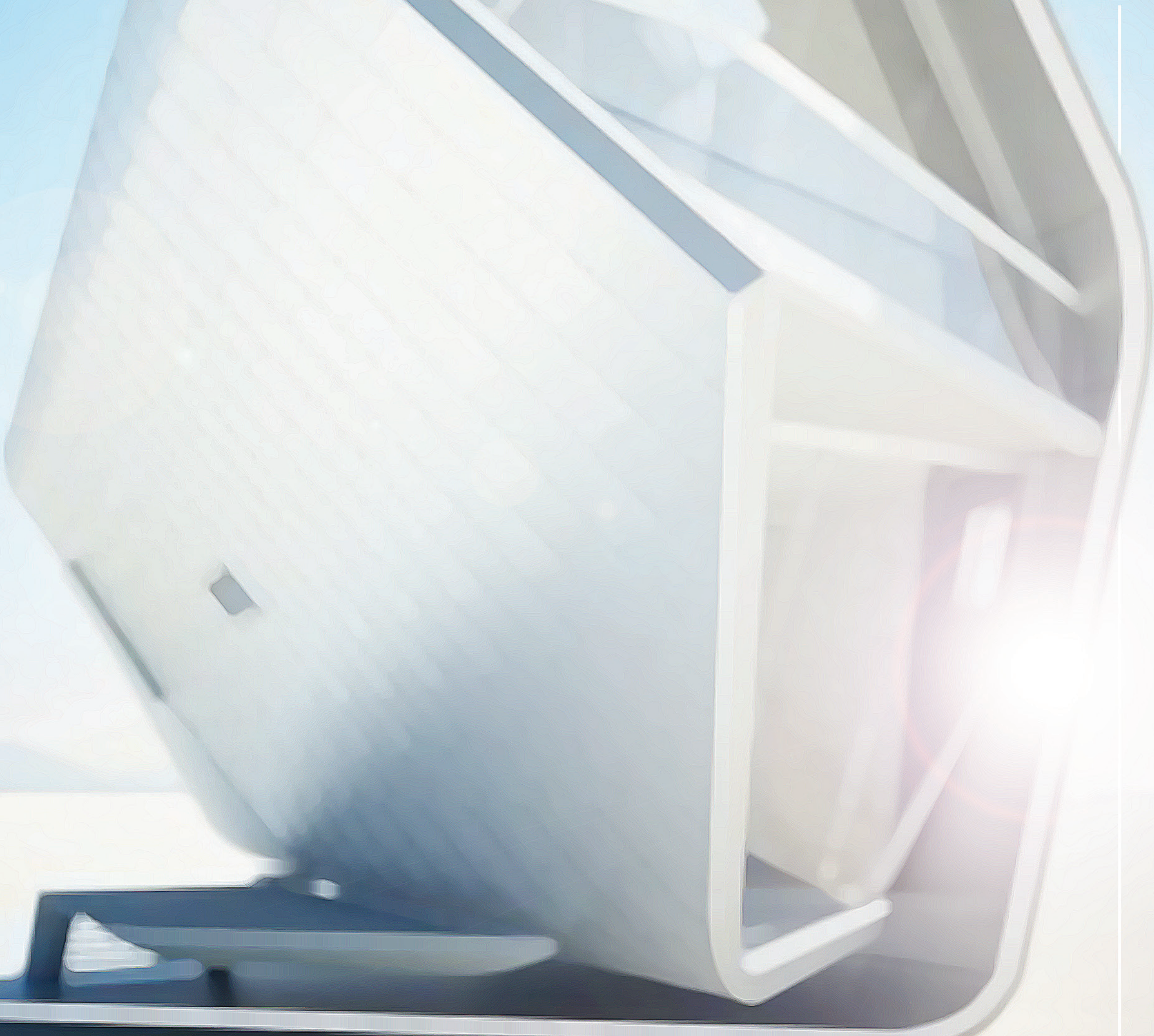
FUTURE PROSPECTS and THE DYNAMIC DEVELOPMENT of PROMISSORY CONFIGURATIONS

A case study on the history of the Smart Home technology



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Abstract

This paper explores the development of promissory configurations. The concept promissory configuration is introduced in this paper, resulting from a combination of insights from the expectations literature and the notion of configurational technologies by Fleck (1993). Promissory configurations are configurational technologies, but the difference is that they do not appear on the market. They only exist in terms of expectations about the technological configuration, hence the word promissory is included. Configurational technologies, as mentioned by Fleck (1993), have a peculiar development process because the configuration is heavily influenced by the particular application of the technology. Configurational technologies are ad hoc in the sense that (re)configuration will occur when contingencies of the particular application change. The smart home technology is chosen as case for studying the development of promissory configurations. Results of Peine (2008; 2009) let us presume that different expectations and promises are present in the development of the past three decennia's of the smart home technology. The results of this research show that there are three promissory configurations in the development of the smart home technology. Each promissory configuration is specified in application expectations and expectations about the underlying technology. By applying the concept of promissory configurations, the disorderly development of the smart home technology can be better understood. Concluded is that the underlying technology co-develops with the application of the underlying technology, whereby the combination of these two developments are the core of the promissory configuration. Within the three promissory configurations, the core idea of interoperability between appliances has been stable, only the underlying configuration enabling this interoperability has been altered over time.

Table of contents

1. Introduction

1.1. Research Problem

When investigating the development of technology, expectations about future developments are of significant importance. Research by Van Lente (1993) about the role of expectations in the development of technology provided a model describing the role and dynamics of expectations. In this model, which is called the promise-requirement cycle, Van Lente (1993) describes the process of expectations turning into more concrete prospects about the future. These prospects about the future, when shared, will result into requirements which need to be met in order to fulfill the shared expectations. This process of expectations turning into requirements shows the coordinating role expectations can have. Expectations itself shape and direct the behavior of actors within the field of technology development. These actors are heterogeneous and vary from institutions, firms, NGO's, and governmental organizations (Konrad, 2006; Van Lente, 2010).

However, actors are forced to make decisions about future developments, which are per definition not yet established, regarding (societal) problems which are not fully known (Van Lente, 2010). Whether expectations about future developments are true, can only be assessed in a retrospective way. When time proceeds, expectations about future developments change and future needs regarding societal problems alter. These alterations in expectations about societal problems to be tackled have its influence on the direction of technological development (coordination). This is especially the case for configurational technologies. *Configurational technology* is introduced by Fleck (1993) and is defined as a combination of components whereby its specific configuration depends on the function the technology should fulfill. The function of a configurational technology is under debate because of the continuously developing local contingencies. The result is that configurational technologies have a fluid character, whereby the configuration continuously changes according to the developing local contingencies (Fleck, 1993). In this sense it differs from generic systems, whereby the requirements and thereby the application form are relatively stable, and components of the system can evolve according to natural trajectories (Fleck, 1993). This means that configurational technologies are ad hoc in the sense that (re)configuration will occur when contingencies of the particular application change. As Fleck (1993) further states, the development of such non-technological factors (especially human factors) contribute to the generation and evolution of technology. More concrete, the underlying technical configuration of a configurational technology will change when the application purpose alters. The sociology of expectations studies this coordinating function of expectations in the development of technology.

Several examples exist of such configurational technologies. For instance, Fleck (1993) refers to the highly specialized robotics in the manufacturing industry. A robotic with the task to place windshields cannot be used to place tires. This requires other features and thereby determines the configuration of the technology. Also Konrad (2006) states that the first peak in expectations of *interactive television* already stems from the 1960s and during the development of this technology alterations in expectations and the form of application can be identified. Ruef and Markard (2010) investigated the development of expectations and the relation with innovation activities and came up with interesting insights. Ruef and Markard (2010) state that during a period of increased expectations, three different types of expectations evolve: project specific-, general-, and framing expectations. Depending on what type and which combination of expectations decrease or alter, the technological development (or innovation activities) will stop or continue in a different or modest way. This process of changing expectations according to Ruef and Markard (2010) will be further elaborated in the theory section.

Because the contingencies of the application are not stable and clearly defined, the configuration of the technology cannot develop into a standardized system. This research introduces the concept of *promissory configurations*, which is based on the notion of a configurational technology. The word promissory is included, because the technology is not adopted yet but yields many (positive) expectations for a particular application. A promissory configuration in this research is defined as: the combination of 1) the envisioned underlying technical configuration of the technology, and 2) the envisioned application. It is expected that promissory configurations will continually develop and (re)configure as long as contingencies of the particular application change, which makes the aspects interdependent. Changing expectations regarding different applications of the technology will influence the underlying technical configuration and thereby (re)coordinate the technological development. The process before a standard design emerges can take decades, even though it is not sure a standard design will establish (Fleck, 1993).

1.2. Research Question

The aim of this research is to increase insights into the development of a promissory configuration, characterized by the changing form of application and the underlying technical configuration. To investigate this phenomenon, a case study towards the development of the Smart Home technology is chosen. Smart Homes are configurations enabled through interoperability between (home) appliances, and the underlying technology is then the basic idea through which interoperability becomes facilitated. Hereby, (home) appliances range from washing machines, heating, lighting, televisions, alarm systems, notification systems (e.g. if a window is open) etc.. Studies of Peine (2008; 2009) suggest that in the history of the Smart Home technology periods with different expectations and alterations in the configuration can be identified. From the first ideas about Smart Homes in the 1970s a continuous process of innovation can be witnessed in the case descriptions of Peine (2008; 2009) and still no standard design has been established. Therefore, it is expected that the development of Smart suits the concept of promissory configurations, changing expectations and a continuing innovation process what makes it interesting to illuminate this further. The period from the first introduction of Smart Homes in the 1970s (Peine, 2009), till mid 2012 is investigated. The goal of this study is to identify different periods of expectations within the history of Smart Homes and describe each period in terms of a promissory configuration. In order to provide these insights the main research question is:

> ***"How did the promissory configuration of Smart Homes develop in terms of the envisioned applications and the envisioned underlying technical configurations?"***

In order to provide a sophisticated answer on the research question, sub questions will give direction in formulating an answer.

1. Which periods in the Smart Home technology development can be distinguished?
2. What envisioned applications circulated in the different periods?
3. How did the technical underlying configuration of the Smart Home technology change across the periods?

4. When reviewing the identified and specified promissory configurations, what can be said about patterns and mechanisms in the development of the promissory configurations of Smart Homes?

Until now the understanding of expectations in the development of configurational technologies is limited. The study of Van Lente and Spitters (2009) provided interesting insights in the development of expectations (hype cycles) of different technological developments. Van Lente and Bakker (2010) studied competing expectations in the development of one technology. However, both these studies focused on the development of an emerging technology which ultimately reached the market phase. This research investigates the development of the promissory configurations of Smart Homes, a technology which only exists in terms of expectations and is not available on the market. Promissory configurations are expected to pass different periods of expectations, whereby unfulfilled promises are replaced by new (altered) expectations. The unfulfillment of expectations thus does not imply failed innovation, but a development which leads to a re-organization of the promissory configuration. Changing local contingencies will (mutually) influence the technological configuration, especially in the case of promissory configurations. This research questions whether a dominant design will ever be established in the case of promissory configurations. It is important to study promissory configurations, because decreasing or changing expectations are something else than failed innovation. In order to understand the co-evolution of technical and application expectations this research studies the development of promissory configurations from a diachronic perspective. Hereby, this research endeavors to complement to the current ideas about the development of configurational technologies.

Investigating the case of Smart Homes and gaining deeper insights in the development of this technology can contribute to solutions for societal problems such as aging (Demiris, 2008). In Europe aging and demographic change is one of the grand challenges which calls for attention. The fact that there is a European Program (AAL, 2012) set up in 2008 emphasizes the call for innovative solutions in elderly care. This program includes a budget of 700M € of which half is public funding. Insights gained from this research can contribute to this program and therefore increase the efficiency of the money spent in this program. This way the societal contribution is twofold; it increases the efficiency of public money spent on programs as AAL and insights gained can contribute to solutions for the aging problem in general.

In chapter 2 the concept of Promissory Configurations is further elaborated which results into the theoretical framework this research is based on. In chapter 3 the methods chosen to collect en process the data are described, where in chapter 4 the results of the analysis is presented. In chapter 5 and 6 the results are discussed and conclusions are drawn about the development of the Promissory Configurations of Smart homes.

2. Theoretical Framework

In his book *Mastering the dynamics of innovation* (Utterback, 1996) describes the process innovations go through from entering the market till market saturation, including the establishment of a *dominant design*. This model states that selection between different technologies takes places from market entrance till the point a dominant design is established. However, it is argued that this model ignores the selection between technologies during the prototype phase which takes place during the *Research and Development* within firms (Bakker, Van Lente and Meeus, 2012; Konrad, 2006). Research towards the role of expectations stems from the sociology of expectation literature (Bakker et al., 2011; Konrad, 2006; Van Lente, 2010). This strand of literature deals with the agenda setting process of scholars, firms and governments resulting from the collective created and shared expectations about future (technological) developments. When looking at the model of Utterback (1996), the *Expectations Literature* studies the role of expectations in the development of technology and looks at the phase before market entrance, the pre-market phase (Bakker et al., 2012). However, for promissory configurations it can be argued whether a dominant design will ever exist, because mostly they are mainly promissory and do not get a foothold on the market. Such technologies are not standardized solutions but develop along the changing functionality (local contingencies) and technological process. Insights from the expectation literature complemented with the notion of promissory configurations will be the fundament of this research. In this chapter both are elaborated and combined into a conceptual model.

2.1. Theoretical Embedding

With empirical examples, Van Lente (2005) shows how expectations shape the direction of technology development. Where initially only ideas about future developments exist, after the research guided by these expectations technology is developed accordingly, and expectations are becoming more concrete. Expectations motivate a heterogeneous group of actors, namely; research groups, business firms, financial actors, NGO's, policy actors and other governmental organizations (Konrad, 2006; Van Lente, 2010). This process of expectations about the future developing into a more concrete future is modeled by Van Lente (1993) as the promise-requirement cycle and further applied by Van Lente and Bakker (2010) in the case of hydrogen technologies. The basic idea is that expectations are able to coordinate actions of actors and thereby shape developments in science and technology. Such expectations which comprehend positive predictions about future developments are called *promises*. When promises are shared by actors in the field, they can be used as resource to legitimize choices about strategy and direction of research. In other words, they fulfill the role of a heuristic. This mechanism of expectations and promises shared by actors and the coordinating function shows the agenda setting process which occurs from this mechanism. Agendas, by definition, are lists of priorities, that is, items that require action (Kingdon, 1984). Expectations are performative (Van Lente, 2010); the articulation of an expectation 'does' something, it influences and moves actors in the field. In short, an expectation is not only a sketch of the future, but also the creation of a new truth (Guice, 1999). Further, when expectations are used to direct research, the expectation becomes a *requirement* because it is now a goal which should be met. This requirement includes a distribution of tasks among the actors, which is kept in the script as mentioned above (Van Lente, 2005; Van Lente and Bakker, 2010). However, requirements are not always met. Insights gained during the development of a technology lead to other, often more specific expectations that, in their turn, may result in new requirements. When new promises are built, the promise-requirement cycle starts over. This process of developing expectations can take a long time, and thereby directs the development of technology.

2.2. Promissory configuration

Konrad (2006) describes the role of expectations as shaping technology and particularly in the form of application scenarios. This strengthens the point made by Fleck (1993) that technology on itself has no power, only in association with human agency technology can act on the world. The point is made that human actions in the way of setting expectations give meaning and value to technology. Before delving deeper into the relation between expectations and promissory configurations, first some background information about configurations, as used by Fleck (1993), is needed. Configurations are closely related to systems, and you could say configurations are systems. Both are built out of (technical) components and the whole complex works together. However, a distinction can be made between generic systems and configurations (Fleck, 1993). Generic systems have a clearly defined overall function (and thereby also markets to address), which makes it possible to standardize components and incrementally improve those components to optimize the system. In contrast, configurations lack this clear overall function and are more open to the contingencies of applications. The effect is, as Fleck (1993: p. 18) says: " *The overall 'shape' of the configuration stems from the particular requirements and exigencies of the application addressed – i.e. the scheme or plan according to which the components are arranged varies according to the contingencies of the particular application*".

Going back to the promise-requirement cycle of Van Lente (1993), the establishment of '*the particular requirements'* results from the expectation setting process. Expectations are statements about future (technological) developments; these include (societal) problems which should be tackled. The agenda of problems to be tackled regarding expectations about the future changes when time proceeds because new insights are gained, which have influence on the particular application of a technology. For example, where in the first place the Smart Home technology was seen as a solution to increase the efficiency of facility management in offices (Wacks, 1991) and has changed to be the expected solution for the problem of high rising prices for elderly care (Song et al., 2008).

The relation between the (social) problems to be addressed and the underlying technological configuration determines the so called 'promissory configuration'. A promissory configuration in this research is defined as the combination of: 1) the envisioned underlying technical configuration of the technology, and 2) the envisioned application of the technology. The identification and specification of the promissory configuration is one of the aims of this research. Because it is expected that expectations about the particular application change in the history of the Smart Home technology, it is expected that the underlying configuration will alter. The description of the promissory configuration is modeled in Figure 1, whereby Technology A, B, 'n' refer to the combination of technologies and Envisioned application A, B, 'n' refer to the different envisioned applications of the promissory configuration.

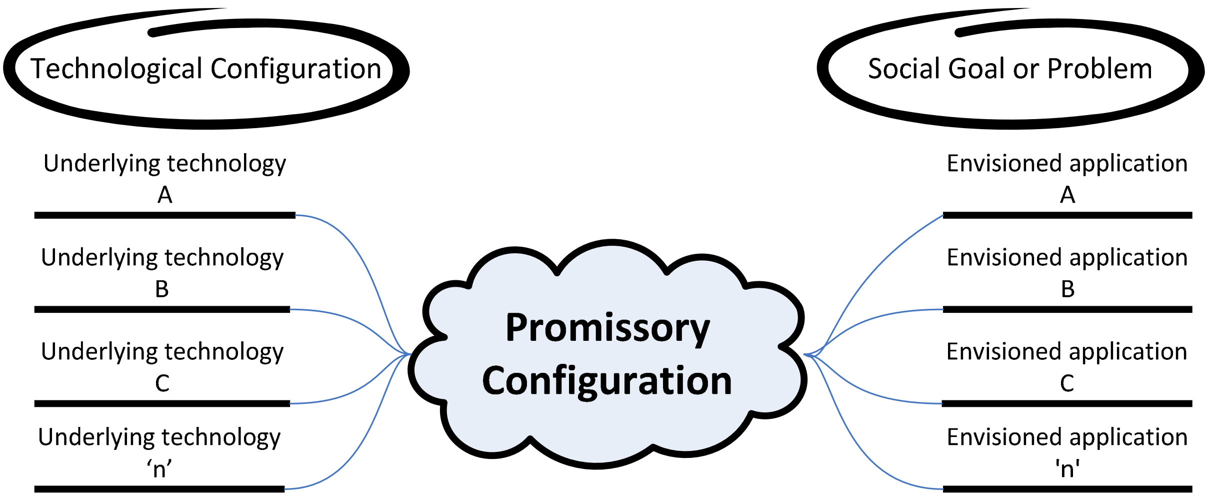

Figure 1: Conceptual model of the Promissory Configuration

2.2.1 Changing expectations

When an expectation becomes shared among more actors, the attention given and the ‘height’ of the expectation increases (Konrad, 2006). However, as described above, the extent to which the requirements are met are uncertain, and sometimes are not met at all (disappointment).The period of increased expectation can turn out to be exaggerated ex post (Ruef & Markard ,2010). As Borup et al. (2006: p.291) say: “*Here technologies are seen to move along a path from trigger, to a peak in expectations, then plummeting into a trough of disillusionment before eventually giving rise to a range of somewhat more modest applications*.” As seen in the examples of Konrad (2006) with the interactive television and Van Lente (2010) with the development of nuclear fusion, some technologies face evolving and changing expectations over long periods. The promises are never met, but the attention and expectation did never fully disappear. This evolution of expectations is further investigated by Ruef and Markard (2010). An important notion by Ruef and Markard (2010) is the classification of expectations into generalized-, and framing expectations. Generalized expectations are related to the discourse activities of players in the field and to actual technological achievements. Generalized expectations include specific expectations which are about the applications and commercialization perspectives of the technology. Framing expectation are more overarching and about the role of the technology in society and can be shaped and changed by a broader societal or political agenda. Both types of expectations can develop independently. When the period of increased expectations turns into a disappointment, it dependents on which type of expectations will change or become negative, ergo the innovative activities will stop. Insights from the study of Ruef and Markard (2010) explain why innovation activities can continue after a period of increased expectations regarding the different developing types of expectations.

2.3. Co-evolution

The co-evolution of the application and the underlying configuration of the technology is a new approach to investigate particular technological developments, for instance promissory configurations. Therefore, investigating this gap in literature will extent the knowledge base about the dynamics of expectations in the development process of promissory configurations. The insights from Ruef and Markard (2010) complement the insights form Van Lente’s (1993) promise -

requirement cycle, which stated that insights during the development of technology will result into new or adjusted expectations and a new promise – requirement cycle will start. It is expected that in the history of the Smart Home technology this phenomena of subsequent promise-requirement cycles can be traced, and alterations in the configuration will be identified. Possibly, the different periods of expectations will show different waves of attention given to the Smart Home technology. Changes in societal and political agendas will influence the framing expectations and thus the particular application of the Smart Home technology. An altering form of application will influence the configuration of the Smart Home technology, and indirectly influence more generalized expectations (according to Ruef and Markard (2010)), about the Smart Home technology itself. The combination of the different literature results into the model presented in Figure 2, which will guide the process of answering the research questions.

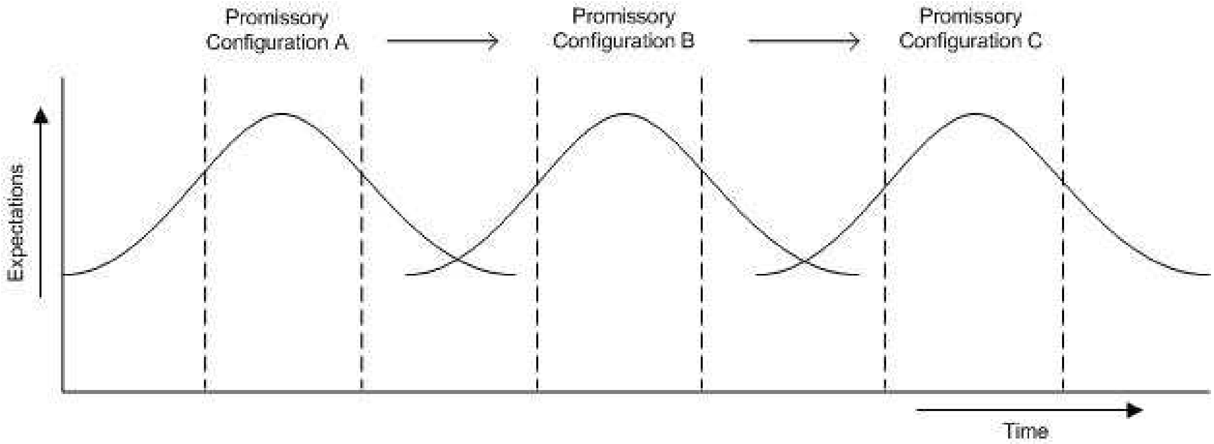

Figure 2: The development of Promissory Configurations

This model will be explored in the empirical case of Smart Homes. The Promissory Configuration (A, B, …) mentioned in Figure 2 refers to the description elaborated in Figure 1. This research will further explore if and how the different periods of expectations and the subsequent promissory configurations are related to each other. Thus, will the inheritance of promissory configuration A have an influence on promissory configuration B etc.. In the model above this would mean that when there is a relation, the line in the graph will be flowing through without interruptions.

3. Method

3.1. Research design

The design of this research is a historical case study, because evolving expectations and the subsequent promissory configurations can only be studied in a retrospective approach. Further, promissory configurations are complex phenomena and cannot be clearly described and measured at the hand of a specific number of defined variables. A case study approach allows studying complex phenomena, such as expectations and promissory configurations, in their context (Yin, 2003). Moreover, in order to fulfill this research, a descriptive research structure is chosen to conduct the empirical case study. This will give an overview of the different promissory configurations in the history of the Smart Home and provides in-depth account of the phenomena, the evolving expectations and configurations concerning the Smart Home technology. Therefore, the function of this research is mainly descriptive.

The unit of analysis in this research is the development of the promissory configuration of Smart Homes. The promissory configuration is characterized by the underlying technical configuration to meet the particular functionality. Eventually, the particular functionality can be embedded in societal issues. Because this phenomenon of promissory configurations is new and not investigated before, an open, qualitative methodological approach is chosen to describe the development. Also, the qualitative approach is chosen, because a small number of cases is investigated whereby a large number of aspects are under study (Ragin, 1994). Relationships between the different defined periods of promissory configurations will be revealed, and a basis for new (complementary) theory will be formed. The intended domain is the development of promissory configurations, while the achieved domain is the development of promissory configurations of Smart Homes in the period 1970s-mid 2012.

3.2. Case Selection

The case descriptions within the studies of Peine (2008; 2009) let us presume that different expectations and promises in the development of Smart Homes are present. Although the very idea of the *smart home* has been declared dead for a number of times, innovative activities still prevail. The idea of the *Smart Home* has been under the attention under different labels, resulting in the continuous reappearance of the Smart Home technology. It can be said that Smart Homes is still in the prototyping phase, but variation and selection is constantly occurring. However, this can be related to the fact that the Smart Home technology is a promissory configuration which is subject to change. This character makes the case of Smart Homes suiting to the aim of this research to study the development of a promissory configuration. The period between the 1970s and mid 2012 is chosen, because in this period the promissory configurations of Smart Homes are present in terms investigated in this study. The greater part of this study is to identify and specify time periods of coherent expectations and the subsequent promissory configuration, in this specific period under study. Within these periods the promissory configurations will be thoroughly described according to the conceptualization set up.

3.3. Methods of data collection

3.3.1 Exploration of the field

The first stage of this research consisted of exploring the field of the smart home technology. When I refer to the field of smart home technologies, I refer to "the field spanned by those organizations that are recognized as contributing to the development of Smart Home technologies", as defined by Peine (2008: p.515). An internet search on initially the search query "smart home" resulted into a broader set of search queries related to the field of the smart home technology. To cover the entire field of the smart home technology, including its origins and ramifications, the search queries used are: "home automation", "smart home*" and "bus system". The process of selecting appropriate search queries and indirectly data sources (articles) was not a straightforward process. Interpretation of texts leaded to additional search queries which resulted in additional data sources, which is in line with what Flick (2006) describes as the process of collecting (additional) data. The process of collecting data and subsequently analyzing was thus not a linear process, but interwoven.

This research makes use of theoretical sampling in order to get deeper insights in the phenomenon under study. The initial data source was IEEE Transactions on Consumer Electronics. This journal publishes papers on new technology oriented to Consumer Electronics, and has as key factor the emphasis on technology rather than product. This journal is very suitable to investigate the development of Smart Homes in the scientific world, because the journal already exists since the introduction of Smart Homes as investigated in this research. After analyzing articles of the first data source, two other data sources were added to the analysis; Personal and Ubiquitous Computing and European Framework programs. Personal and Ubiquitous Computing publishes peer-reviewed international research on handheld, wearable and mobile information devices and the pervasive communications infrastructure that supports them to enable the seamless integration of technology and people in their everyday lives. Personal and Ubiquitous Computing is a technical journal which is consistent with the character of this research. To retrieve governmental expectation statements, I searched in European Framework Programs[1]. Within these programs there had been searched for governmental funded projects concerning the Smart Home technology. The direction of research will be articulated in these projects, which encompasses expectation statements about technical developments. By combining the three different data sources, data triangulation was applied (Yin, 2003).

The expectation statements were analyzed according to the classification made by Ruef and Markard (2010). Van Lente et al. (forthcoming) established a framework which operationalized the different level of expectations, see Table 1.

Table 1: Analytic framework to determine the level of expectation (Van Lente et al., forthcoming)

Label	Description	Example of fragment
Project-specific	Future characteristics of a technology specific to a product project or firm.	"FReCon offers remote control features over a wide range of appliances located within a room, with a unique controller implemented on portable devices

[1] For example the most recent 7th Framework Program for Research (2007-2013), but also earlier programs.

expectations	Micro level.	like PDAs, handheld PCs, mobile phones, etc. More than the controller itself, FReCon means the whole Freely Connected world in which FReCon-enabled users and appliances interact: though acting naturally, the user can freely connect to the desired appliance, control it, disconnect from it and start communicating with another." (Sanguinetti et al., 2003: p.163)
Generalized expectations	Expectations referring to generalized features of a technology, expressed in impersonal statements. Expectations address the level of the technological field.	"Beside direct interaction with devices in the house, interaction with the eHome system based on personal computers, PDAs, and mobile phones is realized. Service providers are connected to the systems via the distributed IP-based platform to provide digital content, applications, and services." (Kirchhof & Linz, 2005: p.323)
Frames	Rather overarching expectations which place the technology in the context of generic societal problems or promises (societal debates).	"The purpose of the Smart Home Project is to devise a set of intelligent home appliances that can provide an awareness of the users' needs, providing them with a better home life experience without overpowering them with complex technologies and intuitive user interfaces. Our main aim for the project is to improve day-to-day home life with smart computer technologies while still keeping the home life as normal as possible – we refer to this as ''digitally engineering analogue home life''. (Park et al., 2003: p.189)

3.3.2 Theoretical coding

In this research theoretical coding is applied, which is used to break up the data: paraphrasing, summarizing, categorizing (Flick, 2006). The process of theoretical coding consists of *open-, axial-, and selective coding*. Each of these phases will be described below. The interpretation of the data was shaped by the theoretical framework set up in this paper. This is in line with what O'Callaghan (1996) calls *a perspective to build analysis from*. The main elements under study are the envisioned form of application and the envisioned underlying technological configuration. Therefore, during the coding process the focus was on text fragments which could serve as imputes for creating an explanatory theory and ultimately answering the research question.

The first step in the process of analyzing the articles consisted of writing memos. These memos are analytical writings which contain a brief description, in terms of events and behaviors, of the article. These memos are used as a means of documenting the first impressions of the researchers and as a guidance to move beyond the raw date (Goulding, 2002). Once the memos were written open coding was applied to the articles. The data were first 'segmented' which means that units of meaning (key words or phrases) in solving the research question were identified and consequently were given codes (see appendix, Table 5). These codes stick as close to the text as possible in order to provide a detailed overview of how the code is constituted. In this process of coding you are constantly comparing the codes with each other and with other articles, which results into multiple small empirical cycles. Important to note is that during the process of coding all articles, codes were becoming more uniform when more texts were analyzed due to constant comparative analysis. Concepts assigned to codes in earlier texts were adjusted by insights gathered in later analyzed texts. This reflects the iterative character of the analytical process. In this research different promissory configurations are identified. Part of the coding process was about identifying these different periods where the promissory configurations were present. The process of establishing concepts was thus divided into different periods.

After each article was coded, a brief summary was made about the identified envisioned underlying technological configuration and the envisioned form of application. These summaries where used to further structure my thoughts and enabled me to go on to the following step of the open coding process. After coding several[2] articles a sort of pattern in the codes emerged and I was able to cluster groups of codes that seemed to indicate a relationship. This competency is called 'pattern recognition' as indicated by Patton (2002). The analytical step of open coding moves from describing what has occurred, to linking codes together with the aim of developing concepts on a more abstract level. This last step of developing concepts at a more abstract level can also be seen as the starting point of the axial coding process.

In the next step, which can be called axial coding, those concepts were selected that seemed most promising in answering the research question. Concepts with a lack of recurrence in the data or without explanatory power were left out according to Goulding's (2002) analysis process. By comparing the selected concepts on their properties and relationships the coding moved to yet a higher level of abstraction; conceptual categorization (Goulding, 2002). During the formation of categories, earlier developed concepts served as characteristics and dimensions of the final category. During the formation of categories, it appeared that some concepts fitted to multiple categories. Due this fact, relationships between categories were identified. Further, these relationship were specified which resulted in conceptual thickness (Flick, 2006). In the end, when all categories were formed and relationships were identified and specified, an explanatory scheme regarding the research question was built. At this final stage of the research, the explanatory scheme will provide an answer to the main research question.

[2] This was done already after several articles, but was finished when all articles were analyzed. It is difficult to specify the place of this step in the process, because the process is not linear.

4. Results

The development of the Smart Home Technology is divided in three periods, which are demarcated by the envisioned underlying technology. Smart Homes are configurations enabled through interoperability, and the underlying technology is then the basic idea through which interoperability becomes facilitated. Within the identified promissory configurations, the basic idea remains the same during the development of the smart home technology. In contrast, the configuration of the underlying technology alters. Technologies are added, removed or replaced in the configuration of the envisioned smart homes. The identification of three corresponding promissory configurations of smart homes[3] is the first result of this research. This identification of promissory configurations of Smart Homes resulted from a first analysis of the IEEE Transactions on consumer electronics (IEEE T CONSUM ELECTR) journal. The periods were further specified by theoretical coding of the IEEE T CONSUM ELECTR journal, Personal and Ubiquitous Computing[4] (PERS UBIQUIT COMPUT) and projects from the EU Framework programs[5]. The identified periods will be further specified according to technological expectations and expectations about the applications, function and wider societal problems which are addressed.

4.1. Promissory Configuration I – The Home Bus System

The first article identified was in 1983 in the IEEE T CONSUM ELECTR journal. This article is taken as the starting point of the development of the smart home technology in this research. The first identified promissory configuration covers the period from 1983 till 1997/1998. The first smart homes were envisioned to have a large variety of appliances in house interconnected over a Home Bus System (HBS). The function of a smart home was envisioned to increase comfort, convenience, security and health care (at home). In order to facilitate these functions, centralized monitoring and control of the smart home was desired. The overall architecture was as follows. In a HBS a central transmission media serves as a backbone where all appliances were connected to. By connecting one (or more) controlling unit(s) to the backbone transmission medium all appliances can be controlled from a single controlling unit. This is called centralization of control, which means that for instance the washing machine and the kitchen light can be switched on from a single controlling unit, instead of switching on the light switch and pressing the power button of the washing machine. A schematic example is provided in Figure 3. The architecture of an HBS can be divided into three main elements;

- Input/Output: These devices are the input for the HAS and the output towards the user. Examples are controllers (input), smoke detectors (input) or televisions which present information about the state of other appliances (output).
- Appliances: All sorts of appliances can be connected to the home bus system, varying from refrigerators, ovens and washing machines to intruder detection systems and garden sprinklers. These appliances are monitored and controlled by the input/output devices.

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[3] *In this research the smart home technology is discussed and there will further be referred to smart homes when discussing the application of the smart home technology.*

[4] *Including its predecessor Personal Computing.*

[5] *Within the result section I will refer to [A#, B# and C#] which are the respective three different data sources (see Appendix II).*

- To perform the communication between the input/output devices and the appliances, there is an interface, transmission medium and communication protocol needed. The transmission medium is the wired of wireless hardware enabling the communication, whilst the communication protocol is the language used to communicate over the transmission medium. The interface is referring to the connection between the appliances and Input/output devices and the transmission medium. The interface enables interaction between the appliances/devices and the transmission medium.

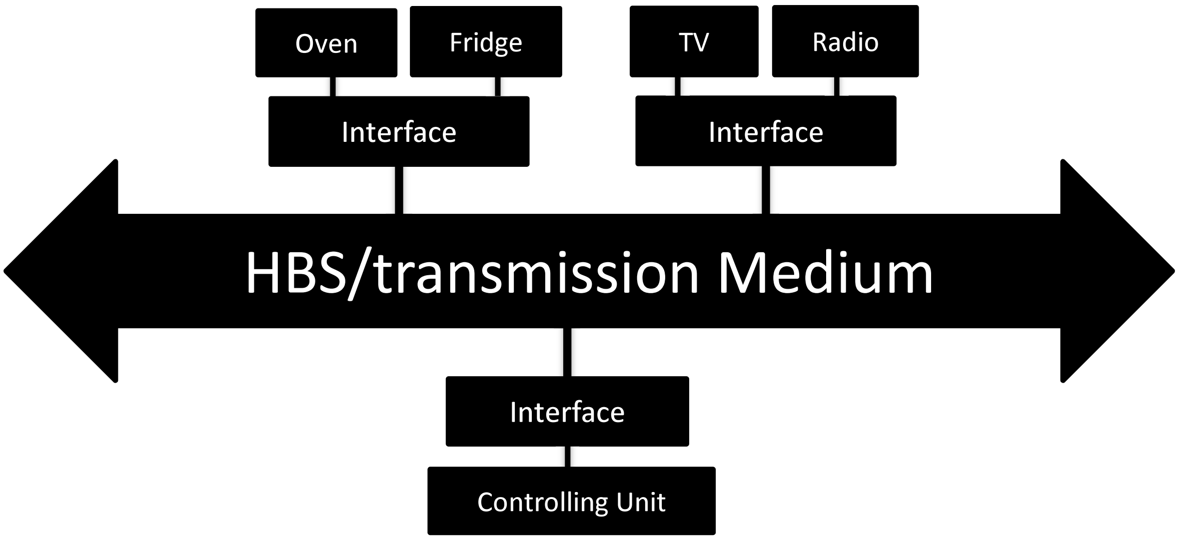

Figure 3: Schematic architecture of a Home Bus System

4.1.1 Conventional technologies

In the first smart homes the transmission medium was adopted from the ordinary cable television system (CATV) using a coaxial cable (CAT5) [A14, A41, A43, A51]. Another transmission medium used in this first period was twisted pair wiring, the standard wiring for telephone networks in homes. Both transmission mediums used where conventional, already present in homes, wired systems. Hamabe et al. (1988) mention the difficulty of laying cables in existing houses as an argument to use CATV system. Because the systems were based on conventional (already present) technologies, the telephone is mainly used as user interface in order to give impetus for the smart home. The telephone system was not only used to control from inside the house, public phone lines were used to remotely control (part) of the smart home. Other input signals for the smart home were safety detectors like smoke- and gas detectors. In order to detect intruders, infra-red motion detectors were used. Output of the smart home was mostly (again) the telephone. When for example a fire was detected by the smoke detector, the phone would ring and an automatic voice message was broadcasted [A41]. The application of the smart home technology was placed in the overarching frames of comfort, security, energy savings and convenience. Although these frames are mentioned in the different data sources, over time the interpretation of the various frames differs. In this period the more general function of a smart home was the remote control of appliances. Important to note is that controlling the appliances was very limited. The most common commands were ON/OFF and dim/bright. However, controlling appliances in an efficient and convenient way is the envisioned desired application. In order to make it convenient, the control should be centralized, which means that different appliances could be controlled from a single controller. Information about the status of appliances, but also who is entering the front door is a function the smart home is envisioned to provide. Security would be increased when a monitor could provide a video stream of the person entering the door. Therefore, great emphasis is on integrating an Audio/Video (A/V) system in the house to fulfill the function of security, information transmission and also comfort by broadcasting movies from the VCR throughout the house.

Hamabe et al. (1988) made an interesting classification of the different functions of a HBS:

- Housekeeping: lighting control, fire detection, electric lock
- Management: care for the aged, medical examination at home
- Culture: FM/TV receiving, game
- Communication: emergency broadcasting, tele-control

In subsequent articles Hamabe (as first writer) wrote in this period (1988/1989), Hamabe continued using this classification of functions. Notable in his description of the different functions is *care for the aged*, which was rarely envisioned in Smart Homes during that time. Although, in none of his articles this function is elaborated in terms of specific functions or technologies required. An overview of Hamabe et al.'s (1988) system is provided in the appendix (Figure 11: System design of a Home Automation System by (HAMABE et al., 1988)).

4.1.2 First HBS standards

The underlying technology of a smart home was based on a Home Bus System (HBS), as provided earlier in Figure 3. The communication over the bus system was not standardly defined, which resulted in compatibility problems between devices from different vendors. To increase the compatibility between the (heterogeneous) products from different vendors, a (communication interface) standard was needed (1988 – 1997). Ultimately, there was striven for an 'off the shelf system', where components from different vendors could be configured into a scaleable and flexible (modular) smart home. Hereby is referred to the application of the smart home technology in various different houses. Therefore, the composition of the systems appliances should be adoptable to the environment and the specific user needs, as so the system should be able to be enlarged when required and be composed out of devices selected by the user itself.

In 1988 a Japanese standard is introduced for HBSs (Ayugase et al., 1989). Increase of compatibility was the main reason for establishing the (Japanese) HBS standard:

> "*The Japanese Home Bus System (HBS) standardization activities have been carried out to meet the needs of connecting various devices for constructing home information systems*" (Ayugase et al., 1989: p.698) (AYUGASE et al., 1989).

In 1992[6] the first US HBS standard (CEBus) is officially introduced by the Electronic Industries Alliance[7]. CEBus is an open architecture protocol for communication through power line wire, low voltage twisted pair wire power line wire, low voltage twisted pair wire, coax, infrared, RF, and fiber optics (EDDEN, 1990). See Figure 4 for an example of a power line based HAS. When comparing with

[6] *Within the IEEE T CONSUM ELECTR journal the CEBus standard is already discussed from 1990.*

[7] *Standards and trade organization composed as an alliance of trade associations for electronics manufacturers in the United States*

the schematic architecture sketched in Figure 3 you will see that this CEBus system is originated from the initial ideas about a HBS.

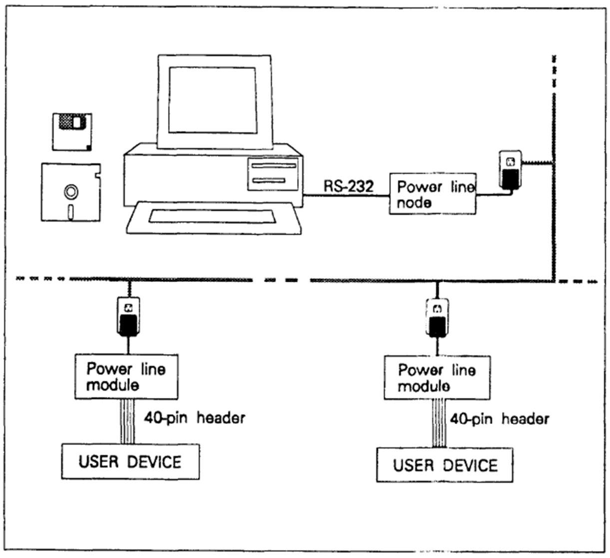

Figure 4: Example of a CEBus based home automation network (Bertsch, 1990)

In the same year (1992) a European standard was released, the European Home Systems (EHS) (Guillemin, 1998). The European standard was (initially) focusing on transmitting data over the (existing) power line or telephone system. A reason to choose the power line system was the possibility to transmit signals over high speed, where the telephone was safer and more secure system.

The reasons behind establishing all standards were quite similar. Interoperability between the heterogeneous bunch of devices from different vendors should increase the possibility of mass adoption. However, the releases of these first standards were only a beginning. All three standards were established in cooperation with industry actors, research centers and governmental institutes in the respective regions. From the first moment (and even before) the standards were released, further specification to meet the 'needs' of the Home Automation industry were articulated. The phrase below is an example of a reaction on the released CEBus standard.

> *"[…] resources needed for home automation in a multi-product, multi-vendor environment: controller, housewide bus, communications protocols, standard interfaces, and basic user controls."* (Stauffer 1991: p. xxix).

The expectation was that *Home Automation* was 'just around the corner' (Greichen, 1992). Sub-technologies (expected to) influencing the field of the smart home technology were the semi-conductor, HDTV and OSI layer model/protocol and especially LSI technology.

> *"Because of recent advantages in LSI technology, many home devices have been equipped with micro-computer chips. Housekeeping equipment, home computers, entertainment devices such as audio/video equipment and telephones have been enhanced by LSIs. Therefore, it is necessary to construct a residential network to interconnect all home equipment."* (Ayugase, Yamamoto et al. 1989: p. 698)

The advances in LSI technology thus resulted into an increased desire for an interconnected home network. However, the developments in micro-chip computers resulted in much more possibilities, whereby also the complexity of the smart home technology (from the view of the user) was increasing. This resulted into a new objective: decreasing the amount of complexity by enhancing the usability of the smart home technology.

4.1.3 **Human-Machine interfaces**

Because of the increasing amount of devices which were becoming part of the smart home architecture, the system was becoming more complex. However, the smart home system should be installed and operated by any (inexperienced) user. In other words, the human-machine interface was under discussion and various (potential) solutions were developed (1991-1997/1998). The envisioned function of the smart home was to control (and monitor) all appliances by a single unit (controller). The function the smart home technology could fulfill was also under development, which emphasized the urge for an increase in usability. Various projects [B2, B3, B5, B9] envision the smart home technology as a assistive technology for the elderly population. Especially for elderly (which mostly suffer from cognitive or physical disabilities such as being visual impaired), the ability to control the home environment in a more convenient matter (by centralization of monitoring and control) could increase the quality of life of elderly. [B9] Even foresees that the smart home technology could prolong the period of independent living of elderly suffering from dementia.

Where first the conventional telephone was used as user interface (UI), in this period terminals were developed especially for the interaction between the user and the smart home. The envisioned terminals firstly had a keyboard or multiple buttons, and ideas where there to possibly integrate a small display. The challenge was to develop a UI terminal with a minimum amount of buttons, in order to keep it simple to operate. In the same period [A18] was the first introducing Artificial Intelligence to address the problem of interaction between the user and the smart home. The functioning of the HAS was described as adapting to the context, with a minimum amount of user interaction. This was a new vision on how the smart home technology was configured and functioning. According to Evans (1991), "*products must be able to adapt to their environment. They have to know what to do without telling the home owner having to tell the device*" (Evans, 1991: p.395). In some envisioned smart homes, voice recognition in combination with various sensors was envisioned as the solution for the user interface problem. Multiple microphones were installed inside the envisioned house which should gather the commands from the user. However, there was a great challenge to make the voice recognition work in an uncontrolled environment as a home.

4.1.4 External communication

After the release of the HBS standards, various transmission mediums were envisioned to be part of the underlying technical architecture of the smart home. It is important to note that within a single envisioned smart home, the use of a combination of transmission mediums was becoming more common. Next to the function of increasing the quality of life of elderly, another envisioned application was energy management. The possibilities to use smart home technology in order to perform energy management in households resulted in the need for two-way communication between the smart home and the energy supplier [B6, B8, B10, B12]. To perform this communication with an external service provider, the existing telephone gateway was envisioned as the transmission medium. Functions as load management could be performed when communication between the electric appliances and the energy supplier was available. However, the communication between the (electric) appliances in house could be performed over the various transmission mediums available. However, the main (in-house) transmission mediums used in the case of energy management was power line communication (PLC).

To summarize, the transmission medium used after the establishment of the standards varied between; PLC, low voltage twisted pair (telephone system), coax, infrared, RF, and fiber optics. However, fiber optics was less represented within the analyzed articles. A reason to base the system on fiber optics was the expectation that cable companies would replace coaxial cables by fiber, which meant that the standard transmission medium input for homes would change (Cross & Douligeris, 1993).

4.1.5 Summary of expectations

The first promissory configuration of the smart home is characterized by the technology driven promises. Much debate was about the development of standards to enable interoperability between appliances, which ultimately should result in mass adoption of the smart home technology. The envisioned smart home was based on a home bus system and configured out of devices from different vendors. The main focus was centralized and remote control of the smart home. By enabling this function, the smart home could increase the quality of life of users. The possibilities to address health care at home issues do pop up, but received minor attention. The expectations in the first identified period of the development of the smart home technology are summarized in Table 2.

Table 2: Classification of expectations - promissory configuration I.

Project-specific expectations	Generalized expectations	Framing expectations
Audio/Video system is integrated in the smart home	Variety of appliances interconnected over an Home Bus System	Smart Home will increase quality of life; comfort, convenience, safety, security and health care (at home)
Smart home configured out of devices from different vendors (standards required)	Centralization of control: appliance can be controlled by a single controlling unit	Standardization of HBs will result in mass adoption
Dominant transmission mediums were the conventional wired systems; coax cable and twisted pair (telephone) in the US and East Asia and the Power Line System in Europe.	Remote control of appliances (control was limited to basic commands)	Smart home technology could serve as assistive technology for elderly
Telephone system is safer than PLC, but transmit signals at lower speed	Scaleable and flexible smart home	Smart homes could be used for Energy Management, therefore external communication was required

LSI technology enhanced the possibilities of interconnecting home appliances	Standard communication protocols were needed	
UI terminal with a minimum amount of buttons	Smart home should be installed and operated by any (inexperienced) user	
External communication over telephone network	Smart home technology difficult to install in existing houses because of wiring	

4.2. Promissory Configuration II – The Internet enabled Smart Home

Where the energy management systems discussed in the previous section already showed the need to connect the smart home with an external source, the emergence of the internet had a tremendous influence on the configuration of the smart home technology. Therefore, a new promissory configuration is specified in this research: *the internet enabled smart home*. Promissory configuration II covers the period between 1997/1998 and 2003/2004. The internet connected smart home distinguishes itself from the previous promissory configuration by the standard connection with the environment, which subsequently enables the opportunity to perform a broad range of 'new' functions. In short, household appliances (e.g. washing machine, computers, TVs, meters, surveillance cameras, and alarms) would be able to communicate within or outside the smart home through any type of communication network [B16]. The architecture is modular and capable of supporting user interaction varying from a single push-button to a home computer with secured servers for remote configuration and security. Another important development within the second promissory configuration is the emphasis on an *open system*, and the usage *of divergent standards* and *open source software*. The second promissory configuration was mainly envisioned to improve the (*day-to-day) quality of life*. Under the header of day-to-day life, functions as; information, entertainment, security and energy management were present. An important feature the internet enabled was informing the user when there is an abnormality at home [B15]. The functions mentioned above were in particular helpful for the elderly and disabled. However, configuring the smart home for the use by elderly and disabled did put an extra emphasis on the interaction between the user and the smart home. During this period, the problem of complexity and thus the lack of a practical user interface was however still present. The urge for a practical user interface and the increasing complexity (because of developments of underlying technologies) of the smart home technology can be seen as a self-reinforcing cycle.

4.2.1. Information Society

The integration of the internet in the smart home technology resulted into the ability to communicate with external sources and also to receive information from external sources. More concrete this meant, for example, the following function could be performed:

"The smart wardrobe digitally looks up the weather forecast for the user so that they can comfortably and adequately coordinate what they wear with the outside environment before they leave the house" (Park et al., 2003: p.190).

These functions the Smart Home could fulfill can all be placed under the header of information provision. Within the data analyzed multiple times there is referred to the rise of the Information Society influencing the field of the smart home technology [A56, B26, B29, B45]. Next to the reference to the rise of the Information Society, expectations are drawn that recent developments within the smart home technology will affect daily life at home. Webster (1995) describes that the developments of inter alia the personal computer, the internet, cable television and other information services has led to a reconstruction of the social world. Hereby, it is implied that new 'needs' arise, referring to the ability to monitor (and control) your house anywhere anytime. In other words, being informed about the status of your smart home anytime anywhere. Further, the internet not only addressed the urge for remote access to the home network, it was also a new input (information source) in order to anticipate on user needs (see below).

4.2.2 Personal Computer and the internet

In this period of the second promissory configuration the Personal Computer (PC) was becoming a settled appliance in consumer households. More than half of the US households in the year 2000 had a personal computer, of which 40% had a direct internet connection (National Telecommunications and Information Administration, 2000). This development enriched the possibilities for incorporating the PC in the smart home technology to connect the Smart Home to the outside world by internet. The next paragraph is a typical example of a statement about the influence of the internet development on the smart home technology:

"*Remote access to a home automation network from a computer with an Internet connection, using a Internet/Home Bus gateway has previously been demonstrated [1, 2]. Further, it is evident that a significant proportion of homes are, or will shortly be, connected to the Internet. This, in turn, is leading to the growth of many new Internet-based products and services, and the convenience of these for consumers will lead, in turn, to an increasing number of homes with permanent, high-bandwidth Internet connections. The Internet-enabled home is likely, in turn, to catalyse the market growth of home networks as manufacturers of domestic appliances and consumer electronic products seek to gain competitive advantage by adding functionality and providing new services via the developing home-Internet infrastructure*." (Cucos & Corcoran, 1998: p. 482)

With the rapid development of the internet the underlying technological architecture of the envisioned Smart Home was developing into a new system (compared to the architecture sketched in Figure 3). The rise of the internet made it possible to easily monitor and control the house remotely (via web interface, see Figure 6), but was also the access point for the networked home to gather information from external sources (i.e. weather forecasts, traffic information). Figure 5 gives an example of a (rather schematic) typical envisioned Smart Home in period II.

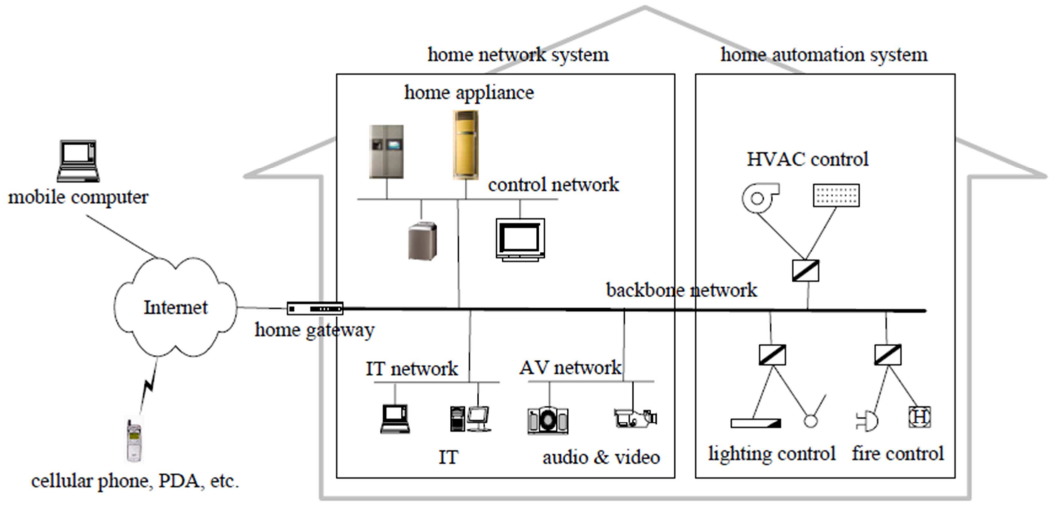

Figure 5: Internet connected Smart Home (Lee & Lee, 2004)

The in-house transmission mediums (backbone network) within the envisioned Smart Homes in this period varied between; Twisted Pair, Radio Frequency, WLAN, Bluetooth, PLC and Infra-red. Interesting in the underlying transmission technology of the Smart Home is the development of wireless networking technologies [A10, A70, B15, B16, B20]. The possibility to configure wirelessly (part) of the Smart Home enriched the possibilities for modular and scalable system, and also the possibility to develop a retro fit design which could be implemented in existing houses. In this period a common used communication language was the TCP/IP protocol, which was the standard internet communication language. However, the TCP/IP protocol was not the standard in-house communication language, because in-house protocols were still in development and multiple protocols were used. In order to enable communication between the Smart Home and the environment by means of the internet, a new device is integrated in the architecture, the *home gateway*. The home gateway is the link between the Smart Home and the environment.

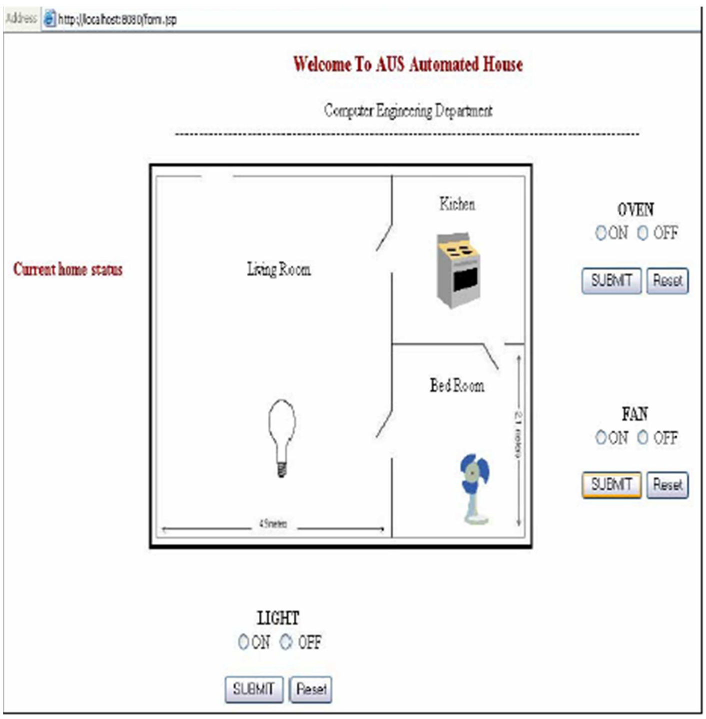

Figure 6: Web interface to control Smart Home (Al-Ali & Al-Rousan, 2004)

To enable remote control over the home, the internet was the dominant way of communication. By developing a web browser interface, the house could be controlled and monitored continuously, since the user has internet access throughout the entire house. Parallel to the emergence of the internet as envisioned external communication technology was the GSM system [A31, B19]. Mobile phones where becoming smarter in the sense that java applications could be run, which enables communication with the Smart Home [B19] (See Figure 7 for an example). Mobile communication technologies such as WAP (and emerging GPRS) could be connected to the internet gateway of the home. A variation on WAP was the use of SMS in order to command the home, however this technology was more restricted to simple commands. A great benefit of using the GSM system over the internet was the proven security and reliability of the technology.

Figure 7: Example of mobile phone as user interface (Koskela, Väänänen-Vainio-Mattila, 2004)

4.2.3 Natural interaction

Where in the first promissory configuration of the Smart Home voice interface was already envisioned occasionally as complementary user interface, more attention was given to this modality in the second promissory configuration [A70, B19, B20, B22, C3]. In order to optimize the amount of convenience and to enable elderly and disabled to interact with the Smart Home, voice interface was envisioned as a complementary modality for controlling the Smart Home from inside. But to optimize the practical user interface, besides voice, also (hand) gestures were becoming more integrated in envisioned Smart Home s. There is referred to realizing *natural interaction* between the user and the Smart Home, as the desired mode of interaction. The development of networking all appliances in house and also enabling communication between various different appliances resulted into new possibilities as impetus for the Smart Home. For example:

> "*Consider the alarm-system motion detectors. These can detect activity in rooms and can therefore be used to for instance: 1) start the running hot water circulation pump when an occupant approaches the bathroom or kitchen, or 2) avoid ringing the phone in a bedroom with no activity (where presumably an occupant might be sleeping) when activity in another room indicates that someone else might prefer to pick-up the phone.*" (Spinellis, 2003: p.59)

In other words, the different appliances can share their resources with each other in order to optimize the anticipation on user needs. The Smart Home is developing into an *ubiquitous and pervasive computing system*, that provides the user with adequate information at the desired moment and also provides a digital (home) environment that is both natural and friendly [C1, C2].

4.2.4 Summary of expectations

The second promissory configuration of the Smart Home is heavily influenced by the emergence of the internet and the Personal Computer. Where the internet enabled sophisticated remote control regarding the previous external communication technologies (see 4.1.4 External communication), also the envisioned underlying architecture to enable interoperability altered and was not based anymore on the home bus system. By means of wireless technologies and the emphasis on an open system, the envisioned Smart Home was becoming more flexible and could therefore be better adjusted to user preferences. Consequently, expectations arose that more devices will be internet enabled. Emphasis was on the anywhere anytime information provision about the status of the envisioned Smart Home, and the ability to control (remotely) in a natural manner. At last, the Smart Home was developing into a system whereby the emphasis was on anticipating on user needs. Hereby, anticipation occurred with a minimum of user intervention. The expectations in the second identified period of the development of the Smart Home technology are summarized in Table 3.

Table 3: Classification of expectations - promissory configuration II.

Project-specific expectations	Generalized expectations	Framing expectations
Internet network as the external communication medium	Appliances are able to communicate within or outside the Smart Home through any type of communication network	Rise of the information society influencing the urge for information systems incorporated in Smart Homes
PC based Smart Homes	The internet enables variety of new functions, especially provision of (context related) information. E.g. *smart wardrobe*	The Smart Home will increase quality of life; information, entertainment, security and energy management
Increasing amount of internet connected homes	The Smart Home is an open system with divergent standards	Especially elderly can benefit from the application of the Smart Home technology
Increasing amount of internet based products	Being notified when an abnormality is at home was a desired application, what emphasized the need for external communication	
Control the Smart Home via a web interface	Anytime and anywhere access to the Smart Home	
Using external information sources via the internet to adapt to user needs	Wireless technologies influencing the architecture of the Smart Home. Enables retrofit designs	
Common (but not standard) communication protocol was the TCP/IP, fostered by the rise of the	More emphasis on developing a user interface based on natural	

internet	interaction (voice, gestures)	
GSM technology to control and monitor Smart Home	Smart Home anticipates on user needs	
Appliances can share resources to anticipate on user needs		

4.3. Promissory Configuration III – The Sensing Smart Home

Where the previous promissory configuration of the Smart Home was developing into the direction of a *ubiquitous and pervasive computing system*, the third promissory configuration is characterized by the incorporation of the *ubiquitous sensor network*. The (wireless) ubiquitous sensor technology is originated from the military, but was now used for consumer purposes. The ubiquitous sensor network should address the need for a minimum of human intervention and should subsequently increase the automation and anticipation ability of the envisioned Smart Home. In combination with the earlier development of the incorporation of the internet, the input system of the Smart Home was radically developing. As Zhang et al., (2008) state: "*The objective is to sense and gather information from multiple sources (sensors, internet etc.), combine the information and use to intelligently control internal and external environments*" (Zhang et al., 2008 p. 1157) (see Figure 8) [A77 & A49]. The ubiquitous sensor network was becoming a solid part of the underlying envisioned technological configuration of the Smart Home.

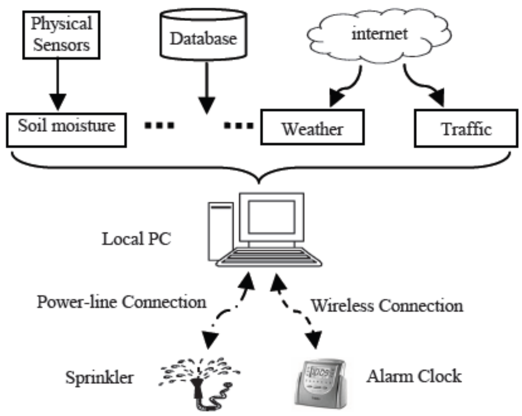

Figure 8: Multiple sources as input for the Smart Home (Zhang et al., 2008)

4.3.1 Embedding in broader societal issues

In the earlier promissory configurations of the Smart Home the application purpose was to interconnect home appliances in order to increase the level of convenience, comfort and subsequently safety and security. Further attention was given to the possibilities of energy management and increasing the quality of life of elderly. However, in this third promissory configuration an important development is witnessed, broader societal issues are seen as repository for possible applications. The Smart Home technology was explicitly addressing the societal problems[8] of the aging population [B29, B32, B33, B34, B35, B36, B37, C16] and the (subsequent)

[8] In the developed countries

rising health care costs, and secondly the problem of energy shortage which resulted in the need for efficient energy usage and incorporating alternative energy sources.

The function of the envisioned Smart Home becomes more and more directed at assisting the user in their needs. As Zhang et al., (2008: p.1157) define the Smart Home: "*Smart Home refers to a domestic environment that applies knowledge to improve the quality of resident's life by facilitating a flexible, comfortable, healthy and efficient environment*". The Smart Home technology is envisioned to facilitate elderly and disabled to live longer independent, and also increase their privacy by limiting the amount of care needed from nurses [A59]. Different authors discuss the possibilities for the Smart Home technology to facilitate the independent living by developing an assistive system, and thereby increasing the quality of life [A20, A46, A49]. The application of the Smart Home technology to provide care at home is called Ambient Assisted Living (AAL). AAL also includes the possibilities of monitoring elderly at home, by a professional located externally. In sophisticated envisioned AAL environments, users wear light wireless devices which measure specific vital signs [B33, B36, B61, C16, C18]. The technique of attaching sensors on the body of the user is radically different from the hitherto envisioned Smart Homes. Also the ability to be monitored yourself instead of controlling and monitoring your own house is different from the previous envisioned Smart Homes. Overall, the heterogeneous functions the Smart Home technology was envisioned to fulfill are presented in Figure 9.

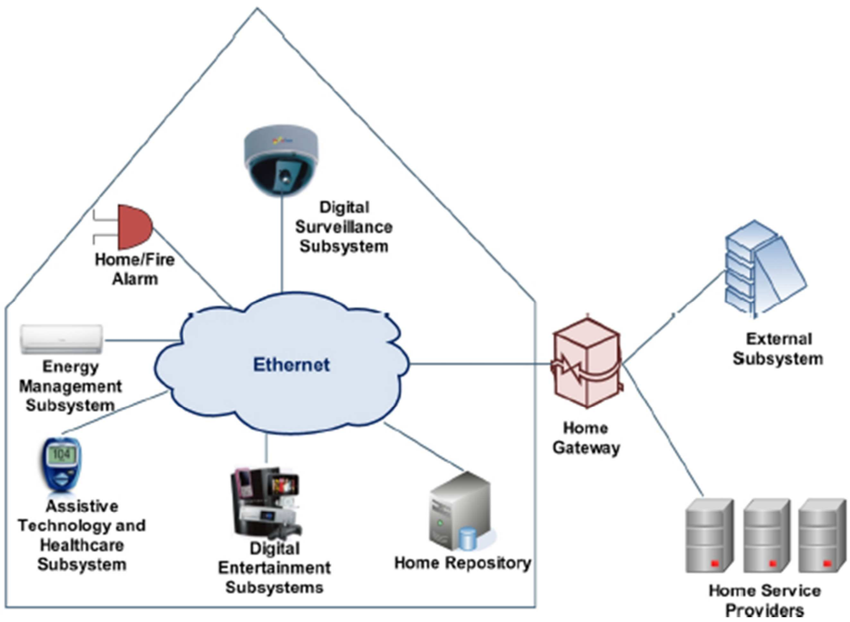

Figure 9: Heterogeneous subsystems in Smart Home environment (Leong et al., 2009)

4.3.2 Context aware

In order to fulfill these functions the envisioned Smart Home should be able to adapt to user needs with a minimum of user effort. Therefore, the Smart Home should be able to anticipate on user movements, be context aware, predict behavior, recognize living patterns, devices having a conscience, etc. Especially in the case of care for the elderly and disabled, the function of a Smart Home was developing towards a Home Assistance System and becoming closer to a really "Smart" Home. For example, (Zuo & de With, 2005: p. 183) state: "*Consequently, it is desirable that electronic devices can consciously sense and understand their surroundings and adapt their services according* *to the contexts (e.g. environments).*" In order to perform these functions, the Smart Home was envisioned to have *intelligence*:

> "*[…] imitating human intelligence and the processes of decision-making and fusion of information acquired from multiple sources, including sensors, databases, open sources, and human sources*" (Zhang et al., 2008: p. 1158).

This phrase above shows the common use of sensors in the envisioned Smart Homes in this period. By applying information fusion between the information obtained from sensors, user input and (internet) open sources, the Smart Home was able to perform situational analysis to optimize anticipation on user needs. The envisioned functions of the Smart Home were both beneficial for assisting an (elderly or disabled) user, as well as to configure the use of electric appliances in a certain way to conserve energy. Where a ubiquitous sensor network can monitor the activity of an elderly and compare this with the activity pattern, early inconsistencies aiming at health issues can be identified. Further, this same information about the activity and movement of a user can (in the simplest manner) be used to switch of electric appliances in rooms where the user is not present (e.g. lighting and television).

4.3.3 Communication technologies

The growth of wireless sensor networks within Smart Homes resulted in a request for new communication technology. Because sensors where ubiquitous and not (always) close to a power outlet, sensors were equipped with a small battery. The energy needed to transmit the signal was therefore desired to be low. A new communication medium/protocol was developed to address this problem, Zigbee. The first technological Zigbee standard is released in 2004 by the ZigBee Alliance (ZigBee Alliance, 2012). According to Song et al., (2008: p.1688): "[…] *ZigBee standard for wireless sensor networks available now, we are given more opportunities to build wireless control and monitoring applications that can guarantee low cost, low power, large range and high reliability*". See Figure 10 for an example of a Zigbee network.

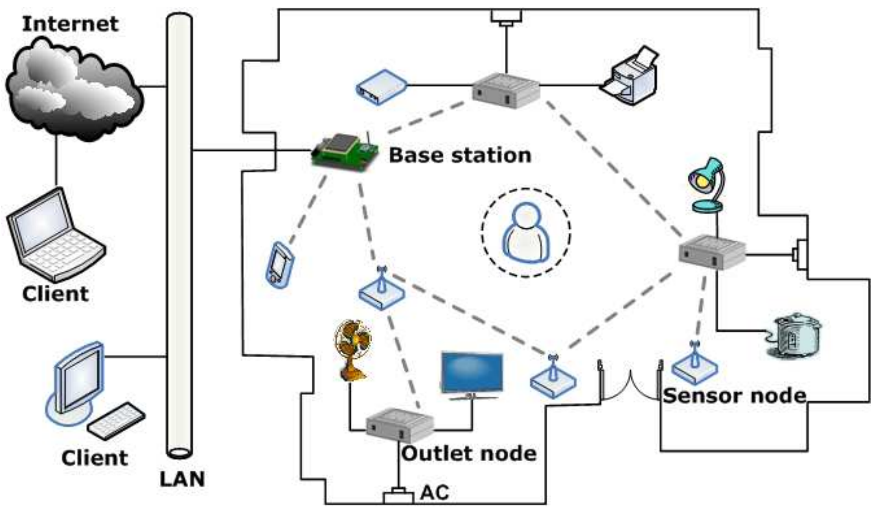

Figure 10: Zigbee Network (Song et al., 2008)

Zigbee is designed as a complementary communication technology parallel to the existing transmission mediums (e.g. Wi-Fi and Bluetooth). Where Wi-Fi is the fastest communication technology, it also demands the most energy. Zigbee is designed to transmit small data with very low energy usage. Bluetooth can be placed in between these two technologies. The construction of a Zigbee network is rather different from the previous mentioned communication technology. Where thus far every appliance or sensor communicated with a coordinating (or gateway) device, appliances or sensors in a Zigbee network forward the signal to each other, where ultimately the signal arrives at a coordinating device connected to the rest of the Smart Home (see *base station* in Figure 10). Depending on the type of appliances connected to the Smart Home, different communication technologies are desirable. Therefore, no single communication medium is dominant in the third promissory configuration. In the envisioned Smart Home, a combination of wired and wireless technologies is used, depending on the type of appliance connected. This development is in line with the endeavor to a scaleable and modular home, not restricted to appliances and/or devices from a single vendor.

4.3.4 User Interface

The discussion about the UI was still going on. However, overall agreement was on the fact that the interaction between the user and the Smart Home should be as natural as possible. This is still because of the complexity of the Smart Home, but also the new development that elderly and disabled should be able to operate the Smart Home. Therefore, there is referred to a *Design 4 All* principle, which means that everyone should be able to operate the Smart Home. However, interesting is that the principle of configuring a Smart Home in such a way that anyone should be able to install it is deserted. The only focus is on the ease of operation. A combination of UIs was becoming a more dominant solution within the envisioned Smart Homes. Possible UIs were; PC, PDA, Smartphone, LCD touch panel, voice, face recognition, cellphone (SMS), TV (STB) and a GUI terminal combined with buttons. Because of the emphasis on a natural interface between the user and the Smart Home, perceptual interfaces (voice, gestures, and face-recognition) were envisioned to become the dominant communication modality. However, within the envisioned Smart Homes in this period, these modalities were only complementary or labeled as future visions. Further, the development of the smart phone had a great influence on the search for a practical UI (Kim et al., 2010). The possibilities of smart phones to run java applications have increased the interoperability with the computer based environments. And in the later years, the touch screen smart phones were seen as very user friendly.

4.3.5 Summary of expectations

The third promissory configuration of the Smart Home is characterized by the incorporation of the ubiquitous sensor network. Worthy to mention is the development that broader societal issues are seen as repository for possible applications of the envisioned Smart Home. In the progressive/sophisticated AAL environments, the technical configuration of the envisioned Smart Home was complemented with body attached sensors which provided the Smart Home information about vital signs of the user. In this development, the mutual relation between local contingencies and the underlying technological configuration of the configuration of the envisioned Smart Home is clearly visible. The envisioned Smart Home is required to have a conscience and be able to make decisions based on user behavior, what was enabled by the fusion of information sources. The expectations in the third identified period of the development of the Smart Home technology are summarized in Table 4.

Table 4: Classification of expectations - promissory configuration III.

Project-specific expectations	Generalized expectations	Framing expectations
Fusion of information sources; sensor, internet, direct user input	Smart Home architecture based on ubiquitous sensor network	The Smart Home will increase quality of life; information, entertainment, security and energy management
Zigbee technology becoming standard sensor communication system	Smart Home anticipates on user need with a minimum of user effort	Smart Home applications are embedded in societal issues[9]; energy shortage and aging population
Combination of wired and wireless transmission mediums dependent on the signal to be transmitted	The Smart Home will have a conscience and will be able to make discussion in favor of user needs (context aware)	Prolonging independent living of elderly to increase the quality of life and decrease the health care costs
Body attached sensors for AAL applications	Smart Home anticipates on user behavior and is able to learn living patterns	
Smart meters for sophisticated energy management	Smart Home consist of heterogeneous sub-systems	
Combination of user interfaces based on a Design 4 all principle. The Smart Home should be operated by disabled and elderly people	Perceptual interfaces (voice, gestures) are the future user-machine interfaces	
Smart phone as dominant user interface, ability to run java		

[9] In the western world

5. Discussion

This research is based on a qualitative analysis, where by means of theoretical coding three data sources are analyzed. Where the two scientific journals were providing a scientific perspective, the EU framework projects provided insights from the industry/government perspective. The journal Personal and Ubiquitous Computing was a result from theoretical sampling, after the journal IEEE Transactions on Consumer Electronics was analyzed. The three different data sources complemented each other and reinforced findings from the different perspectives. Afterwards, this indicated to be a fruitful source, because the smart home technology was greatly influenced by developments in ubiquitous computing and sensor systems which was thoroughly discussed in the Personal and ubiquitous Computing journal. The analysis of the data is performed by only one researcher, what can be assigned as a weakness of the methodology. The interpretation flexibility could be minimized by assigning secondary researchers to be involved in the coding process. However, by accurately describing the steps taken in this research, the reliability of the result can be assured. Because of the qualitative approach the results are subjected to interpretation. Therefore, the background of the researcher is probably of influence on the data analysis process. Further, the role of prior theory has served as heuristics during the data analysis. However, the role of prior theory is discussed in the methodology chapter, in order to provide transparency.

By looking at the Smart Homes technology through the lenses of the promissory configuration concept this research enhances our understanding of the Smart Home dynamics. By applying the concept of promissory configurations, the disorderly development of the Smart Home technology can be better understood. Where the insights in the expectations literature did not give a sufficient answer how innovative activities can continue after periods where (positive) expectations disappear, especially on the long term (multiple decennia). In other words, how is it possible that the Smart Home idea never fully disappeared even though it has been declared dead for numerous times? Looking through the lenses of the promissory configuration it becomes clear how the idea of Smart Homes evolves over time and pops up in different configurations. When expectations about both application and configuration of the technology change, a new promissory configuration emerges. By applying the concept of promissory configurations, better insights can be provided into the development of the Smart Home technology which is continuously developing within a fluid state. Other than the dominant design model of Utterback (1996), which states that after the fluid phase, a dominant design will establish and the technology will develop in a settled manner.

6. Conclusion

This research studied the development of the promissory configurations of Smart Homes. The research question to be answered was: *"How did the promissory configuration of Smart Homes develop in terms of the envisioned applications and the envisioned underlying technical configurations?"* The first result of this research is the identification of three promissory configurations in the development of the Smart Home technology; 1) the home bus system covering the period from 1983 till 1997/1998, 2) the Internet enabled Smart Home covering the period from 1997/1998 till 2003/2004, and 3) the Sensing Smart Home covering the period from 2003/2004 till mid-2012. These promissory configurations are demarcated by a characterizing underlying technical configuration. Further, for each promissory configuration expectations regarding the application and technological developments are specified.

During the development of the promissory configurations patterns are recognized. It appeared that the basic idea of interconnecting (home) appliances was present in all the three identified promissory configurations. Where the basic idea remained stable, the envisioned underlying technical configuration of the Smart Home technology altered.

The first promissory configuration is characterized by the underlying technical architecture of the home bus system. Emphasis was on centralization of control, to enable this function all appliances where interconnected over a home bus system. In this period, much debate was about communication standards between devices, in order to increase to compatibility between devices from different vendors. The user should be able to buy an off the shelf Smart Home, and able to configure it to his or her wishes. The overarching application of the Smart Home was increasing quality of life by increasing the level of comfort, convenience, safety, security and enabling healthcare at home. The second promissory configuration is heavily influenced by the rise of the internet and complementary the personal computer. The development of the internet enabled the Smart Home to be connected to the environment. Where the internet enabled anytime anywhere access to the Smart Home, it was also a new information source. Where the Smart Home was envisioned to provide context related information and anticipate on user demands, the internet was a fruitful (complementary) source. Traffic information could for instance be combined with the *smart alarm clock* or weather information could reschedule the sprinkling system. During the second period, along with the development of the internet, wireless technologies were developing at high speed and were incorporated in the envisioned Smart Homes. This enabled the Smart Home architecture to be more flexible and adjustable to different houses and user wishes. Next to the internet, also the GSM system was envisioned to perform the anywhere anytime access to the Smart Home. The GSM system was a reliable and safe infrastructure and the developments of smart phones enabled the use of java applications to control the Smart Home. Where in the previous promissory configuration the Smart Home was envisioned to anticipate on user needs and being context aware, the third promissory configuration is characterized by the incorporation of a ubiquitous sensor network. Sensor networks where originally used and developed for military purposes, but were integrated into the Smart Home technology. Information fusion was the most important feature of the envisioned Smart Home in order to optimally anticipate on user needs. Information was fused from sensors, the internet and (direct) user input. The Smart Home was able to recognize living patterns and was developing into an assistive system. Therefore, the third promissory configuration is named as the sensing Smart Home. Notable in the third period of the development is that the application of the Smart Home technology is embedded in broader societal issues. The aging population and request for energy conservation were problems the Smart Home technology was envisioned to be applicable to. Ambient Assisted Living environments where developed where elderly and disabled could prolong their period of independent living. This was facilitated by the sensing Smart Home. The sensing Smart Home could also monitor the user itself, and report to an external medical professional or other care giver.

6.1. Patterns and Mechanisms

When focusing on the envisioned underlying technical configuration, developments take place on two different levels. The first level is that of the development of the underlying technologies themselves. To give an example, in the envisioned Smart Home where Zigbee was incorporated as the communication medium between sensors, the Zigbee standard itself was developing over time. This is a development which can take place within a promissory configuration. The second level where developments take place is the envisioned underlying technical configuration itself. Underlying technologies are added, removed or replaced in the architecture of the envisioned Smart Homes over time. Incorporating underlying technologies from outside the field of the Smart Home technology resulted in the emergence of a new promissory configuration. This occurred by the incorporation of the internet in the envisioned Smart Home of promissory configuration II, and next the ubiquitous sensor networks nested in the envisioned Smart Homes in promissory configuration III. Both underlying technologies were originated from outside the field of the Smart Home technology, and subsequently radically influenced the development of the promissory configurations. A tentative conclusion from the results of this research indicates a technology push during the first promissory configuration of Smart Homes, represented by the prevailing discussions on technological standardization.

6.2. Further research

This research provides insights in the development of promissory configurations, however, the developments on the existing markets are not integrated in the analysis. Further research could focus on the development on the existing market, investigating the availability of sub-systems of the Smart Home technology. In this manner insights in the development of Smart Homes can be further elaborated. Further, the transition from one promissory configuration to another is characterized by the incorporation of a new underlying technology in the envisioned underlying technical architecture of the Smart Home. The motivation behind the incorporation of a new technology has become less clear in this research, therefore I suggest further research to identify on revealing motives regarding technology incorporation. Hereby is referred to the different motives as technology push or market pull. Looking at the developments over the three promissory configuration, the motives for changing the envisioned configuration where more related to changes in the local contingencies. Especially in the case of establishing an AAL environment, the envisioned application purpose resulted into e.g. body attached sensors. However, these conclusions are tentative and further research is required to investigate the motives behind these alterations.

7. References

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8. Appendix I

Table 5: Example coding

Phrase	Code	Concept
Utility Load Management using Home Automation (Wacks, 1991: *p.168)*	Energy Management	Energy Management
The objective is to allow continued appliance operation during energy shortages (Wacks, 1991: *p. 168)*	Energy shortage	Energy management
The recommended system diagram is not complex, with wired and wireless connections to every electronic and electrical object in the home (GREICHEN, 1992: *p.xxxvii)*	Not complex system	Reducing complexity

9. Appendix II

Table 6: Numbering articles IEEE Transactions on Consumer Electronics journal

#	IEEE Transactions on consumer Electronics
A1	Al-Ali, A. & M. Al-Rousan. (2004), Java-based home automation system. Ieee Transactions on Consumer Electronics 50(2), pp.498-504.
A2	Alheraish, A. (2004), Design and implementation of home automation system. Ieee Transactions on Consumer Electronics 50(4), pp.1087-1092.
A3	Alkar, A.Z., J. Roach & D. Baysal. (2010), IP Based Home Automation System. Ieee Transactions on Consumer Electronics 56(4), pp.2201-2207.
A4	Alkar, A. & U. Buhur. (2005), An Internet based wireless home automation system for multifunctional devices. Ieee Transactions on Consumer Electronics 51(4), pp.1169-1174.
A5	AOKI, T., T. NAKATSUBO, Y. MINAGAWA et al. (1988), An Experimental Conformance Test System of Home Automation System. Ieee Transactions on Consumer Electronics 34(3), pp.723-727.
A6	AYUGASE, N., K. YAMAMOTO & S. SHINOHARA. (1989), Lsi Architectures for System Telephones using the Home Bus System Standard. Ieee Transactions on Consumer Electronics 35(3), pp.698-706.
A7	Balasubramanian, K. & A. Cellatoglu. (2008), Improvements in Home Automation Strategies for Designing Apparatus for Efficient Smart Home. Ieee Transactions on Consumer Electronics 54(4), pp.1681-1687.
A8	Balasubramanian, K. & A. Cellatoglu. (2009), Analysis of Remote Control Techniques Employed in Home Automation and Security Systems. Ieee Transactions on Consumer Electronics 55(3), pp.1401-1407.
A9	BERTSCH, L. (1990), Development Tools for Home Automation. Ieee Transactions on Consumer Electronics 36(4), pp.854-858.
A10	Bigioi, P., A. Cucos, P. Corcoran et al. (1999), Transparent, dynamically configurable RF network suitable for home automation applications. Ieee Transactions on Consumer Electronics 45(3), pp.474-480.

A11	Choi, K., M. Kim, K. Chae et al. (2009), An Efficient Data Fusion and Assurance Mechanism using Temporal and Spatial Correlations for Home Automation Networks. Ieee Transactions on Consumer Electronics 55(3), pp.1330-1336.
A12	CIOCAN, C. (1990), The Domestic Digital Bus System (D2b) a Maximum of Control Convenience in Audio Video. Ieee Transactions on Consumer Electronics 36(3), pp.619-622.
A13	Corcoran, P. & J. Desbonnet. (1997), Browser-style interfaces to a home automation network. Ieee Transactions on Consumer Electronics 43(4), pp.1063-1069.
A14	CROSS, D. & C. DOULIGERIS. (1993), A Fiber Optic Home Automation System. Ieee Transactions on Consumer Electronics 39(3), pp.636-645.
A15	Cucos, A. & P. Corcoran. (1998), Real time atm for remote access to home automation and digital home A/V networks. Ieee Transactions on Consumer Electronics 44(3), pp.482-489.
A16	de Lucena, V.F., Jr., J.E. Chaves Filho, N.S. Viana et al. (2009), A Home Automation Proposal Built on the Ginga Digital TV Middleware and the OSGi Framework. Ieee Transactions on Consumer Electronics 55(3), pp.1254-1262.
A17	EDDEN, F. (1990), Modeling Cebus Home Automation with Knowledge Based Tools. Ieee Transactions on Consumer Electronics 36(3), pp.623-627.
A18	EVANS, G. (1991), Solving Home Automation Problems using Artificial-Intelligence Techniques. Ieee Transactions on Consumer Electronics 37(3), pp.395-400.
A19	Giannakopoulos, T., N. Tatlas, T. Ganchev et al. (2005), Practical, real-time speech-driven home automation front-end. Ieee Transactions on Consumer Electronics 51(2), pp.514-523.
A20	Gill, K., S. Yang, F. Yao et al. (2009), A ZigBee-Based Home Automation System. Ieee Transactions on Consumer Electronics 55(2), pp.422-430.
A21	GREICHEN, J. (1992), Value Based Home Automation for Todays Market. Ieee Transactions on Consumer Electronics 38(3), pp.R34-R38.
A22	HAMABE, R., S. HATANO, K. TATEMATSU et al. (1988), Conformance Test Concept for the Home Bus System. Ieee Transactions on Consumer Electronics 34(3), pp.700-704.
A23	Hamabe, R., T. Kawamura & M. Murata. (2000), Remote Conformance Test System for Home Bus System (HBS). Ieee Transactions on Consumer Electronics 46(1), pp.215-220.
A24	HAMABE, R., M. MURATA & T. NAMEKAWA. (1986), Home Bus System (Hbs) Interface Lsi and its Standard Protocol Example. Ieee Transactions on Consumer Electronics 32(1), pp.9-19.
A25	HAMABE, R., M. MURATA & T. NAMEKAWA. (1986), A Revised New Proposal for Standardization of Home Bus System for Home Automation. Ieee Transactions on Consumer Electronics 32(1), pp.1-8.
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A27	HAMABE, R., M. MURATA & T. NAMEKAWA. (1987), System-Design of Home Bus System for a Single House. Ieee Transactions on Consumer Electronics 33(4), pp.580-586.
A28	HAMABE, R., M. MURATA & T. NAMEKAWA. (1988), A Protocol Example on Super Home Bus System (S-Hbs). Ieee Transactions on Consumer Electronics 34(3), pp.686-693.

A29	HAMABE, R., M. MURATA & T. NAMEKAWA. (1988), System-Design of Super Home Bus System (S-Hbs) for Apartment Building. Ieee Transactions on Consumer Electronics 34(2), pp.327-333.
A30	HAMABE, R., T. NAMEKAWA, Y. WATANABE et al. (1989), A Conformance Test Method for Home Bus System (Hbs). Ieee Transactions on Consumer Electronics 35(3), pp.564-570.
A31	Han, D. & J. Lim. (2010), Design and Implementation of Smart Home Energy Management Systems based on ZigBee. Ieee Transactions on Consumer Electronics 56(3), pp.1417-1425.
A32	Han, D. & J. Lim. (2010), Smart Home Energy Management System using IEEE 802.15.4 and ZigBee. Ieee Transactions on Consumer Electronics 56(3), pp.1403-1410.
A33	Han, I., H. Park, Y. Jeong et al. (2006), An intergrated home server for communication, broadcast reception, and home automation. Ieee Transactions on Consumer Electronics 52(1), pp.104-109.
A34	Han, J., J. Yun, J. Jang et al. (2010), User-Friendly Home Automation Based on 3D Virtual World. Ieee Transactions on Consumer Electronics 56(3), pp.1843-1847.
A35	Han, K., T. Shon & K. Kim. (2010), Efficient Mobile Sensor Authentication In Smart Home and WPAN. Ieee Transactions on Consumer Electronics 56(2), pp.591-596.
A36	HIROSE, H., Y. MATSUMURA, K. SHIMADA et al. (1989), Local-Control Bus System for Consumer Vcrs. Ieee Transactions on Consumer Electronics 35(3), pp.589-596.
A37	HONDA, Y., M. INOUE, R. IWATSUBO et al. (1990), Protocol Analyzer for Home Bus System (Hbs). Ieee Transactions on Consumer Electronics 36(3), pp.586-592.
A38	Hong, S., B. Kim & D. Eom. (2007), A base-station centric data gathering routing protocol in sensor networks useful in home automation applications. Ieee Transactions on Consumer Electronics 53(3), pp.945-951.
A39	Hwang, K., B. Choi & S. Kang. (2010), Enhanced Self-Configuration Scheme for a Robust ZigBee-based Home Automation. Ieee Transactions on Consumer Electronics 56(2), pp.583-590.
A40	Hwang, Z., Y. Uhm, Y. Kim et al. (2010), Development of LED Smart Switch with Light-weight Middleware for Location-aware Services in Smart Home. Ieee Transactions on Consumer Electronics 56(3), pp.1395-1402.
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A43	KHAWAND, J., C. DOULIGERIS & C. KHAWAND. (1992), A Physical Layer Implementation for a Twisted Pair Home Automation System. Ieee Transactions on Consumer Electronics 38(3), pp.530-536.
A44	Kim, H.S., J. Song & S. Lee. (2007), Energy-efficient traffic scheduling in IEEE 802.15.4 for home automation networks. Ieee Transactions on Consumer Electronics 53(2), pp.369-374.
A45	Kim, T., H. Lee & Y. Chung. (2010), Advanced Universal Remote Controller for Home Automation and Security. Ieee Transactions on Consumer Electronics 56(4), pp.2537-2542.

A46	Lee, D. & K. Chung. (2010), Adaptive Duty-cycle Based Congestion Control for Home Automation Networks. Ieee Transactions on Consumer Electronics 56(1), pp.42-47.
A47	Lee, K. & H. Lee. (2004), Network-based fire-detection system via controller area network for smart home automation. Ieee Transactions on Consumer Electronics 50(4), pp.1093-1100.
A48	Lee, S., K.N. Ha & K.C. Lee. (2006), A pyroelectric infrared sensor-based indoor location-aware system for the smart home. Ieee Transactions on Consumer Electronics 52(4), pp.1311-1317.
A49	Leong, C.Y., A.R. Ramli & T. Perumal. (2009), A Rule-Based Framework for Heterogeneous Subsystems Management in Smart Home Environment. Ieee Transactions on Consumer Electronics 55(3), pp.1208-1213.
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A57	SAKON, T., M. IKEZAKI & T. YAMAMOTO. (1989), Telematique Home-Bus System Equipped with Multi-Service Switcher Function. Ieee Transactions on Consumer Electronics 35(3), pp.597-604.
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A69	Wu, J., L. Huang, D. Wang et al. (2008), R-OSGi-based architecture of distributed smart home system. Ieee Transactions on Consumer Electronics 54(3), pp.1166-1172.
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A76	Yuksekkaya, B., A.A. Kayalar, M.B. Tosun et al. (2006), A GSM, Internet and speech controlled wireless interactive home automation system. Ieee Transactions on Consumer Electronics 52(3), pp.837-843.
A77	Zhang, L., H. Leung & K.C.C. Chan. (2008), Information fusion based smart home control system and its application. Ieee Transactions on Consumer Electronics 54(3), pp.1157-1165.
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Table 7: Numbering EU Framework Programs

#	YEAR	EU reference
B1	1991	5140
B2	1991	5448
B3	**1992**	**101**
B4	1992	6782
B5	1994	1102
B6	1996	21314
B7	1996	21667
B8	1996	21499
B9	1996	BMH4960943
B10	1997	JOE3971017
B11	1997	22937
B12	1997	24315
B13	1999	DE3209
B14	1999	29708
B15	2000	IST-1999-20138
16	2000	IST-1999-12295
B17	2001	IST-2000-30023
B18	2001	IST-2001-32080
B19	2001	IST-2000-26086
B20	2002	IST-2001-33507
B21	2002	IST-2001-37613
B22	2002	IST-2001-32746
B23	2004	4217
B24	2004	511298
B25	2004	
B26	2004	507667
B27	2005	14815

B28	2006	45301
B29	2006	45089
B30	2006	34624
B31	2006	30313
B32	2006	34707
B33	2007	45215
B34	2007	45622
B35	2007	45515
B36	2007	45563
B37	2007	45282
B38	2007	45088
B39	2007	45148
B40	2007	45056
B41	2007	45459
B42	2007	45212

B43	2007	45508
B44	2007	45061
B45	2007	26920
B46	2007	45061
B47	2008	217050
B48	2008	224309
B49	2008	222165
B50	2008	224342
B51	2008	223984
B52	2008	215754
B53	2008	216487
B54	2009	238710
B55	2009	249322
B56	2010	247950
B57	2010	257245
B58	2010	248730

B59	2010	247730
B60	2010	247765
B61	2010	247620
B62	**2011**	**288705**
B63	2011	288146
B64	2011	269914
B65	2011	287708
B66	2012	312092
B67	2012	288121
B68	2012	317674

Table 8: Numbering Personal and Ubiquitous Computing journal

#	Personal and ubiquitous computing
C1	Athitsos, V., H. Wang & A. Stefan. (2010), A database-based framework for gesture recognition. Personal and Ubiquitous Computing 14(6)
C2	Bamis, A., D. Lymberopoulos, T. Teixeira et al. (2010), The BehaviorScope framework for enabling ambient assisted living. Personal and Ubiquitous Computing 14(6)
C3	Conejero, J.M., P.J. Clemente, R. Rodriguez-Echeverria et al. (2011), A model-driven approach for reusing tests in smart home systems. Personal and Ubiquitous Computing 15(4)
C4	Dowad, T. (2006), PAWS: Personal Action Wireless Sensor. Personal and Ubiquitous Computing 10(2-3)
C5	Ha, T.S., J.H. Jung & S.Y. Oh. (2006), Method to analyze user behavior in home environment. Personal and Ubiquitous Computing 10(2-3)
C6	Haines, V., V. Mitchell, C. Cooper et al. (2007), Probing user values in the home environment within a technology driven Smart Home project. Personal and Ubiquitous Computing 11(5)
C7	Hayes, G.R., D.J. Patterson, M. Singh et al. (2011), Supporting the transition from hospital to home for premature infants using integrated mobile computing and sensor support. Personal and Ubiquitous Computing 15(8)
C8	Hynes, M., H. Wang, E. McCarrick et al. (2011), Accurate monitoring of human physical activity levels for medical diagnosis and monitoring using off-the-shelf cellular handsets. Personal and Ubiquitous Computing 15(7)
C9	Jara, A.J., M.A. Zamora & A.F.G. Skarmeta. (2011), An internet of things-based personal device for diabetes therapy management in ambient assisted living (AAL). Personal and

	Ubiquitous Computing 15(4)
C10	Kirchhof, M. & S. Linz. (2005), Component-based development of Web-enabled eHome services. Personal and Ubiquitous Computing 9(5)
C11	Koskela, T. & K. Vaananen-Vainio-Mattila. (2004), Evolution towards smart home environments: empirical evaluation of three user interfaces. Personal and Ubiquitous Computing 8(3-4)
C12	Koufi, V., F. Malamateniou & G. Vassilacopoulos. (2010), A system for the provision of medical diagnostic and treatment advice in home care environment. Personal and Ubiquitous Computing 14(6)
C13	Lezoray, J., M. Segarra, An Phung-Khac et al. (2011), A design process enabling adaptation in pervasive heterogeneous contexts. Personal and Ubiquitous Computing 15(4)
C14	Mavrommati, I., A. Kameas & P. Markopoulos. (2004), An editing tool that manages device associations in an in-home environment. Personal and Ubiquitous Computing 8(3-4)
C15	Munoz, A., J. Carlos Augusto, A. Villa et al. (2011), Design and evaluation of an ambient assisted living system based on an argumentative multi-agent system. Personal and Ubiquitous Computing 15(4)
C16	Nakajima, T. & I. Satoh. (2006), A software infrastructure for supporting spontaneous and personalized interaction in home computing environments. Personal and Ubiquitous Computing 10(6)
C17	Pan, G., J. Wu, D. Zhang et al. (2010), GeeAir: a universal multimodal remote control device for home appliances. Personal and Ubiquitous Computing 14(8)
C18	Park, S.H., S.H. Won, J.B. Lee et al. (2003), Smart home - digitally engineered domestic life. Personal and Ubiquitous Computing 7(3-4)
C19	Rich, C., C. Sidner, N. Lesh et al. (2006), DiamondHelp: a new interaction design for networked home appliances. Personal and Ubiquitous Computing 10(2-3)
C20	Rode, J.A. (2006), Appliances for whom? Considering place. Personal and Ubiquitous Computing 10(2-3)
C21	Sanguinetti, A., H. Haga, A. Funakoshi et al. (2003), FReCon: a fluid remote controller for a FReely connected world in a ubiquitous environment. Personal and Ubiquitous Computing 7(3-4)
C22	Spinellis, D.D. (2003), The information furnace: consolidated home control. Personal and Ubiquitous Computing 7(1)
C23	Taylor, A.S., R. Harper, L. Swan et al. (2007), Homes that make us smart. Personal and Ubiquitous Computing 11(5)
C24	Terrenghi, L., O. Hilliges & A. Butz. (2007), Kitchen stories: sharing recipes with the Living Cookbook. Personal and Ubiquitous Computing 11(5)
C25	van Kasteren, T.L.M., G. Englebienne & B.J.A. Krose. (2010), An activity monitoring system for elderly care using generative and discriminative models. Personal and Ubiquitous Computing 14(6)
C26	Vassis, D., P. Belsis, C. Skourlas et al. (2010), Providing advanced remote medical treatment services through pervasive environments. Personal and Ubiquitous Computing 14(6)
C27	Vergados, D.D. (2010), Service personalization for assistive living in a mobile ambient healthcare-networked environment. Personal and Ubiquitous Computing 14(6)

10. Appendix III

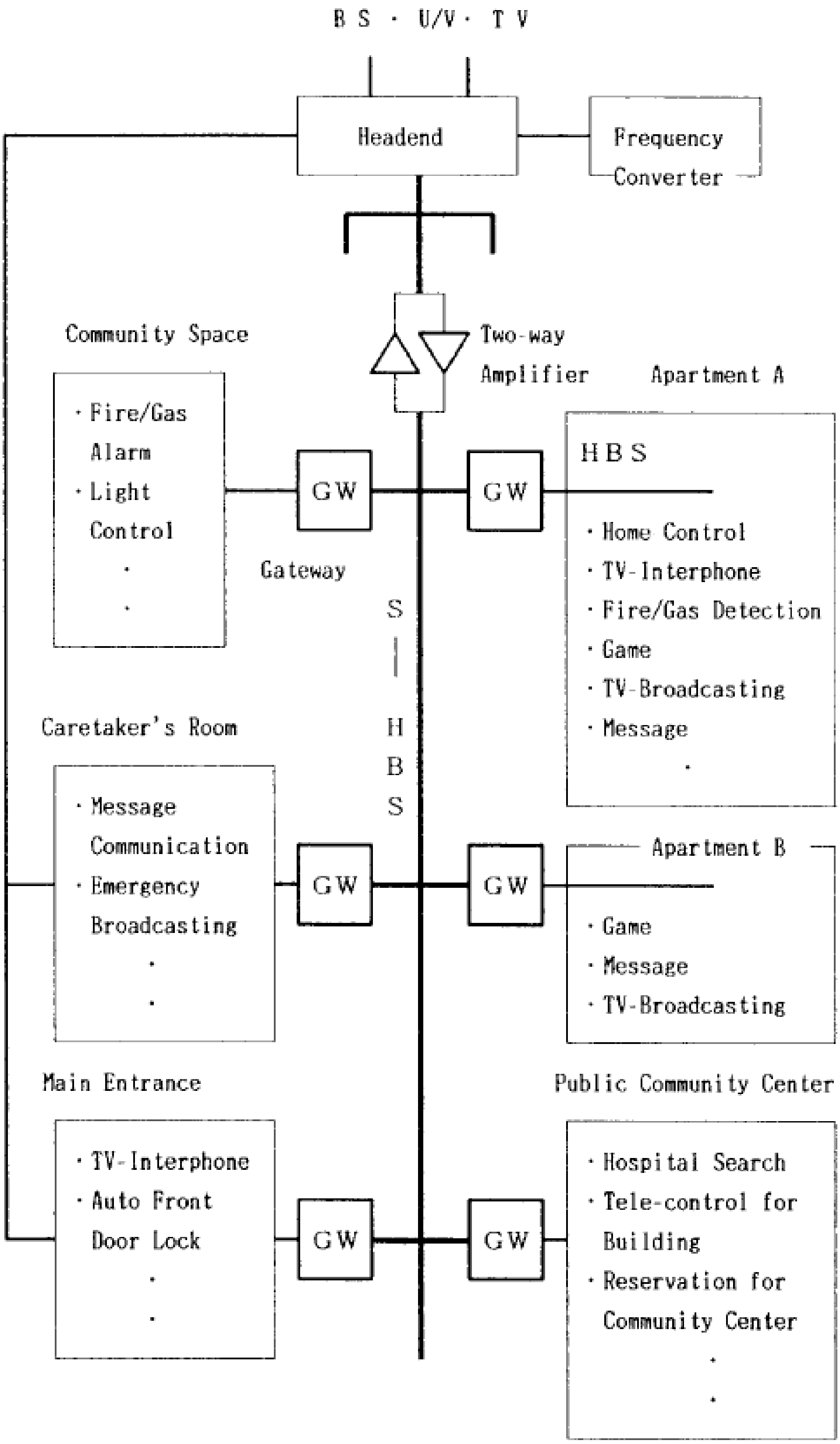

Figure 11: System design of a Home Automation System by (HAMABE et al., 1988)