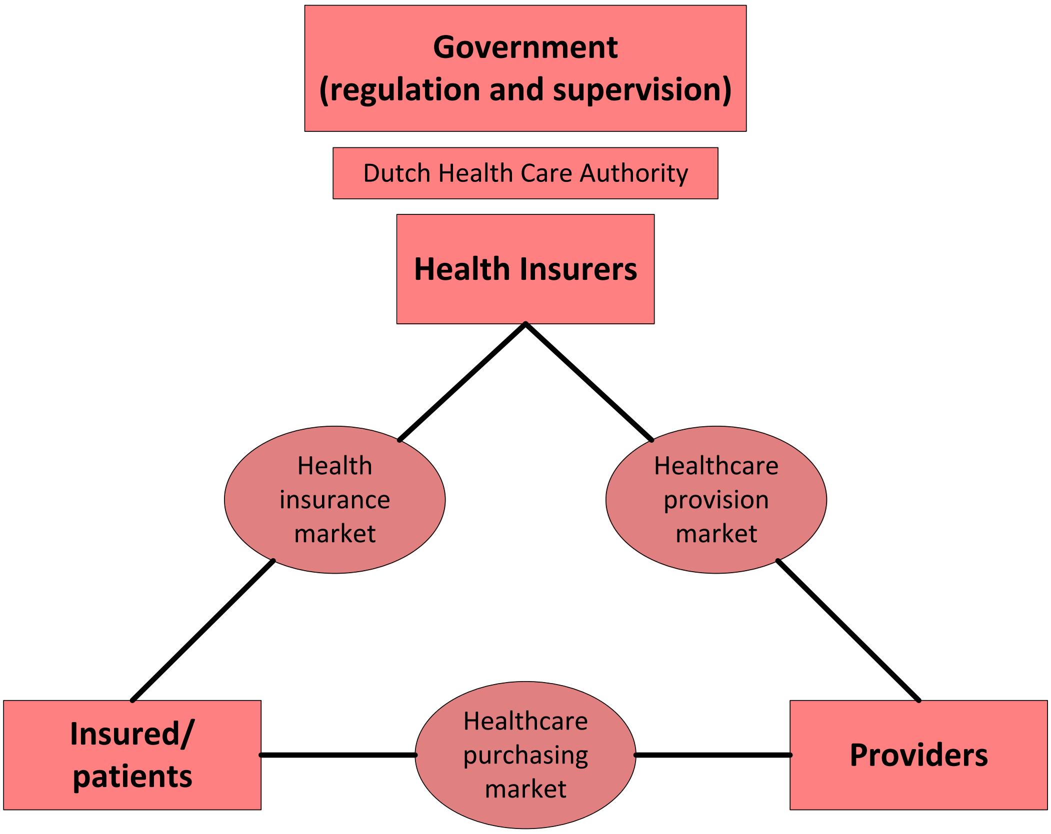

Figure 1.1: Actors and markets in the Dutch healthcare system since 2006 according to [1].

possible quality of life in the final phases of a patient's life. This care tries to provide terminal patients with emotional support and pain relieve for the patients and those in close relation to the patient

2. Chronicle care
   Patient care belongs under the chronicle umbrella if care for a single issue lasts at least six months. Often many different disciplines are involved in the treatment plan for a patient.

3. Elective care
   Elective care is care in which there is a possibility to plan, to some extent, the treatment accordingly to the patient. Therefore, a patient can choose a preferred time for his or her surgical procedure for example.

4. Preventive care
   Within the preventive care domain, a distinction can be made between three different levels: primary, secondary and tertiary preventive care.

   – *Primary prevention* focuses on the prevention of health issues. This is done via for example nutritional advice or health education.
   – *Secondary prevention* focuses mainly on the early discovery of health issues with patients. Mostly risk in particular are included in secondary prevention. A good example of this is

the female population screening on breast cancer.

– *The tertiary prevention* care is aimed at the prevention of recurrence of an existing health problem. Self-measurements and home monitoring are illustrative examples of tertiary prevention.

5. Immediate care
Care falls within this domain if the treatment of a patient must take place as soon as possible and no time can be wasted. Acute care can be subdivided into three separate cares. Emergency care, where an ambulance is dispatched to aid at a car crash for example. Clinical intervention, which is among others, a reanimation attempt. And finally, obstetric care, a good example of obstetric care is the c-section.

6. Urgent care
And last but not least, urgent care, which is a less urgent version of the immediate care domain where steps must be undertaken, but they don't have to be executed at the immediate moment. A good example is the investigation of a knob or birthmark.

As can be seen in **Figure 1.2**, the most fatalities in the Netherlands in 2018, according to statistics of the Dutch Central Bureau of Statistics are disease which have high recurring rates or require constant monitoring like cancer or heart- and vascular disease.

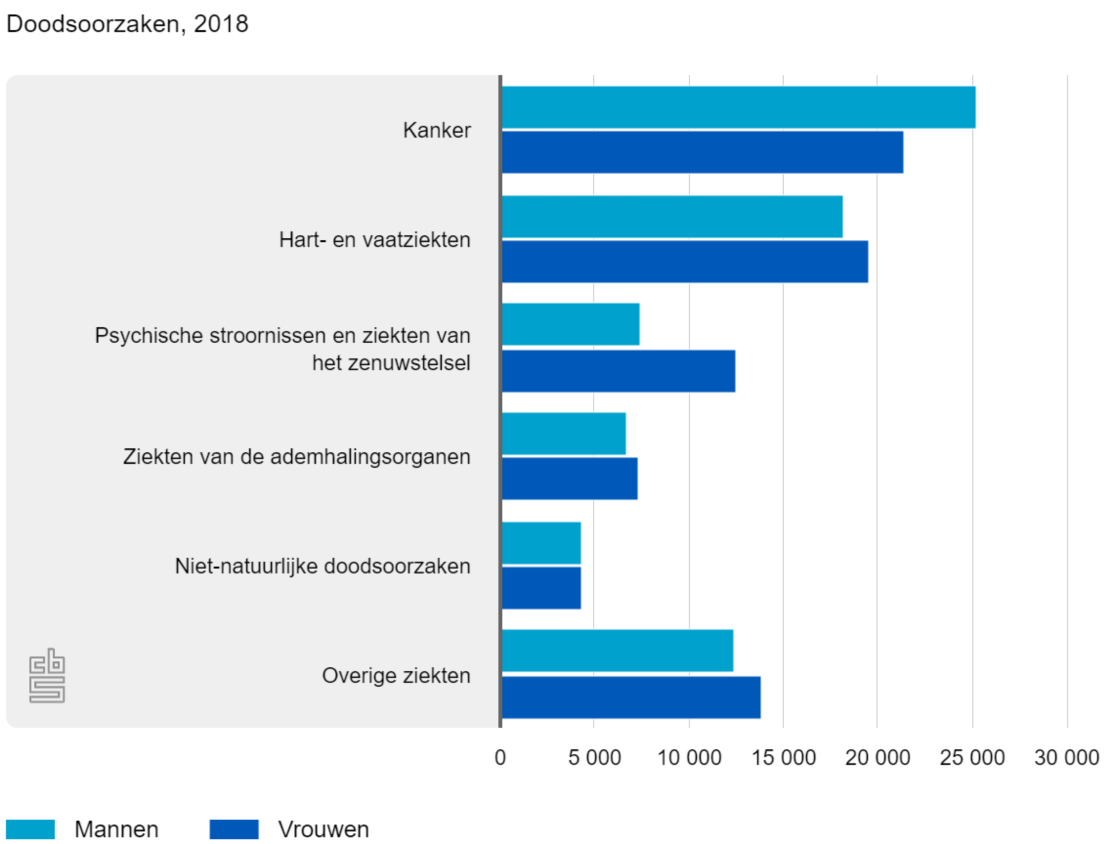

Figure 1.2: Dutch fatalities in 2018 [2]

Also, Nictiz, which is the Dutch e-health expertise center and contributes to better health through better information. Nictiz states [28], in their yearly report on e-health usage within the Dutch healthcare, that health professionals are being more and more positive about the influence and effects on e-health solutions on the healthcare processes. The report also mentions several goals formulated by the then Minister Schipper of the Ministry of Health, Welfare and Sport. The following goals where formulated for the Dutch healthcare system within the 2019 e-health report of Nictiz [28]:

1. *Digital access to medical data for the patient and online viewing possibilities.* The awareness of the possibility to access health data online is to low. This goal has been formulated by the Dutch government in order to improve awareness of this online possibilities in particular to healthcare users and chronically ill.

2. *The possibility of 'self-measurement and tele-monitoring'.* 4 out of 10 chronic sick people will check their health values themselves in 2019, whether or not automatically. The use of tele-monitoring among medical specialists is also increasing. This is much less the case among general practitioners and nurses (in elderly care). Self-measurement and tele-monitoring improve the self-reliance and quality of patients' lives. In addition, it relieves the medical staff enormously. The more patients use (or can make) self-monitoring, the higher the quality of care.

3. *Promoting the use of 'screen care and home automation supported care'.* By promoting the use of screen care and care supported by home automation, patients will have the possibility to stay home for a longer time. This trend will improve the well being of patients, as well as quality of care and will relieve medical support staff of work pressure.

1.1.3 Current problems in (Dutch) healthcare

As stated in the subsection before, the Dutch healthcare system belongs to the most expensive of the European union and maybe even of the world. The total costs of the Dutch healthcare system according to Zorgwijzer [29] accumulate to 97,5 billion euro's in 2017. And, according to the Central Bureau of Statistics, in 2018 the 100 billion euro mark has been crossed [30]. These enormous costs on a population of around 17 million citizens put enormous pressure on the affordability and sustainability of the Dutch health care system.

Several points are being made with respect to the quality of the Dutch healthcare system and the rising costs of the healthcare system. Sources like BDO, KPMG, RTL nieuws, Medicalfacts and the NVZ which is the Dutch Association of Hospitals all point out the same things:

- Financial health of hospitals is declining [31], [32].
  - A decrease in financial return
  - An increase in healthcare costs
- Enormous increase in patients [31].
  - Elderly patient support
  - Chronically ill
  - Dementia and other senior diseased patients
- Insufficient healthcare personnel [33].
- Increased pressure on current healthcare personnel [34].
- Slow adoption of new technologies in the Dutch healthcare system [*Mark Wagenaar, Lead Architect NWZ*].

And even though research from the Health Consumer Powerhouse [35] and the OECD and European Observatory on Health Systems and Policies [36] state that the Dutch health care system is effective and accessible. Both researches though, also put a nuance to this statement informing us that the cost drivers of the Dutch healthcare system are under pressure and can't be uphold like this forever.

An other factor, besides increasing healthcare costs is the aging population of the Netherlands. Dutch newspapers already published articles about the impact of the aging population on the Dutch healthcare system dating back to 2004. Here, *'de Volkskrant'* published an article in which, based on CBS numbers dating from 2002, it is presented that the aging population will induce an extreme increase in costs because of the growing number of people which will be in need of healthcare. Also, *Zorgenstelsel.nl* [37] brings us numbers about the Dutch aging population showing that the Dutch population indeed is aging rapidly, based on numbers of the 'Volksgezondheid Toekomst verkenning' (VTV) which shows an astonishing increase of + 55% of 65 and above and an even bigger + 191% increase of 90 and above.

In response to this aging population it can be assumed that the pressure on healthcare personnel will increase accordingly. More people to take care for imply that healthcare personnel will have to care for more people then say 20 years ago. Several Dutch sources report on this among others the Dutch news organization NU.nl, an investigative journalistic part of national channel the AVROTROS, the Central Bureau of Statistics [38], [39] but also nursing research articles found on SpringerLink [40], [41] show us the ever growing pressure on Dutch healthcare personnel on a scale where it actually leads to decline of quality in the healthcare and repression of healthcare personnel from management or board.

Where BDO in its Zorg manifest [31] states, that in order to improve the Dutch healthcare system the Netherlands should facilitate a fitting data infrastructure and innovation and digitization in the healthcare system. Not only to decrease the cost of caring for a patient, but also to relieve current health care personnel from the enormous pressure they are under at the moment. This will make sure that health care personnel have more time treating those patients which directly need care, ensuring other care can be facilitated with digital innovation. Preventive care, one of the main care pillars in the Dutch healthcare shows a lot of promise for digital innovation. But, as can be seen in **figure 1.3**, currently there is no prominent role for IT innovation within the healthcare process ass defined within the ZiRA.

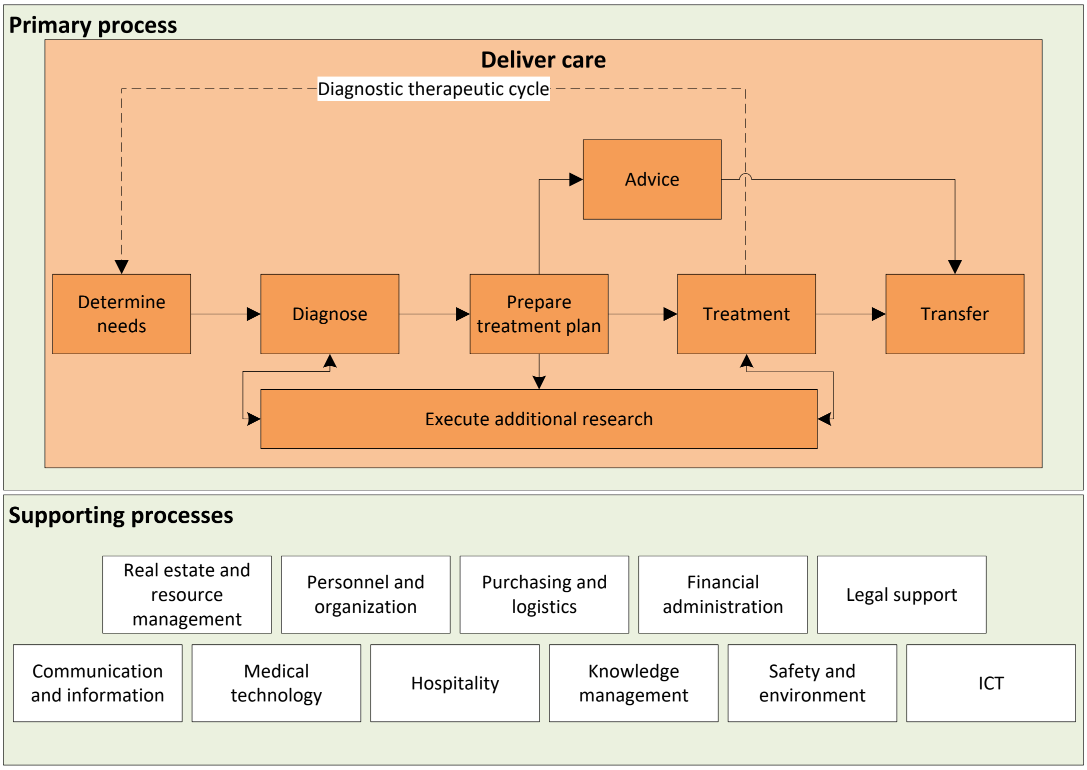

Figure 1.3: ZiRA defined processes of the Dutch health care system [3]

A final problem that is currently hampering digital innovation within the Dutch healthcare system is the meticulous testing on compliance to (privacy) rules and regulation. Mark Wagenaar, a lead architect of the Noord West Ziekenhuisgroep stated in an interview that it takes 5 – 10 years for an organization to get their product certified so that a hospital, or any other healthcare institution, is allowed to use it. With the current rate at which IT innovation are created, a waiting period of 5 – 10 years will effectively kill all relevant digital innovation within the healthcare system.

1.1.4 The need for IoT

The use of IoT in a medical setting is ever increasing. The global IoT in healthcare market size is projected to reach a stunning 534.3 billion USD by 2025 according to [42]. Whereas overall estimates vary between a couple of hundred billions up to 534.3 billion, an equal consensus with regard to the growing IoT market within the healthcare sector has therefore not yet been reached. Although there is still no clear consensus, it is clear that the medical IoT market is booming at the moment and amassing more and more momentum as we speak. [23] presents several advantages and disadvantages of the use of IoT in a medical setting in **Table 1.3**. These disadvantages can be seen as a cause of the relatively slow acceptance and implementation of medical IoT solutions within the healthcare sector in the Netherlands, when compared to markets such as the United States or China where significantly more is invested in these types of solutions. Some interesting statistics about IoT and the healthcare sector have been gathered via open sources and presented in **Table 1.2**.

Global Medical IoT market statistics
1. The global market size of the Internet of Things in healthcare was $147.1 billion in 2018.
2. The global market size of IoT in healthcare is expected to exceed $500 billion by 2025.
3. Almost a third of all medical organizations in the world have adopted some healthcare IoT technology.
4. 73% of healthcare organizations use IoT for monitoring and maintenance.
5. The U.S.A. alone could save $175 billion on healthcare by halving administrative costs.
6. The number of IoT devices in healthcare will double from 8.5 million in 2015 to 17.3 million in 2020 in Europe.
7. The global IoT healthcare market is growing at an unbelievable 30.8% per year.

Table 1.2: Medical IoT statistics surveyed under recipients among 20 countries [21] & [22].

According to, among others, [7], [43] IoT-based smart rehabilitation is just one of the more recent introductions to the medical IoT for the problem of scarce resources due to aging population. A problem that is found in most western countries. IoT systems have come a long way since the beginning of which IoT has been introduced as an 'auto-ID' which could represent any sort of identification technology together with a Electronic Product Code network which made it possible to track the object. This electronic product code network was the beginning of the IoT paradigm [7]. From those beginning days IoT is being used, implemented and researched more and more and also covering a more broad area then ever before. A good example of this is the introduction of medical IoT systems. These medical IoT systems don't differ from regular IoT systems only in the sense that the sensors, networks and other elements of the IoT system are being used to pursue medical goals. An overview of several advantages and disadvantages of IoT use in medical settings is shown in **Table 1.3**.

Besides, [44] states that the Internet of Things has been defined by the International Telecommunication Union and European Research Cluster on the Internet of Things as *"a dynamic global network infrastructure with self-configuring capabilities based on standard and inter-operable communication protocols where physical and virtual things use intelligent interfaces and are seamlessly integrated into the information network"*. This definition with regard to IoT, though this definition can also be mirrored to the medical IoT domain. This can be found in the way sensors and actuators within these medical systems are being implemented and used. For example, an IoT system for heart rate monitoring, these kind of systems require constant communication with different systems, therefore standard and inter-operable communication is necessary for this kind of system, as well as the constant processing and analysis of data gathered by the sensors.

A few distinct definitions of Medical IoT have been found in literature and on the web, because of the novelty of this concept, all three found definitions will be presented here. [45] proposes the following definition of Medical IoT: *Medical Internet of Things is the group of devices connected to Internet, to perform the processes and services that support healthcare* [46] proposes the next

		Explanation
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.
	Sensing	IoT with intelligent medical sensors will enhance the quality of life significantly and prevent the occurrence of health problems.
	Low-cost solutions	Reduce unnecessary visits by doctors, and re-admissions come from patients with chronic diseases and reduce testing cost.
	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.
	Better quality	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.
	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.
	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.
Disadvantage	Complexity	The IoT is a diverse and complex network. There is a need of multi-ple 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.
	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.
	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.
	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.

Table 1.3: Advantages and disadvantages of IoT use in a medical setting [23]

definition found: *The so-called medical Internet of Things is a kind of technology that embeds wireless sensors in medical equipment, combines with the internet and integrates with hospitals, patients and medical equipment to promote the new development of modern medical model.* And finally, [47] proposes: *The Internet of Medical Things (IoMT) is the collection of medical devices and applications that connect to healthcare IT systems through online computer networks. Medical devices equipped with Wi-Fi allow the machine-to-machine communication that is the basis of IoMT. IoMT devices*

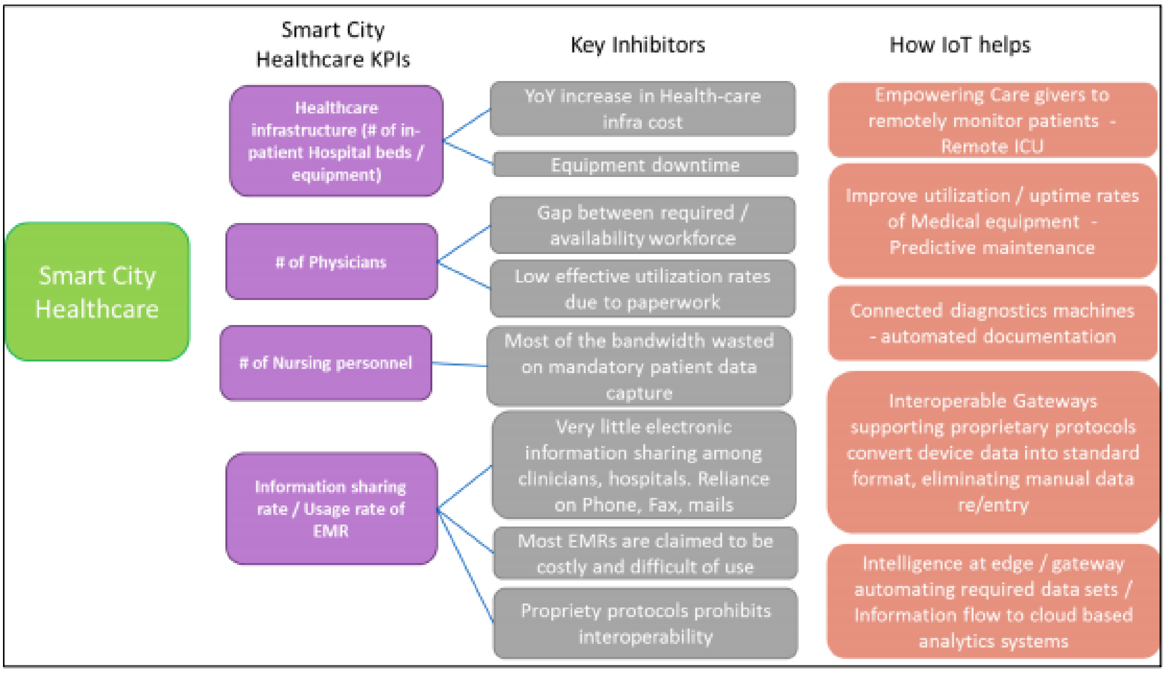

Figure 1.4: Smart City Healthcare (KPI's - Inhibitors - IoT) [4].

link to cloud platforms such as Amazon Web Services, on which captured data can be stored and analyzed. IoMT is also known as healthcare IoT.

Literature also contributes different expressions of the concept, names like Medical IoT, Internet of Medical Things, Cyber-Physical-Human Systems, E-Health and Health IoT are names that have been given to these systems be researchers. In order to maintain a clear and unambiguous vision during this research, building upon the foundations of the IoT with the goal to aid people and healthcare organizations in improving and streamlining medical efforts for patients as well as doctors, nurses and other professions within the health care sector are key factors in explaining goals of these systems. For clarity throughout this research. The definition of [45] for Medical IoT will be used because of the concise and clear definition and similarities of our own vision of Medical IoT systems.

[4] shows us in the below image which key inhibitors are currently present for smart city healthcare KPI's and states current possibilities to how IoT can help overcome these inhibitors: And these KPI's and inhibitors match the current challenges faced by the Dutch healthcare system. Therefore, IoT shows significant promise in helping oppose these developing problems in current western healthcare systems like the Dutch healthcare system.

To conclude, the use of IoT within the Dutch healthcare system can greatly improve performance and quality of the healthcare system, as well as have the potential to decrease costs of healthcare by allowing patients to monitor themselves instead of being hospitalized for certain ailments. However, Complexity, compatibility and the security and privacy issues that go along with the availability of an enormous amount of medical data are reasons to not adopt IoT solutions within the Dutch healthcare system. Also, the testing and certification of new and innovative technologies in combination with these aspects can significantly reduce adoption willingness. It is therefore of the upmost importance that a solid, clear and concrete business model can be created incorporating IoT and other techniques and innovation to battle the aforementioned issues of IoT in healthcare making it possible for IoT to battle aforementioned issues within the current healthcare system.

1.1.5 Edge/Fog computing

Another technology that is proposed alongside the use of IoT in the medical domain is edge- and fog computing. Fog computing is a relatively new technology within the medical domain, and having said that, fog computing is a very new technology anyway, about which little research has been done so far. [48] defines fog with the following definition:

> ”*Fog computing is a decentralized computing infrastructure in which data, compute, storage and applications are located somewhere between the data source and the cloud. Like edge computing, fog computing brings the advantages and power of the cloud closer to where data is created and acted upon.*”

And, as already stated earlier introduced by Cisco. Also fog has been introduced by [49] as: ”*a highly virtualized platform that provides compute, storage, and networking services between end devices and traditional Cloud Computing Data Centers, typically, but no exclusively located at the edge of network*. Besides Cisco, [50]–[52] and many more support the idea of fog computing being an extension of the Cloud and not a complete replacement.

The concept of fog and edge computing show promise in creating a safe, privacy aware and secure IoT environment because it potentially addresses the most problems incurred by the use of IoT and Cloud in the medical domain. Fog and edge computing show the potential to not only deal with non-repudiation but shows multiple advantages. According to [53], the advantages can be summarized with the term SCALE, this stands for:

- Security
- Cognition
- Agility
- Latency
- Efficiency

As of yet, the use of fog computing in collaboration with IoT within the medical domain is a new concept that is not yet being applied in practice. However, theoretical research is available with regard to IoT and fog computing within the medical domain. Also, the concept of fog computing has been described as the next step in Cloud computing and shows promise in several different sectors according to [54], like smart city concepts, vehicular fog concepts, smart grid concepts and healthcare concepts.

There is a clear need in healthcare systems to increase efficiency, low cost solutions and better quality of healthcare and on the other hand also maintain security and privacy standards as well as maintaining compatibility and complexity levels. As of yet, the creation and use of IoT in combination with fog computing to support future health care innovation has not yet gone far beyond academic explorations and has only been described as visions for health care solutions. For health care systems, fog computing has been described as a central layer between the application layer and the Cloud layer [52] that facilitates the use of IoT for several smart health care applications. Questions remain regarding the role and function and viability of fog computing with the Dutch healthcare system. Furthermore, the implications of fog computing for the involved stakeholders are not yet understood.

- To design and validate a business model and case for IoT driven healthcare services; and
- To document the IT implications of the medical IoT system for the stake-holders

...in order to promote the use of remote health monitoring applications within the Dutch healthcare. The contribution of this research will therefore be a starting point for further medical research into the integration of IoT and remote monitoring solutions in the treatment of patients within the Dutch healthcare. This is achieved by developing a business model for remote monitoring health applications through the use of IoT.

1.2 Goal and research questions

For a successful research, a clear, concise and concrete research question is indispensable for the quality and progress of this research. The problem statement and the goal of this study are used to formulate the main research question. To start off, the goal of this thesis is twofold:

- To design and validate a business model for IoT driven healthcare services; and
- To document the IT implications of the medical IoT system for the stake-holders

...in order to promote the use of remote health monitoring applications within the Dutch healthcare. The contribution of this research will therefore be a starting point for further medical research into the integration of IoT and remote monitoring solutions in the treatment of patients within the Dutch healthcare. This is achieved by developing a business model for remote monitoring health applications through the use of IoT.

Besides the goal of this thesis, the main research question will be important as it will guide the research through the entire life cycle of the project. The following main research question has been formulated for this research towards the use of edge computing and IoT within a remote monitoring health care setting:

What is a business model for an IoT supported mobile edge computing system to support remote tele-healthcare and what are the (IT) implications for current hospitals?

To keep this thesis structured and organized, the main research questions has been subdivided into several successive sub questions. The structure of the continuation of the thesis will also conform to these prepared sub-research questions and therefore the answers will be provided consecutively throughout the thesis.

RQ1 *What is the current state of IT being used in healthcare?*

The answers to the above stated sub question will be provided in the literature review section. They provide an understanding of how IoT currently is being used in healthcare for healthcare services.

RQ2 *Which stakeholders are present within the Dutch healthcare chain?*

RQ3 *What is the business model for IoT driven edge healthcare services?*

RQ4 *To what extent does the business model fulfil the needs of the stakeholders?*

In order for the business model to be viable, it will need to deliver value to the involved stakeholders. The developed business model is validated by stakeholders and experts in the field on the likelihood of adoption and will be adjusted where necessary according to feedback received from these stakeholders and field experts.

RQ5 *What are the IT implications of the IoT business m odel for the key stakeholders?*

In order to improve adoption and digital transformation in the Dutch healthcare sector, guidelines and implications of the business model for the current (ICT) environment of healthcare providers are presented.

RQ6 *How can we evaluate and validate the business model?*

Finally, we want to evaluate whether the proposed business model is a viable case for any of the stakeholders. For the evaluation we will draw on the expertise of external stakeholders and experts in the field.

1.3 Research Methodology

This section provides information about the research methodology employed during this research. An introduction is made on the research approach, subsequently different forms of data and knowledge gathering are introduced, respectively *literature reviews* and *expert interviews*. Finally, the way the business model design is made is introduced and described.

1.3.1 Research approach

In order to conduct this research study, the method used is that of the Design Science Research. Design Science Research has proven to be a useful method when research with respect to the development of information systems is being conducted [55]. They also mention various characteristics of design science problems which make this research extremely suitable for design science research. Here, the utility of the artefact is the main goal in this research, where the artefact will be a blueprint of a fog computing medical IoT system based on a business model framework. The business model framework used in this research will be further explored in section 1.3.4

To structure the current research, the design science research methodology of peffer has been reviewed and chosen as structure for this research. The Design Science Research Methodology (DSRM) as defined by peffers, Tuunamen, Rothenberger, & Chatterjee [5] will be applied. Figure 1.5 shows the graphical visualization of the entire DSRM process. Based on the DSRM, the following phases have been distinguished in the current research:

1. **Problem identification & motivation**
   During the initial phase, the research problem is being identified and defined, and the research motivation showing the importance of this research is presented.

2. **Define objectives of a solution**
   During this second phase of the DSRM the objectives of this research will be defined. This includes a definition of how the, to be designed, blueprint is expected to support solutions to the problems addressed in the previous phase. Often used resources include knowledge of the state of problems and current solutions to these problems.

3. **Design & development**
   This third phase involves the design and development of the reference architecture, describing the to-be situation of the state of fog computing within a medical IoT system setting using a business model.

4. **Demonstration and evaluation**
   The DSRM proposes separate phases for *Demonstration* and *Evaluation* purposes. A thorough demonstration and evaluation of this Master research though, goes far beyond the existing possibilities of a Master research. Therefore, for the purpose of this research the phases demonstration and evaluation have been aggregated into a single phase. In this phase, the reference architecture is presented to experts in the field and validated by means of a structured interview in order to measure how well the reference architecture has been defined and contribute to further developments.

5. **Communication**
   Finally, the research will be presented in a colloquium that is part of the examination of the master project by the examination committee. In addition, the main results of the current research will be processed into a business white paper for BDO and its clients.

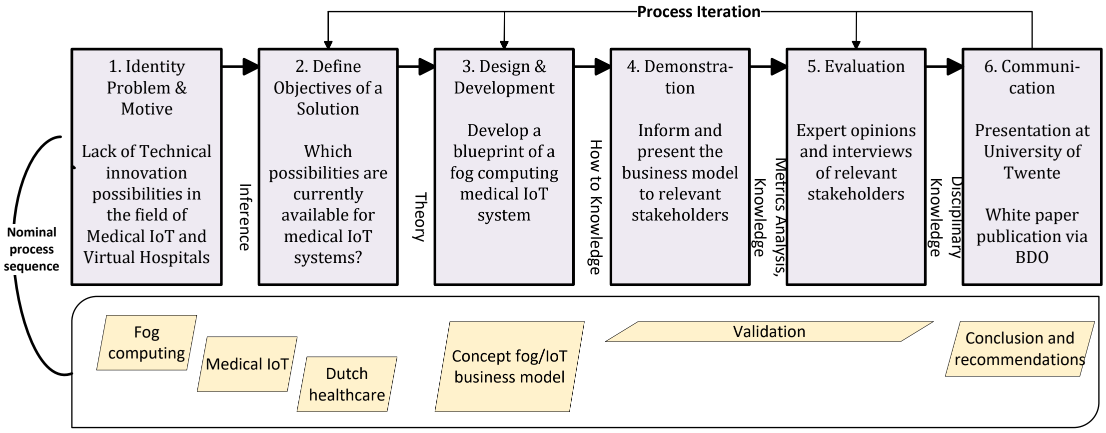

Figure 1.5: Research approach based on DSRM [5]

As can be seen in **figure 1.5** the research generally consists of six distinct phases. During this research most of the activities of phase one and two have been combined. The same holds truth for phases four and five. This has been done because the outcome of the phases collide making it a logical step to merge the phases together up to a certain point.

1.3.2 Literature review

The phases one, two and three, Problem identification & motivation, Define objectives of a solution and Design & development are primarily done through literature review. Literature has been selected from a broad range of different sources. In addition to relevant scholarly articles and papers, white papers and so called technical documentation of commercial parties have also been used in this research. Finally, relevant internet sources, blog post and online statistical databases have been consulted for this research and adopted in the thesis. The relevant literature is identified from the available scholarly databases. The databases used for this literature review are IEEE Xplore®, SCOPUS, Google Scholar, ScienceDirect and Web of Science. The search strategy applied for these databases involved a number of key words used to search for relevant material for this research.

For the execution of this literature review, a systematic review will be performed in order to the map current state of the fog computing literature. According to [56] a systematic review outperforms a regular review because you get a much more complete image of the current state of the art with respect to the investigated topic. As for where a regular review mostly is biased towards the opinion of the researcher and therefore doesn't give an independent and complete image of the current state of the art.

In order to search for relevant literature for this research, [56] mentions six different search methods.

1. Search texts for keywords
2. Search based on references/footnotes (Snowball technique)
3. Consulting experts
4. Searching within 'Subject Indexes'

5. Browsing in libraries
6. Citation indexing

And for this systematic review, the methods (1) and (2) will be used to gather relevant literature and information. After completing the searches, the title and abstract where used to determine the relevance of the papers in order to adhere method (1). To adhere to method (2) during this literature review, the list of sources used for the chosen relevant papers where also examined in order to find any other relevant sources of literature for this research.

1.3.3 Expert interview

As a follow-up to the literature study conducted, which, among other things, revealed a problem statement and research questions, interviews will also be held with experts from the professional field. For example, various medical experts in the field of business and IT are being interviewed to support the preliminary work that has been done through literature research. The interviews conducted were set up and held in an unstructured manner in order to gather a range of perspectives on the subject under investigation, both from technical experts as well as managerial experts in the medical domain. Open interviews are desirable during this phase of the research in order to prevent tunnel vision within the investigation.

During the design and validation phase of this research, more structured interviews will be held with, preferably, the same experts in the field. The more structured character of these interviews will allow for any deviations. This because it is vital for this research to have a more flexible approach taking into account the more exploratory nature of this research. The final goal of these semi-structured interviews is twofold. On the one hand, the expert interviews will result in valuable input regarding the creation of a fog computing medical IoT system blueprint, the artefact of this research. On the other hand, the expert interviews are used to validate the model and propose improvements to the artefact if needed. This way, the artefact will gain usability towards the relevant stakeholders. Together with the findings in the literature study, these results will be used to answer the research questions posed in this thesis.

1.3.4 Business model design

The tele-health system is designed through the method of business modeling. This is a process of designing business models to a specific nature. For this research, a business model for hospitals taking into account the new technology concepts of fog computing and IoT will be created. [24] states in his phd research the following definition of a business model:

A business model is a conceptual tool that contains a set of elements and their relationships and allows expressing a company's logic of earning money. It is a description of the value a company offers to one or several segments of customers and the architecture of the firm and its network of partners for creating, marketing and delivering this value and relationship capital, in order to generate profitable and sustainable revenue streams.

After reading the definition by Osterwalder, one can reason that a business model demonstrates a kind of structure with respect to revenues and costs associated with the costs of operation and architecture required for the business to run. One can assume a business model design helps decision makers communicate and asses the business.

The business model concept, as presented by Osterwalder will be used to better understand and think about the possibilities of, and needs of stakeholders from, a fog computing assisted medical

IoT system. Within this study, the Business Model Canvas (BMC) will be used to understand the business logic of the fog computing assisted medical IoT system(s). During this study, the BMC has been chosen because it has proven to be a successful and complete framework, and besides, has been used in many business and during many studies. The foundations of the BMC have been laid down by Osterwalder in [57] where he proposes the building blocks of the later created BMC. The following pillars and building blocks where proposed by [57]:

- Product pillar
  - Value proposition
- Customer Interface pillar
  - Target Customer
  - Distribution Channel
  - Relationship
- Infrastructure Management pillar
  - Value Configuration
  - Core Competency
  - Partner Network
- Financial Aspects pillar
  - Cost Structure
  - Revenue Model

Osterwalder further works these building blocks out, eventually creating the BMC [10]. In this design study, Osterwalder used the business building blocks from previous research and created the canvas. During this research osterwalder also changed his definition of a business model from his earlier definition from [24]. In [10] Osterwalder defines a business model as follows:

A business model describes the rationale of how an organization creates, delivers and captures value

[10] created a canvas as can be seen in image 2.5. Thus far, the use of business modeling techniques for the use of fog computing within medical IoT applications has been limited to non existing. So far, no clear business model has been designed and developed. In order to complete the building blocks associated with the BMC for fog computing within medical IoT applications, current IoT business models, as well as regular business models with respect to hospitals and healthcare will be analyzed. Also, a review of academic and professional publications on these topics have been conducted and combined with current available literature with respect to dutch healthcare business models, IoT business models and relevant stakeholders.

Chapter 2

State of the art

Within this chapter some state of the art will be presented with respect to three subjects. The following three relevant topics will be discussed in this chapter subdivided by sections:

1. Previous work
   Within previous work, several relevant literature about edge computing, fog computing and other relevant technologies mentioned within the research topics assignment named: '*Fog computing and its applications in the health sector*' is presented.

2. Medical IoT
   The medical IoT sections presents several IoT applications within health care and medical context. It also provides some information about relevant reference architecture models for remote care and IoT within the medical domain.

3. Business models
   The business models section finally presents two different business model frameworks and approaches to use in this research. Both the business model canvas as well as the e3 value model are briefly explained and elaborated.

The goal of this section is to present state of the art literature about subjects relevant to this research providing context and scientific support to this research.

2.1 Previous work

Within my research topics named: '*Fog computing and its applications in the health sector*' an exploratory literature research has been conducted to the possibilities of fog computing and other related edge computing concepts. Several survey papers with respect to concepts like edge computing, fog computing and Cloudlets have been studied and consulted. And also literature with respect to the security of edge computing and overall surveys with goals of identifying and categorizing these new cloud and edge paradigms. In **table 2.1** an overview of some relevant literature has been presented based on topic.

Most of the literature argues that fog computing, as well as edge computing show great promises in fields like 5G technology, self driving cars and vehicular fog networks, health care, latency reduction and within industrial control systems where limited internet connectivity is available. Though it can be argued that more research into the feasibility and usability of application is needed before large scale tele-health IoT systems can be specifically introduced within the healthcare sector.

Aspects	Survey Papers	Contributions
Cloudlets	[58]	An open ecosystem based on the concept of cloudlets.
	[59]	A cloudlet-based architecture.
	[60]	A Context-Adaptive Middleware for Mobile Edge and Cloud Computing Applications.
Edge computing	[61]	A comparison of the standardization efforts, principles, architectures, and applications of three edge technologies.
	[62]	A comprehensive study of recent edge advancements.
	[63]	The promise of Edge computing
Fog computing	[51]	A comprehensive survey on fog computing. It critically reviews the state of the art in the light of a concise set of evaluation criteria.
	[64]	Presenting an fog architecture overview, service and resource allocation approaches and an extensive overview of state-of -the-art network applications.
Edge security	[65]	This paper provides an overview of existing security and privacy concerns, particularly for the fog computing
	[66]	The relationship between IoT and fog computing and their security issues and solutions by different researchers.
	[67]	Holistically analyze the security threats, challenges, and mechanisms inherent in all edge paradigms.
Complete survey	[50]	First to provide tutorials, next to provide a taxonomy and through a comprehensive survey, we summarize and categorize the efforts on fog computing and its related computing paradigms
	[68]	This comprehensive manifesto brings cloud advancements together and identifies open challenges that need to be addressed for realizing the Future Generation Cloud Computing.

Table 2.1: Overview of current existing survey articles on Edge computing and related concepts

2.2 Medical IoT systems

The field of medical IoT applications is relatively novel and builds upon the advancements in the field of the IoT. In this chapter the fundamentals and background of IoT, along with the relation towards medical systems are explained and how this is being applied in current medical settings. Subsequently, various limitations of the current medical IoT systems are mentioned. In response to that, various state of the art is presented in potential solutions to improve these medical IoT systems and patient care. To conclude, a problem analysis will be presented proposing a solution to the described problems of medical IoT systems in their current state.

2.2.1 Current situation

The current situation of patient monitoring, and most importantly remote monitoring, consists for the most part of medical devices who send data to care givers. According to [69] the biggest part of remote monitoring consists of pacemakers and Implantable Cardioverter Defibrillator (ICD) systems for the monitoring and reaction to heart patients. Besides these heart monitoring systems, the current growth area's can be found in the sleep therapy. The third major segment can be found within the *'tele health'* and is being defined as communicating with a doctor or other care giver at a distance. A live feed with a specialist at a hospital is a good example of this.

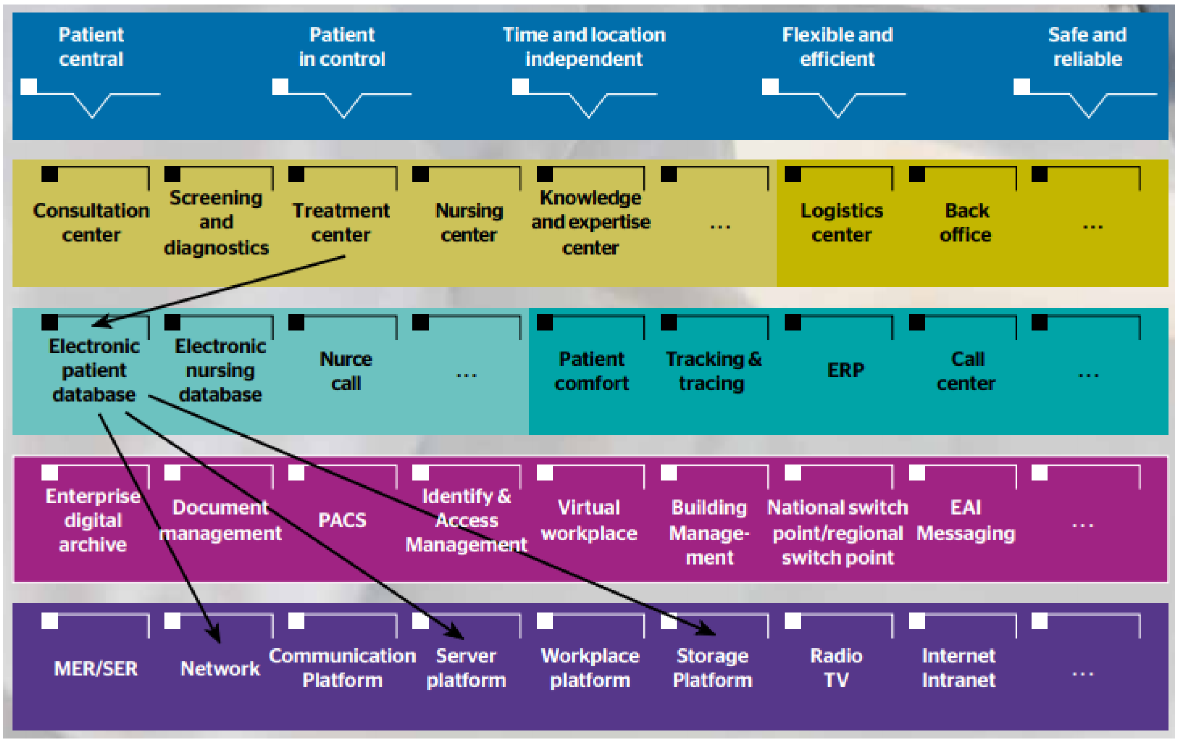

Figure 2.1: Basic healthcare reference architecture by Atos [6]

Also, according to Nictiz, mostly the use of patient portals and the connected EPD are being deployed and actively used within hospitals and their patients. Nictiz [70] has organized several meetings in recent years in which patients, healthcare providers, project leaders and information managers talked about their experiences with the implementation of a patient portal and its use. During these meetings there was a great need for it more insight into the user numbers of patient portals. Insight into user numbers is possible namely an important input for a targeted communication strategy on the portal.

Portals are more often used around outpatient visits and by 60-79 year old patients [70]. Besides, about half of the hospitals being included in the study provides insight into the percentage of patients that of a portal used after contact with a hospital care provider. This usage rate is between 5% and 20%, with an average of 12.5%. The patient portal seems about it generally used more often by patients visiting the outpatient clinic (average user rate of 22.2%) and by patients between the ages of 60 and 79 years (31-40%).

Atos has described the following regular IT reference architecture for hospitals [6] as can be seen in **image 2.1** shows a big dependence on the electronic patient database where most of the information is being stored. Also, most of the applications being used rely on the information from the electronic patient database. Besides Atos, also Nictiz created a regular reference architecture for hospitals, mainly focused on the Dutch hospitals. Currently, all the data gathered and stored within Dutch hospitals is being kept in the EPD, the Dutch equivalent of the electronic patient database. And these EPD systems are generally delivered by Chipsoft, as already showed in the previous chapter where the distribution of Chipsoft's EPD system among the Dutch hospitals has been presented. The patient file and the patient portal are becoming more and more important, not only to hospitals but also to patients because it allows them to keep a closer eye on their own medical data. As is also shown in the above statement about usage numbers of the patient portals by [70].

2.2.2 Enabling technologies

[7] presented several enabling technologies. These enabling technologies for MIoT can be further divided in three sub levels. *Identification technologies, Communication and location technologies* and *Sensing technologies*.

Identification technologies

According to [7] an increasingly amount of of data generating and processing nodes will be introduced. This because of the large amount of smart sensors and actuators being introduced in these MIoT systems. Identification of the correct unit in the system is of upmost importance for doctors and nurses associated with a patient. In order for this system to work correctly, all systems must be associated with a digital Unique Identifier (UID). As part of the interoperability of these kind of systems, a framework standard for identification could prove usefull. [7] states that the Open Software Foundation developed a universal unique identifier as part of the Distributed Computing Environment (DCE). Though currently even the need for multiple identifier support for sensors and actuators is increasing.

Communication technologies

Communication technologies play an important part within IoT systems, and therefore also in MIoT systems. These communication technologies can be subdivided into long-distance and short-distance communication technologies. Important long-distance and short-distance technologies can be grouped into three major areas according to [53] into Wireless Wide Area Networks (WWAN), Wireless Local Area Networks (WLAN) and Wireless Personal Area Networks (WPAN). [53] notes the most important cellular technologies for WWAN networks as 3G, 4G LTE and 5G with minimal featured transfer rates (>1Gbps). Important to note is that the more southbound in the network (e.g. the closer to the edge) the lower the data rate requirements per element become. This for the obvious reason that the closer to the edge, the smaller the data packets, and after aggregation data gets combined more and more on less devices therefore increasing the need for higher transfer rates per element. For those scenario's where low power is available, Low-Power Wide Area Networks (LPWAN) is mentioned as a potential solution being tested by the LoRa Alliance and Sigfox and show potentially great promise in supporting IoT systems

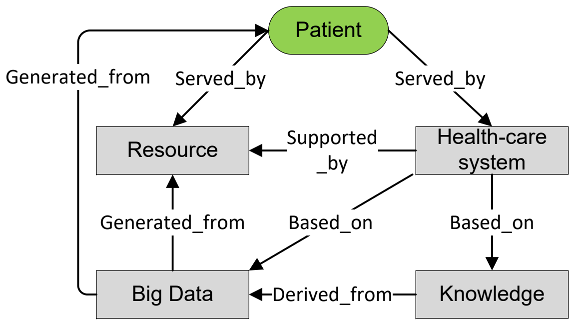

Figure 2.2: Semantic relations among key methodologies in IoT-based systems according to [7]

WLAN, according to the following sources [7], [53], [71] utilize several topologies 's and protocols even though mainly associated with WiFi. WiFi is just simply a trademarked phrase that means IEEE 802.11x which is a generic term to refer to the IEEE 802.11 standard for defining communication over a wireless LAN (WLAN). Finally there is WPAN, which can be found in the lowest layers of an MIoT system architecture. [7] and [53] propose the following technologies as enablers for WPAN networks: Bluetooth, Near Field Communication (NFC), Infrared Data Association (IrDA), Ultra-Wide Band (UWB) and ZigBee. These technologies mainly focus on short range data transmissions and low data transfer rates making it ideal for home network or other edge or near edge networks in MIoT systems. This makes these techniques ideal for the lower levels of an MIoT architecture. [7] finally proposes the following semantic relations among key methodologies in IoT-based systems as can be seen in **Figure 2.2**

An example of medical IoT currently being applied in the Netherlands is Bio-Sensor from Philips. A Dutch hospital, NWZ, was one of the first hospitals in the Netherlands to start a half year lasting pilot study with the Bio-Sensor system. Though in the end the system did not make it through the pilot study for several reasons. Firstly, the used components where very old, making it prone to security issues. Also Rijnstate Ziekenhuis is currently working with the Bio-Sensor system to implement as a way of introducing remote monitoring of patients in a cooperation with Vitalys and Phillips. Also, an artificial pancreas has been developed by a Dutch researcher automating the process of glucose measuring and insulin and glucagon administering. This system has been setup as a standalone system and therefore no data is being transferred to a hospital, specialist or GP. Privacy wise, this setup has a lot less risk involved then remote connected systems, though with current innovations on data analysis one could argue that using a stand alone system would ignore the enormous possibilities introduced by data analysis on the gathered data.

A sole solution focused on the IoT aspect of it all is proposed by [8] in a book about an IoT reference architecture. In this work, the following transport monitoring example has been highlighted by [8] in **figure 2.3**.

However, [8] also states that in order to make it possible for devices with the ability to sense, like a remote monitoring sensor for diabetic patients, the devices must be inter-operable with both ends of the service. So the local service as well as the private cloud, here connectivity via gateways or proxies are an important consideration. [8] proposes the following pros and cons of three different

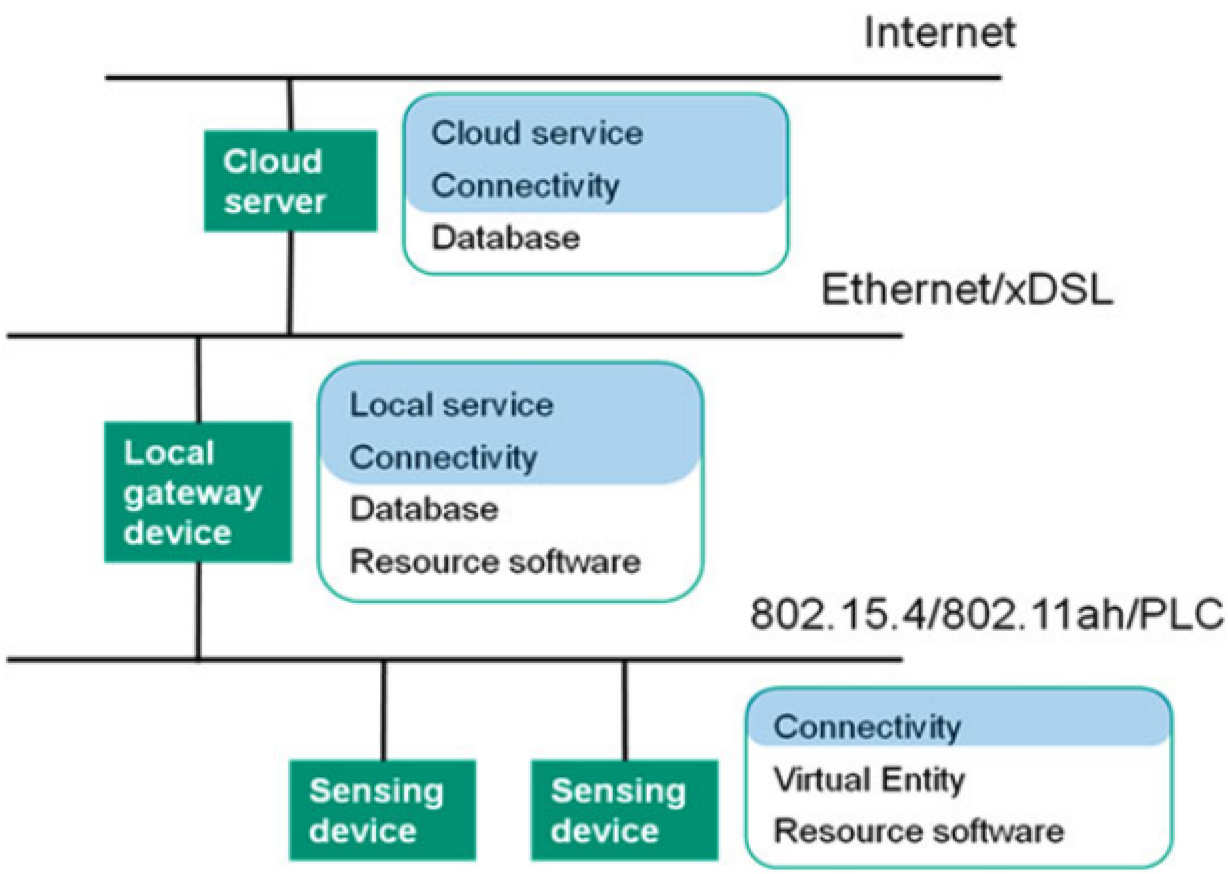

Figure 2.3: Transport monitoring example as proposed by [8]

connectivity considerations:

- Cabled sensors
  - Pro: reliable, possibility to use the same cable for connectivity and power
  - Con: high installation costs
- Wireless sensors (802.15.4)
  - Pro: decent hardware and lifetime as well as relatively easy and cheap
  - Con: the possibility of data loss
- Low power WiFi sensors
  - Pro: easy and cheap installation accompanied by higher costs but also higher possible data rate
  - Con: the shortest lifetime

The main solution for medical IoT systems comes down to the use of Cloud foundations, whether these are private Clouds, public Clouds or hybrid systems remains unclear in literature, though via expert opinions it is noted that many hospitals are reluctant to use public clouds for medical data. And even though most remote monitoring IoT systems are still in their pilot phases, it can be stated that current solutions mainly rely on Cloud foundation. Or on local communication (e.g. a closed circuit) as can be seen in the project of [72]. To support these cloud foundations, a mobile edge computing paradigm can be used to support remote monitoring of diabetes patients by using the mobile phones of patients as edge nodes.

Mobile computing

So what is mobile computing? To understand this [50] states the following about mobile computing:

At the heart of mobile computing is the vision for adaptation in an environment of low processing power and intermittent, sparse net- work connectivity.

Mobile computing is the predecessor of new technologies like fog computing, (mobile) edge computing and cloud computing in general and challenges (e.g. low bandwith, user mobility & network heterogeneity) related to this paradigm have been researched in literature intensively before 2000 [50]. Robust caching, transmission hardware & protocols and compression algorithm's are solutions created for these problems [50]. Mobile computing therefore laid the foundation for an evolution into mobile cloud computing. Where mobile computing, according to [50] had several drawbacks in its use like poor resource-constraints, the interdependence versus autonomy balance, latency and the need for mobile clients resulting in constraints that make the processing of large amounts of data not feasible.

Within the mobile computing and Internet of Things crossroads there are three main implementation models according to [9]. These three models are:

1. IoT-mobile
2. Mobile-IoT
3. IoT-mobile-IoT

This division of different mobile computing scenarios have been visualized in the following image, to a freely interpreted translation from the paper's visualization.

Within the above image three scenarios have been presented, scenario i, scenario ii and scenario iii. The first scenario comprises of one, or multiple IoT devices. These devices can be anything from system sensors to RFID sensors. [9] proposes to use this kind of scenario mainly for accessing these external smart devices in order to assist in making more informed decisions based on the information gathered from these IoT devices.

To counter these limitations, edge computing and edge computing related concepts have been proposed [9]. In the same paper Elazhary presents several basic idea's based on scenario i in the medical domain. Some of these basic idea's are also presented here [9]:

1. A ring-type sensor linked to a mobile health application for continuous monitoring purposes.
2. Indoor localization of patients and people using smartphones based on iBeacons.
3. A software architecture for fast prototyping of medical health applications linked to wearable medical sensors for continuous monitoring.

The above use cases are a few, of the in Elazhary's paper mentioned, idea's for scenario i.

The second scenario, which is presented in **Figure 2.4** is a completely different approach and scenario to use IoT systems using mobile computing. The core of scenario ii depends on input of a mobile device, a smart phone for example. This device sends input to a controller which then sends the command(s) to the relevant actuators. Often used components for this kind of setup are Arduino's or a Field Programmable Gate Array's (FPGA). Arduino is an open-source platform with hardware and software available to create a remote controller for different sensors and actuators. A user could

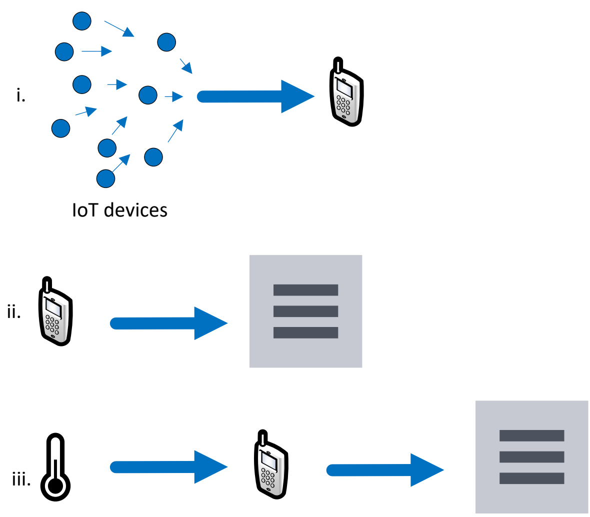

Figure 2.4: Visualization of scenarios of mobile IoT computing: (i)IoT-mobile, (ii) mobile-IoT and (iii) IoT-mobile-IoT [9]

connect different sensors to the Arduino board and control all these sensors via the Arduino board. There are many more possible applications for an Arduino board and the associated software from Arduino but that is out of scope for this research. Besides Arduino's, an FPGA can also be used for this, though the configuration of an FPGA requires significantly more IT and programming knowledge then Arduino's.

Finally [9] mentions the iii scenario which in short is a combination of scenario i and ii. In this scenario the step from gather sensory data from IoT devices to analysis on a mobile device and consecutive assign tasks to IoT devices depending on the input will be achieved in one single flow in stead of manually checking and ordering the different sensors. This third scenario also shows most benefits to medical IoT systems for continuous and remote monitoring of patients.

Finally looking at a last part of mobile computing for health care applications we draw knowledge from Aloi. [73] proposes a smartphone-based gateway to support opportunistic and medical IoT scenarios. The following requirements have been proposed for this gateway in order to make mobile computing feasible for these kind of cases:

1. Multi-communication technology
2. Multi-protocol interaction
3. Bi-directional information exchange
4. Physical mobility
5. Co-located transient service execution

To conclude, mobile computing can be a viable solution for autonomous, continuous and remote patient monitoring. Though, it is needed that every patient owns at least a smart phone with sufficient storage and computational powers to fulfil all required tasks. And with the current trend of increasingly powerful mobile phones and a paradigm shift to the edge, and Edge computing business model for adoption of patient smartphones to serve ass Edge node can result in a viable business model.

2.3 Business model

Finally, it is important to decide how the to-be designed business model will be formulated and which scientific foundations will be used to formulate the business model. Literature will be reviewed in order to describe and choose the business model framework best suited for this research. A sub selection of two main business model frameworks has been chosen after information retrieved by experts in the field. The two most mentioned business model frameworks that have been mentioned by experts from BDO, as well as by my supporting professors Maria-Eugenia Iacob and Marten van Sinderen as two important business model frameworks. The two frameworks mentioned are the Business Model Ontology [24] and the e3 Value Model by [11]. This subsection will consist of an informative describing section about the business model canvas and of the e3 value model and will conclude with a decision for one of the two business model frameworks and is guided by a scientific literary foundation. This subsection will conclude with the choosing of one of the two business model frameworks, the business model ontology by Osterwalder or the e3value by Gordijn.

2.3.1 Business Model Ontology

The business model ontology is, as described in [24] influenced upon the idea of the balanced score card approach as presented [74]. Emphasizing on four main areas that, according to the business model ontology, must be addressed in order to design a business model. The four areas have been identified by [24] as the following four:

- Product:
  The product encompasses the object, product, system and the accompanying value proposition which is being offered to the market.

- Customer Interface:
  What customer segment does the organization tries to reach with its designed product, how the organization delivers the product to their new customers and how the organization builds trust and a strong relationship between the organization and the customers.

- Infrastructure Management:
  How the logistical and infrastructural issues of the product and the accompanying customers are being solved.

- Financial Aspects:
  And finally, how is the product sustainable financially speaking and how are the costs being paid.

These four area's are, as already mentioned influenced by Kaplan's balanced scorecard approach.

Osterwalder and pigneur eventually drill down deeper into the four main areas, referring to the four main areas as pillars and defining more specific "*Building Block of Business Model*" [24] to specify the main pillars of the business model ontology. The following table has been taken from the phd dissertation of Osterwalder in order to visualize how [24] defined the building blocks of the business model ontology:

To prevent misinterpretation of the pillars and specific building blocks of Osterwalder en Pigneurs business model ontology, the table and its content has been cited from [24] as a source to view the main building blocks and use as a reference within this thesis. According to [24], the nine elements of the business model ontology basically cover the most important and relevant business model building blocks in order to design a valuable business model.

Pillar	Building Blocks	Description
Product	*Value Proposition*	A Value proposition is an overall view of a company's bundle of products and services that are of value to the customer.
Customer Interface	*Target Customer*	The Target Customer is a segment of customers a company wants to offer value to.
	Distribution Channel	A Distribution Channel is a means of getting in touch with the customer.
	Relationship	The Relationship describes the kind of link a company establishes between itself and the customer.
Infrastructure Management	*Value Configuration*	The Value Configuration describes the arrangement of activities and resources that are necessary to create value for the customer.
	Capabilities	A capability is the ability to execute a repeatable pattern of actions that is necessary in order to create value for the customer.
	Partnership	A Partnership is a voluntarily initiated cooperative agreement between two or more companies in order to create value for the customer.
Financial Aspects	Cost Structure	The Cost Structure is the representation in money of all the means employed in the business model.
	Revenue Model	The Revenue Model describes the way a company makes money through a variety of revenue flows.

Table 2.2: The nine business model building blocks according to the business model ontology by [24]

A business model can be a complex concept which is referring to a complete design of certain activities to create a product in the broadest sense of the word. In order to map the theoretical business model ontology to a visual design, the business model canvas has been designed. The business model canvas, as can be found in the image below, can be used in order to map the building blocks of the business model into a graphical representation.

In order to create a business model in accordance to the business model ontology, the researcher has to fill out the components of the business model canvas to the best of his abilities in order to create a truthful business model. Therefore assisting healthcare managers, hospital boards, government and health insurers in assessing a formulated business model for viability within the sector.

Also, the business model canvas makes it relatively easy to iterate through the design process. When certain elements of a business model end up being less likely or underestimated, through validation and expert review a business model according to the elements within the business model canvas can be easily changed and adapted without severely impacting the entire structure of the business model.

The business model ontology and the business model canvas shows itself as a modular way of defining a business model for edge computing IoT systems to support remote monitoring of diabetic patients. At first glance, the business model ontology and canvas show great promise for making it relatively simple to design a theoretical business model for edge computing, therefore making it well suited for this research. But first, the e3 value of [11] will also be examined and presented in the following subsection in order to differentiate between the e3 value model and the business model ontology.

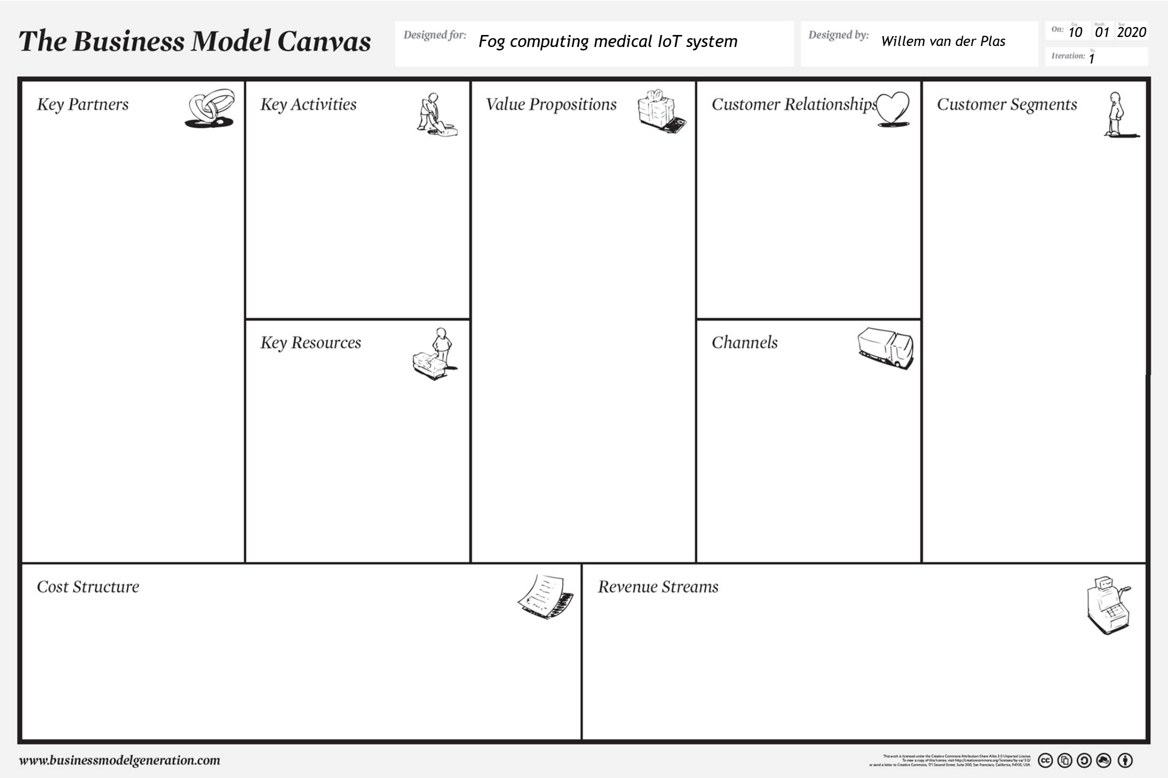

Figure 2.5: Layout business model canvas, by [10]

2.3.2 E3 Value Model

In order to understand the e3 value model, it is imperative that the rationale behind the e3 value ontology is clear. To get a better grasp of what the e3 value ontology is intended for, who the e3 value model is intended for and how this is being done. According to [11] the e3 value can be briefly summarized as follows:

"In short, the ontology is intended to design and analyse innovative e-Business models. We restrict ourselves to innovative e-Business models, meaning that we focus on e-Business models with value propositions that are not understood by the large audience. Furthermore, we look at e-Business models that are about doing business transactions between enterprises and/or end-consumers, often referred to as e-Commerce

By extension of the above citation about the e3 value ontology, the main goals and purpose of the e3 value ontology can be listed by the following two reasons [11]:

- to reach a better understanding of the e-Business model by the stakeholders involved.
- to be able to do an analysis and profitability assessment of the e-Business model for all parties involved.

And these two reasons are to articulate the business model for specifically networked enterprises [11].

According to Gordijn and his e3 value ontology, the reason that e-Businesses, and by extension innovations, mostly fail is because of misinterpretation of the underlying business idea. Especially for technical ideas this plays a part because of the lack of common knowledge of employees, shareholders and other active stakeholders within a business. To overcome this misinterpretation gap or misunderstanding gap, the e3 value model and the e3 value ontology come in to the picture. The ontology will, according to [11], provide concepts, relations between these concepts and rules which should be interpreted by one or more stakeholders of the business idea in order to conceptualize a specific domain of the business idea.

In Gordijn's paper, value creation from e-Business models, the e3 value is being divided into several viewpoints which all represent related statements on e-Business models. To be precise, [11] has sub divided the e3 value into three viewpoints:

- Global actor viewpoint
  According to [11] the **Global actor** shows the following viewpoints:
  - Involved actors to an e-Business idea.
  - economic value object created, exchange and consumption of object.
  - objects of value, economic reciprocity for an object.
  - object offer or request combinations.
  - phenomena like consumer needs or other object exchange causes.
- Detailed actor viewpoint
  The detailed actor viewpoint shows the following:
  - Partnerships between different actors, potentially showing object offer and request values.
  - constellation of actors.
  - specific expressions of actors in the detailed viewpoint.
- Value activity viewpoint
  The value activity viewpoint shows:
  - Value creating activities.

A visual representation of the concepts and relations of the e3 value ontology from a global actor viewpoint has been taken from [11] in order to correctly visualize the global actor viewpoint.

To prevent misinterpretation from the presented textual representations, the image of the concepts and relations of the e3 value ontology from a global actor viewpoint has been taken from [11] in order to act as a reference in this thesis to the logical relations within the e3 value ontology. **Figure 2.6** consists of an Unified Modelling Language (UML) representation of the global actor viewpoint using class diagrams.

The total image consists of actors, value objects, value ports, value exchanges, value offerings and value transactions. Here, as can also be seen in **figure 2.6**, the actors exchanges value objects among each other. As defined by [11], a value object is a service, product, money or can even be an experience which has some degree of economic value to at least one relevant actor. Using a value port an actor can request or offer a value offering to other actors as where the value interface connects in-going and out-going value offerings. Finally, a value exchange binds two value ports together to eventually lead up to a value transaction between 2 or more actors in order to complete the value ontology from a global actors viewpoint, leaving the market segment implicit.

When [11] delves deeper into the e3 value ontology, the concepts and relations of the ontology are extended for the detailed actor viewpoint in order to, as the name suggests, provide more detail

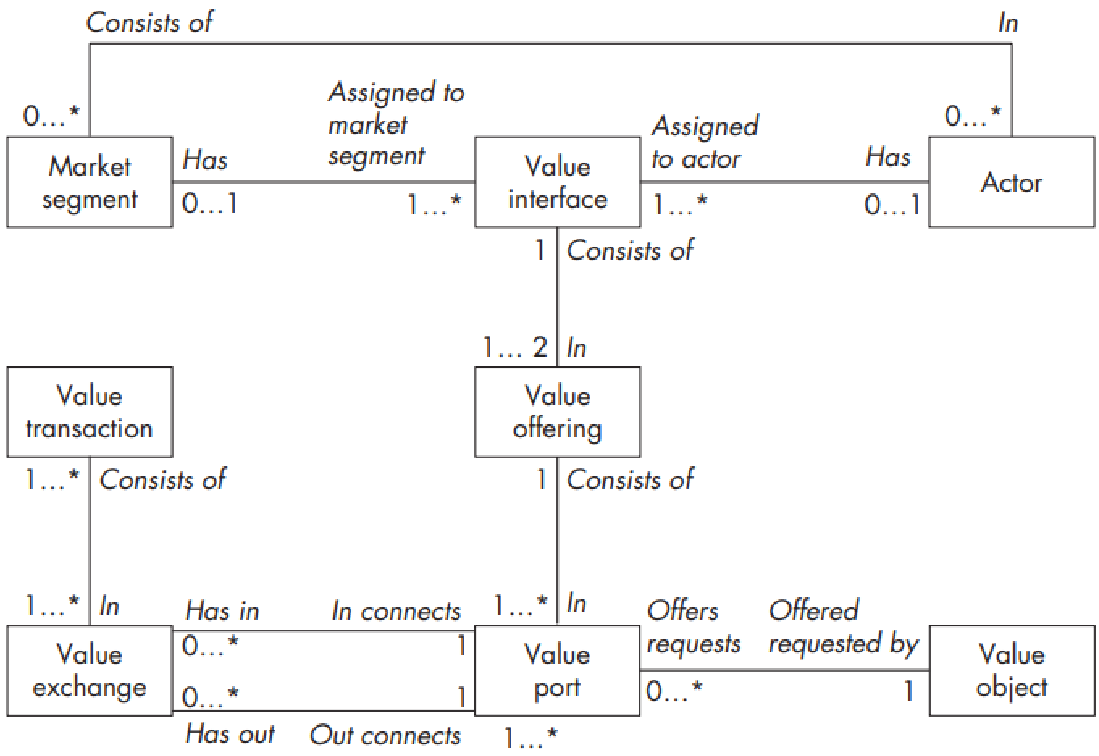

Figure 2.6: Concepts and relations of the e3 value ontology from a global actor viewpoint [11].

to the value model. To support this thesis, a visual representation of the detailed actor viewpoint will be cited from [11] in **figure 2.7**.

As defined by [11], the purpose of the detailed viewpoint within the e3 value ontology is twofold:

1. The detailed viewpoint will be used to detail the global actor viewpoint into several sub actors, essentially creating multiple actors called a *value constellation*.

2. To introduce the representation of partnerships between two or multiple different actors.

Figure 2.5 showing the specializing of the actor into a composite or elementary actor. According to [11] the difference between an composite and elementary actor basically boils down to composite actors grouping together value interfaces of different actors as where elementary actors do not contain value interfaces of different actors.

The ultimate goal of the e3 value ontology and model is, according to [75]:

Its main focus is on identifying and analyzing how value is created, exchanged and consumed within a multi-actor network, hence, taking the economic value perspective and visualizing what is exchanged (which kind of economic value) by whom.

Making it possible to use UML for the description of business models. The e3 value model is therefore an ideal complement for designing e-business systems with UNL. Therefore making it obvious, to make the e3 value model work, UML diagrams must be created in order to visualize and model the business model and value streams.

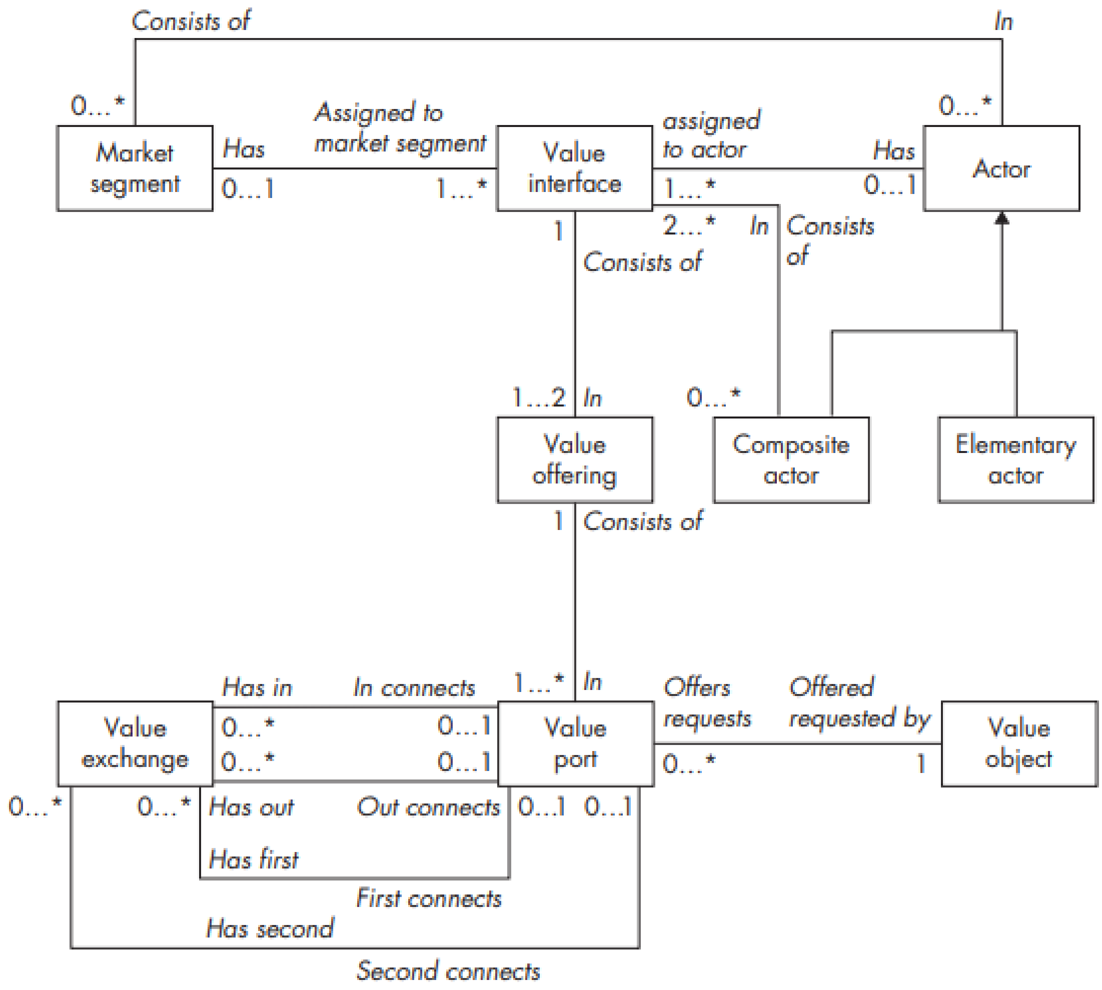

Figure 2.7: Concepts and relations of the e3-value ontology extended for the detailed actor viewpoint. A composite actor and an elementary actor are generalized into an actor as cited from [11].

2.3.3 Business Model Choice

In order to decide which business model ontology is best suited for the design of this business model for implementing edge computing networks in the remote monitoring of diabetes patients, both the business model ontology's will be compared to each other. According to [76], design patterns are essential to the business model development for especially e-health business model design. He states that, especially e-health models do not fit regular business models because of the different value goals of e-health systems and applications. [76] states that, even though it is possible to model a business model for e-health applications, it is not a trivial task because of business model patterns that are not domain specific. Therefore, the design patterns do not reflect e-health specific design problems like privacy and patient data and value streams as important aspects.

Mainly the deviation of e-health business goals and revenue streams is making the e3 value model less relevant then the business model canvas. The business model canvas providing flexible design pattern, even to cases where money making is not the main goal, as it is with certain e-health business models. Also, up front it is hard to assess what value transactions edge computing adoption within diabetic remote care will result in. Osterwalders business model ontology and canvas therefor promise a more flexible approach to the design of a business model for edge computing adoption then the e3 value model. The value the e3 value model adds to a business model is not denied, though for this research, the e3 value model comes to early and it is recommended to use the e3 value model and the UML modelling to be used within de development of an edge network or system in stead of purely the modelling of a business model.

Also, the decision for the use of the business model ontology of Osterwalder and Pigneur, [77] states that the business model canvas is the ideal choice compared to the e3 value model. He argues that the use of the e3 value model, although unrivaled in modeling the value network, the value network in this part of the research is not the main aspect. Also, a more complex e3 value diagram can contain an immense amount of arrows and boxes inside of more boxes making the diagram enormous and very complex. This is something which must be avoided during this stage of the research and the design of a first business model.

To conclude on the choice for the business model ontology and business model canvas, two professional experts on new healthcare business models, digital transformation within the public and health sector and and audit & assurance partners of BDO's healthcare sector group, Vincent Eversdijk and Chris van den Haak have also proposed the Business model Ontology as a good starting point for the design of an innovative business model for edge computing in the healthcare sector. An important aspect for their choice of not using the e3 value model is related to the exploratory nature of this research. It is already a lot more difficult for health care business models to create a value model, especially with new innovative IT business models. The elaboration of final value models for this business model is reserved for individual hospitals and individual pilot cases that will be rigged after this research and is important as follow up research. As stated by Chris van den Haak: ' *Coming up with new business models is one thing. Getting them off the ground is of a completely different order*'.

Chapter 3

Problem analysis

This thesis describes the ways in which edge computing and IoT can support innovative healthcare projects in order to adhere and facilitate Smart City healthcare KPI's. This fog computing IoT system is aimed to improve on the in **figure 1.4** mentioned key inhibitors preventing IoT innovation in healthcare. This thesis takes two different perspectives when describing the design and implications of fog computing within a medical IoT system. A business and a technical perspective. The description of value caption and creation of business is done via a business model. The business functions of edge computing within a medical IoT system are written from a managerial perspective to allow hospital management, as well as consultants, to better understand and appraise the business behind an edge computing and IoT solution. This may help them in the formulation of a business strategy that will allow fog computing and IoT to be adopted and implemented in the future by healthcare organizations. Similarly, the description of IT requirements may provide BDO, as an IT, compliance and service provider, with insight into the applications of fog computing IoT systems with regard to their current product portfolio. And, also providing their hospital clientele with more insight into the technical possibilities of IoT systems in light of the current legal and privacy risk factors that have arisen concerning the use of data and medical data

In this section, a problem within the current Dutch healthcare system is addressed and analyzed for added value in order to determine whether or not this research has any potential for contributing value to the eHealth community. Several promising health care cases are currently present for potential improvement via the use of medical IoT systems. From the six main types of care, Chronicle care shows the most promise for medical IoT systems. Before proceeding to the stakeholder analysis and medical IoT business model, first two medical cases which are potentially viable for medical IoT solutions are discussed below. These two cases will be used to make a stakeholder analysis, business model and feasibility study for the medical IoT system(s) and cases presented below. One case from the chronic care domain and one case from the preventive care domain will be worked out below.

3.1 Chronic care

Care for people with diabetes is an intensive process which consists of a certain amount of processes. Diabetes consists of two types, type 1 diabetes and type 2 diabetes. The definition of diabetes, as proposed by the website *levenmetdiabets.nl* will be used during this thesis. [78] defines diabetes as follows:

> *Type 1 diabetes is an autoimmune disease and also a chronic condition. The body of people with type 1 diabetes cannot produce insulin anymore. The body mistakenly considers the cells that*

produce insulin for "enemies", after which these good cells are destroyed. A serious problem, because insulin is an indispensable hormone that regulates blood sugar levels in the pancreas. If you have type 1 diabetes, you will need medical aid every day. You must measure your blood sugar 365 days a year, inject insulin yourself or carry a pump with you.

After the diagnosis of diabetes, the care for diabetes patients serve two main goals. Normalizing blood glucose levels in the blood and preventing complications (cardiovascular diseases) in the long term. Where the prevention of complications in the long term mostly is largely based on keeping blood glucose levels well under control. The following steps in the treatment of the care for diabetes are:

- Continuous healthy lifestyle
  The healthy lifestyle is an important part of the treatment of diabetes. One of the main goals of treating diabetes is preventing complications and keeping a stable blood sugar level, because of the implications unstable blood sugar level has with regard to the possible long term complications. By keeping a healthy lifestyle, blood sugar levels are more easily controlled, as where also the risk of long term complications declines. The risk of long term complications decline because of the healthier lifestyle as well as the better controlled blood sugar levels. So the healthy lifestyle has a double positive effect on diabetes patients.

- Continuous monitoring of blood sugar levels
  For diabetes patients it is vital to continuously monitor the blood sugar levels to adhere to the main goal of normalizing blood sugar levels of the diabetes patient. The longer someone has diabetes, the better a diabetes patient gets a feeling for his or her blood sugar levels, though when asked to any physician or specialist in the field a well known one liner is often heard: '*measuring is knowing*'.

- Calculate carbohydrate intake
  In order to adhere the stable blood sugar after eating, and preparing for the next step in the process, administering insulin, it is important for diabetes patients to calculate the carbohydrate intake during food consumption. This to calculate whether or not the administering of insulin is needed, and if it is needed, how much insulin has to be administered. This is vital for keeping the main goal of normalizing blood sugar levels and as an extension thereof, improving quality of life by decreasing the risk of long term diabetes induced complications.

- (Continuously) administer insulin
  The administering of insulin is probably the most vital aspect of the care of diabetes. Without insulin, both main goals will not be achieved because the patient is not allowed to eat carbohydrates whenever the administering of insulin is impossible. Because the body itself can (almost) no longer produce insulin, the treatment consists of injecting insulin. Often you have to inject several times a day for this. It is important to properly coordinate factors that increase blood glucose (eating) with factors that lower blood glucose levels (exercise, and administration of insulin). Good coordination ensures that the glucose level stays within the desired limits as much as possible (between four and seven mmol / l). If the balance is incorrect, there is a chance that the glucose level is too high (hyper) or too low (hypo) [79].

- Half-yearly checks with doctor, specialist and dietitian
  In order to have a good coordination between immediate care of diabetes, preventive care on the (long term) implications and a healthy lifestyle. Regular check ups with physicians, specialists and dietitians is needed to check whether or not the treatment for the patient is

optimal or sub-optimal. Besides, also being able to check for complications in an early stage making it possible to act on the first signs of potential complications making treatment of these complications significantly easier.

- Biennial check-up by the eye doctor
  The same counts for the check ups at the eye doctor, because the eyes are very vulnerable spots of a diabetes patient.

3.1.1 The state of Diabetes in the Netherlands

According to a study carried out by Novo Nordisk, Novo Nordisk is a global healthcare company with more than 95 years of innovation and leadership in diabetes care. Novo Nordisk has their headquarters in Denmark and is founded in 1923. In the Novo Nordisk study has calculated the total cost of diabetes patients for the Dutch economy, the total costs have been calculated around 10 billion euro's [80]. Where the medical costs have been estimated between two and three billion euro's, the other seven to eight billions euros are caused by long term complications which also need care and loss of productivity. Also estimates have been made for the year 2020 wherein the total costs can become as high as 16 billion due to aging population and an increasing population diagnosed with diabetes.

Numbers by the volksgezondheidzorg website and the Central Bureau of Statistics support these numbers in the following ways. The numbers from the StatLine database have been presented at [81] and it is being stated the direct costs for care for diabetes patients sums up to 1.6 billion euros a year. Though this number does not include the costs made for treating complication diseases caused by diabetes neither does it encompass the loss of productivity every year of 1.2 million diabetes patients [82]. Where, according to StatLine database data of hospital admissions of diabetes patients in the year 2017 sums up to a total of 74.070 Clinical admission days [83]. Making the total costs of diabetes to the Dutch economy significantly higher then the stated 1.6 billion in 2017. Actual numbers about 2020 are not available at the time of writing, though bearing in mind the aging population of the Netherlands, the financial impact will probably be significantly higher.

For knowledge about how diabetes patients experience the treatment of diabetes, a patient has been asked about what he thinks about the treatment of diabetes and if he thinks some elements are good, or not. A diabetes patient who has diabetes over 10+ years has been chosen for this interview. During this unstructured interview, he has been asked about how he views the diabetes care process. This has also been done with a diabetes care specialist of the Alrijne Hospital Leiden. The medical specialist also has been asked the question how she views the diabetes care process, what problems are currently prevalent and how this potentially could be solved.

According to the diabetes patient, one of the hardest parts of the treatment of diabetes is the constant monitoring of blood sugars, carbohydrate intake in combination with a health lifestyle and the accordingly administering of insulin to keep blood sugar in a steady and good level to prevent long term complications and improve the quality of life for the diabetes patients. According to the interviewed patient, he is not aware what the financial gain would be if his blood sugar levels where to be stable all the time, though he did mention that the quality of life would greatly improve, not only on a physical level, but also on the mental level. When the process of monitoring blood sugar, eating food and exercises, calculating the impact of these factors onto the processing of sugar out of the blood, and coherently with all that, administering the correct dose would be greatly beneficial to diabetes patients, according to the interviewed diabetes patient. Not to forget that the continuous check ups for complications and the adjustment of medicine would not be necessary anymore because the smart system would take care of all the medicine intake calculations.

The diabetes specialists sees positive sides to a complete system, as well as possible risks to the system. Because, before implementing a system like this, one must be sure that the system calculates the insulin dose correctly, for administering a too high dose of insulin to a diabetes patient could, in the worst case, lead to the death of a diabetes patient. This is something that must be avoided at all cost, and if there would only be the slightest of chance something like this could happen, the system should not be implemented according to the specialist. Besides this risk, the specialist sees a lot of potential in a IoT system that could monitor and calculate all the necessary steps in order to make the care of a diabetes patient function fully automatically and autonomously. Especially the long term effects on diabetes patients would significantly increase, according to the specialist. The specialist states that diabetes patients HbA1c values will potentially stabilize to a regular level making the chance for long term implications equally low as for people without diabetes. Greatly improving the quality of life for diabetes patients, as well as significantly reducing the need for medical care and medicine for this group of patients. HbA1c stands for *hemoglobin A1C* and is chemically linked to sugar, the hemoglobin in the blood is used to calculate the average blood sugar levels of a diabetes patients over the past 3 months. In order to be able to have a clear view of diabetes patient sugar levels, a patients has to schedule a hospital appointment at least one time every three months. The diabetes patient therefore sees a lot of positive things in the complete autonomous automation of the care for the diabetes patients blood sugar level, though it is mentioned a real doctor should be present for final checks.

3.1.2 Problem solution

After analysis of the steps in the treatment of diabetes and the information provided by a diabetic patient and a medical diabetes specialist, a complete automated system for the monitoring of blood sugar levels together with the analysis of carbohydrate intake, and carbohydrate consumption by the body and the final calculation and administering of insulin to the body shows promise for future adoption by increasing quality of life, decreasing long term complications, decreasing immediate and long term (medical care) costs for diabetes patients. Though it is important to mention that current trends with respect to IoT and (wireless) sensor technology, also in the medical domain, is not equally positively received by everyone. Today, a very critical look is taken at contemporary medical IT applications when it comes to securing privacy and security of medical IT applications. With the rise of corona and medical monitoring apps in countries like China, Singapore and South Korea, European citizens take a close look at the current development of medical apps. therefore it is vital that patients are being assured that their privacy will be uphold by the application. The adoption of edge computing can be a solution here because it has the potential to give control back to the users (patients) of these medical applications.

This possible solution will have to be further elaborated in a technical business model, to be validated among key stakeholders to eventually. In order for the validation of the business model, a stakeholder analysis will be formulated which will form the basis for the business model and the validation of the business model.

3.2 Stakeholder analysis

Before a viable business model for edge and IoT deployment in healthcare services can be created, it is essential to have a clear overview of current stakeholders within the healthcare chain. The more accurate the different stakeholders and their motivations can be captured, the more suitable a business model for IoT driven healthcare services can be created. In this chapter we will first discuss the theory used for the stakeholder analysis. After that, a description of how the stakeholder analysis became and finally a description of all relevant stakeholders for this research towards a business model for IoT driven healthcare services. The distinction of stakeholders for this research will be made on an organizational level. Because the goal of this research is to design an eHealth business model for the entire Dutch care system, it is important to also look at the stakeholders from this point of view. Therefore, the stakeholders will be chosen in organizational form and not on individual level.

3.2.1 Stakeholder identification

Mitchell, Agle and Wood speak in their theory about stakeholder identification not only about stakeholders as constructs, but also elaborate on the identification and definition of different stakeholders. For this research it is important to understand how different stakeholders can be identified and defined in order to gain a better insight and understanding into the needs and wishes of the stakeholders involved in the business model. Because without the support of the stakeholders involved, the business model is doomed to fail in advance. In [25] study, several rationales for stakeholder identification are presented, gathered via several different works of literature. A summary of the relevant constructs for identifying stakeholders to gain a better understanding on how to identify relevant stakeholders for this research is presented in the list below from [25]:

An existing relationship

- **The firm and stakeholder are in relationships:**
  Where stakeholders have legitimate, non-trivial relationships, moral responsibilities towards or interaction with the goal or firm.

- **The stakeholder exercises voice with respect to the firm:**
  Where stakeholders actively making their '*stakes*' known towards a goal, firm or organization.

Dominant stakeholder dependency

- **The project or firm is dependent on the stakeholder:**
  Projects or organizations of whom without, the stakeholder would not exist. In other words, the stakeholder, has been created or founded to participate in a certain project or firm, and without the project the stakeholder would cease to exist.

- **The stakeholder has power or direct control over the firm or project:**
  Stakeholder groups can affect or are affected by achieving the project or business model goal. And the stakeholder has the direct ability to influence the project or business model in order to change the possible outcome.

Dominant firm or project dependency

- **The stakeholder is dependent on the project or firm:**
  Stakeholder groups or organizations of whom without the support, the project or organization would cease to exist. In other words, the project, organization or in this case the business model and case would cease to exist without the support of dominant stakeholders with a power dependence to the project.

- **The project or firm has power or direct control over the stakeholder:**
  The outcome of the project, or in this case the business model would have direct impact on the stakeholder group. Making it possible for a project to affect the day-to-day work of certain stakeholders in a positive or negative way.

Mutual power dependence

- **Mutually dependent actors (e.g. firms and stakeholders**
  Stakeholders are depending on the project or business model in order to achieve personal goals and on whom the project is depending for its existence. This way both parts are depending on each other equally.

Legitimacy-based relationship

- **Contractual relationship between stakeholder and counter parts:**
  Stakeholders and projects are legally bonded by contractual agreements.
- **Stakeholders has rightful claims:**
  Stakeholders have a real claim or stake in the project or business model. Moral as well as legal claims can be found, for example ownership, rights or interests in certain activities, corporation or goals.
- **Stakeholder is, in some form, at risk or exposed:**
  The stakeholder bears some form of risk of a result of participating or investing in the project, business model or corporation. Either financial, capital, human or something other of value of the stakeholder can be at stake.
- **Stakeholder has rightful moral claims:**
  Stakeholder has a moral claim on a project or business model, specifically no legal claim.

Stakeholder interests – legitimacy is not implied

- **Stakeholder has specific interests:**
  Asserts to have any stake in the matter, a right to ownership or legal title are among the possibilities.

All the above presented and summarized information regarding rationales for stakeholder identification has been brought together by [25] and merely paraphrased in this research for interpretation and identification of relevant stakeholders within this research. Also, [25] mentions power as a crucial part in a stakeholder management theory. But, on its own, does not explain salience for example: there are stakeholders which do not posses any power but still matter to a project, manager, supervisor or organisation. What is important here is the visibility of a stakeholder or, as Mitchell calls it, "*the degree to which managers give priority to competing stakeholder claims*". [25] describe one more important attribute related to stakeholders.

3.2.2 Salience model

Below the three attributes are described as can be found in the salience model, created by [25] and further explained by [12]:

1. Power
2. Legitimacy
3. Urgency

These are attributes with which stakeholders can be identified. The presence or absence of these attributes determines what kind of stakeholder it is and how important this stakeholder is. A graphical representation of the salience model can be found below in figure

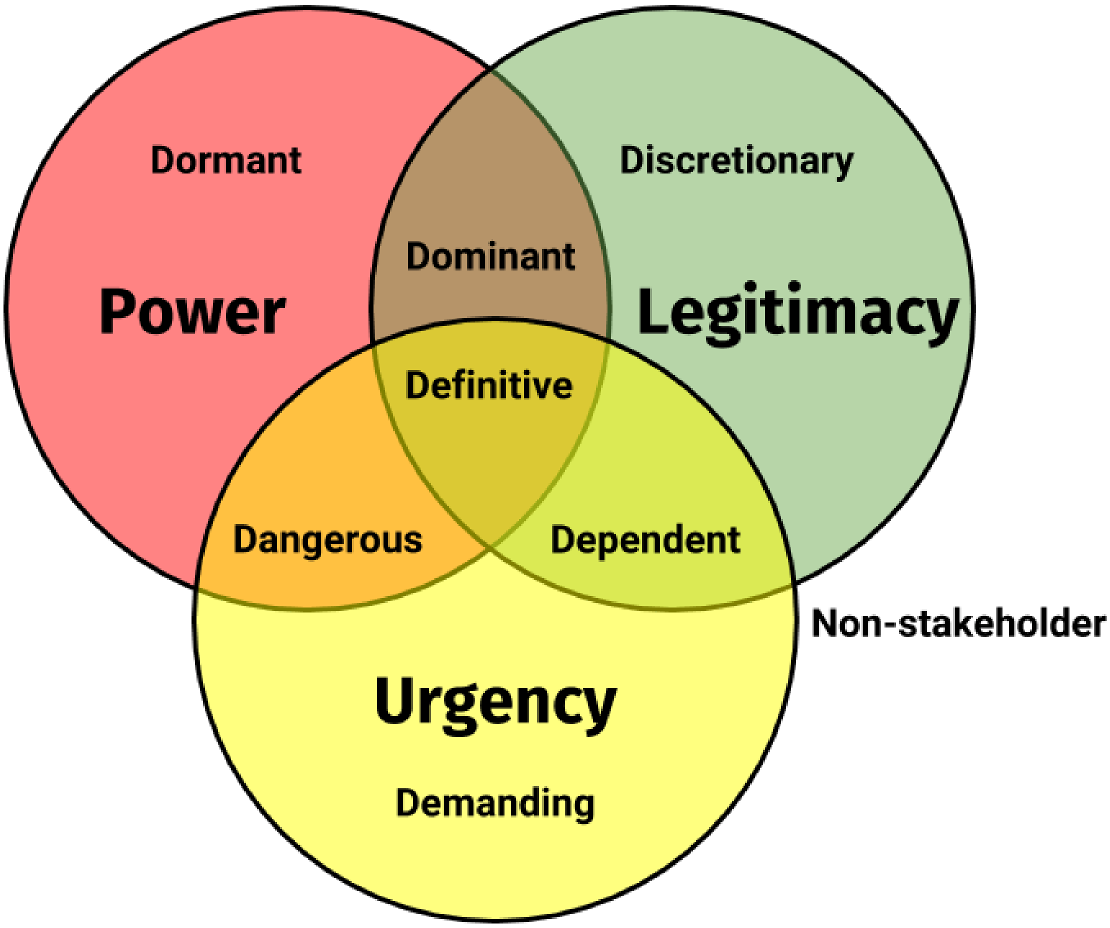

Figure 3.1: The three stakeholder attributes within the salience model [12]

- Power
  The *Power* attribute has been derived from the early Weberian idea that: '*the probability that one actor within a social relationship would be in a position to carry out his own will despite resistance*' as presented by [84]. If the relationship between actors take a form, where the person or actor in power can let the other person(s) or actor(s) do something that the latter would not otherwise have done. The power can be used in a coercive (force / perseverance), utilitarian (for example material or financial) or normative power (the ethical, prestige, reputation, certain status) way [25].

- Legitimacy
  The extent to which the actions of an actor are desirable, justified, decent or appropriate within a system of norms, values, beliefs and definition. To what extent are the actions that the stakeholder carries out correct or desirable based on their position within the organization encompasses the notion of *Legitimacy* according to [25]. Also, [84] states that legitimacy and power are two distinct attributes, which combined may create *authority*. Despite Weber's notions of distinction between both constructs, not all in stakeholder literature agree to this notion. Davis presented the notion of Legitimacy as the *Institutional Principle* and he stated that [85]: '*in the long run, those who do not use power in a manner which society considers responsible will tend to lose it*'. This statement assumes that power and legitimacy are closely related. Though

despite this common linkage proposed by Davis, in this thesis we will build upon the notion of Weber that power and legitimacy are two different attributes, both of which can be assigned to an actor.

- Urgency
  Finally there is the attribute of *Urgency*, mentioned by [25]. Urgency builds upon viewing the attributes of power and legitimacy as independent variables. Urgency beholds the extent to which direct attention is needed. This may have to do with time pressure; or when a claim has significant importance and criticality about it, it cannot wait because of the degree of importance for the stakeholder, creating an urgency driver which calls for immediate attention towards the goal, project, business model or organisation [25].

According to [25], actors who do not have any of these attributes are not stakeholders, and in the prolonged do not posses any of the dependencies or relationships towards the project, business model, goal or organisation. An actor is a person, agency or organization that is involved.

A stakeholder is an interested party who wants something. This can also be an organization, person or agency. Stakeholders who have one attribute are called latent stakeholders, these are dormant stakeholders (dormant stakeholder), weak or discrete stakeholders (discretionary stakeholder) or the demanding stakeholder (demanding stakeholder). These stakeholders may hardly be noticed or even ignored. Two attributes refer to expectant or expectant stakeholders. They have a more active attitude, are visible and have an average interest. These are the dominant stakeholder, the dangerous stakeholder or the dependent stakeholder. If all the attributes are present, they speak of an authoritative stakeholder. At that moment there is direct attention and priority for the claim of this stakeholder. This is the ultimate stakeholder (final stakeholder).

[25] distinguish seven categories of stakeholders, the extent to which a stakeholder possesses these attributes determines the category to which the stakeholder belongs. Finally, [25] concludes with the following three additional features which support a dynamic theory of stakeholder identification and salience:

1. Stakeholder attributes are variable.
2. Stakeholder attributes are socially constructed.
3. Consciousness and willful exercise may be present.

In the deeper examination of the theory of stakeholder analysis, [25] distinguish seven categories of stakeholders where the extent to which a stakeholder possesses these attributes determines the category to which the stakeholder belongs. Table **table 3.1** below sums up the seven stakeholder types presented by [25]:

Stakeholder types	Power	Legitimacy	Urgency
Dormant stakeholders	X	-	-
Discretionary stakeholders	-	X	-
Demanding stakeholders	-	-	X
Dominant stakeholders	X	X	-
Dangerous stakeholders	X	-	X
Dependent stakeholders	-	X	X
Definitive stakeholders	X	X	X

Table 3.1: Stakeholder type attribute comparison by [25]

The seven stakeholder types, as presented in the table above, have been subdivided further by [25] into three overarching typologies:

1. Latent stakeholders
   Latent stakeholders include stakeholder types whom only posses one of the identifying attributes. The less stakeholder attributes are present and know, the lower the stakeholder salience will be. Stakeholder types which fall into this category are Dormant stakeholders, Discretionary stakeholders an demanding stakeholders. Dormant stakeholder posses the relevant stakeholder type of Power. These stakeholders posses, according to [25] power to impose their own will though with only power, are not salient enough to actually impose a difference.

   Discretionary stakeholder types include the possession of the legitimacy stakeholder attribute. According to [25], discretionary stakeholders are especially interesting stakeholders for scholars and researchers whom research the social responsibility and performance. The most important point with regard to discretionary stakeholder types is, that in the absence of power or urgency, the discretionary stakeholder has no way to enforce their own views towards the project, goal, business model or organization.

   Finally, the Demanding stakeholder type is the final stakeholder type belonging to the latent stakeholder sub group. The demanding type name has became due to the constant urgency with which the demanding stakeholder advocates his needs and wishes. Though also here, if not backed-up by an other stakeholder attribute, the cause of the demanding stakeholder will all be largely forgotten by the masses and therefore exhibits little to none persuasiveness [25].

2. Expectant stakeholders
   A second stakeholder type sub group is the Expectant stakeholder. Where the latent stakeholders encompass three stakeholder types, so does the expectant stakeholder sub group encompass three different stakeholder types. According to [25] the stakeholder types which fall under the expectant stakeholder group are the Dominant stakeholders, the Dangerous stakeholders and finally the Dependant stakeholders. The most influential difference between latent stakeholders and expectant stakeholders is that the latter stakeholder types possess two key stakeholder attributes making them more persuasive or credible.

   It is said that dominant stakeholders have a big impact on projects, though are by no means the only stakeholders to which a project must adhere. Where dominant stakeholders possess the power and legitimacy attribute, the attributes ensure the stakeholders influence on the project. For a business model, these kind of stakeholders have the power to overrule other stakeholders and shape a project to their according to their wishes. As where dangerous stakeholders possess the power and urgency attributes. Dangerous stakeholders lean mostly towards coercion and violence compared to all the other stakeholder types, according to [25]. Finally there are the dependant stakeholders which include the legitimacy and urgency attribute. Even though dependant stakeholders have legitimate and often urgent claims towards a project, they usually lack the power to enforce this, therefore the name 'dependant' as this stakeholder type is dependent on others to enforce their message or needs.

3. Definitive stakeholders
   The definitive stakeholder is the definitive stakeholder, and only one stakeholders sub group can possess all three attributes. [25] quoutes the following about definitive stakeholders:

   Proposition lc: Stakeholder salience will be high where all three of the stakeholder attributes – power, legitimacy, and urgency – are perceived...

Therefore, dominant and definitive stakeholders will usually have the most impact on projects, and therefore it is important to acknowledge these stakeholders during the creation of an IT business model for medical IoT functions within the medical domain.

In order to be able to correctly place the various stakeholders present within this research, it is important to first get an idea of which stakeholders are present within the Dutch healthcare domain according to experts from the Dutch healthcare sector, experts and auditors of the medical domain from BDO and public literature. Experts in the field from BDO, (*Sander Rurup, Senior manager forensic and data analyst & Chris van den Haak, Partner / BDO Branchegroep Zorg*) mention the following stakeholders to be relevant within the Dutch healthcare sector from an trusted financial and auditing partner view:

- Ministry of Health, Welfare and Sport
- Health Insurers
- Health and Youth Care Inspectorate
- NVZ Dutch Hospitals Association
- ActiZ — trade association of healthcare organizations
- Government of the Netherlands

Medical experts in the field from among others Noordwest Ziekenhuis groep's (*Mark Wagenaar, Lead Architect NWZ & Ed de Myttenaere, CIO NWZ & Lianne van der Plas, clinical care Inforsa*) mention the following stakeholders to be relevant within the Dutch healthcare sector:

- Medical application developers
- Medical specialists
- Patients
- Nictiz is the national, independent knowledge organization in healthcare
- Government of the Netherlands
- Health Insurers

International literature mentions the following stakeholders within eHealth environments. [13] mentions the four P's. The four P's consist of the following stakeholders:

1. Policymaker
2. Patient
3. Pay-or
4. Provider.

To illustrate, [13] provides visualisation of the routes in the eHealth network of the four P's in image **figure 3.2**.

Because the goal of this research is the design of a technical business model for the Dutch health sector, it is important to not only focus our aim on international literature but gather input from Dutch written sources to complement our literature supported eHealth stakeholders group. According to [14] the following stakeholders are relevant within the Dutch healthcare sector:

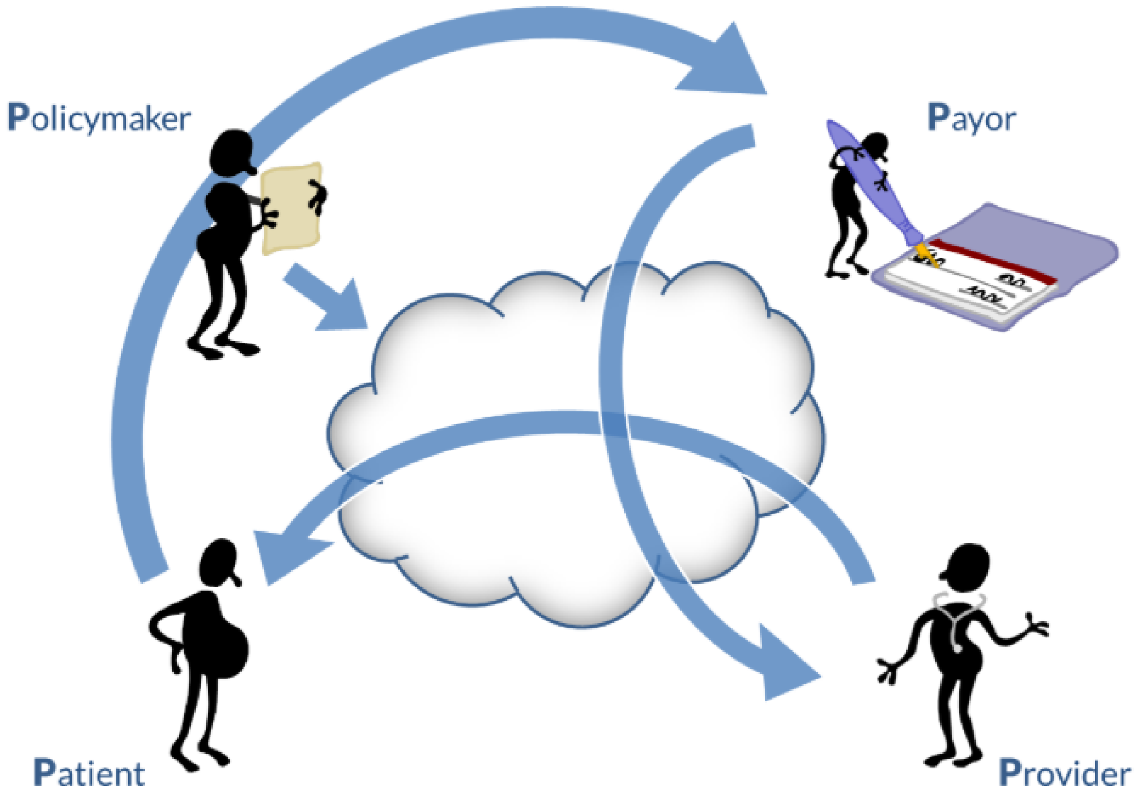

Figure 3.2: The four P's of stakeholders in the eHealth network according to [13]

- Patient (association) (**P**atient)
- Government of the Netherlands (**P**olicymaker & **P**ayor)
- Municipality (**P**olicymaker)
- Healthcare provider (**P**rovider)
- Professional association(s) (**P**rovider)
- health insurer (**P**ayor)

As can be seen from the list above, all the relevant stakeholders, mentioned in Dutch literature can be mapped towards the four P's of [13]. In the following chapter we will briefly enumerate and group the relevant stakeholders for this research, further on we will discuss the four P's more in depth, how this relates to the relevant Dutch eHealth stakeholders and how the stakeholders potentially impact the business model.

3.2.3 Stakeholder defining

The next step is to assess the stakeholders, mentioned by literature and experts in the field, on usability within this study. In order to assess this usability the study of [25] will be used to assess the mentioned stakeholders before analyzing the stakeholders within the aforementioned typing and attributes. As already mentioned before, we will use three critical stakeholder attributes to place the stakeholders mentioned in interviews and literature in one of eight types. The eight stakeholder type comes down to not being a stakeholder because the 'stakeholder' does not possess any of the critical stakeholder attributes. Also we will briefly enumerate and group the relevant stakeholders for this research. We will discuss the four P's more in depth, how this relates to the relevant Dutch eHealth stakeholders and how the stakeholders potentially impact the business model.

Stakeholder	**BDO**	**Specialists**	**Literature**	**Total**
Dutch government	I	I	I	III
Health insurers	I	I	I	III
Health and Youth-care inspectors	I	-	-	I
NVZ Dutch Hospitals / healthcare providers	I	I	I	III
ActiZ-trade association of healthcare organizations	I	-	-	I
Specialist/professional association	-	I	I	II
Patient (association)	-	I	I	II
Medical technology	-	I	-	I
Municipality	-	-	I	I

Table 3.2: Stakeholder type attributes according to BDO, medical specialists and literature [25].

For overview, all the stakeholders mentioned by BDO, specialists and literature will be placed into **table 3.2**. For clarity, mentioned stakeholders with only different pronunciation will be coined together during evaluation.

In the above pictured table, the final relevant stakeholders for this project have been chosen. After revisiting some of the interviewed specialists and based on [14] the following stakeholder / actors have been identified with the following roles: 'Patient, Insurer, Healthcare provider, Patient association, Government, Municipality, Professional association'. In the following paragraph, the relevant stakeholders will be typed on the basis of the salience model described above and the associated stakeholder attributes. A network drawing will also be designed in which all stakeholders and the connections with other stakeholders will be visualized. Finally, it must be stated that the stakeholder attributes are social constructs. In the representation below, therefore, one cannot speak of an objective reality, attributes can also change over time and a stakeholder characterization based on the salience model is always a snapshot of a specific moment in time.

Four P's

Before further deepening and elaborating on the stakeholders present in the Dutch (e)Health chain, we will introduce the concept of the four P's. This concept has been described by [13] and elaborates the four key stakeholders present in health systems and health information systems. The four P's stand for Patients, Providers, Payors, and Policymakers, as already stated in section before. This subsection will therefore provide a more detailed elaboration about the information provided and extracted by the four key stakeholders for the eHealth infrastructure and the roles they play in reflection to the other key stakeholders.

- **Policymakers**. Policymakers. Policymakers establish the framework within which health care is provided to the country's citizens. In this book, "policymaker" is a synonym for "ministry of health" or whatever jurisdictional entity is responsible for the health of the population. The policymakers aggregate data from patients, providers, and payors to develop population-level metrics that inform their health and health economic policies. In this context, policies answer the crucial questions:
  - Who is eligible to receive care?

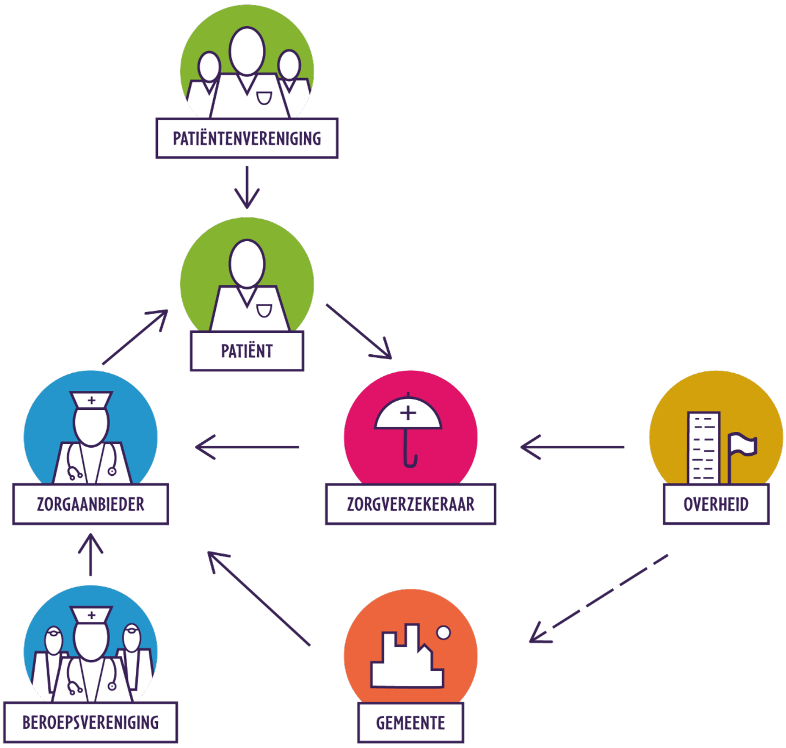

Figure 3.3: The stakeholder environment for Dutch IT innovations in healthcare [14]

– What care services are provided?

– How are care services paid for?

– How is accessibility of care services?

– What future healthcare concerns do we need to take into account?

- **Patients**. All of us—at one time or another—are patients. Patients are typically citizens, and voters, and sometimes taxpayers. Policymakers have a fiduciary duty to this population, and the country's policy framework is established to benefit patients. Patients receive care services from providers and are the beneficiary customers of the payors. Patients also may want to access information about their care via an electronic device (e.g., personal computer, mobile phone).

- **Providers**. Providers operationalize care delivery within the policy framework. They provide health services to patients and maintain health information about them. The providers coordinate patient care with other providers as care team members. Many providers are independent businesses that must manage their own operations and finances.

- **Payors**. Payors operationalize the financial elements of the policy framework. Payors enroll patients as beneficiaries. They procure care services from the providers on behalf of their patient beneficiaries. They also must take on the actuarial task of ensuring the financial sustainability of the care program. They report to policymakers.

3.2.4 Current Stakeholders

Patient (Patiënt)

The following information elaborates the stakeholder group *patients* according to [14].

Role

The patient is the center of care that is provided and therefore often also the user of an application. He or she can passively undergo the care offered, but can also play an active role in it (own control, self-management). Not everyone has the required attitude and skills to the same extent. Develop and evaluate an application together with the intended target group. People in the immediate vicinity of the patient / client often play an important or even leading role. Caregivers, parents, or children can exert a great influence on the willingness to use an application.

Interests

The patient (and his environment) may have the following interests in an eHealth application:

- Improving the effectiveness of care (for example, by increasing compliance).
- Prevention: preventing deterioration or complications (idem).
- Improving the accessibility of care (for example via an online consultation).
- Limiting the impact of the health situation on one's own (social) life.
- Maintaining self-management for patients with a chronic or severe limiting disorder.
- Stimulation of motivation.
- Better insight into your own health situation (for example, access to your own file).
- Comfort, convenience: an application must offer comfort and be easy to use.

Finally, a patient falls into the Patients key stakeholder according to the four P's model.

Insurer (Zorgverzekeraar)

The following information elaborates the stakeholder group *insurers* according to [14].

Role

The health insurer is the party that reimburses the care that is delivered to patients using the eHealth application. Keep in mind that there are several stakeholders within "the health insurer" with different interests in an eHealth application:

- The innovation department, where successful eHealth innovations are selected and assessed.
- The investment fund, where people support the development of eHealth applications financially.
- The purchasing department, where people negotiate with care providers and (preferably efficiently) purchase large volumes of care. With some forms of care, the use of eHealth applications is included in the negotiations, but the share is still limited.
- The commerce department, where supplementary insurance for individuals and collective insurance for organizations are put together and eHealth is seen as a distinctive feature.

So keep in mind that the enthusiasm of the innovation department is not always shared by the purchasing department!

Interests

Good health care at a low price is central to the health insurer. The health care insurer, among other things, sets the following requirements for an eHealth application:

- The application must have support among care providers and patients (eg through co-creation).
- The application must yield health benefits (higher quality of care or quality of life).
- The application must reduce healthcare costs (due to increased self-reliance of the patient, or workload reduction of the healthcare provider).
- The application must lead to substitution (no extra care but replacement of existing care).
- The application must comply with national agreements (NIA eHealth; purchasing guides ZN).
- The application must lead to a reduction in absence, for example through prevention or faster recovery (specifically for collective insurance).
- The application must lead to image enhancement or to attract or retain more insured parties (specifically for supplementary insurance policies).

Health insurers do business with health care providers and therefore see them as a discussion partner. It is therefore important that an enthusiastic care provider (and not the entrepreneur himself) enters into a conversation with the health insurer. Finally, an insurer falls into the Payors key stakeholder according to the four P's model.

Healthcare provider (Zorgaanbieder)

The following information elaborates the stakeholder group *healthcare provider* according to [14].

Role

The healthcare provider is the party that uses the eHealth application to offer healthcare to patients or clients. Keep in mind that there are different parties within the organization of the 'healthcare provider' who have something to say about your application. The following roles can be represented:

- The investment decision maker, for example a partnership or the board of a healthcare institution.
- The users of an application: medical specialists and / or nurses.
- The IT department that must integrate and maintain new systems and applications.

Early involvement of these internal parties in the development (co-creation) guarantees that there is support for an application.

Interests

The healthcare provider may have the following interests in an eHealth application:

- The quality of care improves, for example through increased safety.
- The efficiency of processes increases, for example through smarter registration.
- The application leads to labor savings, so that more care can be provided with the same number of people.
- Increased service level, for example through more accessible care.
- Strengthening one's own right to exist by being ahead of other healthcare providers.

- Image enhancement, for example by allowing patients to have more control of their own.
- The application must be compatible with existing care processes and users must see the benefits.

Finally, a healthcare provider falls into the Providers key stakeholder according to the four P's model.

Patient association (Patiëntenvereniging)

The following information elaborates the stakeholder group *patient association* according to [14].

Role

Patient associations represent the interests of a specific group of patients (for example epilepsy patients) by influencing healthcare providers, health insurers, professional associations, and the government. In addition, they encourage and fund scientific research into better care for their target group, and they provide information to affiliated patients and to the wider public. They are well aware of the specific situation and needs of their target group (experiential expertise). A patient association can be an important partner for testing the added value of an innovation at an early stage. If a patient association recognizes the added value of an innovation, it can be a strong cooperation partner in the development (for example, financing with its own resources), the evaluation (through good contacts with its own target group), and in the promotion of an application among patients and healthcare providers. , professional associations, health insurers, and the government.

Interests

The main interest of the patient association is to improve care for their own target group. The patient association may have the following interests in an eHealth application:

- Improving the effectiveness of care for the target group.
- Improving the accessibility of care for the target group.
- Limiting the impact of the health situation on the (social) life of the target group.
- Retaining independence and control for the target group.
- Prevention (if applicable) and information for the wider public.

Finally, a patient association falls into the Patients key stakeholder according to the four P's model.

Government (Overheid)

The following information elaborates the stakeholder group *government* according to [14].

Role

The government - the Ministry of Health, Welfare and Sport - regulates the healthcare market and determines which healthcare is reimbursed. It does this through the Dutch Healthcare Authority and the Netherlands Care Institute.

The Dutch Healthcare Authority (NZa) supervises the healthcare market. It does this by, among other things, drawing up care services and determining rates. Only when an eHealth application has been "translated" into a service can the care in question be offered and charged. The NZa eHealth funding guide makes clear the possibilities of funding eHealth.

Interests

It is important for the NZa that there is sufficient support for the application for a new care performance. Only a combination of care providers and health insurers may apply for a new care performance together. To speed up innovation, the NZa has set up two schemes:

- The policy rule Innovation for small-scale experiments and the accompanying Regulation for innovation for small-scale experiments can be used to set up a temporary performance, so that a new application can be evaluated on a small-scale for several years in practice. You can read more about this in the Information Card Policy Rule Innovation for small-scale experiments.
- Thanks to “optional performance”, healthcare providers and health insurers can also agree a new performance and submit it to the NZa. You can find these optional benefits on the NZa website per healthcare sector under the Care innovations tab.

It is important for the Healthcare Institute that the basic package provides care that is necessary and that healthcare is accessible and affordable. To be able to make careful decisions, the Healthcare Institute uses four ”package principles”:

- Necessity - inclusion in the package is socially justified
- Effectiveness - healthcare is effective
- Cost effectiveness - the cost-benefit ratio is acceptable
- Practicability - inclusion in the package is feasible and sustainable.

Finally, a government falls into the Policymakers key stakeholder according to the four P’s model.

Municipality (Gemeente

The following information elaborates the stakeholder group *municipality* according to [14].

Role

In January 2015, municipalities were given additional tasks in the area of health care purchasing. The municipalities buy care for the residents of the specific municipalities which fall under the following laws:

- The Social Support Act
- The Youth Act
- The Long-Term Care Act

The municipality is responsible for youth care and assistance and support for the elderly and the long-term sick. Think of domestic help, guidance and care, day care, relief, aids, and reintegration. A municipality therefore pays and facilitates healthcare products and healthcare services to its residents. The way in which the municipality does this - directly, via care providers or via welfare organizations - that differs per municipality.

Interests

For the municipalities it is important that the following goals are achieved:

- More patient confidence
- Ability for patients to stay at home longer
- Well-being of patients
- More support for informal care
- Sustainable cost for municipalities

- knowledge acquisition and facilitation of cooperation between different care parties and care entrepreneurs in the municipality and region

An important side-note to these municipality interests is the fact that not all municipalities in the Netherlands weigh these interests the same way. This can mean that municipality A thinks informal care is more important as where municipality B has more focus on getting sustainable health care costs. The exact differentiation of the different municipalities in the Netherlands has not been researched because it is out of scope for this study. Finally, a municipality falls into the Policymakers key stakeholder according to the four P's model.

Professional association (Beroepsvereniging)

The following information elaborates the stakeholder group *professionals* according to [14].

Role

The professional association is a scientific association of a certain professional group of specialists. It offers training and promotes evidence-based practice (professional practice based on the best available scientific information). Professional associations are responsible for drawing up guidelines and standards for good quality and safe care. To this end, they consult with healthcare providers, health insurers, the government and patient associations.

Interests

The importance of the professional association is the promotion of scientifically justified professional practice and thus the promotion of safe and responsible care. The professional association will first ask itself whether an eHealth application contributes to safe and responsible care. That means: good quality and in any case effective, efficient, patient-oriented and tailored to the real needs of the patient. Finally, a professional association falls into the Providers key stakeholder according to the four P's model.

Stakeholder impact analysis

In order to provide a clear overview of which key stakeholder attributes each stakeholder possesses, Table 3.3 will be presented in which all stakeholders are included, including the P for Power, L for Legitimacy, U for Urgency or a combination of these three.

Stakeholder	**Power**	**Legitimacy**	**Urgency**	**Salience type**
Dutch government	-	L	-	Discretionary
Health insurers	P	-	U	Dangerous
NVZ Dutch Hospitals / healthcare providers	P	L	U	Definitive
Specialist/professional association	P	-	-	Dormant
Patient (association)	-	L	U	Dependant
Municipality	-	-	U	Demanding

Table 3.3: Final stakeholder type attribution

3.2.5 Stakeholder Conclusion

In the above chapter, different stakeholders and a stakeholder analysis for different stakeholders within the Dutch (e)Health network has been presented. The importance of this stakeholder analysis is to identify and acknowledge the different needs and possibilities of the involved stakeholders in order to maximize the positive effect of the business model. Also increasing the potential adoption and acceptance of the business model within the Dutch healthcare domain for medical IoT services.

To conclude this stakeholder analysis, we define the healthcare providers as the definitive stakeholders. The healthcare providers must be triggered to initiate upon the new technologies and, with or without the support and guidance of BDO, start up pilot cases for edge computing to support remote monitoring. The patient will be a dependant stakeholder, the patient fills up an important gap in this stakeholder analysis, but lacks the power of development, engineering, technical expertise and funding making them dependent on the healthcare providers to kick-off certain innovative projects. Because this study is an exploratory study, the Dutch government and health insurers do not play a big part in this research because pilot studies must still be set up. This research is to pave the way and validate if a valid business model for edge computing can be achieved. Policy and insurer funding will be more prominent in the next steps of pilot and case studies. Then, all regulation and adoption of new techniques has to be audited and accepted by, included in law and funded by the government. Below the government, municipalities and health insurers are mostly guided by the Dutch government in the provision, facilitation and reimbursement of medical services. As where specialist are mostly Dormant, having power, but are mainly focused on their job, as where hospitals are mostly Discretionary, as for the real power lies with the specialists but do have a legitimacy to the facilitation of care among patients. In the remainder of this thesis, the stakeholders will be treated accordingly to their place in the salience model described here.

Chapter 4

A Remote Care Business Model

In this chapter, the main artefact of this thesis will be constructed according to the Business Model Canvas by Osterwalder. Within this chapter, all nine aspects of a complete business model for the use of IoT and edge computing for tele-health and tele-monitoring solutions with a specific focus on diabetic patient care and monitoring. In the first section several contemplation's with respect to the nine elements are being elaborated. In the second section of this chapter, the final business model canvas as it is being proposed, after validation by experts in the field, will be presented.

4.1 Canvas elements

In order to design the artefact for this research, a business model will be designed. This will be done by using the Business Model Canvas. Besides, the two most important stakeholders, as defined in **Chapter 3** will be used as input for the business model. As described earlier on, the most important stakeholders for this tele-monitoring and tele-health business model from a hospital perspective are the patients and the doctors, nurses and the health care providers as these stakeholders have to initiate, work with and undergo the case. In order to design this model, the nine building blocks as described by [24] will together form the business model. All nine building blocks will be formulated for this business model so that the business model can be validated by expert reviews when it is finished.

4.1.1 Customer Segments

The customer segment dimension of this Tele-monitoring and tele-healthcare solution is applicable to a multi-sided market. Healthcare for chronically ill and other long term patient care at a distance consists of at least two sides and therefore two segments. The market for remote- and tele-monitoring for Dutch hospitals: they have patients who need care and must use the systems on the one side and doctors, nurses and other care specialists who must use the system in order to provide care for the patient on the other side. Both customer segment dimensions fall under two of three types of people within a customer segment, **An end user**, and **A beneficiary**. Both the doctors as well as the patients end up experiencing the tele-monitoring system (end user), as well as being better of using the system (beneficiary). Finally, there is the **Customer**, this type makes the decision and pays for the solution. In this business model, the government and health insurance companies will take up the role of paying customer.

Both segment dimensions consist of relevant individual customer types, known as 'Personas', as defined by [86]. These Personas make up the segment composition. In order to have a clear view of the relevant customer composition of a tele-monitoring health care solution for diabetic patients, two personas for each customer dimension will be created as well a persona for the customer in this case. There are two interesting area's to explore about the personas. Demographics and psycho-graphics. Demographics are useful, but limited. Descriptors like age, gender, height, race, wealth and others are descriptors linked to demographics. As were psycho-graphics are more intangible and invisible but more powerful persona descriptors. Think about persona attitude, religion, ethics and worldviews as important descriptors.

Personas	**Age**	**Gender**	**Measurements**	**Physical appointments**	**Sport**	**Lifestyle**
Roy	54	M	+15 a day	+4 a year	Inactive	Non-smoker
Jessy	23	M	-	6-10 a day	Weekly runner	Social drinker
Kelly	19	F	1-2 a day	+1 a year	Cycles daily	Smoker
Celine	40	F	-	+-8 a day	Plays hockey	Abstainer

Table 4.1: Demographics personas

The second important part of defining the personas is the story behind the personas, so in order to complete the narrative combining the demographic aspects with their personality and how they are in life. This is a very important aspect because of the nature of the tele-monitoring and tele-health business model.

Roy is a 54 year old diabetes patient, who has had diabetes for almost his entire life, approximately 48 year now. Roy adheres to a healthy lifestyle, he tries to eat healthy food, does not smoke and barely drinks any alcohol. He is not very active physically though. Roy tries to measure his blood sugar levels as often as possible because of the fact that his last HbA1c value was 10.7, which is to high. Therefore Roy worries about the future and wants to work hard to stabilize his blood sugar levels in order to reduce the risk of diabetes-related diseases. Roy does not have any IT or technical background and is not technically gifted. Roy is also somewhat worried about all the fuzz about privacy regulations and the ever more data gathering of systems which Roy inherently don't really understand.

Jessy is a young male nurse on the internal medicine department. He is a healthy young lad and is also an active runner. Besides that, Jessy knows his way around computers and has build his own desktop system at home. During work, he has around 6 to 10 physical appointments with diabetes patients where the daily blood sugar levels are discussed, weight and height are being measured and an inspection on injection marks take place. He often has long discussions with patients about how they could improve there blood sugar levels and their HbA1c levels. Jessy also notices that a lot of meetings usually take longer then planned, increasing the wait time for patients.

Kelly is a 23 year old female who just recently found out about her having diabetes. Kelly was a regular smoker and has not decided to quit after finding out she had diabetes, also, she is an active cyclist in order to improve her stamina. Kelly still is adjusting to life as a diabetes patient and sometimes shows some rebel behavior with regards to diabetes check ups, medicine intake and blood sugar measurements. Doctors, at least at the moment, have a hard time getting through to her. Kelly finds it a nuisance that she always has to bring measurement equipment and insulin shots when she goes out with friends for food or drinks.

Celine is an experienced diabetes specialist. She has been working in the same hospital for 18 years and has seen a lot of patients progressing, for better or for worse over time. Especially with the patients that regularly visit for health check-ups, Celine has bonded with. Celine also knows her way around current e-health movements and keeps updated about new technologies on the market. Though, this mainly concerns approved systems and applications, Celine is naturally no early adopter and still values old working methods over an all digital working environment. Celine also notes that the digital paper work and other administration about patients is an ever increasing Moloch, where Celine loses more and more time to.

The above personas personify a few different end users and beneficiaries. The customer in this case will be the relevant hospitals. In summary, we can say that the diabetes patients deal differently with both their health and medicine use. The doctors have their own problems that run into them, from spending a lot of time on physical appointments to copious administration.

4.1.2 Value proposition

After the identification of end users, beneficiaries and a customer, it is important to define a value proposition to complement the tele-monitoring and tele-health business model for remote care of diabetes patients. For clarification, the final customer, the actor who will be paying first are the relevant hospitals. The end users and beneficiaries are the diabetes nurse and doctors and the diabetes patients. According to [86] it is vital to create a unique value proposition for each customer segment. Therefore, we will formulate a value proposition for patients, for doctors and for hospitals in general.

Patient value proposition

The patients have a daily caring routine as defined earlier of the continuous monitoring of blood sugar levels, constantly calculating carbohydrate intake and activity levels. Continuously administering food and insulin to the body while always keeping in mind future possible activities and events and keeping half-yearly checks with doctors and specialists. Al these facets of the care for diabetes can be an extremely tiring and complex job, every day without the ability to take a break of this cycle. Only for breaks of the cycle mostly result in unstable blood sugar levels increasing chances of long term complications and immediate exhaustion due to the unstable blood sugars. Also, for diabetes patients, the constant monitoring of the state of their diabetes can become a task they no longer want to fulfil. The use of IoT in combination with edge computing can provide a secure state for diabetes patients to relieve themselves of the constant care of their diabetes without exposing oneself to later complications or other more direct negative influences. And even though a decrease in the chance of negative complications is an important part of the value proposition, the freedom edge computing in combination with IoT can provide patients is the main aspect of this value proposition.

A final important aspect for diabetes patients regarding the use of *Edge computing* within a remote care or monitoring setup is the privacy aspect of it all. Using the latest smartphones as edge node, diabetes patients get the possibility to process all their own medical data within their *'own'* edge node. This ensures the medical data of diabetes patients is processed, stored and analyzed within the confines of the patients own network and device. Only to make it possible for patients to choose what data they share with the hospital and when they do this. What edge computing can do for patients is giving back control over their own medical data improving the feel of freedom even more.

Doctor value proposition

For doctors and diabetes nurses, mainly a functional value proposition is apparent. The more patients can be given access to a monitoring and administering system based on edge computing, focusing on the patients own mobile phone as edge node, therefore creating a positive value attribution towards patients, doctors will have more time to focus on patients with relative severe complications and situations that require fysical access to the patient. While also being able to drop repetitive and administrative tasks and outsource these tasks to the patient.

Hospitals value proposition
The Dutch hospitals are facing ever-increasing healthcare costs and increasing pressure on staff. Quality and care innovation are coming under increasing pressure. In addition, medical innovation is also under pressure from a compliance point of view due to increasingly intrusive privacy legislation and privacy awareness of patients. By introducing edge computing solutions and infrastructures with which patients have more control over their own data and strict privacy legislation is complied with. Edge computing can thus increase innovation and quality of treatments and realize a significant decrease in costs because more patients can 'treat' themselves. Finally, the introduction of a compliant and generally accepted form of e-health and remote monitoring gives staff more time available for direct care for patients who need it.

The 'product' that should support the aforementioned value propositions is a platform on which patients can connect, use the mobile phone, share or unlock data with the hospital and the doctor on duty, but at the same time also be in control of the generated personal medical data. Which ensures that medical information can be shared better and faster with doctors and hospitals. Treatment can be done faster and more efficiently at the same time achieve a high degree of security when it comes to information security and privacy by providing the patients with more control. A vision that is supported by [87] in his paper where he states that healthcare is an IoT rise domain where applications require or even demand privacy, real-time analysis and Quality of Service (QoS) requirements.

4.1.3 Customer Relationships

Within the customer relationship, [86] defines three important spectrum's. In order to formulate a clear and concise customer relation viewpoint for edge an edge computing model, the three below formulated questions must be answered.

1. Short term versus long term relationship?
   Within the remote monitoring of diabetes patients, but also in the more general sense of remote monitoring and tele-health solutions, the aim is for long term relationships between patient and hospital. As is the case that a patient usually does not choose the hospital he gets placed for a chronic disease, it will form a long term relationship of trust between patient and doctor.

2. Personal versus automated relationship?
   Whereas the current state is mainly focused on personal relationships, a patient has a physical appointment with a doctor to undergo certain check ups, as well as the in person blood monitoring. The current business model aims to make a shift from solely personal relationships between patient and hospitals towards more automation within the patient-doctor relationship.

3. Acquisition versus retention of the relationship?
   Finally, as already mentioned, the focus within this remote monitoring and tele-health business model for diabetes patients mainly lies in the acquisition of the relationship. It is important to have innovative solutions for diabetes monitoring in order for diabetes patients to be fully unburdened while also have control over their own data. These key value points can become a unique selling point for hospitals who provide the kind of service proposed in this business model. Besides, for an edge computing platform to work, an economy of scale would greatly improve efficiency and impact, therefore acquiring patients who want to participate are a top priority.

To conclude, communications within a health context will differ from regular commercial and marketing customer communications. It is important to understand what patients want in their treatment and what patients may be concerned about. A final remark with respect to the customer relationship is that within this business model, financial negotiations between hospitals, policy makers and insurance company are out of scope for this business model. The main focus is the need of patients and presenting a suitable solution that fit the needs of patients.

4.1.4 Channels

There can be no one channel fits all perspective, though where current channels are physical and in person communication, the shift will be made towards digital communication, information, monitoring and self care. The main channels where the system will be delivered or experienced by patients are the mobile phone and the digital health patient portals of the large Electronic patients file software suppliers like Chipsoft or Epic. Here, the acquisition channel as described by [86] consists of physical presentation of doctors to the patient, explaining the system and informing the patients of the perks and know how. As where the delivery channel is mainly digital via the patients mobile phone and the patient portal from the relevant hospital.

In future pilot studies, more delivery channels can be investigated but in order to create a small boundary for this business model, introduction of the mobile phone as edge node and therefore the distribution channel to the patient will be used. In future research and scale expansion, home routers or institution and hospital routers could be adopted as edge nodes as stated in the research of Varghese into the challenges and opportunities of Edge computing [88]. Where more applications can be connected to a more powerful edge node, different products and different channels will be introduced to the concept. In this business model however, only tele-monitoring of diabetes patients is included. Creating the business model using only the privately owned mobile phone of the patients also immediately copes with one of the big challenges of edge computing according to Varghese, the public use of edge nodes in a secure manner [88]. Because the edge nodes are all within the private home network or individual mobile network.

4.1.5 Key Resources and Activities

The main key resource for this business model is a high-end mobile phone, strong enough to act as a edge node capable of storing, analyzing and processing monitored measurements of the diabetes patient. A software supported edge and private cloud EPD network and software where patients and doctors can connect to the same environment, as well as making it possible for patients to use their mobile phone as edge node connecting it to a edge network giving internal control to the patient of what data gets processed and shared and what not. The possession of a mobile phone or other sort of mobile device is with respect to the current specifications of mobile phones feasible on short term. There will always be patients that do not own a high-end mobile phone, and especially when looking at a large part of the target patients, the elderly. These patients are more likely to own a much less powerful mobile device, but at the rate current lower end models are increasing the processing power and storage capacity, the possession of a sufficiently powerful mobile device is assessed as feasible.

From the perspective of BDO as digital transformation specialist, some resources are essential for the business model. First and foremost, development capabilities must be available, either from one of the software side *key partners* or from BDO itself to support and develop software and infrastructure in compliance to the edge computing concept. A second important resource is the availability of the EPD software of the respective hospitals, in order for this business model to succeed, it is important that the edge nodes have the possibility and capability to communicate with the hospital environments. Basically this means that the edge node(s) must be able to communicate with the hospitals EPD system.

When looking at this from the BDO perspective of the Zorg Manifest, more and more resources are being put to work for innovative projects with respect to E-health initiatives. Besides, from the interview with Mark Wagenaar, the lead architect of Noordwest Ziekenhuis groep, it became clear that Chipsoft is increasing its exposure to other parties. This makes it more feasible to co-create and deliver sufficient technical expertise, EPD product knowledge and healthcare environments using pilot study settings at one or several hospitals.

The most important activity for BDO is the identification and connection of software providers, hospitals and patients in order to design an interconnected network between the EPD software, private Clouds, hospitals and the mobile phones of patients acting as edge nodes. So, in cooperation with key partners, an edge platform should be designed with logical connections to the Hospital private Clouds and the possibility for patients to use their mobile phone as an individual edge node capable of storing, analyzing, processing and sending medical data of the patient.

A second important activity for support to this business model is the execution of a feasibility and adoption study among key partners, to test the availability of key resources and finally the patients' thoughts regarding the business model and the potential for using an edge computing solution on their 'own' mobile phone.

4.1.6 Key Partners

From the perspective of BDO as advisor and digital transformer for a great deal of the Dutch hospitals, the two main partner categories in this business model are the relevant hospitals and the EPD developers. Here, EPD stands for Electronisch Patienten Dossier and is the Dutch translation of Electronic Patient Record. In order to substantiate on the key partners for the business model from the perspective of BDO, some extra information with respect to the technology stack of a hospital must be provided.

It is important to first have a clear view of current IT infrastructure of the different hospitals within the Dutch healthcare. In order to make the business model as relevant as possible for a multitude of Dutch hospitals, it is important to have a clear idea in advance about which IT infrastructure is used within the relevant Dutch hospitals. In this way, the business model can be generalized to a market-wide business model instead of a specific business model focused on a single hospital. This will ultimately contribute to the impact that the business model can generate and support the validity of the business model. After market research, the following two pages show a multitude of Dutch hospitals, academic as well as regular hospitals, day hospitals and specialized hospitals.

In **figure 4.1** the first part of Dutch hospitals with their respective EPD contract, or ongoing implementation from a respective supplier is presented, including the year the system went live. To validate this data, contact has been made with some hospitals to check whether these EHR systems are actually used within the relevant hospitals. After contact with some BDO client-hospitals, the data presented in Figure 4.1 correspond to the current situation at the hospitals. The same process has been conducted to perform the validation of a subset of hospitals from **figure 4.2**, also this list has been positively validated among a few BDO client-hospitals. In addition, online information was also found regarding the internal EPD software used in annual reports of various hospitals. An example of this is the Diakonessenhuis, which is stated in its annual report that it works with Chipsoft (HiX). After finding all this validating information, it can be concluded that the information presented in figures 4.1 and 4.2 corresponds to the current reality.

Naam ziekenhuis	Plaats	Fusiepartner(s)	EPD/ZIS Contract	Lopende imple-mentatie vanuit	jaar live gang
Noordwest Ziekenhuisgroep	Alkmaar/Den Helder		Chipsoft (HiX)	Nexus	2018
Ziekenhuisgroep Twente	Almelo/Hengelo		Chipsoft (HiX)		2016
Flevoziekenhuis	Almere		Cerner/SAP (IS-H/i.s.h.med)		
Meander Medisch Centrum	Amersfoort		CSC care solutions	Nexus & Easycare	2018
Ziekenhuis Amstelland	Amstelveen		Cerner/SAP (IS-H/i.s.h.med)		
Onze Lieve Vrouwe Gasthuis	Amsterdam		Epic		2015
MC Slotervaart	Amsterdam		Chipsoft (HiX)		2017
Antoni van Leeuwenhoek/NKI	Amsterdam		Chipsoft (HiX)		
VU medisch centrum	Amsterdam	AMC	Epic		2016
BovenIJ Ziekenhuis	Amsterdam		Chipsoft (HiX)		2017
Academisch Medisch Centrum	Amsterdam	VU mc	Epic		2015
Gelre Ziekenhuizen	Apeldoorn/Zuthpen		Cerner/SAP (IS-H/i.s.h.med)		
Rijnstate	Arnhem/Zevenaar/Velp		Chipsoft (HiX)		2018
Wilhelmina Ziekenhuis	Assen		Chipsoft (HiX)		2017
Bravis	Bergen op Zoom/ Roosendaal		Chipsoft (HiX)		2013
Rode Kruis Ziekenhuis	Beverwijk		Chipsoft (HiX)		2017
Maasziekenhuis Pantein	Boxmeer		Chipsoft (HiX)		2017
Amphia Ziekenhuis	Breda		Epic		2011
IJsselland Ziekenhuis	Capelle aan den IJssel		Chipsoft (HiX)	Siemens-i.s.h.med	2018
Ommelander Ziekenhuis Groep (Delftzicht en St Lucas Zkh)	Delfzijl	UMCG	Nexus/EPD		2016
Deventer Ziekenhuis	Deventer		Chipsoft (HiX)		2016
Het Van Weel-Bethesda Ziekenhuis (CuraMare)	Dirksland		Chipsoft (HiX)		2017
Slingeland Ziekenhuis	Doetichem	Streekziekenhuis Koningin Beatrix	Chipsoft (HiX)		2017
Albert Schweitzer Ziekenhuis	Dordrecht		Chipsoft (HiX)		2017
Nij Smellinghe	Drachten		Chipsoft (HiX)		2015
Ziekenhuis Gelderse Vallei	Ede (Gld.)		Nexus ZIS & Norma EPD		
Catharina Ziekenhuis	Eindhoven		Chipsoft (HiX)	Chipsoft (Ezis)	2018
Maxima Medisch Centrum	Eindhoven/Veldhoven		Chipsoft (HiX)		2017
Medisch Spectrum Twente	Enschede		Nexus & best of breed		
St. Anna Ziekenhuis	Geldrop		Nexus/EPD		2015
Admiraal De Ruyter Ziekenhuis	Goes/Vlissingen/ Zierikzee		Chipsoft (HiX)		2017
Rivas Zorggroep Beatrixziekenhuis	Gorinchem		Chipsoft (HiX)		2014
Groene Hart Ziekenhuis	Gouda		Nexus ZIS & Norma EPD		
Universitair Medisch Centrum Groningen	Groningen		Epic		2017
Martini Ziekenhuis	Groningen		Chipsoft (HiX)		2016
Spaarne Gasthuis	Haarlem/Hoofddorp		Epic		2008
Ziekenhuis Röpcke-Zweers (Saxenburgh Groep)	Hardenberg		Chipsoft (HiX)		2017
St Jansdal	Harderwijk		Epic		2016

Figure 4.1: EPD overview of Dutch hospitals part 01 [15]

As can be seen in the above images of the majority of Dutch hospitals with their IT supplier of the electronic patient file software packages. Because for a successful implementation and adoption of edge computing components, not only do we need the acceptance of the patients, we also need the support of the IT suppliers of the Dutch EPD systems to make a logical connection possible between the EPD software used by the relevant hospital and the smartphones, or any other device which could be used as edge node for local processing of medical data.

Figure 4.2: EPD overview of Dutch hospitals part 02 [15]

De Tjongerschans (Zorgpartners Friesland)	Heerenveen		Chipsoft (HiX)		2015
Zuyderland	Heerlen/Brunssum/ Kerkrade/Sittard-Geleen		Cerner/SAP (IS-H/i.s.h.med)		
Elkerliek Ziekenhuis	Helmond		Chipsoft (HiX)		2015
Tergooi	Hilversum/Blaricum		Chisoft (HiX)		2016
Westfriesgasthuis	Hoorn NH	Waterland ziekenhuis	Chipsoft (HiX)		2013
Medisch Centrum Leeuwarden (Zorgpartners Friesland)	Leeuwarden/Harlingen		Epic		2016
Leids Universitair Medisch Centrum	Leiden		Chipsoft (HiX)		2016
Alrijne Zorggroep	Leiderdorp/Alphen aan de Rijn/ Leiden		Chipsoft (HiX)		2016
MC groep	Lelystad/Emmeloord		Nexus/EPD		2018
Academisch Ziekenhuis Maastricht	Maastricht		Cerner/SAP (IS-H/i.s.h.med)		
Isala	Zwolle/Meppel		Chipsoft (HiX)	eigen/Chipsoft (ezis)	2018
St Antonius Ziekenhuis - Zuwe Hofpoort Ziekenhuis	Nieuwegein/Utrecht/ Woerden		Epic		2017
Radboudumc	Nijmegen		Epic		2013
Canisius-Wilhelmina Ziekenhuis	Nijmegen		Chipsoft (HiX)	CSC-iSoft	2017
Sint Maartenskliniek	Nijmegen		Chipsoft (HiX)		2017
Waterlandziekenhuis	Purmerend	Westfries Gasthuis	Chipsoft (HiX)		2014
Laurentius Ziekenhuis	Roermond		Chipsoft (HiX)		2017
Franciscus Gasthuis & Vlietland	Rotterdam/Schiedam		Chipsoft (HiX)		2017
Erasmus Medisch Centrum	Rotterdam		Chipsoft (HiX)		2017
Maasstadziekenhuis	Rotterdam		Chipsoft (HiX)		2017
Het Oogziekenhuis	Rotterdam		CSC care solutions		2017
Ikazia Ziekenhuis	Rotterdam		Chipsoft (HiX)		2017
Havenziekenhuis	Rotterdam		Chipsoft (HiX)	Nexus	2017
Stichting Reinier Haga Groep	's-Gravenhage/Delft/ Zoetermeer		Chipsoft (HiX)		2017
Medisch Centrum Haaglanden - Bronovo	's-Gravenhage/ Leidschendam		Chipsoft (HiX)		2015
Jeroen Bosch Ziekenhuis	's-Hertogenbosch		Chipsoft (HiX)		2016
Antonius Ziekenhuis	Sneek		Chipsoft (HiX)		2015
Spijkenisse MC	Spijkenisse		Chipsoft (HiX)		2017
Treant Zorggroep (Refaja, Scheper, Bethesda)	Stadskanaal/Emmen/ Hoogeveen		Nexus/EPD		2017
ZorgSaam Zeeuws-Vlaanderen	Terneuzen		Chipsoft (HiX)		2016
Ziekenhuis Rivierenland	Tiel		Cerner Soarian & Nexus		
Elisabeth-TweeSteden Ziekenhuis	Tilburg/Waalwijk		Epic	CSC-iSoft & eigen	2018
Ziekenhuis Bernhoven	Uden		Nexus/EPD		2017
Universitair Medisch Centrum Utrecht	Utrecht		Chipsoft (HiX)		2016
Diakonessenhuis	Utrecht/Doorn/Zeist		Chipsoft (HiX)		2017
VieCuri Medisch Centrum	Venlo		Chipsoft (HiX)		2017
St. Jans Gasthuis	Weert		Chipsoft (HiX)		2016
Streekziekenhuis Koningin Beatrix	Winterswijk	Slingeland ziekenhuis	Chipsoft (HiX)		2017
Zaans Medisch Centrum	Zaandam		Chipsoft (HiX)		2018

4.1.7 Cost Structure

Within the first iteration of the design of a business model for edge computing within a remote monitoring healthcare setting, no concrete cost structure has been identified. Discussion with several experts in the fields will contribute within the validation part of this thesis in order to get a better understanding for the design of the cost structure of the business model.

4.1.8 Revenue Streams

After research and after gaining relevant knowledge about the Dutch healthcare system, it has been shown that the entire system is very complex. [31] shares the fact that within the current system, insurers pay to be sick, as where the system should go the a situation where being not sick is rewarded. BDO states that this perverted stimulus is one of the reasons costs and pressure on the Dutch healthcare system keep on rising. The revenue stream, with respect to the current system therefore will result in No revenue stream. This revenue stream will only be achieved when the system has fully changed and/or the model has proven its value in real life.

4.2 Business model canvas representation

This section presents the final designed business model canvas for the use of edge computing within a remote health care environment for diabetes patients. The business model canvas as proposed by [24] is created at first. The final version of the business model, including the final business model canvas will be adapted in accordance to the validation focus group session with several BDO experts in the field of healthcare, finance and digital transformation. The final and relevant feedback delivered via this focus group will be presented in Chapter 6 as where the final business model canvas as designed in accordance to the provided feedback will be presented. In that chapter the lessons learned will be evaluated, and in accordance to these lessons learned, the business model canvas will be adjusted and presented as final. The final business model canvas will also be present in Appendix A.1.

The business model has been validated by a focus group. The validation process and results have been summarized in chapter 6. In this section business model, before this validation session will be presented:

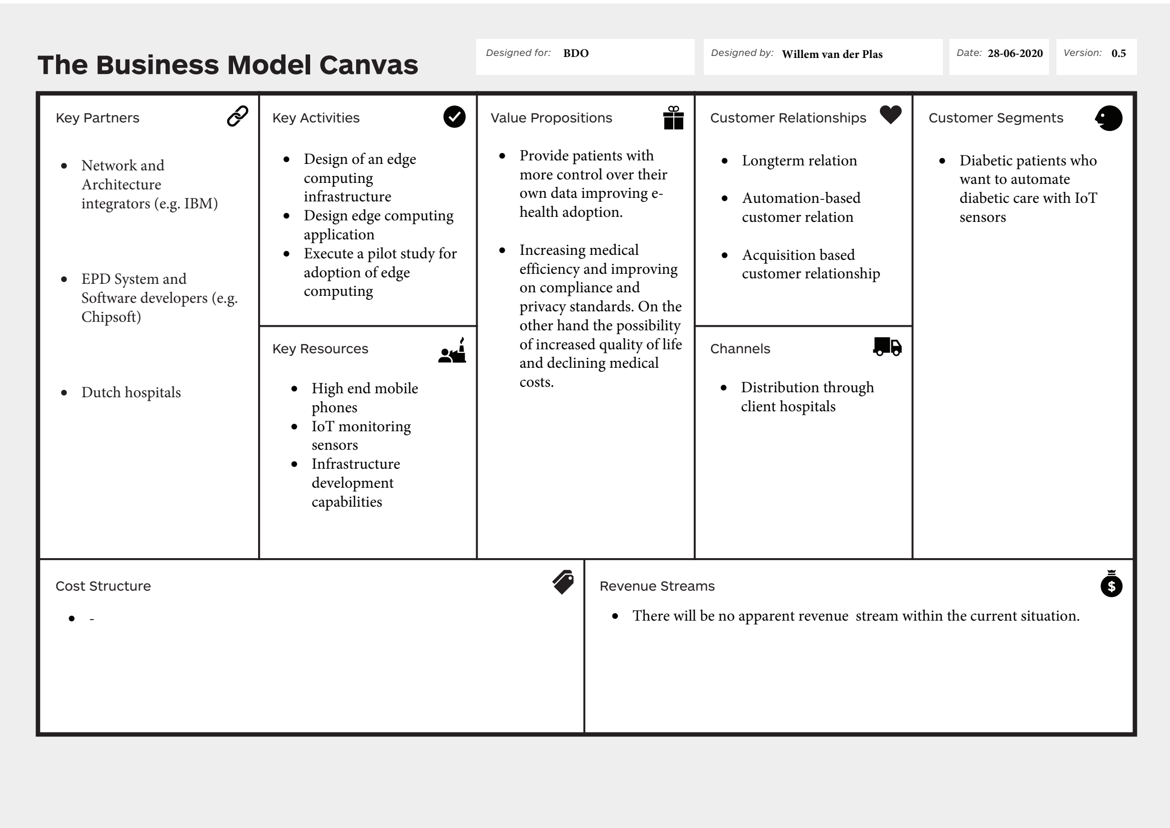

Figure 4.3: Business model canvas v_1.0 (*before validation)*

The business model, as is presented in the above business model canvas is the canvas designed before the validation sessions. During the validation sessions, some important aspects and information has been provided delivering some important lessons learned. These lessons learned have been applied to the above business model canvas resulting in a more complete business model canvas. The final business model canvas, including the feedback gathered during the validation session will be presented in Chapter 6. The areas where most feedback and lessons have been gathered encompass the cost structure, revenue stream, value proposition and customer segments.

Chapter 5

IT Implications

For this business model to be used in future pilot and case studies, it is important to identify in a clear and structured manner what how the in **chapter 4** defined business model affects current IT. The IT implications of the business model have to be clear and understandable in order for relevant actors to make a wel educated decision about the follow up on this business model.

The important aspect of this chapter is the implications on the adoption of an edge computing system can potentially have in the IT infrastructure of hospitals. Several sources have already made some research available about the possible implications of edge computing adoption. Among others, [16], [17], [89], [90] have created white papers and other relevant information sources on the impact of adopting edge computing in A healthcare architecture environment.

IBM has created a high level overview of how edge computing architecture is going to look like which can be seen in **figure 5.1**. There, IBM presents four high-level areas of importance to an edge computing architecture. And from right to left, [16] shows the following:

- **Enterprise hybrid multi-cloud:**
  Within the 'enterprise' region, according to [16], the region offers the classical enterprise-level storage and management model with respect to the IT architecture, as well as dash-boarding, enterprise level analytics and device management.

- **Edge Cloud:**
  Within this region [16] states that new networking technologies are resulting in multiple Edge Cloud instances, these Edge Cloud instances can be better described as micro data centers and can be viewed as local Clouds for communication between different devices. This region can be referred to as the 'Edge network'. These Edge Cloud instances reduce the distance that device data must travel, decreasing latency and addressing bandwidth issues. Also, because more hardware is being used, more additional storage capacity and analytical capabilities are possible at this stage.

- **Edge servers:**
  Another step closer to the edge can be described as the Edge Servers. [16] presents this stage as servers in the Edge which are being used for the deployment of apps used on so-called edge devices. [16] states the following about these Edge Servers:

  These Edge servers maintain a pulse on the plethora of devices, and if something more than inferencing is needed, data from the devices is sent to the Edge server for further analysis. These are general-purpose racked computers located in remote operations facility, like a factory, retail store, hotel, distribution center, or bank. They could have 8, 16, or more cores of compute capacity, 16GB of memory, and several hundred GBs of local storage.

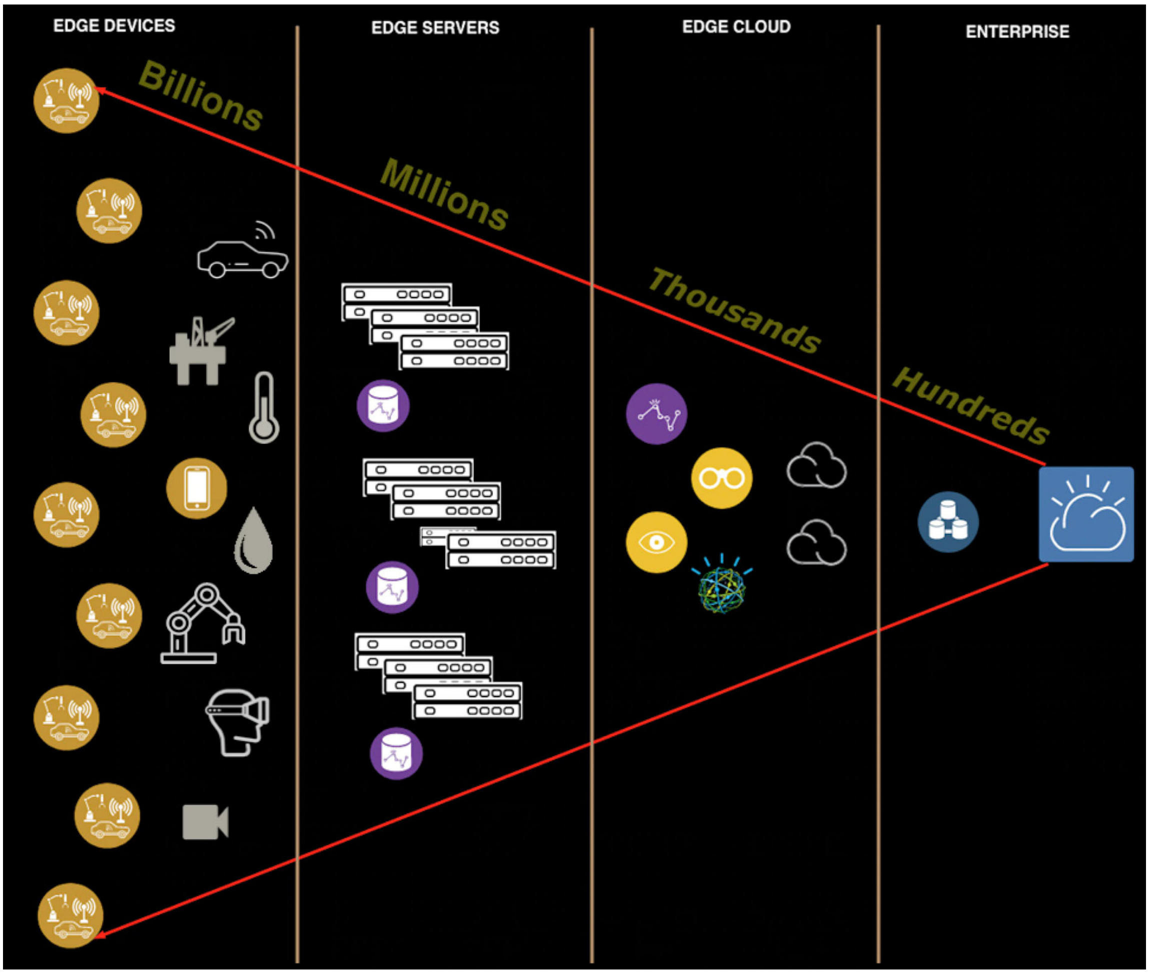

Figure 5.1: High-level Edge computing architecture [16].

- **Edge devices:**
  Finally there are the edge devices. The edge and IoT devices who have been equipped to run analytics, apply AI or machine learning algorithms and have been given the ability to store data locally for Edge operation support. [16] states the following about these edge devices:

> *The devices could handle analysis and real-time inferencing without involvement of the Edge server or enterprise layer. This is possible because devices can use any Software-as-a-Service (SaaS). Driven by economic considerations and form factors, an Edge device typically has limited compute resources. It is common to find Edge devices with ARM or x86 class CPUs with one or two cores, 128 MB of memory, and perhaps 1GB of local persistent storage.*

As within the hospital and patient setup where a patient will use his mobile phone as edge node and the monitoring and medicine applying sensors are the edge devices. Giving the patients the possibility to use their mobile phone as computational and storage hub for their own created medical, but making it possible for patients to share this data via API's with the Hospitals patient portal which connects the internal private cloud of hospitals where mostly the Chipsoft EPD system will be hosted with the edge nodes of the patients. In figure 5.2 the four areas are presented and can be divided

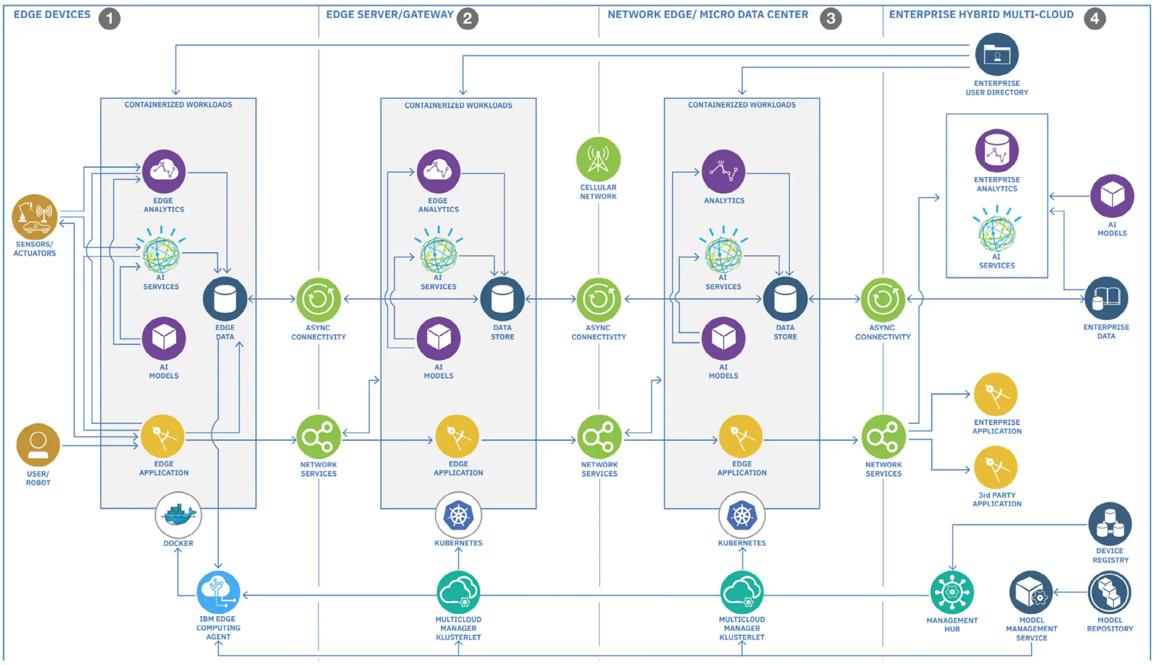

Figure 5.2: IBM's Edge computing reference architecture [16].

into the following if taken into account for the remote monitoring of diabetes patients using mobile phones as edge nodes.

The monitoring sensors fall under the *Edge devices* and provide the data. This data is subsequently gathered, stored and processed on the edge node, in this case that will be the patients mobile phone. As already stated earlier, according to [16] an edge server or node containing 8 cores, 16 GB of memory and several hundred GB's of storage are technical requirements many of the top of the line mobile phones of today can match. Therefore, technically it is possible for a mobile phone to act as an edge node for the patients health sensors. By creating a SaaS application which connects the EPD and Patient Portal functionalities with the mobile phone of the patient, it will become possible for patients to share data with the hospital and store it in the EPD if desired by the patient. This way the mobile phone of the patient can do all the analytics and storage of data needed for the automation of diabetes care providing an almost instant response and decreasing bloodsugar spikes because of the direct response between measured blood sugar levels and insulin dosage administering capabilities.

Ultimately, the IT implications of the current infrastructure of hospitals interested in this edge computing business case are fairly limited. No new hardware is needed in order to support the formulated business case. It is however important that, in co-creation with the hospital, the EPD supplier (Chipsoft) and if required a supporting party for the digital transformation support. Where [17] presented nine requirements for edge computing architecture and edge computing supported systems and applications, the following requirements are most important to this case:

- *Interoperability*
  Because more and more devices are being created for all kinds of purposes adhering to all kinds of standards, interoperability is of the utmost importance when it comes to the technical succes of this edge computing bussines case. If the mobile phone of the patient, and the used applications are not able to communicate with the relevant sensors and back end, the system would effectively be useless [17].

- *Extensibility*
  Because of the rapid deployment of IT application, functions but also hardware and software size and requirements, it is important that the system and applications in the business case have the possibility to grow with the market. Being able to adopt updates and upgrades, improving the system but also making it possible to add new functionalities without instantly breaking the system [17].

- *Abstractions* By creating API's making it possible for the edge nodes to communicate with the hospital EPD and patient portal, a more seamless control and communication between the hospital private cloud and EPD system and the mobile phones of patients is being realized [17]. As to also provide backward compatibility for those patients that accidentally or purposely did not keep their edge node and the related health application(s) updated.

- *Intelligence* Intelligence is an important aspect of the system. The more intelligent the system can be, the faster and more accurately it can predict and act upon certain behaviors of a diabetics blood sugar levels. Having a greater positive impact on the HbA1c of patients. And on the other hand being able to predict and make correct decisions on failures or abnormalities in the data gathering of relevant sensors which normally would not happen, but can have an enormous impact on a diabetes patient if it does happen unnoticed.

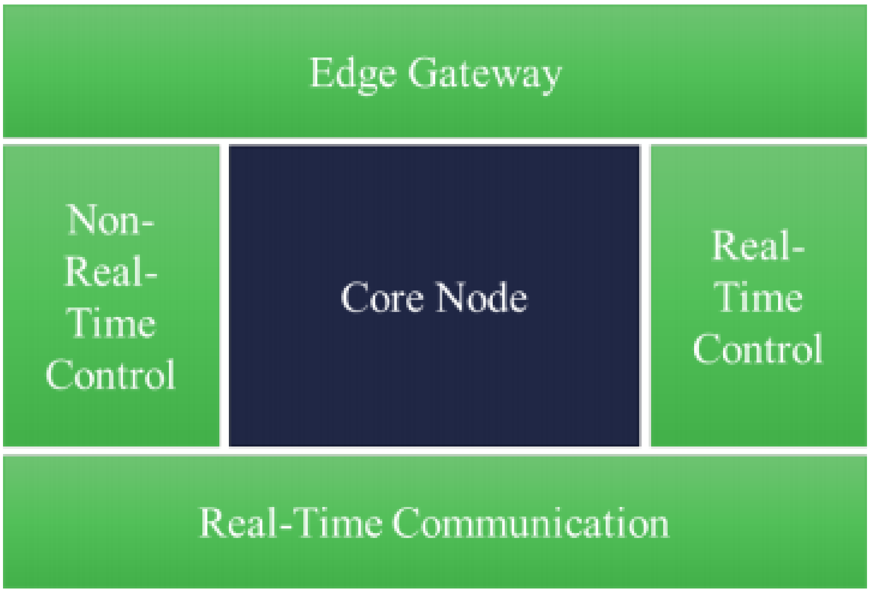

Figure 5.3: View of an extensible edge server architecture, where the green blocks extend the functionalities for the blue core node [17].

[17] mentioned several other requirements for the adoption of edge computing systems and architectures, but for the current business case these requirements are of less importance because of the nature of the system and the fact that every patients yields his or her own edge node through their mobile phone, connecting with the back end private cloud EPD systems only when desired by the patient. And therefore keeping the initial analytics and storage on the edge node of the patient.

[17] has proposed certain core functionalities for an edge server, depicted in image 5.4. This design can potentially also work for the mobile phones as edge nodes in this business case. Details about the design of enablers like message queue brokers, event processing, virtualisation, hyper-

visors and application delivery through docker according to [17] important enabler which will have to play their part during the design of a proof of concept at a hospital.

[91] has designed a three layer IoT architecture comprising of a perception layer, a network layer and an application layer. Here, the perception layer generates or creates the data. This data is subsequently passed through the network layer using an optical fiber or 3G/4G/5G technology for example to eventually end up in the final application.

When edge computing is introduced, an extra layer will be added to the architecture. The gateways will be added to the new layer, the edge layer. This edge layer will consist of the mobile phones of the patients, acting as edge node. This is depicted in figure 5.4. As can be observed in figure 5.4, the addition of the *'edge layer'* provides the sensors the ability to communicate with the application directly excluding the network and internet connections. This ensures data will stay under the control of the patient, potentially improving the security of the medical data. Because of the location of the data, the data is stored on the patients edge node (mobile phone). Important to mention is that the ability to also send the data through the network layer towards the hospital should always remain a possibility for the users. This because the sharing of data with an attending physician or doctor can potentially greatly improve healthcare efficiency and provide better quality and faster custom care specific for the respective patient.

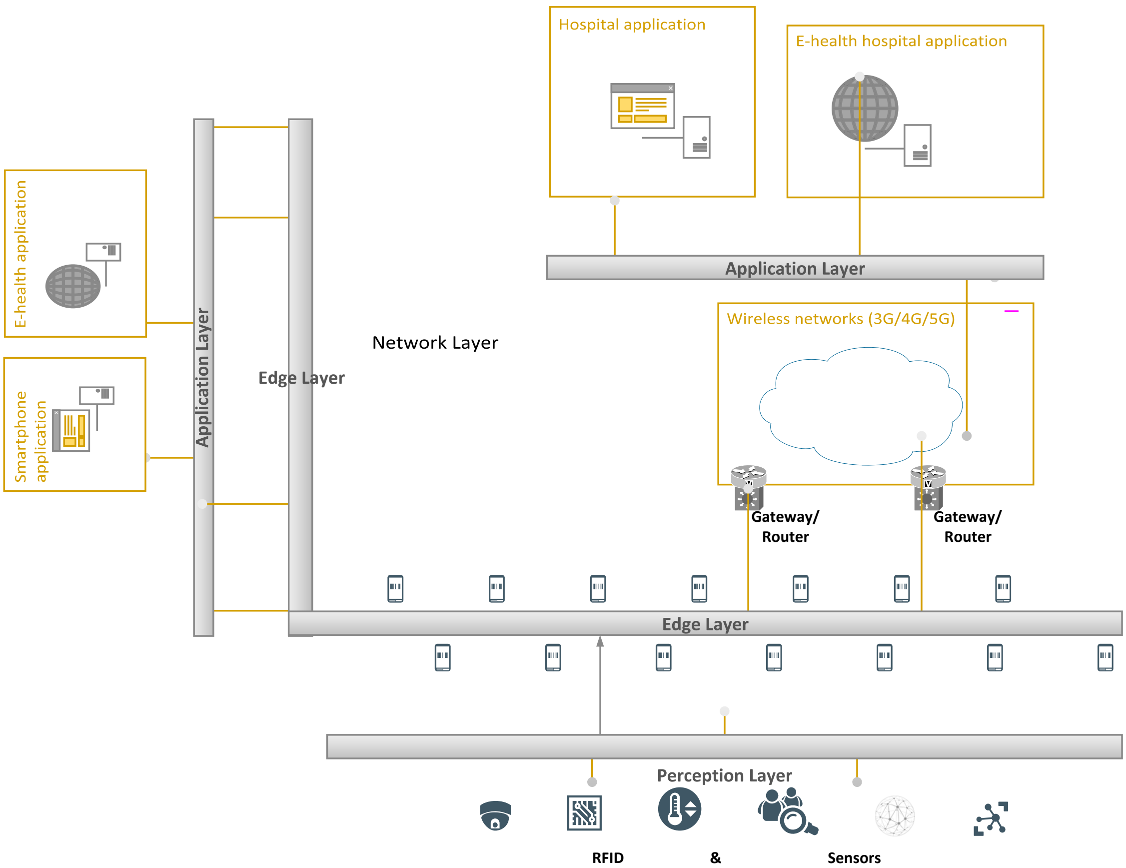

Figure 5.4: A four layer Edge/IoT architecture

To conclude on this [18] proposed a framework how a mobile edge node should be build up. This mobile edge computing framework can be found in figure 5.5. For inventory for a future pilot study it is important to test the technical feasibility of this design with some of the potential key partners. The

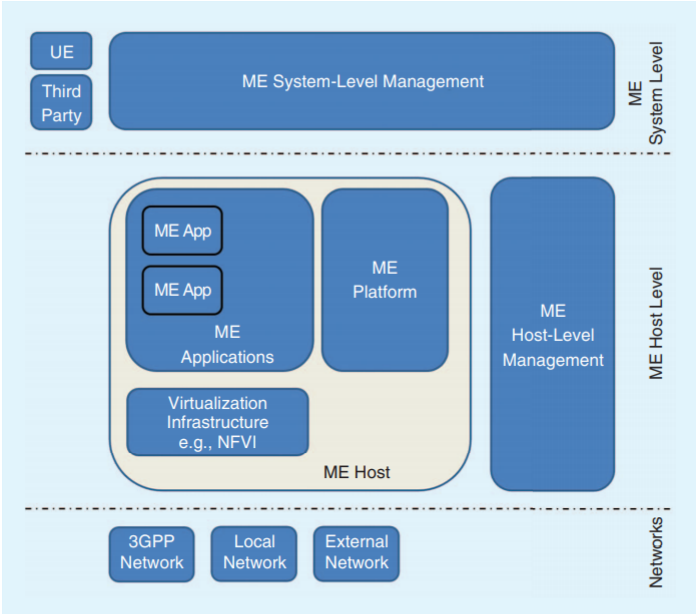

Figure 5.5: A mobile edge computing framework as proposed by [18]

key aspect can be found in the mobile edge levels. This part will reside on the patients mobile phone and therefore has to be designed and developed with the utmost care. The most obvious option is to use a container to host the virtualized infrastructure needed to transform the mobile phone of a patient into an edge node capable of storing, analyzing and processing medical data gathered via monitoring sensors. [19] supports the use of containers within a health care IoT and edge network as can be seen in the below image proposed by [19]:

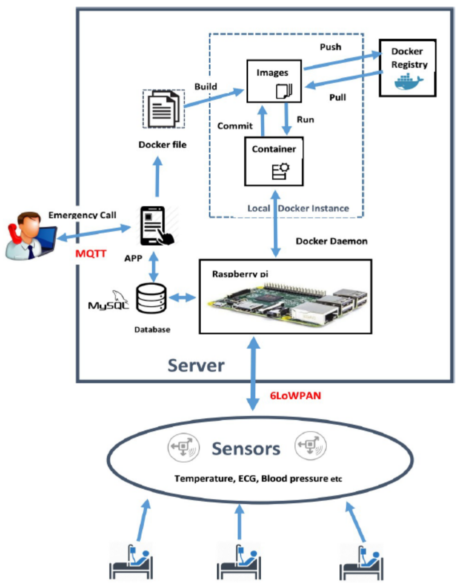

Figure 5.6: Concept design of docker container in medical setting according to [19]

[19] actually proposes the use of a raspberry pi instead of a mobile phone, though in deployment, the use of a mobile phone or raspberry pi are not so different. Here, the container will run on a

daemon, in our model, this daemon will be the mobile phone of the patient. Containers provide the additional benefit that a container can be placed on top of a physical device and operating system. Also, containers only need just enough of the host operating system to run the software needed to run in the container making it relatively light weight and providing the least amount of impact on the patients mobile phone. Also, deploying the software via a container makes it more adaptable for developers to tweak specific containers for specific devices making it possible to provide a container specifically designed for Android or Apple devices, not excluding any patient phones in advance. To be able to create docker images specifically for iOS or Android however, technologically advanced adjustments need to be made to the file systems making docker no feasible for the near future to be used in this business model. In order to make this option feasible, a second design could be made as stated by [19] to make the technical design more accessible and improve on the feasibility of the design. In this way, [19] and [18] complement each other.

Because of the novelty of this subject, not many different and elaborate architecture examples are available. Where [18] proposed a more specific design, based on their own reference architecture, also the official departments have designed a reference edge architecture, jointly issued by the Edge Computing Consortium (ECC) and Alliance of Industrial Internet (AII) as can be seen in the following figure:

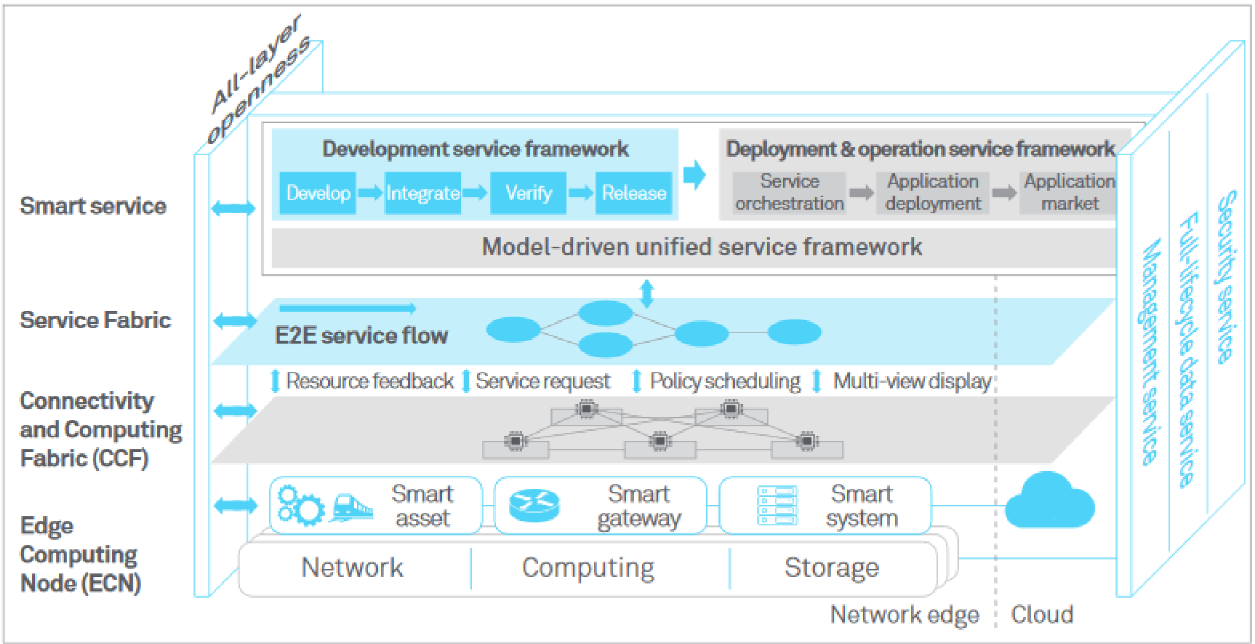

Figure 5.7: Reference Edge Architecture as designed by [20]

Within this research no clear distinction between different possible architectural options for (mobile) edge computing will be proposed. Several more or less different designs have been proposed by different researchers which all divide IoT sensors and smart services, edge nodes and connections through network leading to the cloud. In order to be able to fully grasp the entire field of study of architectural reference designs with respect to (mobile) edge computing within the health sector or in general would require a research entirely dedicated to the mapping of different architectural designs.

Chapter 6

Validation

This chapter will be dedicated to a professional validation of the model described in the previous chapters. The validation will be performed by a focus group of some BDO healthcare professionals in the area of digital transformation, innovative business models within healthcare, audit & assurance, tax advisory and health financial advisory. The choice to pick a professional from a few different areas is based, among others on [92] as he states that subject matter experts often on their own do not render the most insightful advice. This is being illustrated in [92] by a quote from Abraham Maslow:

"*If you only have a hammer, you tend to see every problem as a nail.*"

What is being stated here boils down to experts rapidly formulating a conclusion and tend to only look for data that confirms their own viewpoint. In order to diffuse this, several professionals from different expertise's have been gathered to exchange information with respect to the business model in order to formulate a most complete image of the current state of the business model.

6.1 Validation setting

For the validation of this business model we have chosen for using a focus group consisting of four BDO specialists. The ultimate goal of the validation of this business model is to find a problem-solution-market fit. This is one of the most popular approaches currently being used. Basically, it means that you must find and confirm a problem which is worth solving. Once you have a confirmation from potential customers that this particular problem is a real headache for them, you must create an acceptable solution. Once you have a general approval from customers that the solution is suitable for them, then you ask them to pay for it. If you get paid the price acceptable for you, congratulations! You have found the problem-solution-market fit. But there might be much more important hypotheses which could help in developing your startup business model. During this validation, BDO representatives from the healthcare group will discuss and consider the following hypotheses:

1. Value proposition hypotheses
    - Problems, jobs and wants hypothesis (is a problem or desired benefit strong enough?)
    - Segment hypotheses (do we know our early adopters?)
2. Business model hypotheses
    - How are costs and revenue constructed?
    - Others (technical capabilities)

3. Business growth hypotheses
    - Business growth potential (how large could the new market be?)
    - What are the chance of a high system adoption?

The participants of this focus group discussion about an edge computing business model for a tele monitoring system for diabetic remote care are:

- Chris van de Haak
- Kees Plas
- Willem van der Plas
- Nika Stegeman
- Vincent Eversdijk

For the validation of the business model, we applied a qualitative approach. A gathering of several experts in the fields in a focus group. This focus group discussion has been carried out by 4 experts in the field of three different expertise areas and disciplines involved in this research towards the business model for: ' Edge computing : A business model for tele monitoring IoT applications for diabetic remote care'. Each of the focus group participants joined together in a brainstorm sessions of about a total of 2 hours. The brainstorm sessions within this focus group consisted of an initial presentation on the background, motivation and design choices as made for the business model. Following on this presentation, the business model has been presented to the participants of the focus group. The following participants joined in this validation step of the business model, in this table the names of the participants, the respective company, their profession & professional title and the number of years of experience in certain area's of expertise. The years are not to be added but only give an indication of the amount of years the participants are active in one or more of the area's of expertise.

Interviewee	**Company**	**Profession**	**Healthcare**	**Business / Finance**	**Digital transformation**
Chris van de Haak	BDO	Partner Audit & Assurance, Chairmen industry group healthcare.	15-20y	25y	5y
Kees Plas	BDO	Partner Technology	0y	15-20y	20-25y
Nika Stegeman	BDO	Partner Tax advisory Healthcare	10y	15-20y	0y
Vincent Eversdijk	BDO	Partner new business models & digital transformation healthcare	6y	20y	8y

Table 6.1: *Table of experts, discipline and years of experience, participating in the focus group validating session*

The focus group has been conducted in a linear structure, dealing with different concepts of the business model canvas. The discussion has been broken down into three aspects. The feasibility (Key partners, Key activities, Key resources) aspect, the desirability (Customers relation, Customer Segments, Channels) aspect and the viability (Value proposition, Cost structure, Revenue Streams) aspect.

Finally, during this research, the use of a focus group has been chosen above a series of structured interviews. This because of time constraints, as well as the option of discussion within a focus group can greatly improve the theoretical business case. This discussion elements is of great importance because the artefact, a business model, is purely theoretical at this point of time, therefore the choice has been made to conduct a focus group with certain selected professionals in the field from different relevant disciplines. To keep the focus group structured the discussion topics have been set to the three different area's of the business model canvas as described by [31]. The hypotheses which will be tested during this focus group is whether or not the business model envisions a plausible product for improved privacy for patients, as well as being a minimal viable product solution for current hospitals making it a viable option for executing a pilot study at hospitals.

6.2 Results

Overall, the participants of this focus group session showed confidence in the business model and outlined that the possibility to bring, analyze and store data closer to the patient is the way to go and should be further explored. As where the current mania of compliance and privacy issues can potentially be solved by storing and processing patient data as close to the patient as possible making edge computing a potential technique that can support this movement. All participants however do agree that the biggest issue will be funding and revenue streams because of the enormous complexity of the Dutch care system. And the best possibility to bring this business model into a working pilot study depends on patient response and adoption.

The biggest point of critique is the absence of a more in depth validation with potential patients and a more elaborate insight into the positive healthcare outcomes of the system. Because, as pointed out in the session, the more evident health gains, the easier it will be to pitch the business model to a hospital for a pilot study. Together with the complex intricacies of the Dutch healthcare system, this could potentially result in an entire new study to gain better insights into these contextual information which is absolutely necessary to build upon this business model in order for it to be applicable within the Dutch healthcare system.

6.2.1 Desirability

Desirability mainly focusses itself on customer relations, and the link of the business model to the customer. In this case these are the patients, and from BDO's perspective the hospitals. It is mentioned in the focus group that the Dutch care system is extremely complex and intricate, therefore making it potentially difficult to find the correct customers and the relationship towards them. The participants however al agree on the relevancy of the stated customers, the hospitals, but mostly the patients. It is elaborated that the patient has to use the product therefore making it the final customer. If the patient does not use it, it will also be quite difficult to sell the product to a customer hospital.

During the focus group discussion there were some comments about the channel how to deliver the product. This because the product consists mostly of already existing applications and functions, but the movement of patient data closer to the patient is the goal. The BDO healthcare experts agree that as well the acquisition as the delivery channel should always be initiated through the hospital and the doctors. Medical applications and the relocation of medical patient data is a very precarious situation and no one but the respective doctor or hospital representative should be the one channeling the product to its patients.

The customer segments as been described in chapter 4 where not subject to much discussion. For the chosen case, diabetic patients, a consensus is shown that all diabetic patients will benefit from a more stable blood sugar levels. To conclude, the focus group states that the desirability of this business model is certainly present. The current trend in IT innovations, in particular for the privacy aspect, is to be able to place and store medical data as close as possible to the patient. The currently established business model seems to contribute clearly to this current trend.

6.2.2 Feasibility

The second area of interest is the feasibility aspects of the designed business model. The feasibility aspect is mostly related towards key aspects of the business model, aspects like partners which are vital to the development of the business model. But also activities and resources needed are an essential part of the feasibility aspect of the business model canvas.

With respect to the key partners as defined by the business model, the most important partners are the EPD supplier, the relevant hospital and a networking company like for example IBM. The focus group, overall, agrees on the choice for Chipsoft as an important partner. Chipsoft does encompass almost the entire Dutch healthcare landscape. Chipsoft therefore seems like an important partner, as well as relevant and willing hospitals for this business model. One important aspect that is noticed by the focus group is a network party who will do the network development. Edge computing as specified in this business model will initiate mobile phones to act as computing nodes. The infrastructure and networking capabilities of the architecture must also be developed, IBM, is a partner brought up in this focus group as a potentially important partner for the network development activities.

This immediately brings the discussion to the key activities related to this business model. Everyone agrees that there are an enormous list of activities to be executed, especially when the business model has to be placed in current healthcare system boundaries. The most important activities related to this business model are finding interested hospitals by substantiating patient benefits.

To conclude the feasibility aspect of this business model, all focus group participants agree that, especially due to the current situation, the possibility of this business model and the implementation and setting up of IT innovations and pilot study research has increased significantly. IT innovations with which almost nothing had been done a year ago are now suddenly is being implemented everywhere. This indicates that there is indeed the possibility within the Dutch healthcare sector to create innovative care projects, and also a willingness to put effort and time in to these projects.

6.2.3 Viability

Last but not least in the focus group discussion is the business model viability aspect. The first aspect which has been discussed is the value proposition. The value proposition has already been briefly touched upon during the earlier discussions about desirability. As mentioned by most of the focus group attendees, what has been observed in the health care innovation area, and especially within IT innovations, the focus and the desire currently is to place and story medical data as close to the patient as possible. By all attendees the patient value proposition has therefore been marked as very promising for an IT innovative business model for the healthcare industry.

A point of critique on the value propositions formulated for the business model is the value proposition for doctors, the focus group agreed on the part that the extra hospital value proposition is a valuable asset for the business model has to be 'sold' to a hospital. Therefore making it invaluable to know the value proposition for a hospital. But, the doctors value proposition seems unnecessary within this business model. According to the attendees, you are in fact, already working on a piece of UX / UI design of the solution, taking doctors into account. Something that you do not have to spend a lot of time on at this moment of the research. The market for IT innovations in healthcare, and the Dutch healthcare landscape in itself, are complex and complicated enough. The main focus at the moment should be on creating added value for the hospital, and you create that added value by creating added value for the patient.

The final part of the discussion focused mainly on the financial aspect of the business model. In the first version of the business model, the cost structure and revenue stream have been left blank on purpose and this is being understood by the focus group. The state of the current Dutch healthcare system is complex and intricate with an enormous amount of stakeholders and even more complex funding schemas. Al BDO healthcare specialists agree on the following, also referring back to [31] where the key points are:

1. **New paradigm: not paying for disease, but health [31]** Finland proves that a paradigm shift is not a utopia. The country rose sharply in the list of healthiest countries in the world by introducing a financing system based on financing health rather than production.

   Action point: *upgrade current funding method without perverse production incentives and finance health instead of production.*

5. **Facilitate innovation and digitization [31]** The strangling staff shortage requires radical innovation. Matters such as home monitoring, app technology, online consultations and online platforms for medical conditions are to be rolled out on a large scale in the coming years.

   Action point: *maximize digital transformation. Provide direction at national level so that developed initiatives for innovation and digitization are widely shared.*

9. **It will not happen without (medical) entrepreneurship... [31]** The specter of conflicting interests and regulations hampers the executive power in the sector. That does not bring the future any closer. Doing business to bring network care closer, is to make something out of nothing. And DO.

   Action point: *make medical entrepreneurship and business work accepted. Encourage new initiatives, including in the financing system.*

The combination of cost structure and revenue stream will be focused on a financial loss but added value towards patients. A higher quality of life of patients and less costs in the long run. A final example given by the focus group is the following:

"Hospitals are stuck, costs have been rising for years and there is a huge capacity problem. They (the hospitals) also do not want someone else to run away with innovation in healthcare. Care must be in place, but hospitals want control. The same as banks that take over fintech companies en masse. Bringing in the new technology is what hospitals want to build a proven track record. This means that there will be a loss at the start. What is vital, but that is more for the follow-up to this, is the strict development of a pilot study to measure the actual impact on and adoption of patients."

The cost structure for this business case can be formulated as the costs to involve external organizations like Chipsoft, IBM or BDO to further develop and guide the necessary technical dependencies, as well as making several doctors available for potential testing purposes. Actual hardware will not be necessary at this point of time.

Finally, a revenue stream will be very much absent in the startup phase, this was one of the main outcomes of the validation session with several healthcare industry experts in the fields of digital transformation, Audit & Assurance and Tax Advisory. This because of the extreme complex Dutch healthcare system. Only subjective revenue will be gathered via better patient care, higher ratings and improved quality of life for patients which should eventually lead into adoption of the product and system into the portfolio of health insurers for reimbursement of care.

Topic	Chris van de Haak	Kees Plas	Nika Stegeman	Vincent Eversdijk
Value proposition (*Desirability*)	Store data closer to the patient!	No opinion on Chris, do thinks providing more control is better!	Follows Chris in the discussion.	Supports Chris, this trend is currently present!
Customer segments (*Desirability*)	Chris mostly agrees with Vincent, a one on one copy of diabetes patients towards for example COPD patients or heart patients is not desirable.	Kees mentions that this could benefit not only diabetic patients but more broadly towards a more general remote monitoring solution.	Nika did not actively contributed in this discussion.	Vincent thinks it should be investigated, how and what other requirements of patients can be mapped in order to broaden the scope.
Key resource (*Feasibility*)	Chris thinks the hardware demands for phones are on the edge of current possibility	Kees states that mobile phones are becoming increasingly more powerful every year.	Nika asks what current requirements for patient phones are in order to support as edge node.	-
Extra information regarding hardware requirements.	After explanation of the IBM stated requirements, all attendees conclude that the stated requirements are already possible on some mobile phones, and in the near future this should not pose a significant problem.			
Key activities (*Feasibility*)	All attendees agree, the design of an application as well as the execution of a pilot study are essential and vital activities. Without these activities the project cannot continue.			
Revenue stream (*Viability*)	Mentions improved patient quality of life as a subjective revenue stream. Second mentions: Decline of complications for patients, declining healthcare costs (also subjective)	-	Increased IT innovation capability and remain compliant with law (subjective)	Finally, more patients can be treated by a hospital without expanding on capacity, meaning more income for hospitals. (direct revenue stream)
Cost structure (*Viability*)	Chris agrees with Vincent, also believes Kees has a point.	Kees mentions several aspects like development of edge platforms, including containers and also inter-connectivity between systems.	-	Vincent mentions comprehensive tests should be conducted on the software in order to verify safety and compliance.

Table 6.2: *Topics addressed during focus group, including main contribution per topic and attendee.*

To summarize the overall results obtained during this focus group sessions for the validation of the designed business model, a table with several discussed topics and relevant input of the attendees is added in Table 6.2.

6.3 Validation conclusions

The main overall view with respect to the following hypothesis can be summarized as follows with respect to the following hypothesis: "*The final hypotheses which will be tested during this focus group is whether or not the business model envisions a plausible product for improved privacy for patients, as well as being a minimal viable product solution for current hospitals.*".

1. Positive attitude towards the possibilities of the technology.
   During the focus group session, a lot of discussion with respect to current trends within health-care, IT innovation and data security and privacy where held. The most important aspect mentioned was the fact that it is becoming more and more important to store data as close as possible to the patient. Making sure a patient is always in control of his data en guaranteeing privacy compliance. According to the participants, (mobile) edge computing shows enormous potential with respect to the storing of data as close to the patient as possible. Especially in the case described in this research where the mobile phone will act as edge node. Here, already existing ideas have been confirmed.

2. A current shortcoming, is the lack of actual numbers with respect to benefits for patients and hospitals.
   Because of the complex way the Dutch healthcare system is constructed, it will be enormously difficult to find funding for a project or pilot project with respect to edge computing. A lot of different stakeholders with different requirements and needs play their part in the Dutch health-care system. More concrete numbers could potentially sway a hospital to invest own money in a pilot project for edge computing. Here, it is stated that the financial aspect should be focused towards subjective gains in this stage because concrete patient numbers are not yet available. Placing more focus on the subjective side improves the chance of hospitals investing in this new technology.

3. Al participants see possibilities to start up a project with one or multiple hospital clients for exploring the possibilities of edge computing for remote monitoring capabilities.
   The business model shows great promise also because of its wide applicability. Within this research, a case for diabetes monitoring has been used, though the participants mention that there is a big opportunity to expand this business model to different areas besides diabetes monitoring. Even though the stakeholder analysis has focused mainly on diabetes patients, it is proposed to attach a broader patient scope to the model making the model more attractive and wider applicable for potential hospitals to adopt.

4. The participants questioned the possibility that a mobile phone could be used for deployment as and edge node.
   Some discussion about the possibilities of patient mobile phones was mentioned, where some patient may or may not have the latest smartphones variants, possibly impeding or making it impossible to use the smartphone as an edge node. After a sharing of the IBM stated require-ments for an '*edge server*' or edge node: '*they could have 8, 16, or more cores of compute capacity, 16GB of memory, and several hundred GBs of local storage*'. It was concluded that, even though currently a lot of mobile phones will not be able to host this. More and more mobile

phones will become in this hardware specific range making it a viable possibility for the near future.

5. Finally, the participants advice to start pitching this model to the larger hospitals. The costs associated with the development of an extension of the infrastructure, as well as interoperable environments or containers and internal systems and applications will most likely hold off the smaller hospitals because of insufficient budget and insufficient relevant patients. So for further expanding on this research, the bigger hospitals should be targeted first in order to test the option for executing a pilot study. So also here the doubts and the risks regarding the financing of this business model are apparent through these answers, but they do provide tools for a better key partner approach. This is done by focusing on the larger and more affluent hospitals during this stage of the research.

After the processing of the validation results, a new and more complete business model canvas has been designed, presented in figure 6.1 below:

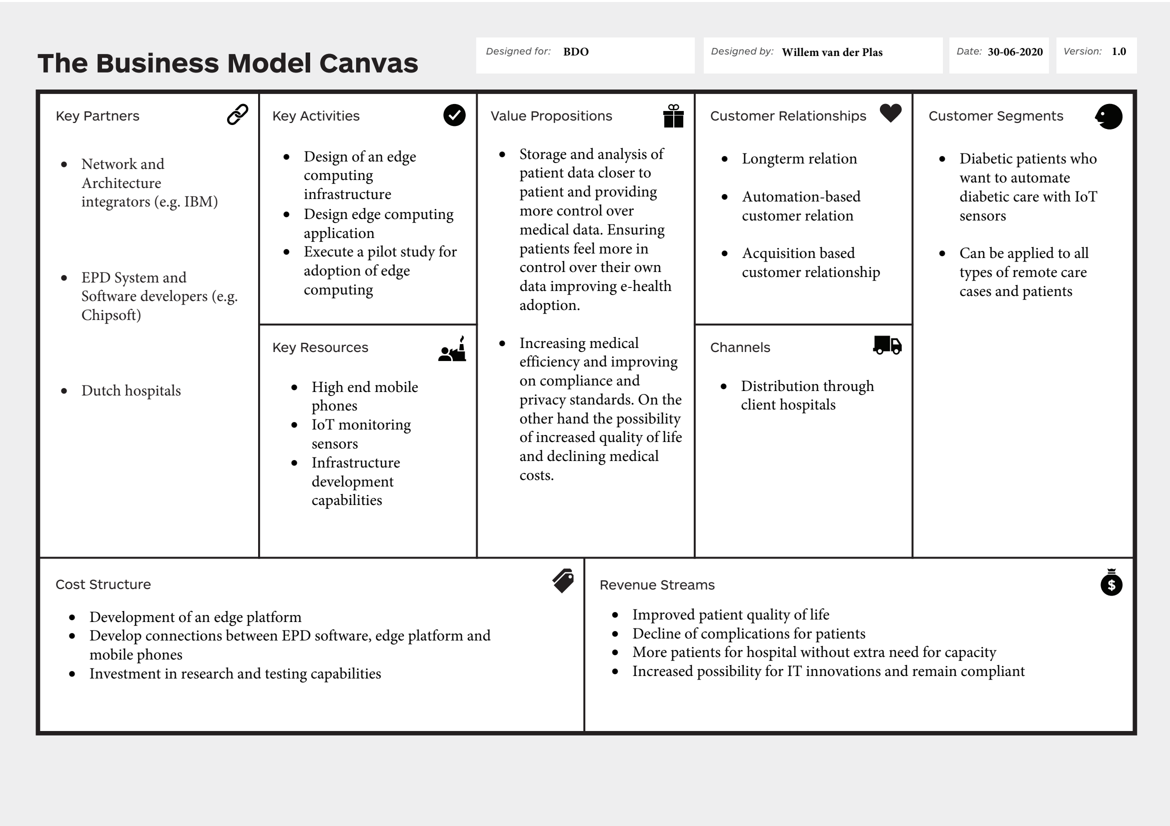

Figure 6.1: Business model canvas v_1.0 (*after validation*)

Chapter 7

Conclusions and recommendations

This chapter consists of two sections. In the first section, the answers to the research questions will be presented and a final conclusion of this research will be formulated. Finally, in the second section of this chapter some recommendations about how the current presented research could be improved and some appropriate follow up questions for future research will be proposed. The goal of this chapter is to answer the research questions defined in section 1.2

7.1 Results and Conclusions

This section will be dedicated to providing an answer to the main research question:
'*What is the business model for an IoT supported mobile edge computing system to support remote tele-healthcare and what are the (IT) implications for current hospitals?*'
The following sub-research questions will be answered in this section:

1. What is the current state of IT being used in healthcare?

IT is becoming a more and more important aspect of (Dutch) healthcare. Where applications as electronic patient records, monitoring sensors, video calls, patient portals and other consumer IT applications are being developed and adopted. IT has been widely represented in hospitals for a long time. The often outdated systems and mixes of applications are proof of this. More and more hospitals are migrating their systems to one of the larger healthcare IT providers, among which Chipsoft is the lead healthcare IT provider. Together with parties such as Chipsoft and Philips, hospitals are also increasingly working on medical IT innovations. These kinds of innovations are often still in their infancy and are limited to make video conferencing with a doctor possible for patients, sharing informative videos or providing an app for patients where relevant information can be found with respect to medical rehabilitation.

2. Which stakeholders are present within the Dutch healthcare chain?

Referring to Table 3.3, six stakeholders have been identified within this research. The top three most relevant stakeholders are:

- Dutch hospitals
- Patients
- Specialists

For this research and the creation of a business model for edge computing within a remote monitoring setting for diabetic patients, these three stakeholders are relevant at this time during the research.

3. What is a business model for IoT driven edge healthcare services?

The final business model as designed for this research can be looked up in figure A.1 in appendix A.1. The creation of the final business model has been presented in chapters 4 and 6. Elaborating on all the different areas of the business model canvas in chapter 4 as where the business model has been validated and improved based on received knowledge during this validation session in chapter 6.

4. To what extent does the business model fulfil the needs of the stakeholders?

Stakeholder needs have been mainly defined within subsection 4.1.1 and subsection 4.1.2. The main focus area of using edge computing for medical IoT systems has been focused on the privacy and control aspect of the system towards the patient. The assumption is that when a system is safe enough and provides the user with sufficient checks and controls on their data, the adoption eventually also increases, ensuring a decrease in administrative tasks for specialists. An increase in the use of this could potentially also lead to less pressure on healthcare personnel increasing productivity and so on. The main reasoning for this has been the recent criticism of development, deployment and adoption of corona apps. Here, a lot of resistance to these apps was caused by poor app security and privacy guarantees. This leads to think that when security on an app is increased and you provide users with more control and guarantees about their own medical data, adoption can increase.

When looking at it that way, the business model for edge computing within a remote monitor setting for diabetic patients has a promising potential to fulfill the need of the patient stakeholder for more security, privacy and control over their data. And, in accordance to the above reasoning, there is the potential for other stakeholder requirements like those of the specialists, hospitals or government can more or less be fulfilled over time. However, it should be mentioned that this business case has not been implemented in a pilot study as of yet. Therefore, it is impossible to state to what extent the business model shall fulfill the needs of the stakeholders, a pilot study must be initiated and real data must be gathered in order to provide a proven answer.

5. What are the IT implications of the IoT business model for the key stakeholders?

The biggest IT implication for hospitals will be the addition of a fourth layer within the IoT architecture. Where current IoT architectures consist of the IoT devices, a network layer where the data and information is being processed and the application layer where the data and information are being presented to the user. The introduction of edge computing to this IT architecture involves the addition of an extra *'edge layer'* where the most significant change will be the possibility of the perception layer to move through to the application layer without passing through the network layer. This because the introduced edge layer will be performing the storage, analysis and processing of the data and information, but keeping the possibility for sharing the data with hospital network and applications. Keeping this data out of the internet and on the local mobile phone, acting as edge node, the will affect current and future IT architecture and software and network design. As can be seen in figure 5.4.

6. How can we evaluate and validate the business model?

The business model and the business model canvas has been validated by the conduction of a focus group with several experts in the field. Overall, the interviewees acknowledged the potential advantages of the business model for current hospitals and patients regarding privacy concerns, adoption of healthcare applications and compliance. Though, some critical notes with respect to information not yet available were noted. At this point of time it just is impossible to quantify potential revenue stream of the business model. Also, subjective impact on patients has been underexposed making it necessary to make some assumptions along the way. Also some clarification with respect to the value proposition, cost structure and revenue stream have been proposed and incorporated in the business model. The new and updated business model and the relevant business model canvas can be found in appendix A.1.

conclusion

To conclude, the designed business model provides insights and potential innovative grow potential for hospitals who seek to adopt or expand remote monitoring systems using IoT. The answer to the main research question:

"What is the business model for an IoT supported mobile edge computing system to support remote tele-healthcare and what are the (IT) implications for current hospitals?"

Starting this dissertation, the hypothesis had been formulated that the adoption of an (mobile) edge computing infrastructure can improve IoT remote monitoring solution adoption because privacy compliance towards patient medical data improves. Based on the fact that edge computing makes it possible to store, analyse and process the data much closer to that patient then in current remote monitoring situations. Besides, to make the research more concrete a specific end user has been chosen to focus on during this research, therefore the main focus has been directed towards diabetic patients. After an elaborate literature review and interviews with patients & doctors and focus group sessions with several experts in the field, we can conclude that edge computing is a potential viable solution to improve privacy compliance. Building upon the improved compliance and control, improve IoT and remote monitoring solution, which eventually even may be leading up to better quality care, less healthcare costs and more care efficiency. And a first business model for the use of edge computing has been provided through this research making the start of a pilot study feasible for BDO to carry out with interested hospital partners.

7.2 Recommendations and future work

Within the recommendations section, we basically look to answer two important questions:

1. How could the presented research be improved if it were repeated?
   The presented research can be improved by gaining more insights into the technical aspect of this research. This research mainly focused on the theoretical design of a business model for edge computing within the healthcare sector as well as focus on potential end users. With future repeating's of this research, actual data with respect to potential adoption rates among patients would prove invaluable for the business model to develop unto a concrete business case for hospitals.

   When the research is to be extended, the design of a pilot study and the exploration of a case study are indispensable next steps for this research, as well as gauge the interest in edge computing among hospitals and healthcare institutions. It is vital for more research into edge computing to be applied onto real world cases, not only to research feasibility and applicability of the technology. But also the actual impact on compliance and performance of hospital and patient systems.

Finally, an important extra aspect for future improvement on this research is to expand on the architectural implications. It is important to better clarify which different solutions are available and applicable for hospitals and patients alike to participate in a explorative pilot study.

2. What would be the appropriate question(s) for future research starting from what is presented here?
   Appropriate questions can be formulated as follows:

   - *Which technical adjustments to the hospital infrastructure are necessary to set up an edge computing platform or infrastructure?*
   - *What medical data does a patient prefer to keep on their own phone as opposed to on the hospital servers?*
   - *How long does it take before a first mobile edge platform for remote monitoring IoT solutions can be launched?*
   - *How should a mobile edge node be designed to be able to support remote monitoring IoT systems?*
   - *How can a national wide edge network be designed for interoperabilty between different hospitals?*

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Appendix A

Appendix

A.1 Business Model Canvas after validation

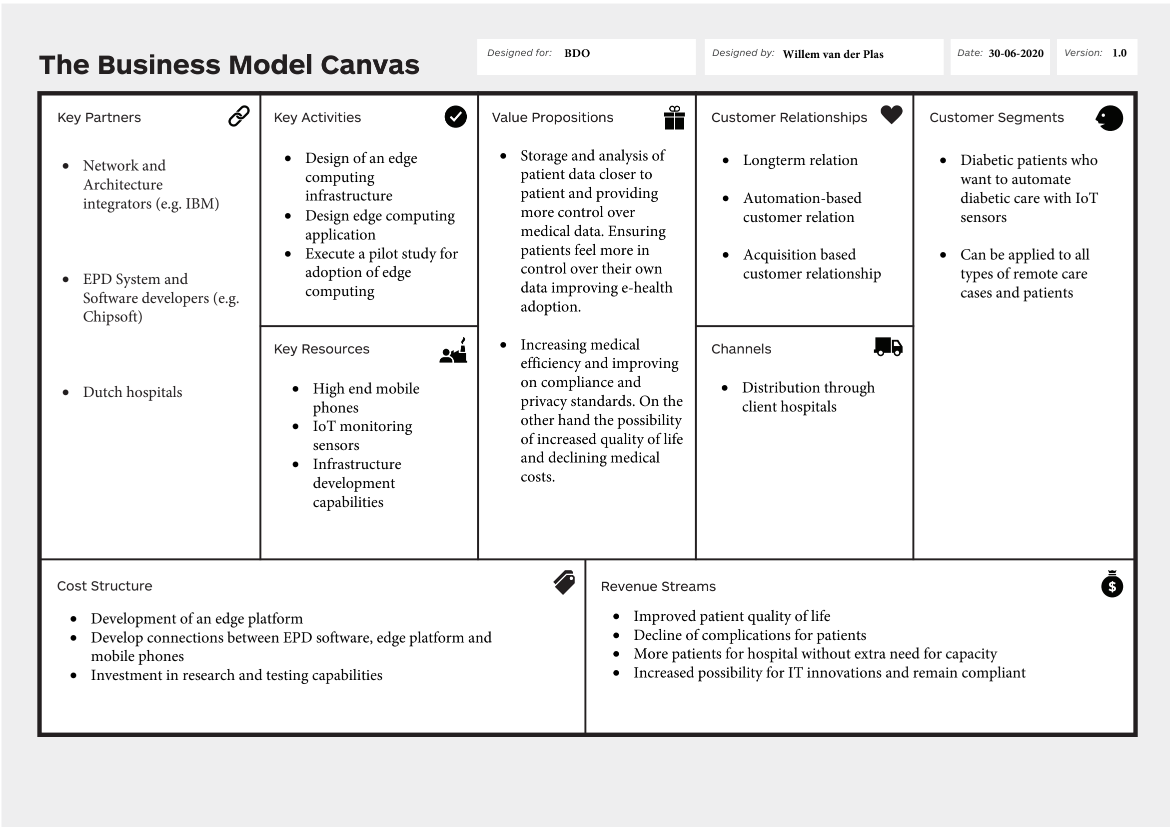

Figure A.1: Business model canvas after the validation session.