GEERTEN VAN DE KAA

Standards Battles for Complex Systems

Empirical Research on the Home Network

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Standaardisatie gevechten voor complexe systemen
Empirisch onderzoek naar het in-huis netwerk

Proefschrift

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voor Aafke
Julian en Thijmen

PREFACE

The first time that I heard about the idea of industries converging with each other resulting in new technologies was during my Master's degree. I was immediately drawn to the subject and to home networks in particular. Imagine a refrigerator that can scan its contents and order products by itself. Or a television with which you can communicate with your doctor without leaving your home. At that time, now almost 10 years ago, such technological developments were technically possible but had not yet been realized. If these innovations are possible, why are they not available?

In 2004, I began my PhD research on the standardization of broadband home networks. At times my research has been somewhat stressful, conducted as it was while at the same time finishing deliverables for an external project (the B@Home project), teaching students how to conduct research, endless evenings and nights spent collecting data, and so on. But in the end I can say that I look back on the last five years with satisfaction.

I could never have accomplished this without the help of many people. First of all, I would like to thank Jan van den Ende who taught me how to conduct good research and inspired me to get the most out of my work - I can never thank him enough. Henk de Vries taught me a lot about standardization and through him I came in contact with several key people from the standardization community. Eric van Heck, although working in another department at the RSM and ERIM made frequent and valuable contributions to my work.

I would like to thank my former colleagues at the Department of Management of Technology and Innovation (RSM), many of whom have become friends over the years. Special thanks go out to my former roommate Ferdinand Jaspers for the sharing of experience concerning fatherhood and the many fruitful discussions about each others work.

Special thanks to the members of the B@Home project and of the Freeband program. I would like to thank Frank den Hartog who taught me a lot about the technical aspects of home networking standards. Special thanks go to the vice president of standardization at Philips, Mr. Eddy Odijk, who helped me to understand the many complexities that exist for companies active in home networking. I would like to thank the people at the Standardization and Innovation in Information Technology conference in 2007 for participating in the Analytic Hierarchy Process interviews (which consisted of 293 questions in total). I would like to thank the many graduate students who I supervised during the years, some of whom helped me in carrying out my research: I am very grateful to them.

I want to thank Cees van Beers for providing me with the opportunity to finish my dissertation at Delft University of Technology, and my other colleagues at the Department of Innovation Systems.

My father is my role model. I am grateful to have learned so much from him. He worked very hard during his career and he even pursued a PhD degree - this makes me very proud. My mother has always been there for me and I could always talk to her about everything. I thank my brothers and my sister in law for their support during the years. And of course, I want to thank my grandmother. Furthermore, I would like to thank my father in law, Ad Voois, who encouraged me to think outside the box. My mother in law, Nanny Voois, has been a continuing source of support over the years.

Finally, I would like to dedicate this book to Aafke and our two sons, Julian and Thijmen, who bring me great joy.

Geerten van de Kaa

Delft, April 2009

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1 INTRODUCTION

1.1 Research problem

The situation where different types of technology in a home environment can communicate with each other and form one home network is becoming a viable one. Such a network would result in tremendous advantages in every day life. It would become much easier to operate the subsystems in the home. Subsystems can include appliances, telecommunication devices, sensors, actuators, switches, controllers, and user interfaces to create novel applications and provide an infrastructure for multimedia distribution (2002). Because subsystems can communicate with other subsystems inside and outside the home, the range of their possibilities increases. When a PC can be connected to a TV, for example, the functionality of the TV is enhanced. One can imagine many forms of information distribution in homes, such as error logs or instruction codes for household appliances and domestic systems being communicated between manufacturer and consumer. Experimental houses are already in operation such as the the Living Tomorrow Home in Brussels (2009) and the Aware Home at the Georgia Institute of Technology (2009).

Irrespective of the fact that the home network sketched has been technically possible for many years and that there seems to be a demand for it (Wacks, 2002), such networks have not become a practical reality. A major reason is the lack of generally accepted common standards for the interconnection between subsystems (Rose, 2001; Wacks, 2001; Wacks, 2002). Such standards are a prerequisite in order for different subsystems to be able to communicate with each other. Most of the different subsystems which are part of a home network have already been developed and these subsystems have their own standards. Several of these existing standards might also be used for the interconnection between subsystems in the home network (Rose, 2001). Another possibility is to develop new standards for this purpose. The problem is not that there are not enough standards, on the contrary, there are many (Van de Kaa, Den Hartog and De Vries, 2007) and the question is which of these standards will reach dominance.

In May 2004, multiple companies, research institutes, and universities in the Netherlands came together and formed the Freeband program, which aims to contribute, on the national and European level, to policies directed at developing broadband. The B@Home project, one of the projects in the program, focuses on the home network in particular. In carrying out this PhD study, we have made a contribution here.

1.1.1 Standards battles

In the situation above, multiple standards are competing for dominance. These so called standards battles are not new. In the mid 19th century, two different standards for the width of railroad tracks existed side by side in the USA. The 4'8.5'' standard was used in the eastern part of the USA and the 5' standard was used in the southern part. Meanwhile, new railroad tracks laid in the western States used the Eastern standard railroad gauge. Ultimately, this led to the dominance of the 4'8.5'' standard over the 5' standard. As a result, the southern railroad companies had to convert all their existing railroad tracks to the 4'8.5'' standard at great expense (Shapiro and Varian, 1999).

The classical battle between VHS (supported by JVC), Betamax (supported by Sony) and V2000 (supported by Philips and others) in the 1970s and 1980s is well documented (Bartlett and Ghosal, 1988; Cottrell and Sick, 2001; Cusumano, Mylonadis and Rosenbloom, 1992; Dai, 1996; Economides, 1996b; Grindley, 1995; Johne, 1994; Klopfenstein, 1989; Ohashi, 2002; Puffert, 1999; Roome, 2006). At that time, Betamax was widely considered to be superior to VHS. Nevertheless, the latter eventually won the standards battle. One of the reasons behind the triumph of VHS over Betamax was that JVC followed a strategy aimed at forming a large network of manufacturers of VCR systems that licensed the VHS standard. Thus, JVC had access to a larger range of manufacturers of complementary goods than Sony (Cusumano, Mylonadis and Rosenbloom, 1992) and the manufacturers also offered a more diverse range of VHS devices (Ehrhardt, 2004).

In the early 1990s, a number of video gaming consoles fought a battle in what is known as the fifth generation video console standards battle. When all gaming consoles were available in the market, both Playstation and Nintendo 64 had roughly the same market share. The early success of the Nintendo 64 console can partly be attributed to its pricing strategy and the availability of complementary goods; the console was priced low and bundled with the popular game Super Mario 64 (Gallagher and Park, 2002). Playstation eventually won the war because it also targeted young males instead of only early teens.

On 19 February 2002, Sony, together with nine other major companies, established the basic specifications for the Blu-ray disc standard (Sony Corporation, 2002). Five months later, on 1 August 2002, Toshiba and NEC proposed the HD DVD standard to the DVD forum (Toshiba Corporation, 2002). Both standards provide specifications for storing high definition video content on optical discs. On 10 April 2003, the first Blu-ray disc recorder was introduced (PC World, 2003). On 7 January 2004, the first HD DVD disc recorder that was fully compatible with the DVD standard was introduced (Toshiba Corporation, 2004). In September 2004, Sony chose to integrate the Blu-ray disc player with the Playstation 3 (Sony Computer

Entertainment Incorporated, 2004), which greatly increased the amount of Blu-ray disc players that were sold. In November 2004, most movie studios announced support for the HD DVD standard. By 2005, it was clear that a standards battle was inevitable and both Sony and Toshiba tried to collaborate with the goal of establishing a common standard – ultimately, unsuccessfully. In September 2005, both Microsoft and Intel joined forces with the DVD forum and gave their support to the HD DVD standard (Toshiba Corporation, 2005). At the beginning of 2006, Microsoft announced that its Xbox 360 gaming console would come with an add-on HD DVD drive (Microsoft Corporation, 2006). On 20 August 2007, both Paramount and Dreamworks announced their exclusive support for HD DVD, instead of Blu-ray (Viacom Incorporated, 2007). At that time, most people thought HD DVD would win the standards battle. However, the Blu-ray disc association paid 500 million to Warner so that they would switch to Blu-ray (Pruitt, 2008). This was the turning point in the battle. Until this event, the battle was at a stalemate but soon after, many companies followed Warner and switched from HD-DVD to Blu-ray. On 19 February 2008, Toshiba formally announced that it would not continue with its HD DVD standard (Computerworld, 2008). So, one of the reasons behind the success of the Blu-ray standard is that the Blu-ray disc association used its financial resources to attract an important manufacturer of complementary goods (Warner) to its network.

In the literature, dominant designs and standards are often used interchangeably (Anderson and Tushman, 1990; Besen and Farrell, 1994; Schilling, 1999), where a dominant design is seen as the design that is recognized as the industry standard. However, there are some important differences between the two concepts. 'Design' may refer to 'a product's design specifications that define the product category's architecture' (Christensen, Suarez and Utterback, 1998), 'technical features' (Utterback, 1994), 'core design concepts' (Henderson and Clark, 1990), 'trajectory' (Suarez, 2004), or 'a way of doing things which is manifested in a product' (Lee, O'Neal, Pruett and Thoams, 1995). Thus, designs include entire products (Suarez and Utterback, 1995) as well as (sets of) features of products or requirements for products or services (Lee, O'Neal, Pruett and Thoams, 1995). 'Standards' refer to specific elements of a design (Gallagher, 2007), in our case interfaces between different components within a design. Thus, since designs and standards can have the same characteristics, in this study we will take into account literature that focuses on dominant designs. In the literature, a distinction is made between compatibility and interface standards, minimum quality and safety standards, variety reducing standards, and information and measurement standards (Blind, 2004). We will concentrate on compatibility standards since these are crucial for the connection of subsystems in a larger system (De Vries, 1998). We define a compatibility standard as a 'codified specification defining the

interrelations between entities in order to enable them to function together' (based on De Vries, 1999; Garud and Kumaraswamy, 1993).

For firms in standards battles, the stakes are high (Shapiro and Varian, 1999) and can even result in firms leaving the market. For firms, the choice of standard is accompanied by a high amount of uncertainty, which has only increased since the amount of time that it takes to fight a standards battle has decreased rapidly over time. Where the battle for one railroad track width standard lasted for many decades, as we saw, the battle for a high definition video disc standard lasted for only a couple of years. There is a need to better understand the factors that influence standard dominance. By doing so, the level of uncertainty may decrease.

Scholars have paid attention to historical battles as the ones mentioned above and have identified factors that can be decisive in winning or losing such battles. Sometimes authors tend to disagree about which factors determine the outcome of a particular standards battle. In the video case for instance, although many of the factors that influenced the outcome of the battle are known, and have been studied retrospectively, scholars still tend to disagree about which factors were crucial (Klopfenstein, 1989; Ohashi, 2002; Rosenbloom and Cusumano, 1987). Clearly, a complete framework for standard dominance is needed. In this study, we will develop such a framework (see Chapter 2) and we will explore its completeness and relevance (see Chapter 4).

1.1.2 Networks of Actors

It can also be concluded that the number of different stakeholders that are involved in standards battles increases as systems become more complex. In the battle for a standard railroad track width, stakeholders included a big buyer (the Union) and two standard supporters (the railroad companies). In the battle for a high definition optical video disc standard, stakeholders included multiple standard supporters and suppliers of complementary goods from a diverse range of product markets (such as information technology, consumer electronics, movie studios, video console manufacturers and video game manufacturers). To decrease uncertainty, these stakeholders tend to organize themselves in networks of actors. Especially in the HD DVD vs Blu-ray battle, the importance of networks of actors becomes apparent. Because of the increasing importance of networks of actors in standards battles, we will pay special attention to this factor in this study.

1.1.3 Complex systems

There exists a trend of technological convergence which leads to the convergence of different product markets (see Appendix 9.7 for an illustration). As a result, complex systems emerge. We define a complex

system as one in which there are multiple interactions between many different components (Rind, 1999) that can be systems in their own right (Simon, 1962; Soh and Roberts, 2003) and that originate from multiple converging product markets (Baker, Green, Einhorn and Moon, 2004; Duysters and Hagedoorn, 1998). Examples of complex systems are home networks, building automation systems, the e-ticket system, and the inland transportation system for maritime containers in the Netherlands. We focus on the home network, which is a typical example of a complex system, consisting of components and technologies that originate from multiple converging product markets, such as consumer electronics, information technology, and telecommunications (Baker, Green, Einhorn and Moon, 2004). This brings us to our research objective and questions.

1.2 Research questions

The main objective of this research is to develop a framework for the selection of standards for systems that consist of established subsystems and to assess which factors are important. This poses the central question: *what are the most important factors which determine the outcome of battles of standards for complex systems that consist of established subsystems?* This research question will be addressed for home networks in particular. The specific research questions underlying the central question are:

1. Which factors affect the selection process of standards in systems that do not consist of established subsystems?
2. What are the specifics of systems consisting of established subsystems with respect to the standard selection process?
3. What are the implications for the factors affecting the dominance of standards for systems that consist of established subsystems?
4. Does the selection process of standards differ when both established and new standards have to be taken into account instead of only new standards?
5. What is the influence of the characteristics of the network of the standard[1] and the flexibility of the standard on the outcome of the standards battle?

[1] The network of the standard can be defined as the set of actors that are involved in a standards organization which serves the objective of developing, maintaining, and/or promoting that standard. See also Chapter 6 for a more detailed explanation of the network of a standard.

6. Which methods are appropriate to determine the most important factors which influence the outcome of standards battles for complex systems that consist of established subsystems?

To understand which factors are most important, we will have to take into account each factor that can affect the outcome of a standards battle. Therefore, we begin this study with an extensive literature review to arrive at a complete framework of factors that affect the outcome of standards battles (question 1). Before we can answer our central research question, we will have to understand the specifics of systems consisting of established subsystems with respect to the standard selection process (question 2). We apply the framework to different case studies of standards battles to explore the completeness and relevance of the framework and to explore to what extent the framework can be used to explain and predict the outcome of standards battles for complex systems (question 3). In complex systems that consist of established subsystems, a choice has to be made between both established and new standards; whereas in systems that do not consist of established subsystems, a choice has only to be made from new standards. A question which will be raised in this study is whether this aspect changes the selection process of standards (question 4).

The analysis in which we explore whether we can predict the outcome of standards battles provides us with a first indication of the comparative strengths of the factors in the case of home networking, thus answering our central research question. It appears that the characteristics of the network of a standard (and especially the diversity in the network) in one of the important factors. This factor has not been studied that often in the literature. Another factor that has not been studied that often in the literature is the flexibility of the standard. In the remainder of our research, we closely examine these two factors (question 5).

To answer our central research question, we will use multiple methodologies. By applying these methods, we can assess whether they can be used to determine important factors which influence the outcome of standards battles for complex systems (question 6).

1.3 Theoretical positioning

According to evolutionary economists, the survival of a firm is the result of a process of natural selection (Arthur, 1989). Technology evolves through periods of incremental change until at some point in time a major breakthrough is introduced in the industry. These so called technological discontinuities increase uncertainty in the industry, usually resulting in a new technological paradigm (Tushman and Anderson, 1986). Within a new paradigm different technological paths can be developed resulting in designs that compete with

each other for dominance (Utterback and Abernathy, 1975). We focus on the period beginning with the technological discontinuity until one design has become dominant.

Hesser, Feilzer, and de Vries (2007) dinstinguish between three stages in the standardization process: standard development, standard selection, and standard implementation[2]. We focus on the second stage; standard selection. A distinction can be made between committee-based and market-based standardization (Farrell and Saloner, 1988). The outcome of market-based standardization can be a de-facto standard which is a standard that has been agreed upon in the market (Blind and Thumm, 2004). In this study we will focus on these standards. We do not restrict ourselves to standards that have been developed by consortia since standards that have been developed by for instance standards development organizations can also compete in the market. Even standards that are mandated by governments are taken into account although when a standard is enforced the outcome of the battle is no longer a market outcome. Several studies have paid attention to the adoption of standards by individual organizations (Gerst and Raluca, 2005; Roy and Craparo, 2001; Weitzel, Wendt, Westarp and Konig, 2003), and to the role of standards organizations on these adoption decisions (De Vries, 1998). Several authors have examined standards battles (De Vries, De Vries and Oshri, 2008; De Vries and Hendrikse, 2001; Gallagher and Park, 2002; Garud, Jain and Kumaraswamy, 2002), while other authors focus on the economic impact of standards (Blind, 2004; Swann, 2000). Some authors in this field also study the topic of standard selection from a game theory perspective (Belleflamme, 1999; Farrell and Saloner, 1988; Park, 2005).

There is a vast body of literature that approaches the topic of standard selection by making use of concepts from industrial economics and network economics in particular (David and Greenstein, 1990; Farrell and Saloner, 1985; Katz and Shapiro, 1985; Katz and Shapiro, 1994). These scholars argue that some technology becomes more valuable when more persons use the technology. Most markets in which network externalities exist are 'two sided' in that they consist of complementary goods for which the standard defines communication (Gallaugher and Wang, 2002). Examples include the markets for VCRs (Cusumano, Mylonadis and Rosenbloom, 1992) and video game consoles (Gallagher and Park, 2002; Schilling, 2003). When more complementary goods are available for the standard this has a positive effect on the installed base of that standard (Schilling, 2002).

[2] Although there are more stage models of standardization (Cargill, 1997; International Electrotechnical Commision, 2009) these emphasize the stage of standards development and pay little attention to standards selection.

Other scholars analyze the topic using institutional theories and focus on how individual firms can increase the possibility that their technology will become dominant (Cusumano, Mylonadis and Rosenbloom, 1992). A firm can try to strategically position its technology so that it will become dominant. Willard and Cooper (1985) examined the influence of several strategic variables on survival in the TV industry and found that strategic factors influence market dominance provided these are matched with the firm's resources and are effectively implemented. The firm's resources include its financial strength, for instance.

Scholars in the field of technology management have developed several frameworks of standard dominance, integrating concepts from both industrial and institutional economics (Lee, O'Neal, Pruett and Thoams, 1995; Schilling, 1998; Suarez, 2004). Some authors have performed literature reviews of the different factors that contribute to standard selection (Shapiro and Varian, 1999b; Suarez, 2004). However, these focus on particular technological paradigms (Dosi, 1982) in which only specific factors apply. The framework developed by Suarez (2004), for instance, applies mainly to the information and communication industry. In this industry, network externalities exist and factors such as the installed base of users and the availability of complementary goods become extremely important. In industries that are not characterized by network externalities, other factors may be more important, which results in an overlap of factors. What most studies do have in common is that a distinction is made between factors that can be influenced by the firm and factors that cannot be influenced by the firm. Lee (1995) refers to these latter as 'external conditions'. They characterize the market in which the battle is fought. In this study, we will distinguish between firm level and environmental factors (Suarez, 2004). The characteristics of the market affect each standard similarly and thus do not directly influence the outcome of the battle; they affect the magnitude of the effect of the firm level factors on standard dominance. For example, in an industry characterized by network externalities, an actor developing a technology for which complementary goods do not exist will have a low chance of achieving dominance with that technology (Schilling, 1998). Apart from other aspects, these scholars emphasize the characteristics of the standard such as its compatibility and other technical characteristics.

Although not explicitly mentioned in any particular literature stream, several studies in different areas (including standardization, technology management, and institutional economics) mention the influence of other stakeholders in the standards battle. Often, stakeholders other than the group of standard supporters have an influence on which standard will become dominant.

Firms can establish cooperation with these stakeholders. Through cooperation, actors can decrease the uncertainty that exists for each of the firms (Gulati and Gariulo, 1999). The influence of cooperation in the

establishment of a dominant standard has been illustrated in multiple examples of standards battles. One form of cooperation is a licensing agreement which can help build an installed base quickly and can increase the acceptance of a firm's standard. This was the primary reason behind the success of Matsushita in the video standards battle (Cusumano, Mylonadis and Rosenbloom, 1992) and Microsoft in the operating systems battle (Wonglimpiyarat, 2005). Licensing agreements have also played a role in the workstations industry (Garud and Kumaraswamy, 1993) and the video game industry (Gallagher and Park, 2002). When firms license their technology to other firms they can increase the availability of complementary goods and thus consolidate their market position (Bekkers, Duysters and Verspagen, 2002). Another form of cooperation is the inter-organizational relationship, which can include vertical relations between buyers and suppliers, horizontal relations between competitors, and diagonal relations between firms operating in different product markets (Nooteboom, 1998). For digital recording technology, two competing standards existed, DCC (Philips) and Minidisc (Sony). Since consumers have continued to wait for one of the standards to become dominant, neither standard has become dominant. In another case, Philips and Sony worked together and developed one standard which achieved dominance; the compact disc (Hill, 1997). A special kind of inter-organizational relationship is that between a firm and a manufacturer of complementary goods (Cusumano, Mylonadis and Rosenbloom, 1992; Khazam and Mowery, 1994; Willard and Cooper, 1985). An advantage of inter-firm relationships is that firms can invest in learning from the actors to which they are connected (Schmidt and Werle, 1998). For complex systems, the advantage of cooperation is that firms can gain access to new product markets (Hagedoorn, 1993). They can gain access to complementary resources from these firms and learn from them. A disadvantage of joining a network is that the firm's influence on the standardization process will decrease.

In social network literature, it is argued that the performance of actors depends on the network in which they participate (Burt, 1992; Burt, 1997; Coleman, 1988; Granovetter, 1973). According to this literature, different aspects of networks influence the performance of actors within the networks. One of the aspects concerns the density of the network, which refers to the number of actual links as a percentage of the number of possible links within the network (Coleman, 1988). Dense networks create benefits in the form of an increased capacity for coordination(Reagans and Zuckerman, 2001), improved communication (Baker, 1984), and trust among members of the group (Coleman, 1988). A related concept, the cohesiveness of a network, relates to the degree to which actors are connected directly to each other by cohesive bonds (Gargiulo and Benassi, 2000). In dense networks, relations between actors can be strong. The strength of a relationship is determined by many constructs such as the emotional closeness and the frequency and duration of the relationship (Marsden and

Campbell, 1984). Relations between different groups of actors tend to be weak. However, Granovetter (1973; 1983) emphasizes the productivity of these weak relations by showing that through these relations more novel information is communicated. Recently, social network literature has been applied to standard selection (Suarez, 2005; Weitzel, Beimborn and Konig, 2006). We apply it to standard selection in complex systems. Groups of actors that support standards that define communication in a single product market can consist of actors that all represent the same product market. These networks tend to be dense and relations between actors are often strong. Groups of actors that support standards that define communication between different product markets could consist of actors that are active in the different product markets for which the standard defines communication. If we apply Granovetter's theory on the strength of weak ties (1973) to this situation these weak relations between firms that represent different product markets are productivein the sense that two groups of actors are connected that were otherwise unconnected. Through these relations, a lot of novel information is communicated between the two groups that would otherwise not be exchanged.

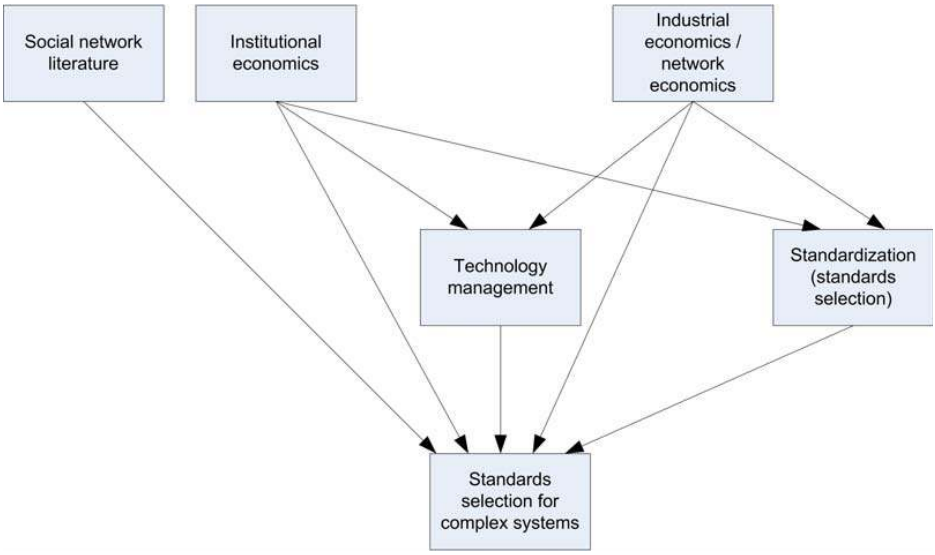

Figure 1-1: Inheritance of theoretical streams of literature forming a perspective towards standard selection for complex systems

In Figure 1-1, we present a graphical overview of the different streams of literature that are used in this research to form a theoretical perspective towards standard selection for complex systems. In the figure, it is illustrated from which theoretical stream the literature draws. So, technology management makes use of concepts from institutional, industrial and network economics. Our focus lies in both the integration of the

different literature streams and in the application of social network literature to standard selection in complex systems. In Table 1-1, we summarize the different literature streams discussed above and we identify the aspects upon which the different streams focus. The order of the streams of literature in the table is no indication of their importance. The theoretical contribution of this research lies in the integration of these different research streams and in the application of social network theory to standard selection for complex systems.

Table 1-1: Theoretical positioning

literature stream / theoretical approach	**Factors for standard dominance**	**Explanation of standard dominance**
Industrial economics / network economics	Market mechanisms (such as network externalities, uncertainty, rate of change)	Standards achieve dominance through environmental factors that cannot be influenced by the firm.
Institutional economics	Characteristics of the firm (such as Financial strength, and Brand reputation and credibility) Strategy (such as Timing of entry, appropriability strategy)	Individual firms can increase the possibility that their technology will become dominant by the possession of superior resources and by strategically positioning their technology.
Technology Management	Characteristics of the standard (such as compatibility, complementary goods, technological superiority) (and Market mechanisms, Characteristics of the firm, Strategy, Stakeholders)	The outcome of standards battles is determined by firm level factors and environmental factors. Environmental factors also moderate the influence of some firm-level factors.
Institutional Economics / Technology Management / Standardization	Stakeholders (such as regulator, suppliers of complementary goods)	Although not explicitly mentioned in any particular literature stream, several studies in different areas (including standardization, technology management, and institutional economics) mention the influence of other stakeholders in the standards battle.
Social network literature	Composition and structure of the network of a standard	The outcome of a standards battle is determined by the composition and structure of the network of the standard.

1.4 Theoretical and practical aims

The first theoretical aim of this study is to review different streams of literature and integrate these streams into a framework consisting of factors for standard dominance. The second aim is to apply this framework to standards battles for complex systems to assess its completeness and relevance and to understand whether it can be used to explain and predict standard dominance in these types of systems. Our third aim is to test the influence of characteristics of networks of actors and the flexibility of the standard on standard dominance.

Our research aims to add to streams of literature on standardization and technology management. The current literature, both in the field of formal and market standardization, mainly concerns the standardization processes of single products (Cusumano, Mylonadis and Rosenbloom, 1992; Schilling, 2002; Suarez, 2004; Utterback, 1994) or of upcoming systems consisting of mainly new components (Bekkers, Duysters and Verspagen, 2002). Very little research has been done on technology systems that interconnect established subsystems and components. Furthermore, little empirical research has been done in either of the two streams of literature on the driving forces behind a standard reaching dominance. This study aims to address this lack of empirical research. Prior empirical studies have attempted to provide weights for factors for standard dominance (see, for instance, Agarwal, Echambadi, Franco and Sarkar, 2004; Klepper and Simons, 2000; Majumdar and Venkataraman, 1998; Srinivasan, Lilien and Rangaswamy, 2006; Tegarden, Hatfield and Echols, 1999). However, most of these studies focus on a small subset of factors. Due to the small amount of empirical research, integrating these studies does not result in a weight for every factor. Also, integrating these studies is difficult since every standards battle is different. In this study, we attempt to provide weights for every factor that can be influenced by the firm. We intend to accomplish this by applying a multi-attribute utility approach; the Analytical Hierarchy Process. This is the first time that a multi-attribute utility approach has been applied to standards battles. This study also aims to contribute to social and interorganizational network literature by focusing on the influence of networks of actors on standard selection.

Our practical aim is to reduce the uncertainty for practitioners deciding upon a standard for complex systems in general, and for home networks in particular.

1.5 Outline of the study

In Figure 1-2, we present the outline of this study. In Chapter 2, we will conduct a review and synthesis of standard selection literature in order to develop a framework that can be used to explain the outcome of

standards battles. In Chapter 3, we apply a step-by-step approach to the identification of standards for home networking. We develop a classification and we use this classification to categorize (sets of) standards. By developing this categorization, we aim to bring order to the chaos of home networking standards. In Chapter 4, we apply the framework to three case studies of standards battles to explore its completeness and the relevance of each factor. In Chapter 5, the outcome of standards battles for complex systems is explored by applying a multi-attribute utility approach to standard selection. This approach is applied to calculate weights for twenty factors from the framework developed in Chapter 2. Finally, the framework is applied to three historical standards battles that have occurred in the home networking industry in order to test its fitness for use in explaining the outcome of standards battles. In Chapter 6, we hypothesize that in complex systems the diversity of the networks of actors that are supporting the different competing standards plays an important role in establishing dominance. We also hypothesize that the flexibility of the standard has a positive effect on this diversity. We test these hypotheses using data that comes from a database which we have created for this study.

This dissertation is a collection of papers that build upon each other and that means that inevitably some overlap exists between the several chapters. This is especially the case for chapters 4 and 5 since these chapters make use of the framework developed in Chapter 2 and the classification for types of standards developed in Chapter 3.

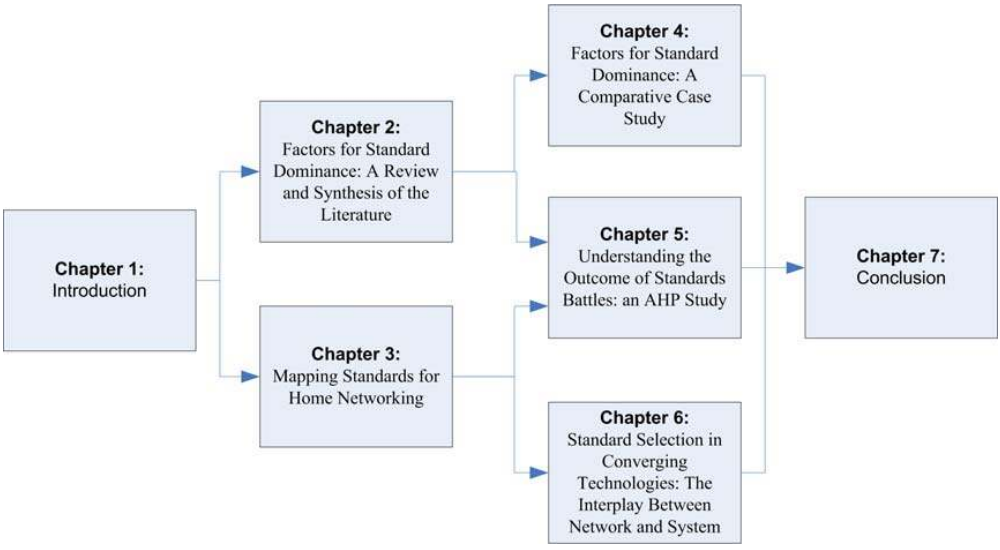

Figure 1-2: Outline of this study

2 FACTORS FOR STANDARD DOMINANCE: A REVIEW AND SYNTHESIS OF THE LITERATURE

Abstract

In this chapter[3] we develop a framework of factors explaining the outcome of standards battles. Based upon a review of the literature, twenty-nine factors were identified and grouped under five categories. We demonstrate that this framework is more complete than previous frameworks. The framework can be used by both theorists and practitioners to better understand historical and current standards battles.

2.1 Introduction

What will be the fourth generation mobile telecommunication standard? Does Mobile WIMAX (IEEE 802.16e) have a good chance of becoming an accepted standard for wireless telecommunication? Which flat screen television technology will we use in the future, plasma or LCD? Early battles include the now classic QWERTY vs Dvorak battle. Similar battles continue to emerge time and again. For firms, consumers and other parties involved, it is important to have insights regarding the chance that a specific standard will dominate. In this chapter, we develop a list of factors affecting that chance.

Scholars have pointed to many factors that affect the outcome of standards battles (Schilling, 1998; Shapiro and Varian, 1999b; Suarez, 2004). However, the literature is fragmented and does not provide us with an overall framework in which all relevant factors are included. Studies that do propose a framework tend to be incomplete and focus on a subset of the total set of factors. An example is provided by the quite extensive literature on the standards battle between the Betamax, Video 2000 and VHS standards for video recording (Bartlett and Ghosal, 1988; Cottrell and Sick, 2001; Cusumano, Mylonadis and Rosenbloom, 1992; Dai, 1996; Economides, 1996b; Grindley, 2002; Johne, 1994; Klopfenstein, 1989; Ohashi, 2002; Puffert, 1999; Roome, 2006). Each author mentions a different, although overlapping, set of factors that have influenced the outcome of this battle. A complete overview of factors is missing. Clearly, there is a need for a complete list of factors that can be used to predict the outcome of standards battles. Our objective is to develop such a list based on the

[3] This chapter is based on Van de Kaa, G., De Vries , H. J., Van den Ende , J. and Van Heck, E. 2008. A Complete Overview of Factors for Standard Dominance: A Meta-analysis of the Literature. Paper presented at the *Academy of Management Annual Meeting*, Anaheim, California. An earlier version of this chapter has appeared as Van de Kaa, G., De Vries , H. J., Van Heck, E. and Van den Ende , J. 2007. Factors for standard dominance - A meta-analysis. Paper presented at the *40th Hawaii International Conference on System Sciences*, Hawaii. An earlier version of this chapter has appeared as Van de Kaa G. & Van den Ende J. 2006. Factors affecting the adoption of standards. B@Home project deliverable 2.16.

available literature. In this list, as many factors for standard dominance as possible are taken into account. Also, since we include factors that can have both a positive and a negative effect on the chances that a standard will dominate; we specify the direction of the effect between each factor and standard dominance.

In this study, we concentrate on compatibility standards which we define as 'codified specifications defining the interrelations between entities in order to enable them to function together' (based on De Vries, 1999; Garud and Kumaraswamy, 1993). Thus, quality standards such as ISO 9000 are excluded. In line with Suarez (2004), we define dominance of standards in terms of market share. We consider a standard dominant when it has achieved more than 50% market share among new buyers in a certain product or service category for a significant amount of time (Lee, O'Neal, Pruett and Thoams, 1995; Suarez, 2004). A distinction can be made between committee-based and market-based standardization (Farrell and Saloner, 1988),. The outcome of market-based standardization can be a de-facto standard which is a standard that has been agreed upon in the market (Blind and Thumm, 2004). In this study we will focus on these standards. We do not restrict ourselves to standards that have been developed by consortia since standards that have been developed by for instance standards developemetn organizations can also compete in the market.

Dominant designs and standards are often used interchangeably (Anderson and Tushman, 1990; Besen and Farrell, 1994; Schilling, 1999), where a dominant design is seen as the design that is recognized as the industry standard. There are some important differences between the two concepts. A 'design' may refer to 'a product's design specifications that define the product category's architecture' (Christensen, Suarez and Utterback, 1998), 'technical features' (Utterback, 1994), 'core design concepts' (Henderson and Clark, 1990), 'trajectory' (Suarez, 2004), or 'a way of doing things which is manifested in a product' (Lee, O'Neal, Pruett and Thoams, 1995). Thus, designs include entire products (Suarez and Utterback, 1995) as well as (sets of) features of products (Lee, O'Neal, Pruett and Thoams, 1995). 'Standards' refer to specific elements of a design (Gallagher, 2007), in our case interfaces between different components within a design. Thus, since designs and standards can have the same characteristics, in this study we will take into account literature that focuses on dominant designs.

We begin by exploring several theoretical perspectives on standard dominance in Section 2.2, leading to five categories of factors. Subsequently, in Section 2.3, we describe methodologically how we develop a complete list of factors. In Section 2.4, we present the results of a systematic search of the literature for factors that belong to each category identified in Section 2.2. Subsequently, we determine the direction of influence for

each factor on standard dominance. In Section 2.5, we discuss our results and in Section 2.6 we present our conclusions.

2.2 Theoretical Perspectives on Standard Dominance

The dynamics in industries that lead to standards has been studied from multiple perspectives and disciplines. According to evolutionary economists, the survival of a firm is the result of a process of natural selection (Arthur, 1989). Technology evolves through periods of incremental change until at some point in time a major breakthrough is introduced in the industry. These so called technological discontinuities increase the uncertainty in the industry and usually change it considerably (Tushman and Anderson, 1986). As a result a new technological paradigm emerges consisting of "its own concept of progress based on its specific technological and economic trade-offs" (Dosi, 1982) and often leads to new markets and applications (Bower and Christensen, 1995). Within a new paradigm, different technological paths can be developed resulting in designs that compete with each other for dominance (Utterback and Abernathy, 1975). Our study focuses on the period beginning with the technological discontinuity and ending when one design has become dominant. The dominant design is the product standard which ends the period of competing designs (Tushman and Anderson, 1986).

Traditionally scholars in the field of industrial economics have studied the dynamics of industries and the role of standards in the emergence of new markets. They developed a three stage life-cycle model of technology according to which in a new industry at the end of the first, 'fluid' phase a dominant design or standard emerges that remains stable over time (Abernathy and Utterback, 1978; Utterback, 1994). In terms of this model, we focus on the first stage. Within the industrial economics field, a separate stream of literature focuses on network economics. Network economists have emphasized the importance of market characteristics, particularly the existence of so-called network externalities, stating that the benefits of a technology for an individual user increases when the number of users grows (Arthur, 1996; Katz and Shapiro, 1985). Users, producers and other stakeholders follow each other in their technology choices because of information advantages, scale effects, and the availability of complementary goods (Van den Ende and Wijnberg, 2003). Network economists demonstrate that as a consequence of such effects the design that has an initial advantage over other designs tends to increase its advantage, resulting in a winner-take-all situation. The costs to switch to another standard increases and as a consequence people get locked into a particular standard (Cusumano, Mylonadis and Rosenbloom, 1992; Katz and Shapiro, 1985; Lee, O'Neal, Pruett and Thoams, 1995; Shapiro and Varian, 1999b; Shy, 2001). Network economists emphasize that not always the best design wins the competition

(David, 1985). From the network economics literature, we learn that there exist specific *market characteristics*, such as network externalities and the level of uncertainty, that affect standard dominance and lock-in, which can hardly be influenced by individual firms. These factors do not directly influence the chances that one particular standard achieves dominance because these factors have the same value for each of the standards competing in the market. These factors influence the pace at which a standard will be reached and the likelihood that in the market a dominant standard will be reached. For instance, a high level of uncertainty in the market will decrease the pace at which a standard will be reached; and the existence of network externalities will increase the likelihood that one dominant standard will be reached in the market. Also, these factors have a moderating effect on the other factors (Suarez, 2004). For instance, the existence of networks externalities will increase the effect of a current installed base on standard dominance.

Institutional theories focus on strategic behaviors of firms to increase the possibility that their standard becomes dominant (Cusumano, Mylonadis and Rosenbloom, 1992; Suarez and Utterback, 1995). In essence, institutional theorists suggest that individual firms can have an influence on the outcome of a standards battle. Especially in the early stages of a competition, the strategy with respect to the position of standards or technologies in the market is of great importance (Khazam and Mowery, 1994). This is also emphasized by Suarez (2004), who stresses the importance of strategic maneuvering in the first stage of the battle for dominance. A *standard support strategy* can be followed which helps firms to promote their own technology and at the same time prevents the adoption of competing technologies. Willard and Cooper (1985) examine the influence of several strategic variables on survival in the TV industry and find that strategic factors such as pricing and distribution strategy influence market dominance, provided these are matched with the firm's resources and are effectively implemented. The firm's resources, including its size and financial strength, will be referred to in this study as the *characteristics of the standard supporter*. Another aspect emphasized by institutional theorists is the time of introduction of the technology in the market (Lieberman and Montgomery, 1988; Suarez and Utterback, 1995), where it is argued that entering early can have both advantages and disadvantages (Lieberman and Montgomery, 1998). Other strategic factors include a firm's appropriability strategy (Teece, 1986), and strategic marketing communications. A firm can support a standard by means of an open licensing policy and, as such, encourage imitation by competitors, which will in general increase the chances of a standard becoming dominant. This strategy has the drawback that the firm itself will often reap lower benefits from the standard (Clarke, 2004; Marasco and Dodson, 2004; Merges, Menell and Lemley, 2004). An open policy contributed to the success of the RISC technology over the CISC technology in the US

microprocessor industry (Khazam and Mowery, 1994). On the other hand, protecting standards from imitation, usually by means of patents (Bekkers, Duysters and Verspagen, 2002), generally increases revenues from the standard but diminishes its chances of becoming dominant. Strategic marketing communications (pre announcements) are used to increase installed base and to discourage users from adopting rivals' standards (Besen and Farrell, 1994; Shapiro and Varian, 1999b). In the video gaming industry, for example, the Nintendo 64 system was announced more than two years before it actually became available (Gallagher and Park, 2002).

Scholars in the field of technology management have developed several frameworks of standard dominance, integrating concepts from both industrial and institutional economics (Lee, O'Neal, Pruett and Thoams, 1995; Schilling, 1998; Suarez, 2004). We follow this literature by distinguishing between factors that can be influenced by the firm ('firm-level factors' (Suarez, 2004)) and factors that are given in specific industries and can hardly be influenced by individual firms (environmental factors (Suarez, 2004)). In our framework, the environmental factors are the market characteristics. We distinguish two categories of firm-level factors based on the institutional economics literature: characteristics of the standard supporter and the standard support strategy. In line with the technology management literature, we add the category *characteristics of the standard*, encompassing compatibility of the standard, the availability of complementary goods, and technical characteristics. Compatibility guarantees connectivity with complementary goods and with earlier (generations of) standards (Gallagher, 2007). Technical characteristics refer, for instance, to specific innovative elements, which can help a standard to become technologically superior and increase its chances of reaching dominance (Christensen, Suarez and Utterback, 1998).

We add a fifth category: *other stakeholders*, since there are stakeholders of importance, other than the group of standard supporters, such as competitors, standards committees, testers and certifiers, (alliances of) implementers, users of the standard and regulatory agencies. We adopt a broad definition of stakeholders proposed by Freeman and Reed (1983) as those actors that *"can affect the achievement of an organization's objectives or who are affected by the achievement of an organization's objectives"*. The importance of competitors appeared in the VCR case, in which a larger group of firms such as Matsushita, JVC, and Hitachi supported the VHS standard that eventually became dominant (Cusumano, Mylonadis and Rosenbloom, 1992).

2.3 Methodology

In our search for specific factors, our starting point was a review paper of the literature (Suarez, 2004). We arranged the factors mentioned in that article in a list. For every new publication that we analyzed, we

searched for factors that had not been mentioned before and we included them in the list. To decrease publication selection bias (Glass, McGaw and Smith, 1981), we did not restrict ourselves to published studies but also analyzed conference proceedings, unpublished sources, and PhD theses. We then classified the factors in order to identify those factors that were closely related or overlapping in meaning. This provided us with a shorter list of unique factors. From the initial article, we moved to the publications cited by the author (backward search) and looked for factors mentioned in those publications. We also reviewed publications that cited the article (forward search). The process was then repeated for these publications until no new factors were found. The forward search was performed by a citation analysis via the ISI Web of Knowledge scientific database. This process is similar to that applied in meta-analyses on transaction cost theory (Geyskens, Steenkamp and Kumar, 2006) and organizational innovation (Damanpour, 1991). Publications that did not explicitly mention specific factors were excluded from our list. In some cases, the same phenomenon was mentioned under different names. When this occurred, we selected one name. Based on similarities between the factors we grouped them under the five categories presented in Section 2.2.

Apart from determining the factors that were mentioned in a particular publication, we also determined the direction of the relationship between each factor and standard dominance. By comparing the directions reported in each study, we came to an understanding of the theoretical relationship between the factors and standard dominance. If each study suggested a particular direction, we followed that direction. It appeared that for some factors, both positive and negative directions were suggested in the literature. For example, thrity-eight studies suggested that early entry of a standard into a market will result in a higher chance of achieving dominance while eight studies suggested the opposite. To determine the direction of the factor in such cases, we selected the publications that were based on an empirical test, and we applied the vote counting principle on those specific studies (Hedges and Olkin, 1980; Light and Smith, 1971). To apply the vote counting principle, we computed the average of the effect sizes reported in each study. We had three categories of outcomes: significantly positive, significantly negative, or no significant relation. Finally, we totaled the number of studies found in each category which provided us with an empirically supported relationship between the factor and standard dominance. For some factors this procedure did not lead to a conclusion. In those cases we concluded that the factor had two possible directions. We therefore describe the conditions under which these factors have a positive or negative direction.

2.4 Results

In the search for factors we found one hundred twenty-seven papers in which one or more factors were mentioned. Fifteen out of the one hundred twenty-seven papers report empirical data. This resulted in a list of twenty-nine factors. A matrix that relates the factors to the publications in which they were found as well as the full list of publications that were taken into account in the analysis is presented in Appendix 9.1. This matrix demonstrates that each reviewed publication provides only a limited number of factors, ranging from one to twenty-three, with an average of 5.82. In Table 2-1, we give an overview of the fifteen empirical studies that were taken into account in this study.

In Table 2-2, we present the results from the study. In this table, we specify the direction of the relations as they are described in the literature (both theoretical and empirical) and the direction of the relations reported in the empirical papers in particular. Based on this data, we determined whether the effect of each factor on standard dominance is positive or negative. Below we discuss each factor.

Table 2-1: 15 Empirical studies studying factors for standard dominance

Authors	Independent variables	Dependent variable as measured by	Type of Statistical analysis	Type of industry
Agarwal et. al. (2004)	Learning orientation Financial strength	Firm survival	Correlation (n = 1180)	Disk drive industry
Christensen et. al. (1998)	Timing of entry Financial strength Flexibility	Firm survival	Regression (n = 453)	Disk drive industry
Dranove et. al. (2003)	Complementary goods	Market share	Regression (n = ?)	Optical disc storage industry
Klepper et. al. (2000)	Financial strength	Firm survival and market share	Regression (n = 83, 134)	Television industry
Majumdar et. al. (1998)	Current installed base Previous installed base Bandwagon effect Rate of change Financial strength	Market share	Correlation (n = 40)	Telecommunications industry
Mitchel (1991)	Timing of entry Previous installed base Learning orientation Financial strength	Market share	Correlation, regression (n = 98, 216)	Diagnostic imaging industry
Schilling (2002)	Current installed base Timing of entry Learning orientation Complementary goods	Lock out	Correlation, regression (n = 89)	Several product categories including PC operating software and video game hardware
Shankar et. al. (2003)	Network externalities Complementary goods Pricing strategy Marketing communications	Market share	Regression (n = 64)	Video game industry
Srinivasan et. al. (2006)	Appropriability strategy Network externalities Learning orientation	Probability of emergence	Correlation, regression (n = 63)	Office products and consumer durables
Suarez et. al. (1995)	Timing of entry	Firm survival	Regression (n = 83, 95, 121, 105)	Typewriter industry Automobile industry Television industry Picture tube industry
Tegarden et. al. (1999)	Timing of entry Pricing strategy	Market share	Regression (n = 21-202)	Personal computer industry
Tripsas (1997)	Number of options available Learning orientation	Market share	Regression (n=154)	Typewriter industry
Wade (1995)	Bandwagon effect Technological superiority	Market share	Regression (n = 51-57)	Microprocessor industry
Willard et. al. (1985)	Timing of entry Current installed base	Firm survival	Multiple statistical analyses (n = ?)	Television industry
Zhu et. al. (2006)	Network externalities Marketing communications Switching costs Financial strength	Standard adoption	Regression (n = 1394)	Internet standards

Table 2-2: List of factors

		Theoretical direction			Empirical direction			Direction
		# studies suggesting a positive effect	# studies suggesting a negative effect	# studies that do not specify a certain direction	# studies reporting a significant positive effect	# studies reporting a significant negative effect	# studies reporting no significant effect	
Firm level factors		**Impact on standard dominance**						
Characteristics of the standard supporter								
1	Financial strength	16			5			+
2	Brand reputation and credibility	40		1				+
3	Operational supremacy	23						+
4	Learning orientation	48	1	2	3	1	1	+
Characteristics of the standard								
5	Technological superiority	38		2	1			+
6	Compatibility	29		6				+
7	Complementary goods	53		3	3			+
8	Flexibility	10			1			+
Standard support strategy								
9	Pricing strategy		33	3		2		-
10	Appropriability strategy		22	9		1		-
11	Timing of entry	1	31	19	1	5		∩
12	Marketing Communications	39		3	2			+
13	Pre-emption of scarce assets.	10		1				+
14	Distribution strategy	24		4				+
15	Commitment	9						+
Other stakeholders								
16	Current installed base	41		1	3			+
17	Previous installed base	7		2	2			+
18	Big Fish	20						+
19	Regulator	30		5				+
20	Judiciary		13	2				-
21	Suppliers	23						+
22	Effect of standard development process	11						+
23	Network of stakeholders	12						+
Environmental factors		**Impact on the speed and likelihood of standard dominance**						
Market characteristics								
24	Bandwagon effect	32			2			+
25	Network externalities	64	2	2	2	1		+
26	Number of options available		4	1		1		-
27	Uncertainty in the market		9	1				-
28	Rate of change		5	2			1	-
29	Switching costs		20	20		1		-

2.4.1 Characteristics of the standard supporter

The first group of factors relates to the strength of the standard supporter (when standards are supported by multiple standard supporters, we refer to the complete group of standard supporters). The stronger the standard supporter, the better are the chances of the supported standard becoming dominant.

1. Financial strength, as defined by Willard and Cooper (1985), is not only the current financial condition of the parent corporation, but also its future prospects. When introducing a standard, financial resources can be used to recover start-up losses (Ehrhardt, 2004); a group of standard supporters that has a higher financial strength than competitors can endure longer periods of low earnings due to low prices, as well as spend more on marketing (Schilling, 1999) and thus will have a higher chance of setting a dominant standard. Sixteen studies mentioned this factor as positive.

2. Brand reputation and credibility plays a significant role in the users' selection of a standard. Past performance in setting dominant standards has a positive impact on the attitude to new proposals (Axelrod, Mitchell, Thomas, Bennett and Bruderer, 1995). Also, a group of standard supporters with a good reputation will find it easier to attract other stakeholders to join the group (Foray, 1994) resulting in an increase in the standard's installed base. Forty studies suggested a positive relation between the factor and standard dominance.

3. Operational supremacy: When a group of standard supporters is composed in such a way that it is able to exploit its resources better than competitors, it has an advantage over them which will positively influence its chances of reaching dominance with the standard. This advantage is called operational supremacy (Schilling, 2002). Operational supremacy can be reached for instance by the possession of a superior production capacity (Suarez and Lanzolla, 2005). A technological advantage of one or more members of a group of standard supporters can increase the chances that their standard will achieve dominance (Axelrod, Mitchell, Thomas, Bennett and Bruderer, 1995). Twenty-three studies mentione this factor as having a positive effect.

4. Learning orientation: Duncan and Weiss (1979) describe the learning capabilities of the firm as "the process by which knowledge about action-outcome relationships and the effects of the environment on these relationships is developed". Failure to invest in learning can increase the likelihood of a standard being locked out (Schilling, 2002). With learning, we refer both to the know-how; the core capabilities, and the extent to which the firm can acquire new knowledge - absorptive capacity. The absorptive capacity refers to both technological know-how (the ability to generate technological breakthroughs) and market pioneering know-how (whether these technological breakthroughs can be commercialized) (Agarwal, Echambadi, Franco and Sarkar, 2004). Learning from experience can increase the chances that a dominant standard will be reached. For

instance, in the television industry, firms that were also producing radios survived longer and had higher market share than those that did not: they were able to make use of their prior experiences in the radio industry (Klepper and Simons, 2000). Therefore, the learning orientation of the group of standard supporters plays a positive role. We found fourty-eight theoretical studies suggesting a positive effect of which, three empirical studies confirmed the suggested effect. However, one study (Tripsas, 1997) shows that the prior experience of incumbents can also have a negative influence on market share as such experience restricted the incumbent in committing to a new standard. This study demonstrates a situation in which firms invest too much in core capabilities and too little in absorptive capacity. Thus, a group of standard supporters can, by investing in learning, increase the chances that its standard reaches dominance, provided it invests in both core capabilities and absorptive capacity.

2.4.2 Characteristics of the standard

A standard that is superior compared to other standards has a higher chance of becoming dominant. This superiority may include:

5. *Technological superiority*: Schumpeter (1934) defines technological superiority of a design as having features that allow this design to outperform other designs. On the other hand, David (1985) emphasizes that the most technically advanced design does not necessarily become the dominant one. Thirty-eight studies suggested a positive relationship between this factor and standard dominance.

6. Compatibility: Another characteristic of a standard is the compatibility that the standard enables. Compatibility concerns the fitting of interrelated entities to each other in order to enable them to function together (De Vries, 1998). Horizontal compatibility concerns the fit between functionally equivalent objects (e.g., two Lego bricks or two telephones) When a standard is backwards compatible the standard is designed in such a way that the technology in which it is implemented is backwards compatible with technologies that implement previous generations of the standard. For example, standards for analogue color television have been specified in such a way that the color signal could be received by black and white television sets. By making a standard backwards compatible the chances that it will achieve dominance increases (Lee, Lee and Lee, 2003) as it can make use of the previous installed base of the standard. Twenty-nine studies suggested a positive relation between the factor and standard dominance.

7. Complementary goods: Complementary goods are defined by Teece (1986) as those other goods needed to successfully commercialize a certain standard. Similarly, Farrell and Saloner (1986) recognize that the

interchangeability of complementary goods creates demand-side economies of scale. Unsurprisingly, when a standard is used in many complementary goods, this increases demand for the standard (Adler, 1992). In fifty-three theoretical studies, it was suggested that a positive effect exists between the availability of complementary goods in which the standard is used and the chance that the standard will achieve dominance. This was supported by three empirical studies.

8. *Flexibility*: The flexibility of the standard refers to the incremental cost and time needed to adapt a standard due to new developments such as changes in customer needs or technological improvements (Thomke, 1996). The technology management literature indicates that flexibility facilitates the adaptation of a product to customer requirements, and thus has a positive influence on the installed base of products (Thomke, 1996). Standardization literature addresses the topic of flexibility as well and implicitly assumes that a more flexible standard adds to technological superiority and thus to standard dominance (De Vries, 1999; Hanseth, Monteiro and Hatling, 1996). We found ten theoretical studies suggesting this positive effect.

2.4.3 Standard support strategy

Here, we survey the range of strategies adopted in a market to win a standards battle.

9. Pricing strategy: This refers to all actions taken to create market share through strategically pricing the standard's implementation. Sellers may be willing to temporarily price below cost in order to build an installed base of users (Adams, 1996; Katz and Shapiro, 1986) and thus make its standard more attractive. Such penetration pricing (Katz and Shapiro, 1985) can also temporarily be used to block possible entrants (Farrell and Saloner, 1986). We found thirty-three studies suggesting that a low price will contribute to standard dominance, with which a further two empirical studies agreed.

10. *Appropriability strategy*: This refers to all actions that are undertaken by firms to protect a standard from imitation by competitors (Lee, O'Neal, Pruett and Thoams, 1995). An open licensing policy will result in an increase in the installed base. We found twenty-two theoretical studies suggesting a positive effect; a more open appropriability strategy will increase the chances that standards will achieve dominance. For instance, Sun's open systems strategy led to the success of Java (Garud, Jain and Kumaraswamy, 2002).

11. *Timing of entry*: This is the point at which a standard enters the market and may be essential for achieving dominance (Kristiansen, 1998; Lieberman and Montgomery, 1998; Mitchell, 1991) – although there is no consensus in the literature here. Early entry can create an installed base and contribute to dominance (Katz and Shapiro, 1985; Lieberman and Montgomery, 1988; Suarez and Utterback, 1995). On the other hand, early

entrants are hindered by a lack of market information and have to make a comparatively higher initial investment, thereby limiting their ability to support their standard going forward (Lieberman and Montgomery, 1988; Schilling, 2002). So, early entrants should have sufficiently deep pockets to exploit the advantage of an installed base (Cusumano, Mylonadis and Rosenbloom, 1992; Suarez and Lanzolla, 2005; Teece, 1986). We found one study suggesting a positive effect and thirty-one studies suggesting a negative effect. Further, the empirical papers are not unequivocal. In most empirical studies (five of six), early entry is considered to contribute positively to dominance. We believe that the relationship between timing of entry and standard dominance is not linear. Instead, following Christensen et al. (1998) and, in particular, Schilling (1998; 2002) who argue that there is an inverted U-shaped relationship between timing of entry and dominance. Christensen et al. (1998) speak of a "window of opportunity" within which it is optimal to enter the market.

12. Marketing communications: Customer expectations play an important role in standards battles (Shapiro and Varian, 1999b) and, therefore, marketing communications are important for gaining greater market share. In the early phase of a battle, pre-announcements can be used to discourage users from adopting rivals' standards prior to the introduction of one's own (Besen and Farrell, 1994; Farrell and Saloner, 1986). For instance, in the DVD format war, the DIVX preannouncement may have slowed down the adoption of the DVD format (Dranove and Gandal, 2003). At later stages, marketing communications, like advertising or public relations, remain important. They can be used to form expectations that a standard will become dominant (Besen and Farrell, 1994). These expectations can become a self-fulfilling prophecy in the sense that the standard that is expected to become dominant will actually become the dominant standard (David and Greenstein, 1990). However, conflicting announcements can confuse potential customers and result in credibility problems (Khazam and Mowery, 1994). We found thirty-nine studies suggesting a positive relationship.

13. Pre-emption of scarce assets: Firms that are able to capture scarce assets at an early stage, thus denying them from other players, are able to create a competitive advantage (Barney, 1991), and can use this advantage to increase the chances of their standard becoming dominant. An example of an asset is an important manufacturer of the product in which the standard is used. The group of standard supporters can preempt rivals by establishing a relationship with that manufacturer. We found ten studies that mentioned this factor as a positive factor.

14. *Distribution strategy*: this refers to the extent to which a firm pursues a strategy which increases the strength of its distribution system (based on Willard and Cooper, 1985). A good distribution strategy, owned or borrowed from others, can make the difference in accelerating the acceptance of a technology (Wonglimpiyarat,

2005). A good distribution strategy was mentioned in twenty-four studies as a factor that positively influences standard dominance.

15. Commitment: For a standard to become dominant in the market, it is important that it has the sufficient attention and support of each of the actors in the group of standard supporters to survive the early stages, when the return on investment is usually low (Willard and Cooper, 1985) (Adner, 2006). When uncertainty is high and a high number of different standards exist, companies tend to commit themselves to multiple competing standards at the same time. This means that the group of standard supporters can consist of companies that are not fully committed to one standard. This divided commitment is likely to decrease a firm's market share position (Tegarden, Hatfield and Echols, 1999) and may be negative for the group of standard supporters of which the firm is a member. We found nine studies suggesting a positive relationship between commitment and standard dominance.

2.4.4 Other stakeholders

The fourth group of factors relates to stakeholders other than the group of standard supporters.

16. Current installed base: Many authors mention the installed base as a factor. This is the number of users of a standard. These users include both the manufacturers of the products in which the standards are applied and the users of these products. The current installed base consists of the actual users of a standard. When a market is affected by network externalities, the installed base of users has an effect on the adoption of the standard. In fourty-one of the studies we analyzed, this factor was cited as having a positive effect.

17. Previous installed base: the standards that rely on a previous generation of users have a previous installed base consisting of users that might upgrade to the new standard (Farrell and Saloner, 1986). We found seven studies suggesting that a higher previous installed base will increase the chances that a standard will achieve dominance.

18. *Big fish*: A big fish is a player (other than the group of standard supporters) that can exercise a lot of influence by either promoting or financially supporting a standard or by exercising buying power that is so great that this standard will probably become the dominant standard in the market (Suarez and Utterback, 1995). An example of a big fish is IBM, who set the MS DOS standard for personal computers. Another example is General Motors, which, by exercising buying power, helped certain manufacturing automation standards to become dominant (Rosen, 1988). We found twenty studies which suggested that the existence of a big fish will increase the chances of the standard achieving dominance.

19. *Regulator*: The *regulator* can prescribe certain standards in the market (e.g., right/left side driving, railroad tracks) (Suarez and Utterback, 1995) in which case the result of a standards battle is no longer a pure market outcome (Axelrod, Mitchell, Thomas, Bennett and Bruderer, 1995). Thirty studies mentioned the regulator as a factor.

20. *Judiciary*: The judiciary can prohibit certain standards from becoming dominant through antitrust laws. An example of this is Microsoft's dominance with its Windows operating system. In 2004, the European Commission ordered Microsoft to make the source code concerning interface specifications of Windows available to its competitors so that they could develop complementary software for Windows (European Commission, 2007). Before this judiciary intervention, Microsoft could solely write software for Windows such as the Windows media player and offer that software with Windows. After the intervention the market share of both Windows and the complementary software written by Microsoft decreased with respect to competitors since both could no longer make use of each other's installed base. The cost of switching from Windows to a competing operating system decreased considerably since it was not necessary to switch complementary software anymore. Another example can be found in the US instant photography market, where Kodak was ordered to leave the market by a federal court because it had violated the patents of Polaroid. This led to the failure of Kodak's standard for instant photography (Mahajan, Sharma and Buzzell, 1993). This factor was mentioned in fifteen studies, of which, thirteen suggested a negative relationship between judiciary intervention and standard dominance.

21. *Suppliers*: Other suppliers that adhere to a standard are the companies that produce complementary goods or services in which the standard is applied (Schilling, 1999; Teece, 1986). A standard supporter can, by influencing these suppliers, increase the chances that its standard will achieve dominance (Besen and Farrell, 1994). They can follow a system lock-in strategy where they attract as many suppliers of complementary goods to their network as possible (De Vries, De Vries and Oshri, 2008; Hax and Wilde, 1999). For example, in the early '90s, both IBM and Microsoft attempted to encourage firms to develop software for their respective operating systems as they competed to make OS2 or Windows the industry standard (Besen and Farrell, 1994; Vercoulen and Van wegberg, 1998). In the battle for a video standard, this factor also played an important role. JVC had access to a larger range of manufacturers of complementary goods than Sony (Cusumano, Mylonadis and Rosenbloom, 1992) and these manufacturers also offered a more diverse range of VHS devices (Ehrhardt, 2004). In twenty-three studies, this factor was mentioned, suggesting that the more a firm can attract other suppliers of complementary goods, the higher the chances are that the standard will achieve dominance.

22. *Effectiveness of the standard development process*: The group of standard developers participating in the standard development process affects the effectiveness of that process (as defined in terms of for instance duration). This affects the potential of the standard becoming dominant (Lehr, 1992). In eleven studies, this factor was mentioned and each study suggested a positive relationship between the effectiveness of this process and the chances that the standard achieved dominance.

23. *Network of stakeholders*: Several characteristics of the network of stakeholders supporting a standard can have a positive influence on the chances that a standard will achieve dominance. We emphasize the diversity of the network of stakeholders. A standard that is supported by a diverse network (in which stakeholders represent each relevant product market for which the standard serves a defining role) will have a high chance of achieving dominance (Gomes-Casseras, 1994). This certainly was the case in the battle for a Digital Video Disc (DVD) standard, where hardware manufacturers worked together with movie studios to establish it (Dranove and Gandal, 2003)[4]. Eleven studies suggested that the diversity of the network will contribute to the chances that a standard will achieve dominance. One study (Bekkers, Duysters and Verspagen, 2002) also showed that a standard will have a higher chance of achieving dominance if the standard supporter has a central position in the network.

2.4.5 Market characteristics

Market characteristics are factors that cannot be influenced by the firm; they just exist. We refer to these types of factors as market characteristics.

24. Bandwagon effect: When some users have chosen to implement a certain solution to a matching problem, others tend to choose the same solution; often for reasons of availability of information (De Vries, 1998). This so-called bandwagon effect positively affects the likelihood that one dominant standard will be reached in the market and was mentioned in thirty-two studies.

25. *Network externalities* describe the effect that the utility an individual user derives from consumption of a good increases with the number of other agents consuming the good (Katz and Shapiro, 1985). A typical example is the fax machine (Katz and Shapiro, 1994). Also, the utitility of a standard increases when the amount and variety of complementary goods that is available for that standard increases. If a standard possesses a higher installed base than its competitor and the network externalities are high, that standard will have a higher chance of achieving dominance. Most studies (sixty-four) suggest a positive effect of network

externalities on the likelihood that one standard will achieve dominance. However, two studies suggested a negative effect and one study has empirically proven this negative effect. Here, it was argued that the existence of the network effects will induce more firms to introduce incompatible standards early on since each firm will want to take advantage of the lock-in effects which increase the number of standards that exist next to each other (Kristiansen, 1998).

26. *Number of options available* or the number of competing standards plays a significant role in the potential market share of a standard (Tripsas, 1997). Four studies suggested that a larger number of competing standards in a market lower the chances for each of them to become dominant.

27. *Uncertainty in the market*: When the uncertainty in the market gets too high, firms and customers are not willing to take the risks attached to choosing one particular standard and will postpone their decision (Leiponen, 2006; Schmidt and Werle, 1998). This decreases both the likelihood that one dominant standard will be reached and the speed at which a standard will achieve dominance. This negative effect was suggested in nine studies.

28. *Rate of change* refers to the speed of evolution within a specific industry both with respect to the technology and the market (Suarez and Lanzolla, 2005). When it is high, this will have a negative effect on the emergence of a dominant standard (Smit and Pistorius, 1998). The rate of change refers, for instance, to the speed at which new generations of the standard are being introduced. When this speed is high it affects the desirability of committing to that standard (Lee, O'Neal, Pruett and Thoams, 1995); the standard may still change considerably and users will be unwilling to commit themselves. In five studies, it was suggested that a high rate of change negatively affects both the speed at which a standard will be achieved and the likelihood that a standard will achieve dominance.

29. *Switching costs* are costs required to switch between competing standards (Suarez, 2004). Types of switching costs include the procurement of complementary goods such as software for a PC or learning to use a new keyboard layout (David, 1985). When switching costs are high, it will take relatively longer before a new standard becomes dominant. This negative effect was suggested in twenty studies.

[4] The importance of network diversity also seems to be important in the more recent battle between HD DVD and Blu-Ray for a high definition digital video disc standard.

2.5 Discussion

If we compare our list of factors to the factors mentioned in the three frameworks presented in the three papers from which we started our study (Lee, O'Neal, Pruett and Thoams, 1995; Schilling, 1998; Suarez, 2004), our list appears to be more complete. The frameworks of Schilling (1998) and Lee (1995) both include fifteen factors which is about half of the number of factors included in our list. The framework of Suarez (2004) is the most complete of those three frameworks since it includes seventeen factors. Moreover, Suarez distinguishes firm level factors and environmental factors which are related to each other. In our framework, five categories with a total of twenty-nine factors are included. Our framework can be used as a checklist to analyze future standards battles.

Table 2-2 shows that some factors have only rarely been mentioned in the literature. This may be due to several reasons. Some papers focus on one specific factor or a set of specific factors, thereby excluding others. Other papers focus on a specific case study, and not all factors apply. For instance, in many cases regulation will not apply. Another possible explanation is that authors were simply not aware of certain factors and, therefore, did not mention them. Gradually, more factors will be discovered. In Figure 2-1, we have looked at whether the total number of factors per article increases with the year of publication. The data provide a first indication of a possible positive correlation between the number of factors per article and the year of publication. Apparently, over time more factors are discerned.

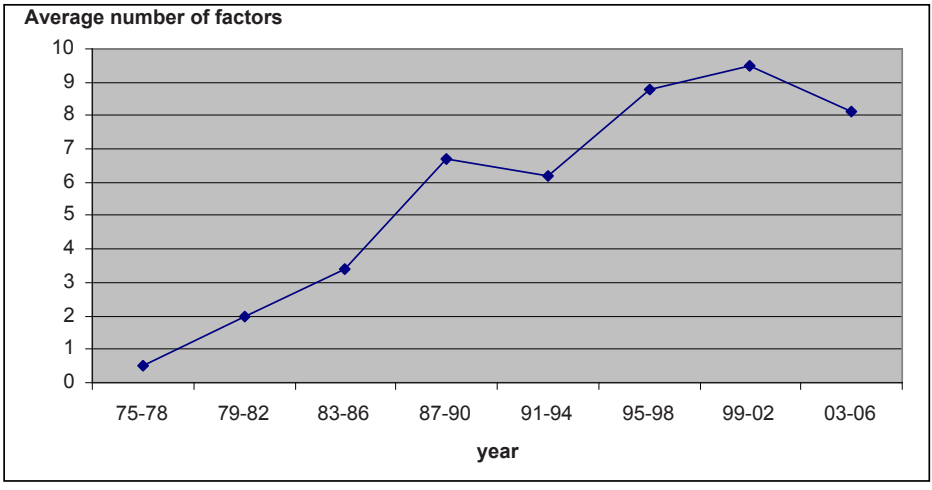

Figure 2-1: Average number of factors mentioned per year

There are some limitations to this study. First of all, only fifteen of the total number of one hundred twenty-seven papers use empirical data, indicating that further empirical research is definitely needed in this field, particularly for factors that have so far mainly received only theoretical treatment (such as the flexibility of the standard and the network of stakeholders), although some of those factors (such as commitment and uncertainty in the market) are difficult to measure empirically. We do not know why there are so few empirical quantitative studies available. Perhaps the standardization field is not yet in the stage where quantitative studies can be performed.

Second, we could not specify "weights" for the factors. The quantity of empirical studies is not sufficient to determine weights. Even when there would be enough empirical studies available the question remains whether the factors are measured in a consisting way. Still, trying to establish weights for factors for standard dominance is an interesting topic for future research.

Another limitation in this study is that we only focus on the influence of individual factors on standard dominance. However, often, in standards battles a combination of factors can affect standard dominance. Schilling (1998) for instance showed that the current installed base and the availability of complementary goods reinforce each other. Also, environmental factors can moderate the influence of some firm-level factors. For example, when a market is characterized by market characteristics such as network externalities, the standard that has a higher installed base then its competitor has a higher chance of achieving dominance (Suarez, 2004). Future research could, by studying standards battles through case studies, search for other possible combinations of factors for standard dominance.

2.6 Conclusion

In this study we performed an extensive literature study of one hundred twenty-seven papers from standard selection literature, identifying twenty-nine factors for standard dominance. We grouped these factors into five categories: characteristics of the standard supporter, characteristics of the standard, standard support strategy, other stakeholders, and market characteristics. By performing a meta-analysis, we specified the direction of each factor on standard dominance. This resulted in a framework with which it is possible to explain the outcome of standards battles.

We hold that this framework is the most complete one possible at this time. However, the framework remains a simplification of reality. Moreover, in an actual standards battle not all factors point for the same

standard to win. Nevertheless, we expect our framework to be a helpful tool to explain future standards dominance. Theorists can use our framework to analyze standards battles and as such gain a deeper insight into these battles. Practitioners can use our framework as a guide to analyze movements in the market of standards influencing the struggle for dominance. They can adapt their behavior to accommodate the factors of the framework in a desired direction, or they can use the framework to make an estimate of future standard dominance in standards battles. To fully exploit this framework, a comparison should be made with the competitor's standard, for which the same framework can be used.

3 MAPPING STANDARDS FOR HOME NETWORKING

Abstract

In this study[5], we apply a step-by-step approach for the identification of standards for home networking. We develop a classification and we use this classification to categorize sixty-four (sets of) standards. By developing this categorization, we have brought order to the chaos of home networking standards.

3.1 Introduction

The situation where different types of technology in a home environment can communicate with each other and form one home network is becoming a viable one. Irrespective of the fact that the home network has been technically possible for many years and that there seems to be a demand for it (Wacks, 2002), it has not yet become a practical reality. The lack of a dominant standard for the interconnection between subsystems of the home network is one of the primary reasons why the home network has not yet emerged (Rose, 2001; Wacks, 2001; Wacks, 2002). One of the explanations behind the fact that not one dominant standard has, as of yet, emerged is the mere amount of standards that exist in the market for home networking. We intend to reach order by applying a step-by-step approach to the identification of standards and we try to classify the standards.

We start by studying the system in which the standards are used with the aim of developing our categorization. Next, we will give an overview of the different standards organizations (SOs) that are involved. Subsequently, for each SO, we will provide the standards and we will classify them according to the categorization developed.

In 2002, Den Hartog et. al. (2002) performed a similar study. Our study builds on, and extends, Den Hartog's (2002) study in several ways. First, we will take into account standards that were developed from 2002 to 2007. Second, by applying a step-by-step approach, we intend to reach a more complete list of standards. Third, we will develop a classification which can be used in future study to better compare the different standards to each other.

[5] This chapter is based on Van de Kaa, G., Den Hartog, F. T. T. H. and De Vries, H. J. forthcoming. Mapping Standards for Home Networking. *Computer Standards & Interfaces.* An earlier version of this chapter has appeared in Van de Kaa, G., Den Hartog, F. and De Vries, H. J. 2007. Mapping standards for home networking. Paper presented at the *Euras Conference 2007*, Thessaloniki, Greece. An earlier version of this chapter has appeared in Van de Kaa G. & Den Hartog F. T. H. (2005) Market potential of standards relating to infotainment, B@Home project deliverable 2.10. 196 pp

3.2 Analysis of the home network

3.2.1 Architecture of the System

The home network should be seen in a larger context in order to fully understand it. In Figure 3-1, an architectural overview of an end-to-end communication network is presented. The core network enables the communication of information between service providers, whereas the access network enables the communication of information between the service provider and the consumer. Our interest lies in the private network, which enables the communication of information in the home. Attached to this network is the home platform in which several subsystems (such as consumer electronic devices) are located which can, by making use of the private network, communicate with each other. Through the home interface, which consists of the residential gateway, the subsystems used in the home platform can communicate with the outside world. In the access platform, access to the internet and billing services are located and the service platform is both a multimedia and an open services platform.

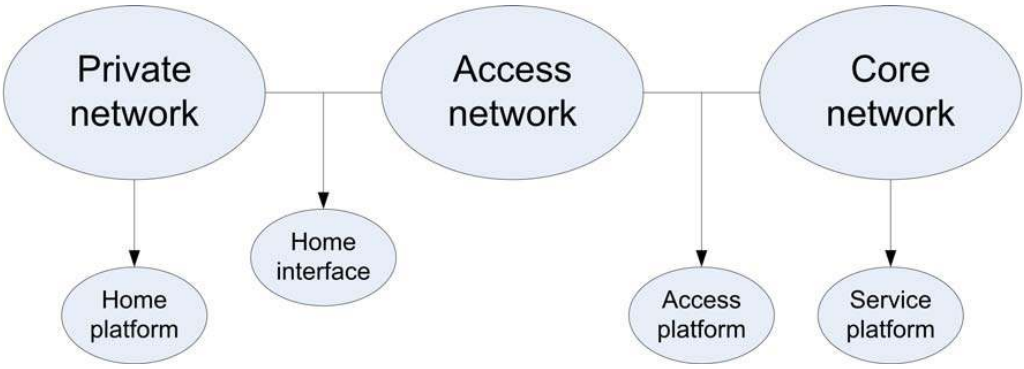

Figure 3-1: Architectural overview of the home system (as adapted from B@home)

3.2.2 Type of Standards Related to the Architecture of the System

In this study, we will primarily focus on compatibility standards since they are crucial for the connection of subsystems in a larger system (De Vries, 1998). We will define a compatibility standard as a codified specification defining the interrelations between entities (Garud and Kumaraswamy, 1993) in order to enable them to function together (De Vries, 1998). In our search, we will take into account both proprietary and open standards, but also understand that the existence of proprietary standards will not always be communicated, decreasing the number of proprietary standards that we find.

Standards are defined at different layers in the architecture of a system (Tanenbaum, 1996). Since home networking standards in practice provide partial or complete solutions for *application*, *communication* or *network* concepts, we will distinguish between application service standards, communication service standards and network service standards. Application service standards originate from the need to resolve the functional, communication and network requirements of one or more applications with independent distributed functions. These concepts specify a generic application model and application messaging process, the process for message communication and the solution(s) for networking that support the application, messaging and communication requirements. Often, these standards are referred to as "middleware". Communication service standards originate from the need to resolve the communication and network requirements in an application environment with unnamed distributed functions. These concepts specify a generic communication model and process to transport data between application processes and the solution(s) for networking that supports the communication requirements. Network service standards originate from the need to resolve the network requirements for the communication support for distributed functions, proposing a typical medium-dependent solution for the transport of certain volumes of data between several (independent) nodes (Den Hartog, Uythof and Groothuis, 2002).

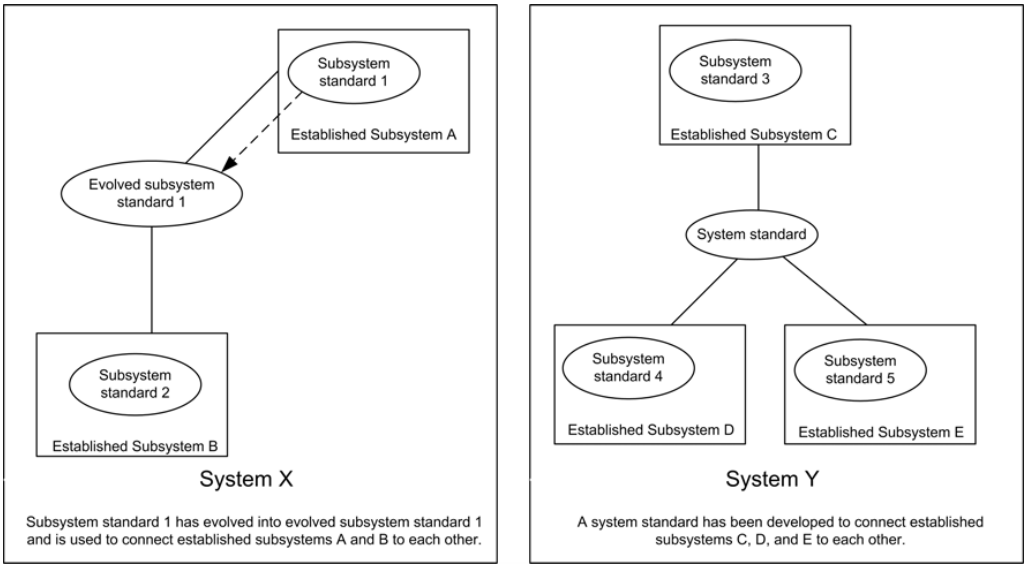

Figure 3-2: System, subsystem, and evolved subsystem standards

We make a distinction between the subsystem and system levels, since we focus on systems that (at least partly) consist of established subsystems. The established subsystems, located in the home platform in Figure 3-1, usually already apply standards which can *potentially* also be used for the connection between these subsystems. We call these *subsystem standards*. Examples include GSM and Coax. We will call the standards that are newly developed for the interconnection of the established subsystems *system standards*. These standards concern the private network. Examples include Konnex and Zigbee. A third category of standards are subsystem standards that were originally used for the interconnection in one subsystem but are now also used to connect these subsystems to other subsystems. We will call these standards *evolved subsystem standards*. Examples include USB and Wifi. In Figure 3-2, this is graphically illustrated. In system X, subsystem standard 1 has evolved into a system standard and now connects established subsystems A and B. Subsystem standard 2 could potentially also be used for the interconnection of established subsystems A and B. In system Y, a system standard connects the subsystems. To determine whether a standard can be categorised as being a subsystem or a system standard, we will look at the original purpose of the standard. When the standard was originally developed for home networking, it is categorised as a system standard. When it was originally developed for one particular subsystem within the home network it will be categorised as a subsystem standard.

3.3 Converging Worlds

The home network market consists of different product markets that are converging with each other. Each product market consists of its own technologies, subsystems, and standards. Standards that originate from one product market may potentially be used to realize communication in the complex system and must therefore also be taken into account in this analysis. This increases the total amount of standards even more. We will distinguish four basic product markets: computer (including hardware and software), consumer electronics, telecommunications, and home automation (Baker, Green, Einhorn and Moon, 2004; Den Hartog, Baken, Keyson, Kwaaitaal and Snijders, 2004).

The information technology product market is characterized by products that have a PC architecture and a generic (Intel, AMD, etc.) processor. There is a fair amount of standardization of communication protocols and accessories (storage, printers, etc.) but little standardization of operating systems and applications (since the market is arguably an oligopoly dominated by Microsoft with Apple and Linux as small players). The average product life cycle is three years, prices and margins are quite high.

The consumer electronics product market is characterized by products having a more specific architecture and processors (Philips, TI, NSC, etc.). Furthermore, there is little standardization of communication protocols but a fair amount of standardization of formats (CD, DVD, MP3, MPEG2, etc.). The consumer electronics product market has an average product life cycle of five to ten years (with the exception of the gaming console market); it is an open market with a high number of suppliers and low prices and margins.

The telecommunications product market is characterized by products having a specific architecture and processors that are delivered by an operator (where the consumer electronics product market and the information technology product market are more retail based). There is a fair amount of standardization of communication protocols and subsidized business models (margins are from subscriptions instead of retail prices). The average product life cycle is lower then three years and there exists a small open market (with few operators, of which one is dominating) and a couple of suppliers (such as Lucent, Alcatel, Ericsson, and Nokia)

The home automation product market is characterized by products with very low prices and margins, an open market with a lot of players (such as Honeywell, Schneider, etc), and little standardization of communication protocols. Product life cycles are longer than ten years.

These markets are converging with each other which results in a total of fifteen different categories of standards. We will call these standard types A, B, C, etc., so a Type A standard is a standard which originates from the information technology product market and a type K standard originates from a convergence of the consumer electronics, home automation and telecommunications product markets, see Figure 3-3.

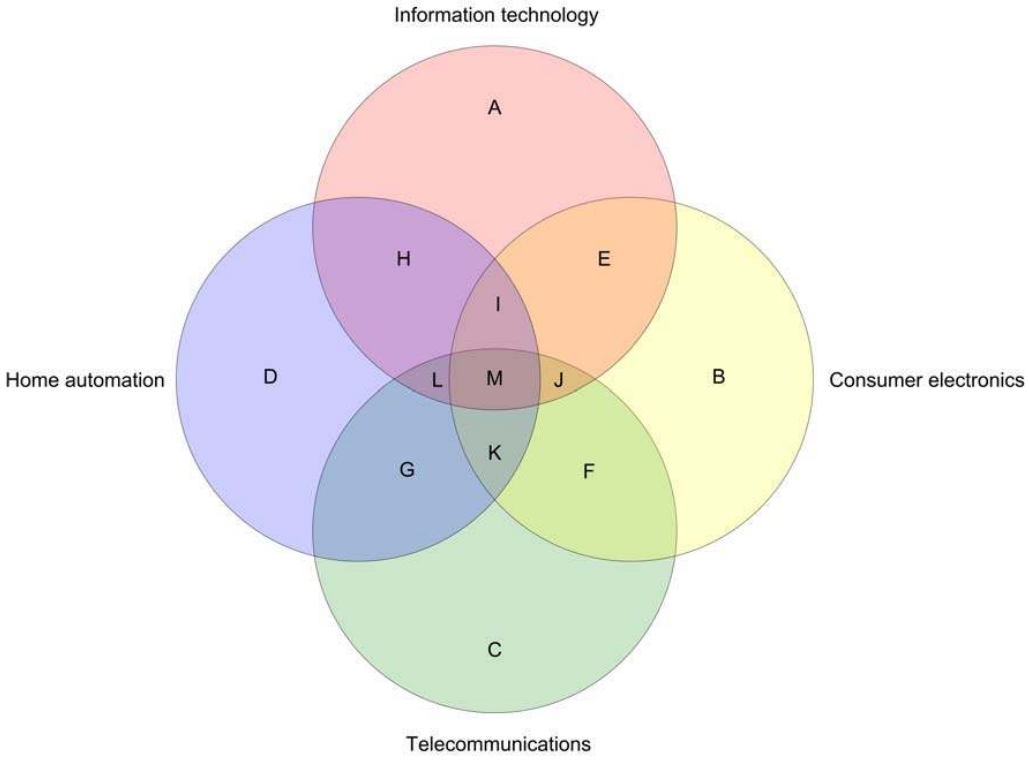

Figure 3-3: The different product markets in home networking

3.4 Classification of Standards

Trade associations and industrial consortia are developing and promoting their own standards. We will concentrate on the different product categories from Figure 3-3 to reach a complete overview of all the SOs involved. To identify these organizations, we have searched the internet using the terms “trade association”, “home network”, “home system”, “Alliance”, etc. Furthermore, we have discussed our list of organizations with several experts to ensure that the most important SOs were included. The resulting list of SOs is presented in Table 3-1, Table 3-2, and Table 3-3.

Table 3-1: Formal standards organizations

Formal standards organizations	Further information
European Committee for Electrotechnical Standardization (Cenelec)	http://www.cenelec.org/
European Committee for Standardization (CEN)	http://www.cen.eu/
European Telecommunication Standards Institute	http://www.etsi.org/
International Electrotechnical Commission (IEC)	http://www.iec.ch/
International Organization for Standardization (ISO)	http://www.iso.org/
International Telecommunications Union (ITU)	http://www.itu.int/

Table 3-2: Other standards organizations (1)

Standard setting organization	Further information
10 Gigabit Ethernet Alliance	http://www.10gea.org/
1394 Trade Association	http://www.1394ta.org/
American Society of Heating, Refrigerating and Air-Conditioning Engineers	http://www.ashra.org/
ARCNET Trade Association	http://www.arcnet.com/
Association of Home Appliance Manufacturers	http:/www.aham.org/
ATM Forum	http://www.atmforum.com
BatiBUS Club International	http://www.batibus.com
Bluetooth Special Interest Group (SIG)	http://www.bluetooth.com/Bluetooth/SIG/
Broadband services forum	http:/www.broadbandservicesforum.org/
Cable Television Laboratories, Inc. (CableLabs)	http:/www.cablelabs.com/
CE Powerline Communication Alliance	http://www.cepca.org
CEBus Industry Council (CIC)	http://www.cebus.org/
COBA Project	http://www.consortiuminfo.org/
Consumer Electronics Association	http://www.ce.org/
DECT forum	http://www.dect.org/
Digital Display Working Group	http://www.ddwg.org/
Digital Living Network Alliance	http://www.dlna.org/
DSL forum	http:/www.dslforum.org/
Easyplug	http://www.easyplug.com
Echonet Consortium	http://www.consortiuminfo.org/
ECMA International	http://www.ecma-international.org/
Electronics Industry Association of Japan (EIAJ)	http://www.jeita.or.jp/eiaj/english/
EHS Association	http://www.ehsa.com/
EIB Association	http://www.eiba.com/
Electronic Industries Alliance	
Enhanced Wireless Consortium	http://www.enhancedwirelessconsortium.org/
Ethernet User Alliance	http://www.consortiuminfo.org/
European Home Systems Association	http://www.consortiuminfo.org/
Extent The Internet Alliance	http://www.consortiuminfo.org/
Fiber To The Home Council	http://www.ftthcouncil.org/
Frame Relay Forum	http://www.frforum.com/
HAVi Consortium	http://www.havi.org/
High-Definition Audio-Video Network Alliance	http://www.hanaalliance.org
HiperLAN2 Global Forum	http://www.consortiuminfo.org/
Home automation association	http://www.homeautomation.org/
HomeAPI WorkGroup	http://www.consortiuminfo.org/
Home Cable Network Alliance	http://www.consortiuminfo.org/
Home Gateway Initiatve (HGI)	http://www.consortiuminfo.org/

Table 3-3: Other standards organizations (2)

Home Phoneline Networking Alliance (HomePNA)	http://www.homepna.org/
Home Plug and Play task force	
HomePlug Powerline Alliance	http://www.homeplug.org/
HomeRF workgroup	http://www.consortiuminfo.org/
Infra-red Data Association	http://www.irda.org/
Institute of Electrical and Electronics Engineers (IEEE)	http://www.ieee.org/
Internet Engineering Taskforce	http://www.ietf.org/
IPV6 forum	http://www.ipv6forum.com/
Konnex Association	http://www.konnex.org/
Lonmark Interoperability Association	http://www.consortiuminfo.org/
MFA / IPMPLS forum	
MPLS and Frame Relay Alliance	http://www.mplsforum.org/
Multiband OFDM Alliance (MBOA)	http://www.multibandofdm.org/
Multimedia over Coax Alliance	
Multi Protocol Label Switching Forum	http://www.mplsforum.org/
OFDM-forum	http://www.ofdm-forum.com
OPC Foundation	http://www.opcfoundation.org/
Object Management Group	http://www.omg.org/
Open PLC European Research Alliance	
OSGi Alliance	http://www.osgi.org/
PLC Forum	http://www.plcforum.org
Power Line Communications Association	http://www.plca.net
Salutation Consortium	http://www.consortiuminfo.org/
Security Industry Association	http://www.siaonline.org/
Telecommunications Industry Association	http://www.tiaonline.org
Wireless LAN Trade Association	http://www.wlana.org/
Universal Home API	http://www.uhapi.org/
Universal Plug And Play Forum	http://www.upnp.org/
Universal Powerline Association	http://www.upaplc.org/
USB Implementers Forum (USB-IF)	http://www.usb.org/about/
UWB Forum	http://www.uwbforum.org/
Video Electronics Standards Association (VESA)	http://www.vesa.org/
WIFI Alliance	http://www.wi-fi.org/
WIMAX forum	http://www.wimaxforum.org/
WiMedia Alliance	http://www.wimedia.org/
Wireless Ethernet Compatibility Alliance (WECA)	http://www.consortiuminfo.org/
Wireless LAN Interoperability Forum	http://www.wlif.org/
Wireless USB Promoter Group	
World Wide Web Consortium (W3C)	http://www.w3.org
ZigBee Alliance	http://www.zigbee.org/

To reach a complete list of standards, we have analyzed standards that have been developed and/or are being promoted by the SOs mentioned in Table 3-2 and Table 3-3. In this analysis, we take into account all four product markets mentioned in Figure 3-3. It might be that standards for home networking have not been developed in one of the four product markets which we analyze. To overcome this problem, we have searched the complete list of standards developed by each SO for the terms “home network”, “home system”, etc. We then filtered out all standards that are not compatibility standards. An expert in the area of home networking

standards chose the most important formal home networking standards (developed by the SOs mentioned in Table 3-1) to be included in the study. This resulted in a list of sixty-four sets of standards that might be used for home networking. Each set consists of one or more standards. In the latter case, the set defines a complete architecture specified in different standards. This list can still be further filtered with respect to the relevance of each standard as a home networking standard. Not all standards are equally relevant. The completeness of the list also depends on whether the standards are publically available on the websites analyzed.

We have categorized the sixty-four sets of standards using the classification developed in Section 3.2 by interviewing several experts in the field of home networking. The results are presented in Table 3-4. For twelve categories, more than one standard exists.

Table 3-4: Classification of standards for home networking

	Application supporting			Communication service			Network infrastructure		
	Subsystem standards	**Evolved subsystem standards**	**System standards**	**Subsystem standards**	**Evolved subsystem standards**	**System standards**	**Subsystem standards**	**Evolved subsystem standards**	**System standards**
A			EMIT				TCP/IP IPv4 XML HTTP Token Ring Token Bus XTP	Ethernet USB Passport WIFI	IPv6 Smart House JINI
B							HAVi AHAM COAX	SCART	
C							GSM GPRS UMTS SSERQ	DECT ISDN Norm88	EIA 570-A
D			KONNEX EHS HES COBA			LonTalk BatiBUS EIB BACnet			X10 Metasys DALI Echonet Spanningsnet
E			UPnP					FireWire HomeCNA	VESA
F									
G									
H			Salutation				IrDA		Zigbee
I						HBS			
J								UWB Fiber Homegateway	Homeplug Powerpacket CableHome
K									
L	HomeGate		OSGi						
M									
N			HiperLAN2					Bluetooth	ATM HomeRF HomePNA IEEE 802.15.3 Corba
O									CEBUS

3.5 Conclusion

In this study, we have applied a step-by-step approach for the identification of standards for home networking. Furthermore, we have developed a classification and we have used this classification to categorize sixty-four (sets of) standards (see Table 3-4). In Figure 3-4, we summarize the standards according to the product market for which they apply. Type N standards define communication for products in both the information technology and telecommunications product markets (such as IP telephony) and type O standards define communication for products in both the home automation and consumer electronics product markets.

It can be concluded that the convergence of home networking standards is only apparent among the product categories of information technology, consumer electronics and telecommunications. Home automation still lags behind. Perhaps the reason for this could lie in the fact that companies active in home automation are mostly small and lack the financial resources for inter industry collaborations. Furthermore, convergence has not resulted in Class M standards yet. A possible explanation for this could lie in the possibility that the actors that promote the standards are primarily interested in keeping their market position in the product market from which they originate. Their secondary objective is to reach dominance in the converging areas of Figure 3-4. Therefore, we surmise that they generally prefer to cooperate with actors within the product market from which they originate than with actors from product markets with which they converge. Furthermore, *if* actors do cooperate across product markets, the primary reason for this cooperation is to keep competitors away from their product market, rather than to work together to try to establish a class M standard. Although this strategy is acceptable in the short run, it is questionable whether it is of value in the long run given that product markets continue to converge over time. A clear recommendation to actors in the home networking industry would be to cooperate across product markets. A recommendation for further research would be to investigate the effects of cooperation across product markets on the chances that home networking standards reach dominance.

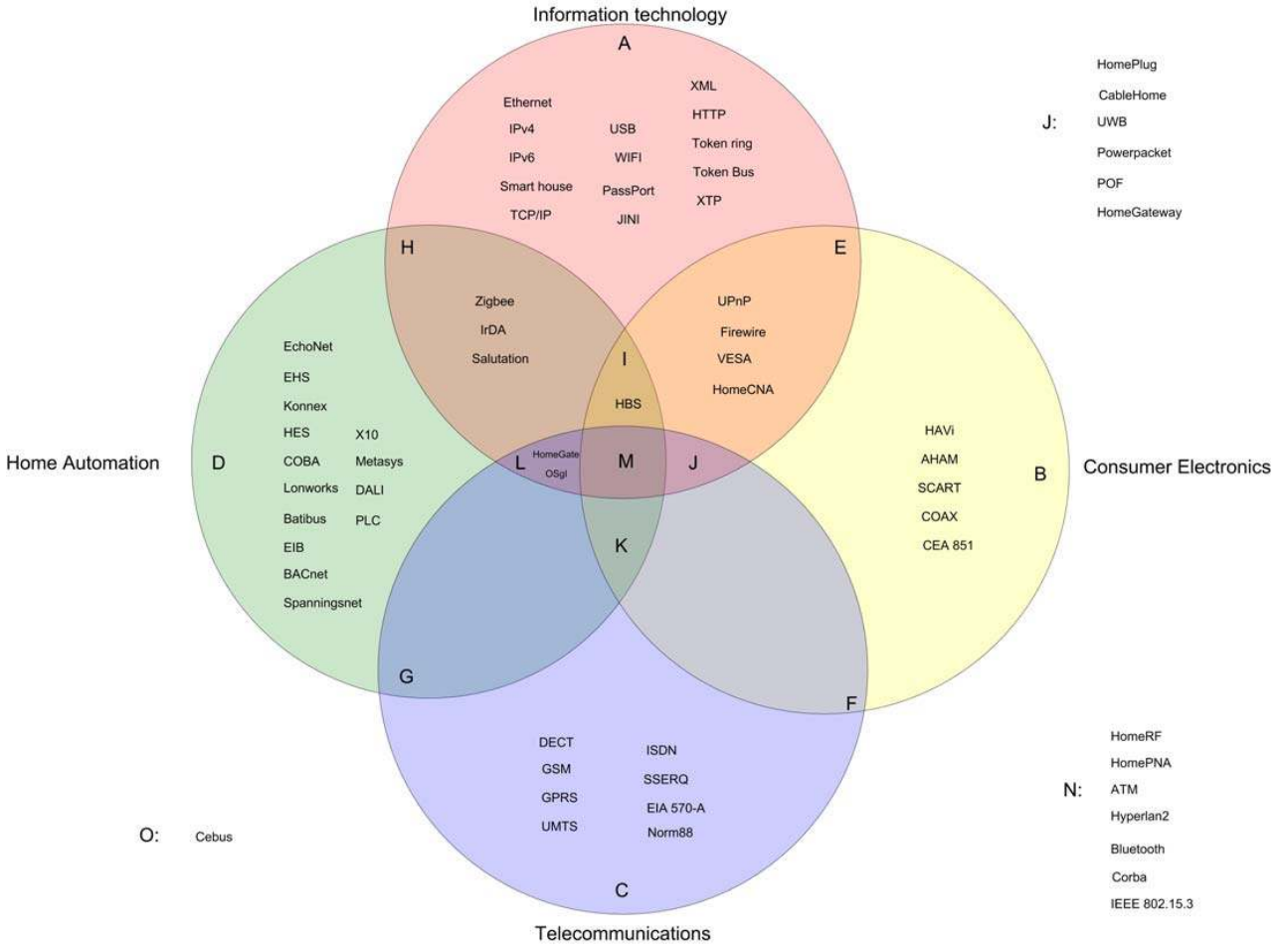

Figure 3-4: Standards originating from different converging product markets

We conclude that by developing a categorization and using it to classify home networking standards we have brought at least a certain amount of order to chaos. However, some problems still remain. For instance, we have found a total of 6,568 formal standards. Furthermore, we know that many more standards exist, but it is more difficult to trace these because they have no common 'address' and in some cases they are not publicly available. This opacity adds to the complexity of the situation and makes it difficult for manufacturers to decide which standards to implement in their products.

Also, in Table 3-4 we presented sixty-four (sets of) standards and we came to the conclusion that not one of them has become dominant yet. This not only illustrates the problem in home networking, but also says something about the remaining formal standards that have not been taken into account. We assume that in these standards the same problems occur.

Some of the 64 (sets of) standards have turned out to be unsuccessful in the market, whereas others have achieved market acceptance, at least to a certain extent. However, none of the standards have become dominant home networking standards illustrating the problem in home networking. It would be interesting to study which factors affect the chances that standards will become dominant in the home networking industry. This could be an interesting topic for further research.

4 FACTORS FOR STANDARD DOMINANCE: A COMPARATIVE CASE STUDY

Abstract

This study[6], investigates factors affecting the adoption of compatibility standards. We begin with an exploration of the literature to develop a framework that helps to explain the outcome of standards battles. We explore the completeness of the framework and the relevance of the factors in the framework by confronting it with empirical data. We did not find new factors and the framework thus appears to be complete. Two factors that were not mentioned in prior frameworks were important in two of the three standards battles that we studied. This signifies that our framework appears to explain the three standards battles that we studied better when compared to existing frameworks in the literature. However, some factors appear to be less relevant. Companies can use this framework to gain more insight into current standards battles in which they participate.

4.1 Introduction

Why has QWERTY become the dominant keyboard layout standard and not DVORAK? Why did VHS win the video standards battle and Blu-ray defeat HD-DVD? Which flat screen television technology will we use in the future, plasma or LCD? Battles between standards emerge time and again. For firms, consumers and other parties involved, it is important to have insights regarding the chance that a specific standard will become dominant since betting on the standard that turns out to be unsuccessful can result in high losses and can even affect the survival of the firms involved (Shapiro and Varian, 1999a).

Several studies (Cusumano, Mylonadis and Rosenbloom, 1992; David, 1985; Rosenbloom and Cusumano, 1987) have analyzed these battles in depth and have proposed factors that explain their outcome (Lee, O'Neal, Pruett and Thoams, 1995; Schilling, 1998; Suarez, 2004). However, in most of these studies, the focus lies on a subset of the total set of possible factors for standard dominance (Schilling, 2002). Moreover, most of this literature lacks empirical evidence for the factors that contribute to standards dominance, while the small number of empirical studies investigate just a few factors. In this study, we take a more comprehensive approach. In previous research, we conducted an extensive literature study resulting in a framework for standard dominance consisting of as many factors as possible. The objective of this study is to explore the completeness

[6] This chapter is based on Van de Kaa, G., De Vries, H. J. and Van den Ende, J. 2008. Factors for standard dominance: a comparative case study. Paper presented at the *15th International Product Development Management Conference*, Hamburg, Germany.

of the framework and the relevance of the factors in the framework by confronting it with empirical data. Therefore, we studied three cases in depth (Eisenhardt, 1989; Yin, 2003). This may result in new factors that have not been mentioned in the literature previously. Also, we explore the relevance of those factors in the framework that have never been studied empirically before. In this way, our work aims to add to the growing body of literature focusing on dominant designs and standardization, so building on the findings of Suarez (2004) and Schilling (1998; 2002).

Our study focuses on compatibility standards, which we will define as codified specifications defining the interrelations between entities in order to enable them to function together (combining De Vries, 1999; Garud and Kumaraswamy, 1993). A standard can be called dominant when it achieves more than 50% market share among new buyers (Suarez, 2004) in a certain product or service category for a significant amount of time (Lee, O'Neal, Pruett and Thoams, 1995). We concentrate on the period beginning with the first standard being released until one of the standards has become dominant, i.e., the *era of ferment* (Anderson and Tushman, 1990).

We begin by exploring several theoretical perspectives on standard dominance in Section 4.2, leading to a framework with five categories of factors. Subsequently, in Section 4.3, we present the results of a previous systematic search of the literature for factors that belong to each category identified in Section 4.2. In Section 4.4, we discuss how we have methodologically conducted the study. In Section 4.5, we present the results from three case studies and in Section 4.6, we discuss our findings. In Section 4.7, we present our conclusions.

4.2 Theoretical perspectives of standard dominance

The dynamics in industries that lead to dominant designs and standards have been studied from multiple perspectives. Traditionally, scholars in the field of industrial economics have studied the role of innovation in the dynamics of industries (Gort and Klepper, 1982). These scholars focus on the environment in which technologies compete and offer, for instance, demand-based explanations for the emergence of dominant standards (Adner, 2002). They developed a three stage life-cycle model of technology according to which in a new industry at the end of the first, 'fluid' phase a dominant design or standard emerges that remains stable over time (Abernathy and Utterback, 1978; Utterback, 1994). In terms of this model, we focus on the first stage. Within the industrial economics field, a separate stream of literature focuses on network economics. Network economists have emphasized the importance of market characteristics, particularly the existence of so-called network externalities, where the value of a particular standard for the individual user increases as more people

use that standard (Arthur, 1996; Katz and Shapiro, 1985). Users, producers and other stakeholders follow each other in their technology choices because of information advantages, scale effects, and the availability of complementary goods (Van den Ende and Wijnberg, 2003). As a consequence of such bandwagoning behaviour, people get locked into a standard (Katz and Shapiro, 1985; Shapiro and Varian, 1999b; Shy, 2001), unless switching costs are very low (Shy, 2001). From the network economics literature, we learn that there exist specific *market characteristics* that affect standard dominance and lock-in which can hardly be influenced by individual firms.

Other scholars analyze the topic using institutional theories and focus on how individual firms can increase the possibility that their technology will become dominant (Cusumano, Mylonadis and Rosenbloom, 1992). A firm can try to strategically position its technology so that it will become dominant. Suarez (Suarez, 2004) stresses the importance of strategic manoeuvring in the first stage of the battle for dominance. A strategy can be followed which helps firms to promote their own technology and at the same time prevents the adoption of competing technologies. In the video gaming industry for instance, marketing strategies in the form of pre-announcements play an important role. For instance, the Nintendo 64 system was announced more than two years before it actually became available (Gallagher and Park, 2002). Also, a firm's appropriability strategy can influence standard adoption. In the US microprocessor industry, complex instruction set computers (CISCs), which dominated the computer workstation industry were being replaced by reduced instruction set computers (RISCs). RISC technology was licensed, while CISC was not (Khazam and Mowery, 1994). Also, Sun's open systems strategy led to the success of Java (Garud, Jain and Kumaraswamy, 2002). Willard and Cooper (1985) examined the influence of several strategic variables on survival in the TV industry and found that strategic factors such as pricing and distribution strategy influence market dominance, provided these are matched with the firm's resources and are effectively implemented. The firm's resources include its size and financial strength, for instance. We distinguish two categories of firm-level factors based on the institutional economics literature: *characteristics of the standard supporter* and *standard support strategy*.

Although not explicitly mentioned in any particular literature stream, several studies in different areas (including standardization, technology management, and institutional economics) mention the influence of other stakeholders in the standards battle. Often, stakeholders other than the group of standard supporters have an influence on which standard will become dominant. Therefore, we add a fifth category: *other stakeholders*. We adopt the broad definition of stakeholders proposed by Freeman and Reed (1983) as being those actors who *"can affect the achievement of an organization's objectives or who are affected by the achievement of an*

organization's objectives". These stakeholders include competitors, standards committees, testers and certifiers, (alliances of) implementers, users of the standard, and regulatory agencies.

Scholars in the field of technology management have developed several frameworks of standard dominance, integrating concepts from both industrial and institutional economics (Lee, O'Neal, Pruett and Thoams, 1995; Schilling, 1998; Suarez, 2004). Suarez (Suarez, 2004) distinguishes between firm-level factors and environmental factors, both of which have a direct influence on standard dominance. Environmental factors also moderate the influence of some firm-level factors. We build on the framework of Suarez and distinguish between factors that can be influenced by the group of standard supporters and factors that are given in specific industries and can hardly be influenced. Thus, the environmental factors in our framework do not directly influence the chance that one particular standard achieves dominance. We extend the framework developed by Suarez by not only focusing on the individual firm but also on other standard supporters (which can be groups of firms united in, for example, standards consortia or standardization alliances). In our framework, the environmental factors are the market characteristics. These factors affect the magnitude of the effect of the firm-level factors on standard dominance. For example, in an industry characterized by network externalities, an actor developing a technology for which complementary goods do not exist will have a low chance of achieving dominance with that technology (Schilling, 1998). Apart from strengthening or weakening the effect of firm-level factors on standard dominance, the market characteristics have an effect on the speed and likelihood of standard dominance. *Characteristics of the standard supporter*, *standard support strategy*, and *other stakeholders* are categories that contain firm-level factors. In line with the technology management literature, we add the category *characteristics of the standard*, encompassing compatibility of the standard, the availability of complementary goods and technical characteristics.

4.3 Factors for standard dominance

In Chapter 2, we conducted an extensive literature review with the objective of reaching a complete framework of factors for standard dominance. In that analysis, our starting point was a review paper of the literature; Suarez (2004). We derived the relevant factors from this article and arranged them in a list. From the initial article, we moved to the publications quoted by the author (backward search) and looked for factors mentioned in those publications. We also carried out a forward search: publications that have quoted the article. The process was then repeated for these publications until no new factors were found. For every new publication that we analyzed we tried to look for factors that were not mentioned before and included them in the list. Based

on similarities, we grouped the factors into five categories according to the classification presented in the previous section, resulting in a framework for standard dominance. For every reviewed publication, we also analyzed whether the effect of the factor on standard dominance is positive or negative. In that analysis, we also came to the realization that some factors such as "pre-emption of scarce assets" have not been studied empirically yet. Other factors such as timing of entry appear to result in contradictory findings. Some studies suggest that it is better to enter early, while others suggest the opposite. In Table 4-1, the twenty-nine factors are presented and defined. In the third column of Table 4-1, we present the direction of the effect of each factor on standard dominance. In the last three columns of Table 4-1, we compare our framework with three prior frameworks for standard dominance. It appears that our framework is more complete.

Table 4-1: Factors explained

				Factors mentioned in prior frameworks		
		Description	Effect	Lee (1995)	Schilling (1998)	Suarez (2004)
Characteristics of the standard supporter						
1	Financial strength	Current and future financial condition of the group of standard supporters (based on Willard and Cooper, 1985).	+			X
2	Brand reputation and credibility	The opinion that people have about a group of standard supporters, based on what has happened in the past (based on Hornby, 2000).	+		X	X
3	Operational supremacy	The characteristics of the group of standard supporters that make them better able to exploit resources then competitors (based on Schilling, 2002).	+	X		X
4	Learning orientation	The extent to which the group of standard supporters expand their knowledge and skills base and improve their ability to assimilate and utilize future information (based on Schilling, 1998).	+	X	X	X
Characteristics of the standard						
5	Technological superiority	A standard is technologically superior when it has superior features that make the standard outperform other standards (Schumpeter, 1934).	+	X	X	X
6	Compatibility	Compatibility concerns the fitting of interrelated entities with each other in order to enable them to function together (De Vries, 1999).	+	X		X
7	Complementary goods	Those "other" goods needed to successfully commercialize a certain standard (Teece, 1986).	+		X	X
8	Flexibility	The extent to which the standard can be changed to suit new conditions or situations (Hornby, 2000).	+			
Standard support strategy						
9	Pricing strategy	The technique of offering low prices to early customers so as to build up an installed base and influence the choices of later adopters (Besen and Farrell, 1994).	-		X	X
10	Appropriability strategy	All actions that are undertaken by firms to protect a standard from imitation by competitors (Lee, O'Neal, Pruett and Thoams, 1995).	-	X	X	X
11	Timing of entry	The point in time at which the standard is introduced in the market (based on Suarez, 2004).	∩	X	X	X
12	Marketing communications	All actions taken to influence customer expectations (based on Suarez, 2004).	+	X	X	X
13	Pre-emption of scarce assets	The extent to which the actor is able to gain advantage by controlling assets before another actor can control them (based on Lieberman and Montgomery, 1988).	+	X	X	
14	Distribution strategy	The extent to which a firm pursues a strategy which increases the strength of its distribution system (based on Willard and Cooper, 1985).	+	X		
15	Commitment	Obligation or pledge to carry out some action or policy or to give support to some policy or person (Webster, 2000). A standard has a higher change of achieving dominance when it is supported by an actor that is committed to the standard.	+			

Other stakeholders						
16	Current installed base	Collection of users of a certain standard (De Vries, 1999).	+		X	X
17	Previous installed base	Users that might upgrade to the new standard (Farrell and Saloner, 1986).	+			
18	Big fish	A player that can exercise a lot of influence by either promoting or financially supporting a standard or by exercising buying power that is so great that it contributes strongly to the market position of the standard (Suarez and Utterback, 1995).	+	X	X	X
19	Regulator	The actor that can prescribe a certain standard in the market (Suarez and Utterback, 1995).	+	X	X	X
20	Judiciary	The judges of a country or state when they are considered as a group (Hornby, 2000) which can prohibit certain standards from becoming dominant for reasons of anti-trust policy.	-		X	
21	Suppliers	Companies that produce complementary goods or services (Teece, 1986).	+			X
22	Effectiveness of the standard development process	The group of standard developers participating in the (further) development of the standard affects that process (for instance, in terms of duration). This supports the potential of the standard becoming dominant (Lehr, 1992)	+			
23	Diversity of the network	The extent to which relevant stakeholders are represented in the group of standard supporters. A standard that is supported by a diverse network in which stakeholders represent each relevant product market for which the standard serves a defining role will have a higher chance of achieving dominance (Gomes-Casseras, 1994; Keil, 2002).	+			
Market characteristics						
24	Bandwagon effect	The effect that the adoption of a specific technology by a set of users stimulates other users to adopt this technology (Farrell and Saloner, 1986).	+			
25	Network externalities	Network externalities occur when the utility of consumption of a good increases with the number of other agents consuming the good (Katz and Shapiro, 1985). According to Gallagher (2007) network effects apply to all compatibility standards. It is one of the causes of bandwagon effects.	+	X	X	X
26	Number of options available	The more competing standards exist in the market, the lower the chance for one of them to become dominant (Tripsas, 1997) and thus the lower the likelihood that one of these standards achieves dominance.	-	X		
27	Uncertainty in the market	The extent to which firms and customers are unwilling to take the risks attached to choosing for one particular standard and will postpone their decision (Jakobs, 2006; Leiponen, 2006; Schmidt and Werle, 1998).	-			
28	Rate of change	The speed of evolution within a specific industry both with respect to the technology and the market (Suarez and Lanzolla, 2005). When it is high, this will have a negative effect on the emergence of a dominant standard (Smit and Pistorius, 1998)	-	X	X	
29	Switching costs	Costs required to switch from one standard to another (Suarez, 2004). The higher these costs are, the more reluctant a company will find its potential clientele to switch from the competitors standard to theirs, and the more “loyal” is its own customer base. The higher these costs, the longer it takes before a standard becomes dominant.	-	X		X

4.4 Methodology

In order to explore the completeness of the framework presented in Table 4-1 and the relevance of the factors, we studied three cases of historical standards battles in depth. The unit of analysis was the standard that was vying for dominance. In order to get the opportunity to take a look behind the scenes of standards battles, we established cooperation with a company involved in many of these battles: Philips. Philips' Intellectual Property and Standards Department gave us access to relevant documents of cases this company has been involved in, as well as access to key informants within and outside Philips. In return, the company was given access to the results of this study. We created a list of candidate case studies and, together with the company, chose three case studies from that list by following three selection criteria. First, the standards battles should consist of standards that are comparable with respect to their function in terms of the interoperability that the standards enable (De Vries, 1998). Second, in the battles, dominance of one standard should have been reached (i.e., we made sure that the case studies were truly historical). Third, information at Philips should be available. The selected cases concerned the battle for wired connectivity in the home in which USB and Firewire competed; the battle for wireless connectivity in the home in which DECTPRS, HomeRF, and WiFi competed; and the battle for a multi-channel sound standard in which MPEG-2 audio and AC-3 competed. These battles were fought in the information technology (IT) industry, the home automation industry and the consumer electronics (CE) industry respectively. The home automation industry can be considered as an industry that is a result of the convergence of different industries including the IT and the CE industries.

For each standards battle, we gathered secondary data by analyzing the press releases of the companies involved, as well as examining several online news archives including Factiva and Lexis-Nexis. Primary data was collected through face-to-face, semi-structured interviews with key persons in the standards battles (the questionnaire used is included in Appendix 9.2). We made sure that for each standard that competed in each standards battle, we interviewed at least one expert that was involved in the development and/or promotion of the standard. Furthermore, for each battle, at least one expert was interviewed that studied the standards battle closely but was not involved in the development or promotion of one of the competing standards (that expert can be considered to be an 'outsider' in the battle). The majority of the interviews were conducted face-to-face. Each interviewee was also asked to provide secondary sources in the form of reports, presentations, news articles, etc., which were analyzed and resulted in a reconstruction of the cases.

Each interview began with an open question in which we asked the respondents to describe, in chronological order, the most important events in the standards battle. The respondent then would mention several factors already, explicitly or implicitly. In subsequent questions, we asked the interviewees more directly which factors played a role in the battle and what were, according to them, the success or fail factors of the standard. We asked whether they followed a particular standard supporting strategy and we asked them to evaluate that strategy. We also asked why the competing standard had either won or lost the battle. At the end of the interview, we asked for every factor that had not been mentioned previously how that factor could have affected the outcome of the battle. Furthermore, to ensure consistency and reliability, interview guidelines were used for all interviews. We did not send the interview questions to the respondents before the interviews took place so that the respondents did not know beforehand what factors we would be focussing on. This, together with the fact that we asked open ended questions, allowed for the generation of factors that we had not included in our framework. All interviews were tape recorded, and transcribed before the data was analyzed. In each interview, we determined whether factors were implicitly or explicitly mentioned and if so, what their value was (high, low, etc.). The results of each interview were processed and communicated to the interviewee for a consistency check.

In the case of the battle for a wired standard for the home, we interviewed four respondents; in the case of the battle for a wireless standard for the home we interviewed six respondents; and in the case of the battle for a multi-channel sound standard we interviewed five respondents. For privacy reasons, we do not provide the names of these persons. In Appendix 9.3, we present each interviewee's function and the type of involvement they had in the development and/or promotion of the standard.

To assess whether a particular factor played a role in the outcome of a standards battle and, if so, to determine its role, we also analyzed the documents provided by each respondent and we analyzed the news from the news archives that we have scanned for evidence pointing to particular factors playing a role. Then we compared these findings with the findings from the interviews. We triangulated evidence obtained from each of the three sources of data. Using this information, we could determine the factors that played a role and how they played that role. These results were communicated to the interviewees for verification.

4.5 Results

In this section, we will describe the case studies in depth. Each case study will begin with a short chronological description of the standards battle and continue with a within-case analysis. In this analysis, we

will explain the outcome of each battle in terms of the factors in our framework. Finally, we will perform a cross-case analysis.

4.5.1 Case study 1: USB vs Firewire

1) Case description: With the emergence of different peripheral computer devices in the 1990s, there was a need to connect these devices to each other. At the end of the 1980s, Apple started to develop the Firewire standard, which specifies a connector that can be used to reliably communicate data requiring a high bandwidth capacity. It can be used to connect CE devices to personal computers. In the mid 1990s, the Universal Serial Bus (USB) standard was developed by DEC and Intel, which specifies a connector which can be used to communicate data that requires a low bandwidth capacity. This standard can be used to connect different peripheral devices such as a keyboard to a personal computer. In 1995, both Firewire and USB (version 1.0) were introduced into the market. The two standards not only differed with respect to the amount of bandwidth capacity, but also with respect to compatibility. Because the Internet was still in its infancy and the promoters of Firewire did not perceive it to become important, they decided that there was no need to let the Firewire standard support the Internet Protocol.

In 1997, a new CEO was appointed at Apple and, arguing that other standards had similar patent fees, he made the decision to ask for a 1 dollar patent fee for Firewire. At that time, the firms that supported the Firewire standard had to pay for the patents held by Apple. This led some firms to opt for the USB standard. In 1998, Apple's iMAC computer was introduced. The iMAC had two USB ports and no Firewire ports. From that moment on, many more complementary goods were introduced which could only be connected through the USB standard. In 2000, a new generation of the USB standard (version 2.0) was introduced. This standard enabled a higher bandwidth capacity than the earlier version, which made it a direct competitor to the Firewire standard. In this period, meetings were held between representatives of the CE industry and the IT industry to try to agree on one universal standard which could be used in both industries. This led to complications between business units within a number of CE companies (Sony, Toshiba and Panasonic) because these companies also produced computers and computer parts. Thus, internally there was a difference with respect to commitment for one or the other standard. The universal standard was never reached because actors in both industries wanted to position their products at the centre of the home network. As one respondent noted: "*the vision of Microsoft was that the personal computer would be the centre of the home network, and that CE products (for example cameras, televisions, video, DVD, and others) could be connected to the personal computer.*" Representatives of the CE

industry wanted CE products to be central and for IT products to play a peripheral role. Thus, the battle between the two standards, USB and Firewire, is essentially also a battle between two industries. One respondent noted: "*Intel wanted to take the initiative for a universal standard so that everyone knew that the standard originated from the IT industry and not from the CE industry*".

Eventually, USB became the dominant standard for the connection of peripheral devices to the personal computer, whereas Firewire was used in a niche market for the communication from between video cameras, computers and televisions.

2) Case analysis: The battle between USB and Firewire is basically a battle between the CE industry and the IT industry. If the promoter of one standard can gather enough actors (from both industries) to support its standard, it can become dominant in the end. The fact that USB was developed by firms that were active in the IT industry made those firms active in the CE industry reluctant to choose the USB standard since they were afraid that this would result in a more central position for IT in the home. That is one of the reasons why the firms that were active in the CE industry choose to support the Firewire standard over the USB standard. In fact, even when the actors supporting Firewire knew that USB would become the dominant standard, they did not support the standard because they were afraid that this could mean that this standard would become dominant in their industry (CE) as well. Microsoft also wanted the PC to become the centre of the home network and therefore it needed a standard that was developed by firms that were active in the IT industry (USB).

In the CE industry, a lot of different manufacturers exist that have comparable levels of market power, whereas in the IT industry the power is in the hands of just a couple of big firms (such as Intel and Microsoft). This has an effect on the battle since when one of these actors chooses a particular standard then the other players have to follow to survive. Since Intel and Microsoft both chose to support the USB standard for communication between peripheral devices and PCs, small players developing peripheral devices had no choice but to also support the USB standard. After the first introduction of the standards, both the USB standard and the Firewire standard continued to evolve. In that respect, the USB standard was more flexible since a smaller amount of firms had to come to an agreement concerning any changes to be made as compared to Firewire.

Comparing the two standards with respect to their technological capabilities, we notice a couple of differences. One important technological characteristic of Firewire was that it was more reliable and could handle content with a high bandwidth capacity. This is an important reason why firms that were active in the CE industry choose to support Firewire instead of USB since to realize communication between their products, a high bandwidth capacity was needed and the connection had to be reliable. However, to realize bandwidth

capacity a high amount of energy was required which considerably increased the weight of the products in which Firewire was incorporated. This led to a decrease in the amount of complementary goods that supported Firewire (such as laptops, keyboards, etc.) for they would become too heavy if they incorporated Firewire. Besides, at the time of the introduction of Firewire, the infrastructure outside the home was not yet ready to support a standard with a high bandwidth capacity. In that respect, Firewire was introduced too early to the market.

Apple was the main promoter of Firewire but still introduced products that supported the competing USB standard. Presumably, Apple was not highly committed to the success of Firewire. An explanation for this lack of commitment lies in the fact that for the USB standard there were far more complementary goods available than for the Firewire standard. Therefore, Apple's iMAC computer supported USB since in order to become successful it needed to be compatible with as many peripheral devices as possible. Also, the promoters of the Firewire standard underestimated the role that the Internet would play in the future and they decided that it was not necessary to make the Firewire standard compatible with the Internet Protocol. As a result, most firms active in the IT industry chose to support the USB standard because that standard supported the Internet Protocol. Still, some large companies (such as Sony) supported Firewire. This soon changed however, because Apple changed to a more strict appropriability strategy, which led Sony to choose to support USB instead of Firewire. Sony had a high reputation and therefore a lot of firms chose to follow Sony and supported USB. With both Sony and Intel supporting the USB standard, the network of that standard consisted of representatives from both the CE and IT industries, which was one important factor contributing to its success. Table 4-2 provides a characterization of this standards battle using the factors mentioned in Section 4.3. In the first column, we mention each factor explained in Section 4.3 and in the second and third columns we present the standards that vied for dominance. With S we refer to success and with F we refer to failure. Thus, in terms of standard dominance, USB was a success and Firewire was a failure. Whenever a factor did not play a role in the success or failure of a standard, we leave that space in the table blank.

Table 4-2: Factors found in case study 1

	Factor	Case study 1		Explanation
		USB (S)	Firewire (F)	
Characteristics of the standard supporter				
2	Brand reputation and credibility	High		Sony had a high reputation and therefore a lot of firms chose to follow Sony and supported USB.
Characteristics of the standard				
5	Technological superiority	Low	High	Firewire was more reliable and could handle content with a higher bandwidth capacity than USB.
6	Compatibility		Low	The Firewire standard did not support the Internet Protocol.
7	Complementary goods	High	Low	Implementing the Firewire standard into a product increases its weight considerably. Thus, a lower amount of complementary goods were available in which Firewire was implemented.
8	Flexibility	High	Low	The USB standard was more flexible since a smaller amount of firms had to come to an agreement concerning changes to be made to the standard as compared to Firewire.
Standard support strategy				
10	Appropriability strategy		Strong	At one point in the battle, Apple changed to a more strict appropriability strategy which led Sony to choose to support USB instead of Firewire.
11	Timing of entry		Too early	Firewire was introduced into the market too early since the infrastructure outside the home was not yet ready to support a standard with a high bandwidth capacity.
15	Commitment		Low	Apple was the main promoter of Firewire and still introduced products that supported the competing USB standard. Presumably, Apple was not highly committed to the success of Firewire. Also, some of the CE companies which also produced computers and/or computer parts had conflicting interests within their own organization which was at the cost of their commitment to one or the other standard.
Other stakeholders				
17	Previous installed base	High		The USB 2.0 standard could make use of the previous installed base of the USB 1.0 standard.
23	Diversity of the network	Diverse		With both Sony and Intel supporting the USB standard the network of that standard included major representatives of both the CE as well as the IT industry.

4.5.2 Case study 2: DECTPRS vs. Wi-Fi vs. HomeRF

1) Case description: At the beginning of the 1980s, there was a need for wireless voice communication in and around the home. In that period, the first analogue wireless phones came to the market. The major disadvantage of these phones was that they experienced a lot of interference and reception was poor. To solve

this problem, several digital versions were developed. The Digital Enhanced Cordless Telephone (DECT) standard, introduced in 1988 by the European Telecommunications Standards Institute (ETSI), was the first secure digital wireless telecommunication standard. ETSI further developed the standard into the DECT Packet Radio Services (DECTPRS) standard for wireless local area networks. The DECT forum was responsible for the promotion of this standard. In the years that followed, the popularity of the Internet increased and with it the demand for wireless data communication in the home.

In 1990, the Institute of Electrical and Electronics Engineers (IEEE) started to work on the development of standards for wireless data communication. In 1997, the first version of WiFi (IEEE 802.11) was introduced. In the years that followed, different generations of that standard were introduced, each with a higher bandwidth capacity.

In 1997, Compaq, Ericsson, HP, Intel, and Microsoft formed the HomeRF Working Group. This consortium developed the HomeRF standard for wireless networks, enabling voice and data communication. The number of members that were involved in the HomeRF Working Group grew to over 100. In 2000, the HomeRF Working Group got permission from the Federal Communications Commission to increase bandwidth capacity from 1.6 Mbit/s to 10Mbit/s. Therefore, the Working Group introduced a new generation of the standard, HomeRF 2.0, which could compete with WiFi and DECTPRS. In March 2001, Intel chose to use 802.11b in its home networking product line, instead of HomeRF, because it found that 802.11b was a more suitable standard from a cost perspective. Intel was one of the six major promoter companies of HomeRF and its decision to leave the group caused many companies to follow until eventually, in 2003, the HomeRF Working Group was disbanded.

WiFi has become the dominant standard for wireless networks in homes and in offices. DECTPRS was never really a success.

2) Case analysis: In this battle we notice that, for a standard supporter, it is important to choose a good point in time to enter the market. DECTPRS was introduced too early since at the time it enabled wireless data communication (beginning of the 1990s) there was no demand for this yet. At that time, there were no products yet that supported wireless data communication. Therefore, customers were not interested in wireless data communication. Around the same time, WiFi entered the business market, where it gained support and made people familiar with the standard. Therefore, at the time that the WiFi standard entered the ‘consumer’ market, wireless networks of PCs and peripheral equipment such as printers and faxes were being used in offices and so people were already familiar with this standard. Thus, essentially, WiFi already possessed an installed base of

users in the business sector. As one respondent noted, "*Wi-Fi introduced the standard first in the business world and after it became well known and accepted they made a home version*". Many people who worked with the application at the office also wanted this application at home, which contributed to the success of WiFi considerably. HomeRF, on the other hand, was too late. WiFi was already available far before HomeRF entered the market and therefore it was difficult for HomeRF to build up an installed base. Furthermore, there was not yet demand for a standard for both voice and data communication.

However, HomeRF also did not promote its standard as much as WiFi did. As one respondent noted, *"if HomeRF had tried to convince the market that one system for both voice and data was less expensive than buying two different systems for the applications, it could have become dominant"*. On the other hand, the DECT forum actively marketed their standard; they developed a DECT brand logo and used a marketing campaign to promote the DECT applications and benefits.

Another disadvantage for HomeRF was that Intel, the leading firm behind HomeRF, was also investing in other standards. This led some companies to conclude that Intel was less committed to HomeRF. The actors behind DECT were also less committed to the DECTPRS standard than to the DECT standard. As the chairman of the DECT group indicated: "*DECTPRS offered too much of what companies did not need, there was a high demand for wireless voice communication but a much lower demand for wireless data communication*". Thus, the actors behind DECT followed the market and were more committed to promoting the voice over DECT standard since promoting that standard led to more immediate advantages at that time.

In a technical sense, WiFi was superior in terms of bandwidth capacity. The amount of bandwidth that the HomeRF standard guaranteed was too low for the price that one had to pay for it. Furthermore, the HomeRF standard was very sensitive to noise and was not secure. WiFi was implemented in different types of products, whereas HomeRF and DECTPRS were not. Furthermore, each generation of WiFi was backwards compatible.

WiFi also had the advantage that it was promoted by a very powerful and diverse network of actors of high reputation. Among its promoting members were companies representing the IT and CE industries. HomeRF, on the other hand, had a less powerful network. One of the primary reasons behind the failure of HomeRF can be attributed to the fact that Intel stepped out of the Working Group in 2001. During the development of the DECTPRS standard, there was a lot of discussion about technical aspects of the standard, which decreased the speed of the development process considerably. The parties involved had different ideas about how to develop the standard. Table 4-3 shows a characterization of this standards battle using the factors mentioned in Section 4.3.

Table 4-3: Factors found in case study 2

	Factor	Case study 2			Explanation
		Wifi (S)	HomeRF (F)	DECTPRS (F)	
Characteristics of the standard supporter					
2	Brand reputation and credibility	High	Low		The actors that supported WiFi had a higher reputation as compared to the actors that supported HomeRF. Although at the formation of the HomeRF working group the group of actors in the group had a high reputation many of these actors soon left the working group including Philips, HP, Intel, IBM, and Microsoft.
4	Learning orientation		Low	Low	If the actors supporting DECT and HomeRF had paid better attention to their customers, they would have known that there was no demand for a standard for both voice and data communication.
Characteristics of the standard					
5	Technological superiority	High	Low		WiFi was superior in terms of bandwidth capacity. The amount of bandwidth that the HomeRF standard enabled was too low. Furthermore, HomeRF was very sensitive to noise and was not secure.
6	Compatibility	High			Each generation of the WiFi standard was backwards compatible so that users could easily upgrade to the new generation of the standard.
7	Complementary goods	High	Low	Low	WiFi was implemented in more types of different complementary goods as compared to HomeRF and DECTPRS.
Standard support strategy					
11	Timing of entry		Too late	Too early	DECT entered too early since there was not yet a demand for wireless data communication at that time. HomeRF entered too late.
12	Marketing Communications	High	Low	High	HomeRF was promoted less then WiFi. The DECT forum used a marketing campaign in which it for instance developed a DECT brand logo.
15	Commitment		Low	Low	Intel, the leading firm behind HomeRF, was also promoting other standards. DECT also was less committed to its DECTPRS standard than to its DECT standard.
Other stakeholders					
17	Previous installed base	High			The actors that supported WiFi could make use of its previous installed base.
22	Effectiveness of the standard development process			Inefficient	The development of the DECTPRS standard was delayed due to long discussions about technical matters.
23	Diversity of the network	Diverse			A diverse amount of powerful actors promoted the Wifi standard.

4.5.3 Case study 3: MPEG-2 audio vs. AC-3

1) Case description: In 1988, Philips, France Telecom, the Institut fur Rundfunktechnik, and others established the Moving Pictures Expert Group (MPEG) to standardize audio and video signals. When, in the early 1990s, the digital radio system for Europe was being developed, there was a need for audio compression. The MPEG developed the standard MPEG-1 audio. At the beginning of the 1990s, the demand for multi-channel sound provisioning rose. People wanted to watch digital television as well as DVDs with multi-channel sound and a standard was needed which could enable this. The MPEG responded by developing a new generation of the standard in 1995: MPEG-2 audio. Because the MPEG-1 audio standard was very successful, they made MPEG-2 audio backwards compatible with MPEG-1 audio.

In the beginning of the 1990s, Dolby Laboratories (Dolby) developed the Audio Coding 3 (AC-3) standard. This standard was a direct competitor to MPEG-2 audio. In 1992, this standard was first used in movie theatres and in 1995 the standard was introduced to home video. In Europe, both MPEG-2 audio and AC-3 existed next to each other, while in the rest of the world only AC-3 was used. At a later stage Warner, one of the companies promoting MPEG-2 audio, withdrew its support which contributed to the dominance of AC-3 over MPEG-2 audio in Europe. So, finally, AC-3 was the global winner of this standards battle.

2) Case analysis: Dolby foresaw that the multi-channel audio sound that was common in movie theatres would also become common in homes. And since films that are aired in movie theatres would eventually also be played in the home, Dolby knew that a prerequisite for gaining dominance in the home was to gain dominance in the movie industry. The United States (and Hollywood in particular) was the market leader in the film industry. Dolby therefore positioned AC-3 as an American standard and tried to position MPEG-2 audio as a European standard. It established many contacts with major Hollywood film makers in order to ensure that they would use the AC-3 standard for their films. Many Hollywood film companies joined the network of Dolby. Dolby convinced the film industry that the format that was used in the film industry was compatible with the format to be used in the home. Later it turned out that this was not the case but at that time already a lot of film companies had chosen AC-3. Eventually multi-channel sound was incorporated in the home just as Dolby had predicted and because there was already large support for AC-3 in Hollywood this contributed to the success of AC-3.

Because the MPEG-1 audio standard had a high installed base in Europe, the decision was made to make MPEG-2 audio backwards compatible with MPEG-1 audio so that it could make use of the previous installed base. However, this also meant that no fundamental changes could be made to the underlying design of

the standard, which decreased the flexibility of the standard considerably. In the end, this backwards compatibility restricted it: the technology underlying the MPEG-2 audio standard was four years old. From this case, we notice that when a standard enables backwards compatibility this does not necessarily mean that this standard will be more successful. In our case, backwards compatibility resulted in technological inferiority which turned out to be one of the reasons for losing the battle. Also, shortly before MPEG-2 audio was introduced into the market, there was a bug in the system that couldn't be repaired in time. When the existence of this bug became known to the public, the reputation of the MPEG decreased considerably. Dolby also convinced several broadcast companies that AC-3 was superior to MPEG-2 audio, which decreased the reputation of the MPEG even further. Dolby was a well known and reliable company in the United States and this positively influenced AC-3's reputation. Dolby's marketing budget was also much higher than that of the MPEG, which also had an effect on the outcome of the battle.

One other aspect that has to be taken into account is the fact that Dolby was more committed to the success of its standard than the MPEG. For Dolby, AC-3 was their only standard while for the MPEG, it was only one of their many activities. Also, one of the main companies behind MPEG-2 audio did not obtain the support of all its business units. This lack of commitment disturbed their relationship with Warner, resulting in Warner, an important content provider, withdrawing its support for MPEG-2 audio. Table 4-4 provides an overview of this standards battle using the factors mentioned in Section 4.3.

Table 4-4: Factors found in case study 3

	Factor	Case study 3		Explanation
		AC-3 (S)	MPEG-2 audio (F)	
Characteristics of the standard supporter				
2	Brand reputation and credibility		Low	The bug in MPEG-2 audio decreased MPEGs reputation considerably. Dolby convinced several broadcast companies that AC-3 was superior to MPEG-2 audio which decreased the reputation of MPEG even further.
4	Learning orientation	High		Dolby foresaw that the multi-channel audio sound that was common in movie theatres would also become common in homes.
Characteristics of the standard				
5	Technological superiority		Low	MPEG-2 audio's backwards compatibility caused it to be technically inferior compared to AC-3. A bug further decreased the technological superiority.
6	Compatibility		High	MPEG-2 audio was backwards compatible with MPEG-1 audio.
7	Complementary goods	High		AC-3 was already used in films in movie theatres.
8	Flexibility		Low	MPEG-2 audio's backwards compatibility affected flexibility negatively.
Standard support strategy				
12	Marketing Communications	High	Low	Dolby's marketing budget was much higher than that of the MPEG.
15	Commitment	High	Low	Dolby was much more committed to the success of its standard then the MPEG.
Other stakeholders				
17	Previous installed base		High	MPEG-2 audio could make use of the previous installed base of MPEG-1 audio.
21	Suppliers	High	Low	Dolby positioned itself as an American firm so as to convince Hollywood film companies to use the standard in their films. This increased its dominance.
23	Diversity of the network	Diverse	Not diverse	Dolby attracted many Hollywood film companies to its network.

4.5.4 Cross-case study analysis

In Table 4-5, we combine the findings from the three case studies. Some factors point to a particular standard winning while that standard does not win. For instance, while Firewire was technically superior compared to USB the latter standard won and while MPEG-2 was backwards compatible and AC-3 was not it still did not win the battle. However, in each case study, the standard that was successful scores high on more factors than the standards that were unsuccessful". This might suggest that just counting the 'high scoring' factors for each case would be sufficient to determine the winner of a standards battle. However, a subset of the applicable factors can be really important for winning and thus just counting factors is not appropriate. In each case that we studied, one or a few factors were important but other factors applied as well.

In the first case study, the battle for a wired communication standard, important actors from both the IT and CE industries chose the USB standard partly because of Intel's reputation, which subsequently attracted many companies. This (together with the fact that a higher amount of complementary goods were available for USB) was the main reason for the dominance of USB over Firewire.

In the second case study, the battle for a wireless communication standard, the actors that supported WiFi chose a better time to enter the market than their competitors. This factor was especially important in this case.

In the third case study, the battle for a multi channel sound standard, Dolby knew that films would make use of multi channel sound and therefore established contacts with the major Hollywood film makers which resulted in AC-3 being used for films. This greatly increased the availability of complementary goods that made use of the AC-3 standard and was one of the main reasons for the dominance of AC-3 over MPEG. Another important factor in this battle was the fact that Dolby was highly committed to the success of AC-3.

Table 4-5: Cross case analysis

	Factor	Case 1		Case 2			Case 3	
		USB (S)	Firewire (F)	Wifi (S)	HomeRF (F)	DECTPRS (F)	AC-3 (S)	Mpeg-2 audio (F)
Characteristics of the standard supporter								
1	Financial strength							
2	Brand reputation and credibility	**High**		**High**	Low			Low
3	Operational supremacy							
4	Learning orientation				Low	Low	**High**	
Characteristics of the standard								
5	Technological superiority	Low	**High**	**High**	Low			Low
6	Compatibility		Low	**High**				**High**
7	Complementary goods	**High**	Low	**High**	Low	Low	**High**	
8	Flexibility	**High**	Low					Low
Standard support strategy								
9	Pricing strategy							
10	Appropriability strategy		Strong					
11	Timing of entry		**Too early**		Too late	Too early		
12	Marketing Communications			**High**	Low	**High**	**High**	Low
13	Pre-emption of scarce assets							
14	Distribution strategy							
15	Commitment		Low		Low	Low	**High**	Low
Other stakeholders								
16	Current installed base							
17	Previous installed base	**High**		**High**				**High**
18	Big Fish							
19	Regulator							
20	Judiciary							
21	Suppliers						**High**	Low
22	Effectiveness of the standard development process					Inefficient		
23	Diversity of the network	**Diverse**		**Diverse**			**Diverse**	Not diverse

So, the sets of applicable and of important factors differ depending on the standards battle in question. No additional factors were found. Thus, our framework can be used as a checklist.

We notice that each time a standard was successful, two factors contributed to this success: complementary goods and the diversity of the network of the standard. Complementary goods were always available in high quantities and the network of the standard was diverse with respect to its composition in that it included actors representing each of the systems for which the standard defines communication.

4.6 Discussion

4.6.1 Completeness and relevance of the framework

In Table 4-6, we compare our results with the literature. In the first three columns, the factors mentioned in prior frameworks for standard dominance from Suarez (2004), Schilling (1998), and Lee (1995) are presented. In the next columns, we present the factors mentioned in prior case studies analyzed in the literature. In the last three columns, we present the results from the current study. The important factors are indicated in black in the table.

We notice that two factors not included in prior frameworks for standard dominance were important in our cases. Both the diversity of the network of the standard and the commitment of the group of standard supporters were important in at least one of the three case studies. Thus, it seems that the framework proposed in this study can better and more completely explain standard dominance compared to prior frameworks.

We also notice that some factors such as the regulator and the judiciary have never been studied empirically and also didn't play a role in any of the three standards battles that we studied. However, this does not mean that these two factors never play a role. Multiple examples exist of standards that have become dominant merely because of the fact that they have been prescribed by the government. For example, in the telecommunications industry, in some regions, the regulator enforces certain standards making them obligatory (Bekkers, Duysters and Verspagen, 2002). Other examples include right/left side driving and railroad tracks (Suarez and Utterback, 1995). Three other factors: operational supremacy, pre-emption of scarce assets, and distribution strategy were also never studied empirically and were also not mentioned in the three cases in this study. We might expect that these factors are less relevant in standards battles.

Table 4-6: Comparison of results with prior literature

		Prior models			Prior cases															Current cases		
		Lee, 1995	Schilling, 1998	Suarez, 2004	Short range communication standards (Keil, 2002)	2nd gen. mobile telecommunication standards (Funk, 2003)	2nd gen. mobile telecommunication standards (Funk and Methe, 2001)	Modem 56K standards (Chiesa, Manzini and Toletti, 2002)	Enhanced TV standards (Chiesa, Manzini and Toletti, 2002)	Keyboard layout standard (David, 1985)	VCR (Rosenbloom and Cusumano, 1987)	VCR (Cusumano, Mylonadis and Rosenbloom, 1992)	Banking chipcards (De Vries and Hendrikse, 2001)	Video gaming console(Gallagher and Park, 2002)	Video gaming console(Schilling, 2003)	HiFi and stereo systems(Langlois and Robertson, 1992)	Microcomputer industry(Langlois and Robertson, 1992)	Microprocessor standards(Garud, Jain and Kumaraswamy, 2002)	Disk drive industry(Christensen and Rosenbloom, 1995)	USB vs Firewire (this study)	WIFI vs HomeRF vs DECTprs (this study)	AC-3 vs MPEG2 (this study)
Characteristics of the standard supporter																						
1	Financial strength																					
2	Brand reputation, credibility																					
3	Operational supremacy																					
4	Learning orientation																					
Characteristics of the standard																						
5	Technological superiority																					
6	Compatibility																					
7	Complementary goods																					
8	Flexibility																					
Standard support strategy																						
9	Pricing strategy																					
10	Appropriability strategy																					
11	Timing of entry																					
12	Marketing communications																					
13	Pre-emption of scarce assets																					
14	Distribution strategy																					
15	Commitment																					
Other stakeholders																						
16	Current installed base																					
17	Previous installed base																					
18	Big Fish																					
19	Regulator																					
20	Judiciary																					
21	Suppliers																					
22	Effectiveness of standard development process																					
23	Diversity of the network																					

4.6.2 Limitations and recommendations for further research

The number of cases we studied is limited to three. Future research might study more cases using the same approach. Then the completeness and relevance of the framework can be further explored. These cases may include the cases already described in the literature; using our lens may show to what extent our approach adds to the understanding of these cases. In addition, it can be analyzed whether the diversity of the network and the availability of complementary goods are necessary conditions for achieving dominance. These factors applied in all our cases. In most previous case studies in the literature, these factors were not mentioned. This does not imply that these two factors did not play a role. It might be that the researchers were not aware of these factors or that the research design limited the set of factors beforehand.

Another limitation concerns the fact that we did not explore to what extent different factors can influence each other and to what extent different combinations of factors influence standard dominance. These combinations certainly exist though. For instance, in the battle for wired connectivity in the home, the brand reputation and credibility of Sony made a lot of manufacturers of complementary goods to choose for USB. Also since USB 2.0 was backwards compatible with USB 1.0 it could make use of the previous installed base of that standard. In the other two cases similar combinations of factors exist. Analyzing to what extent factors influence each other could be an interesting area for further research.

Another limitation of this study is that we only focus on the period beginning with the first standard being released until one of the standards has become dominant. Thus, we do not pay attention to the period before a standard is introduced in the market. Further research could study how standards are developed, managed, and negotiated by the different stakeholders involved.

4.6.3 Managerial implications

A recommendation for managers would be to use this framework to gain more insight into current standards battles in which their companies participate. Managers can decrease the uncertainty attached to the decision as to which standard should be supported by determining the value of each factor (in terms of high, low, etc.). By doing so, they are forced to closely evaluate every factor, which will result in a better understanding of the case. Then, they can make a well informed choice as to which standard should be supported. As mentioned before, the interviews that we conducted began with an open question about relevant factors, and at the end of each interview, we asked the interviewees for every unmentioned factor whether that factor could also have affected the outcome of the battle. This pointed the interviewees to factors which they had

not thought of initially. The interviewees concluded that the discussion increased their understanding of the standards battle. This signifies the added value of the framework for business practice. As a result of our project, our case company (Philips) has incorporated our framework as a checklist in their decision making process.

4.7 Conclusion

In this study, we have explored the completeness and relevance of a framework for standard dominance. We began the study with a review of several theoretical perspectives on standard dominance, resulting in a categorization of factors. In previous research, we conducted an extensive literature review to reach a list of factors that can be grouped under each category. The resulting framework was applied to three standards battles. We did not find new factors and the framework thus appears to be complete. We also came to the conclusion that two factors that were not mentioned in prior frameworks were important factors in two of the three standards battles that we studied. This signifies that the framework appears to explain the three standards battles that we studied studied better compared to existing frameworks in the literature.

5 UNDERSTANDING THE OUTCOME OF STANDARDS BATTLES: AN AHP STUDY

Abstract

Home networks, such as the Living Tomorrow Home at Brussels and the Aware Home at Georgia Institute of Technology, combine components and technologies from the consumer electronics industry (tv, audio, gaming consoles), the information technology industry (such as personal computers), and the telecommunications industry (such as smart phones). Existing standards in these industries and new standards (that are expected to make home networks work) compete with each other. Several standards battles among participants of the home networking industry emerge. It is unclear what the outcome of these battles will be and also how to influence the process to create dominance for one standard or a set of standards.

In this study[7], we investigate the importance of factors that influence the process and outcome of standards battles in the home networking industry. Ten experts were asked to look back at the process and outcome of three standards battles. The empirical study consists of three parts. In the first part, the importance of factors is analyzed. The relative ratio of weight of factors is determined by the multi-attribute utility approach called Analytic Hierarchy Process (AHP). In the second part the relative importance of the factors was analyzed for three types of standards (subsystem standards, systems standards, and evolved subsystem standards). In the third part, for each type of standard a standards battle was analysed and the relationship was determined between factor importance and the actual dominance as the outcome of the standards battle. The results show that there is empirical evidence that (1) the AHP is a useful tool to determine the relative weight of factors; (2) for each of the types of standards different dominant factors emerge For example, when focusing on stakeholders in the standards battle for subsystem standards, the previous installed base is of importance; for system standards, the diversity of the network of stakeholders is a dominant factor; and for evolved subsystem standards, the judiciary is the dominant factor; (3) for three standards battles (representing the three different standards) the experts using the AHP were able to determine the winning standard by identifying relevant factors and their weights. Finally, conclusions, limitations and future research directions are presented.

[7] This chapter is based on Van de Kaa, G., De Vries , H. J. and Van Heck, E. 2009. Understanding the Outcome of Standards Battles in the Home Networking Industry: An AHP analysis. Paper to be presented at the *Academy of Management Annual Meeting*, Chicago, Illinois. An earlier version of this chapter has appeared in Van de Kaa, G., De Vries, H. J. and Van den Ende, J. 2007. Factors affecting the adoption of standards in converging worlds: An AHP analysis. Paper presented at the *EURAS conference*, Thessaloniki, Greece. An earlier version of this chapter has appeared in Van de Kaa G. & Van den Ende J. 2006. Factors affecting the adoption of standards. B@Home project deliverable 2.16.

5.1 Introduction

A complex system is a system in which there are multiple interactions between many different subsystems that can be systems in their own right (Alter, 1996) and that originate from multiple converging industries. An example of such a system is a home network, which combines components and technologies that originate from the consumer electronics, information technology, and telecommunications industries (Baker, Green, Einhorn and Moon, 2004). The situation, where different types of technology in a home environment can communicate with each other and form one home network, is becoming viable. Such a network will result in tremendous advantages in every day life. It will become much easier to operate subsystems in the home. These can include appliances, telecommunication devices, sensors, actuators, switches, controllers, and user interfaces to create novel applications and provide an infrastructure for multimedia distribution (Wacks, 2002). Because subsystems can communicate with other subsystems inside and outside the home, the range of their possibilities increases. When a PC can be connected to a TV, the functionality of the TV is enhanced. Heating and energy properties, but also the lights and drapes in the home, for example, can be remotely controlled. One can also think of other forms of information distribution in homes such as error logs or instruction codes for household appliances and domestic systems communicated between manufacturers and consumers. Experimental houses are already in operation, such as the Aware Home at the Georgia Institute of Technology (2009) and the Living Tomorrow home in Brussels.

Irrespective of the fact that the home network sketched has been technically possible for many years and that there seems to be a demand for it (Wacks, 2002), it has not become a practical reality. A major reason is the lack of generally accepted common standards for the interconnection between subsystems of the home network (Rose, 2001; Wacks, 2001; Wacks, 2002). Such standards are a prerequisite for home networks to emerge because the different subsystems must meet a common set of standards in order to be able to communicate with each other. Most of the different subsystems have already been developed and most have their own standards. Several of these existing standards might also be used for the interconnection between subsystems in the home network (Rose, 2001). Another possibility is to develop new standards for this purpose. The problem is not that there are not enough standards, on the contrary, there are too many. Therefore, both manufacturers of the products in which the standards are applied and the end customers of these products will find it difficult to make a choice: in case others do not choose the same set of standards, the system will be ‘an island’. As a result, users hesitate to invest in such systems and companies hesitate to deliver products, inhibiting possible innovations. When a clear choice for a common set of standards would have been made,

users could evaluate and exchange products in the marketplace more easily (Garud, Jain and Kumaraswamy, 2002). An example of such a standard is HDMI, which is the dominant standard for the interconnection of consumer electronics products. Thus, in a situation where multiple competing standards exist next to each other, there is a need to be able to explain and predict which standard will have the highest chance of achieving dominance to mitigate the uncertainty attached to adopting a particular standard.

In this study, standardization will be addressed from a market perspective (Farrell and Saloner, 1988; Keil, 2002), focusing on the process by which a standard becomes dominant in the market. Building on prior research we develop a framework for dominance of standards for complex systems. The overall objective is to explore whether this framework can be used to explain and predict the outcome of standards battles in complex systems. Thus, the goal of the theory in this study is of Type 4; both explaining and predicting (Gregor, 2006). In terms of explanation, the goal is to identify which factors most significantly influence the adoption of standards in complex systems consisting of established subsystems and to study the moderating role of the type of standard. In terms of predicting the goal is to test whether the results of the study resemble the actual outcome of each of the standards battles that are studied. This work adds to the growing body of literature focusing on dominant designs and standardization (Schilling, 1998; Schilling, 2002; Suarez, 2004). The focus lies on a system which connects two or more subsystems that are already established and already have their own standards.

Basically, the dominance of a standard depends on its selection by the potential users of the standard. If a majority of users choose one particular standard, then that standard will achieve dominance. The user of a standard essentially can be seen as a decision-maker. Thus, the selection of standards can be seen as a decision-making problem and can be analyzed as such. For firms, the decision as to which standard should be supported is a strategic one requiring the satisfaction of many different (often conflicting) criteria (Steward, 1992). Then, a multi-attribute utility approach might be of help. In this study, since the number of criteria is large and it is difficult for decision-makers to compare them, a method is preferred in which judgments can be easily made. Decision making theory is analyzed and a suitable approach is found in the Analytic Hierarchy Process (AHP). This approach is used to compute weights for the different factors that are distinguished and to determine whether the influence of factors for standard dominance is modified by the type of standard. The framework is applied to three historical cases of standards battles. By so doing, the usability of the AHP approach is explored in the area of standardization.

The study proceeds as follows. First, the literature on decision theory and standardization is reviewed. Then, a framework for dominance of standards for complex systems is developed. Subsequently, in a methodology section, the framework is transformed into a decision hierarchy and the weights for the different decision elements in that hierarchy are calculated. Then, the results of the study are presented and subsequently the main contributions, limitations, and areas for further research are discussed. We end with a conclusion.

5.2 Literature review

Authors in the technology management discipline have proposed several frameworks with which the outcome of standards battles can be explained (Lee, O'Neal et al. 1995; Schilling 1998; Shapiro and Varian 1999; Suarez 2004). However, these tend to be incomplete and overlapping (Van de Kaa, De Vries , Van Heck and Van den Ende 2007). Suarez (2004) distinguishes between firm-level factors and environmental factors, both of which directly influence standard dominance. Lee (1995) refers to these latter type of factors as 'external conditions'. They characterize the market in which the battle is fought. These environmental factors affect the magnitude of the effect of the firm level factors on standard dominance. For example, in an industry characterized by network externalities, an actor developing a technology for which complementary goods do not exist will have a lower chance of achieving dominance with that technology (Schilling, 1998). Further, these factors affect the speed and likelihood of standard dominance.

Every battle for standard dominance is fought in a different arena and therefore the "weights" per factor are difficult to establish. However, in certain cases, patterns of weights might apply. Discovering such patterns would make it easier to predict the future dominance of standards within that particular case. Standardization literature has paid some attention to how individual organizations select standards (De Vries, 1999; Weitzel, Wendt, Westarp and Konig, 2003), and to the role of the status of the standardization organization and willingness to adopt a certain standard (De Vries, 1999). The topic has also been studied from a game theory perspective (Belleflamme, 1999; Farrell and Saloner, 1988; Park, 2005). Here, empirical studies exist that analyze weights of factors for standard dominance. However, these studies only focus on a subset of the total amount of possible factors. There further exist some quantitative empirical studies (see for instance (Agarwal, Echambadi, Franco and Sarkar, 2004; Klepper and Simons, 2000; Majumdar and Venkataraman, 1998; Srinivasan, Lilien and Rangaswamy, 2006; Tegarden, Hatfield and Echols, 1999)). Again, these studies focus on a subset of the total amount of factors. Agarwal (2004) examines, among other factors, the influence of financial strength on firm survival and found that firms with greater financial resources will have a higher

chance of surviving. Schilling (2002) studies several product categories, including PC operating software and video game hardware, and tests the relationship between timing of entry and the chances of standards being locked out of the market. The conclusion is that there exists a U-shaped relationship with the likelihood of technological lockout (Schilling 1998; Schilling 2002). Christensen et al. (1998) come to a similar conclusion and show that there exists a "window of opportunity" when it is optimal to enter the market. Willard and Cooper (1985) examine the influence of both corporate level strategy variables and business level strategy variables on survival in the TV industry and find that the strategy employed can influence market dominance, provided it is matched with sufficient firm's resources and is effectively implemented. Finally, there exist a considerable amount of case study-based research (Cusumano, Mylonadis and Rosenbloom, 1992; David, 1985; De Vries and Hendrikse, 2001; Gallagher and Park, 2002) that studies multiple factors, but here actual weights of factors are not provided.

Scholars in the field of management science have played a significant role in the development of decision making theories (Smith and Von Winterfeld, 2004). Basically, three perspectives in decision making can be distinguished: normative, descriptive, and prescriptive (Smith and Von Winterfeld, 2004). In the normative perspective, the focus lies on how to make the best decision assuming a decision-maker is fully informed and makes rational choices. It is from this perspective that the axiomatic foundations of decision theory (i.e. the assumptions that people make when reaching decisions) are formed. In the 1980s, the emphasis shifted from solving the actual decision problem to the decision-maker and his behaviour (Korhonen, Moskowitz and Wallenius, 1992). The descriptive perspective focuses on behavioural decision making and on how people diverge from normative approaches. Here, it is studied whether judgments correspond with actual decisions. One theory developed here is the *prospect theory* in which judgments from people are seen as positive or negative deviations from a certain point of reference (Kahneman and Tversky, 1979). The prescriptive perspective focuses on helping people make better decisions and makes use of both normative and descriptive perspectives. Drawing from optimization theory, another school of thought within management science, Multiple Criteria Decision Making (MCDM) was developed in the early 1970s as a prescriptive theory for decision making (Steward, 1992). Here, the goal is to aid the decision-maker in finding the best possible solution to a decision problem, consistent with his or her preferences (Korhonen, Moskowitz and Wallenius, 1992). In MCDM, the value function is explicit, meaning that the decision-maker's preference for alternatives is rated by directly taking into account the existence of a value function, but not by actually assigning weights to criteria present in the value function. For instance, the decision-maker is presented with all possible solutions

and, on that basis, choses an optimal solution (Korhonen, Moskowitz and Wallenius, 1992). Multi-Attribute Utility Theory (MAUT) is often seen as a part of MCDM and deals with situations where preferences for the value function are articulated interactively with (or prior to) the rank-ordering of the alternatives (Korhonen, Moskowitz and Wallenius, 1992). The value function is thus implicit. In MAUT, an additive value function is defined in which it is supposed that one alternative is preferred over another if its utility is larger (Von Nitsch and Weber, 1993). If uncertainty and risk play an important role in the assessment of alternatives, MAUT is treated separately from MCDM (Dyer, Fishburn et al. 1992; Korhonen, Moskowitz et al. 1992; Belton and Stewart 2003). The choice that has to be made is accompanied by a high level of uncertainty, since at the time of making the decision it is unknown which standard will reach dominance. Sometimes the uncertainty is too high and decisions are postponed. Therefore, in this study, the choice is made to apply a multi-attribute utility approach to standard selection. By so doing, we explore whether this approach can be used to decrease uncertainty and aid decision-making.

5.3 Research model

In Figure 5-1, a model for the selection of standards for complex systems is presented. The elements of the model will be explicated in the following sections.

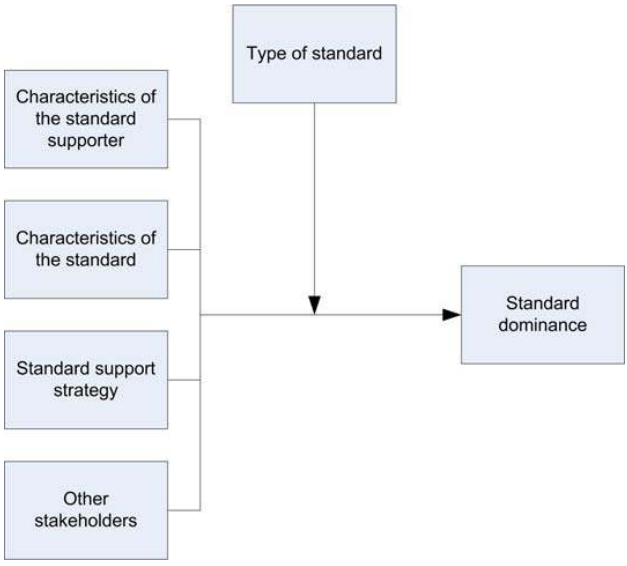

Figure 5-1: Research model

5.3.1 Standard dominance

In the current study, we focus on compatibility standards: codified specifications defining the interrelations between entities, in order to enable them to function together (own definition, combining De Vries, 1999; Garud and Kumaraswamy, 1993). Thus, quality standards such as ISO 9000 are excluded. In line with Suarez (2004), dominance of standards is defined in terms of market share. A standard is considered to be dominant when it has achieved more than 50% market share among new buyers in a certain product or service category for a significant amount of time (Lee, O'Neal, Pruett and Thoams, 1995; Suarez, 2004). In the remainder of the study, the term "standard" refers to a compatibility standard.

5.3.2 Factors for standard dominance

In prior research (Van de Kaa, De Vries, Van den Ende and Van Heck, 2008), we conducted an extensive search for factors for standard dominance. This procedure resulted in a list of twenty-nine factors. Based on similarities, we grouped the factors into five categories resulting in a framework for standard dominance. We explored both the completeness and relevance of that framework by applying it to three historical standards battles(Van de Kaa, De Vries and Van den Ende, 2008). That resulted in the framework that will be used in this study. Thus, the factors that are less relevant are not taken into account. Furthermore, in this study we focus on the factors that can be directly influenced: firm-level factors. Then, twenty factors remain. In Table 5-1, these factors are listed together with their directions.

Table 5-1: Factors and directions

Category / factor	Direction
Characteristics of the standard supporter	
Financial strength	+
Brand reputation and credibility	+
Learning orientation	+
Characteristics of the standard	
Technological superiority	+
Compatibility	+
Complementary goods	+
Flexibility	+
Standard support strategy	
Pricing strategy	-
Appropriability strategy	-
Timing of entry	∩
Marketing Communications	+
Commitment	+
Other stakeholders	
Current installed base	+
Previous installed base	+
Big Fish	+
Regulator	+
Judiciary	-
Suppliers	+
Effectiveness of the standard development process	+
Diversity of the network	+

5.3.3 Type of standard

We distinguish between "subsystem standards", "system standards", and "evolved subsystem standards" (Van de Kaa, Den Hartog and De Vries, 2007). We expect that the influence of factors for standard dominance differs between these different types of standards. It could be argued that subsystem standards have a higher installed base compared to system standards since the former possess a previous installed base of users, whereas the latter have been newly developed and thus a lack previous installed base. System standards, on the other hand, may guarantee a higher level of compatibility, which is an important requirement for a standard to become dominant for use in the design of complex systems.

5.4 Methodology

The empirical study consists of three parts. In the first part, weights for the factors in the framework presented in Section 5.3.2 are determined. In the second part, we investigate whether the influence of factors for standard dominance is modified by the type of standard. In the third part, for each type of standard a standards battle was analysed and the extent that the application of our framework resulted in a prediction that resembles

the actual outcome of the standards battle was determined. In each study, a Multi-Attribute Utility Approach was applied. In the paragraphs that follow, it will be described how the empirical study was conducted.

5.4.1 Analytic Hierarchy Process

To establish weights for the factors and rankings for the alternatives, a multi-attribute utility approach was applied. Essentially, there exist three different schools of thought to represent preferences in the context of multi-criteria problems: value measurement models; goal, aspiration or reference models; and outranking models. Value measurement models are models where weights are derived for criteria and, based upon these weights, alternatives are chosen. Goal, aspiration, or reference level models are models where, for each criterion, acceptable values are chosen and, subsequently, the alternatives are analyzed with respect to how close they are to achieving the desirable goal. In outranking models, each alternative is compared for each criterion but weights for criteria and not established (Belton and Stewart, 2003). In value measurement models, the basic underlying assumption is that there exists an additive model where weights of criteria are multiplied by the value for that criterion for the particular alternatives. To determine the ranking of an alternative, one has to multiply the weight of each criterion to the value of that criterion for the alternative. One particular value measurement model is the Analytic Hierarchy Process (AHP) (Saaty, 1980). When decision-makers are confronted with difficult multi-criteria choices (such as making a choice as to which standard should be supported), it may be assumed that they would prefer a simple method of scoring to decrease complexity (Steward, 1992). A decision-maker is unable to examine even a small number of criteria or alternatives at the same time and needs a certain amount of simplicity when making a choice (Saaty, 1986). Saaty (1990a) states that “the decision making process should be mathematically rigorous and operationally simple and transparent to the decision-maker”. AHP is a suitable approach that makes use of simple scoring questions to derive judgments for criteria. It is used in multi-attribute utility models to derive the optimal decision to a problem, when multiple criteria have to be taken into consideration (Korhonen, Moskowitz and Wallenius, 1992; Saaty, 1988). Since relative ratios of weights of importance can more easily be provided by decision-makers than absolute weights (Mitrof, Emshof and Kilmann, 1979), the method ascribes a relative importance to both the different criteria and alternatives taken into account by comparing those decision elements pair wise. The AHP is especially suited for decision problems where the criteria are difficult to compare since they are measured on different scales (Saaty, 1977) and it is difficult to standardize the values of the criteria. In that respect, AHP’s advantage lies in problems that are too fuzzy for traditional techniques (Schoemaker, 1982). Although the AHP

method has been applied in many research areas and for many applications (Shim, 1989; Vaidya and Kumar, 2006; Vargas, 1990), it has never been applied in the area of standard selection. There are a number of excellent surveys on AHP (Saaty, 1990a; Zahedi, 1986) in which the method and its applications are described in detail. Furthermore, in Appendix 9.4 a detailed description of the AHP method is included.

In the remainder of this paragraph, a decision hierarchy will be developed and it will be described how the weights for the different elements in the hierarchy are computed. The decision hierarchy that is developed will be used in each of the three studies - "A problem well structured is a problem half solved" (Belton and Stewart, 2003). In AHP, the problem is structured by developing a decision hierarchy of objectives, criteria, subcriteria, and alternatives. This study will make use of three separate hierarchies. In each hierarchy the objective of the decision problem is to choose the standard that will become dominant in the market. Although, in AHP, the decision hierarchy should be created in close cooperation with the decision-maker and therefore in essence the formulation of the decision elements should be part of a methodology section (Steward, 1992), one of the characteristics of the decision problem in this study is that decision-makers are insufficiently aware of the different factors that play a role. Therefore, this study draws on the results of prior research in which we developed a complete framework for standard dominance. The categories and factors of that framework have been used to develop the second and third level of the hierarchy resulting in Hierarchy 1 (see Figure 5-2). In Hierarchy 2, a fourth level in which a distinction is made between three types of standards is added. In Hierarchy 3, a fifth level is added consisting of three standards per type of standard.

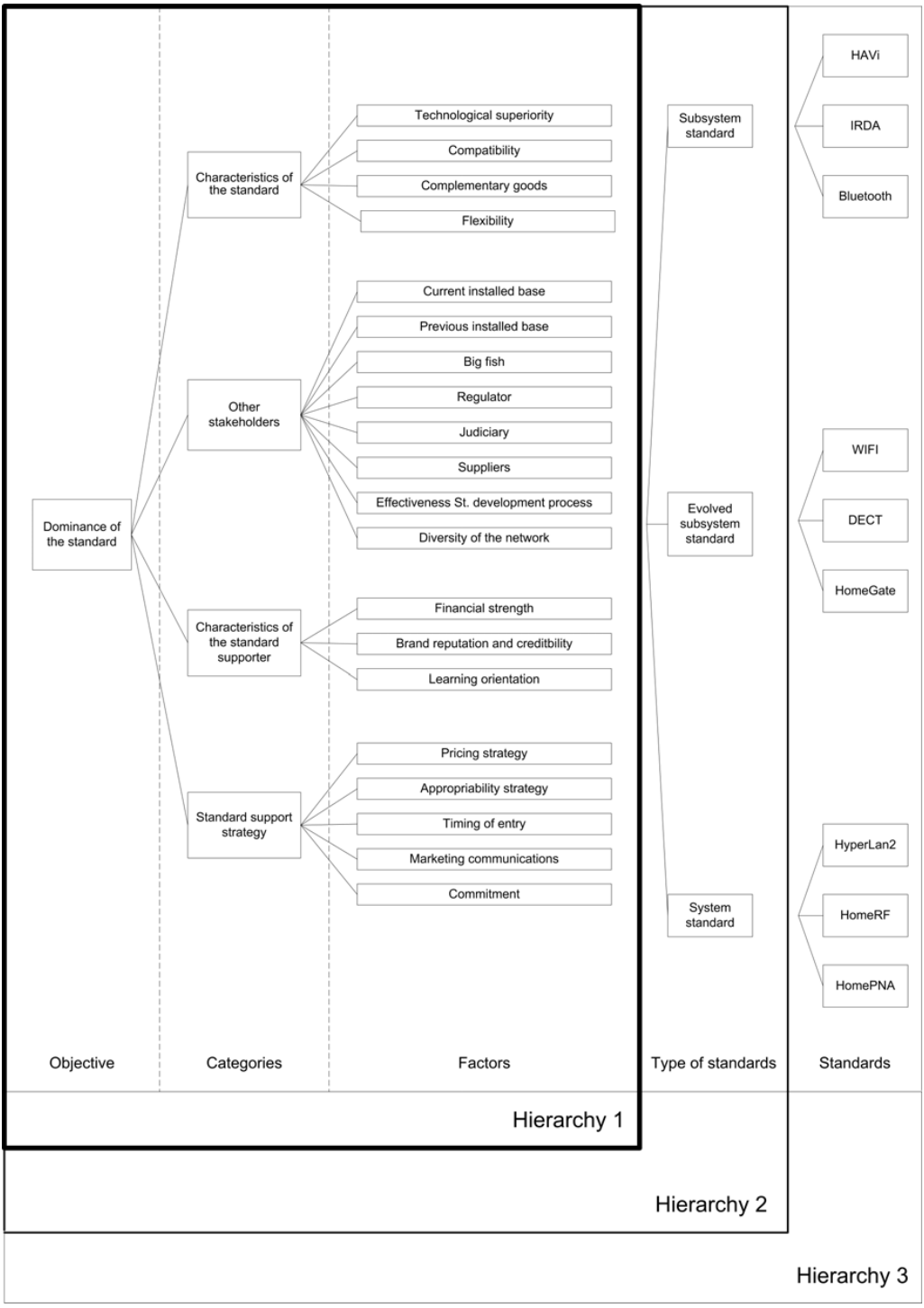

Figure 5-2: Decision hierarchy

When decision-makers compare two decision elements, they automatically think of the properties of (a set of) all the alternatives and ask themselves which of the decision elements are more important in expressing a preference among the alternatives (Saaty, 1990a). Also, they express the relative importance of the decision elements in a context-free sense. Thus, people will express essentially the same ratio of importance for one element relative to another, irrespective of the context of the specific decision problem (Belton and Stewart, 2003). So, each level in the hierarchy can be analyzed independent of the elements in the levels lying below it.

According to the method as defined by Saaty (1990b) and others, when multiple decision-makers are interviewed, an aggregation procedure should be followed (Ramanathan, 1994). We will apply the weighted arithmetic mean method where the individual priority vectors are combined into one group priority vector.

For each part of the empirical study, a separate questionnaire was developed. To guarantee the validity of each questionnaire, the framing of each question was carefully chosen such that it reflected the relation between levels (Saaty, 1980). The consistency ratio in the judgments of the respondents was calculated. Where the consistency ratio was above 0.10, the arithmetic methods suggested by Saaty (1980, 65-66) for judgmental revision were applied and changes were referred to the respondents for their observations. If the respondents concurred, changes were made and new priority vectors were computed. If the respondent did not concur, other revisions that would also increase consistency were suggested. This was repeated until an acceptable level of consistency was reached.

5.4.2 Empirical study, Part 1

In the first part of our empirical study, an AHP analysis was conducted using decision Hierarchy 1 (see Figure 5-2). A questionnaire was developed in which the categories and factors were compared pair wise. Structured interviews were conducted with ten standardization experts. The interviews were partly conducted at the Standardization and Innovation in Information Technology 2007 conference. The characteristics of our group of respondents are shown in Table 5-2. The names of respondents have been omitted for privacy reasons.

Table 5-2: Characteristics of the group of respondents

#	Active in Product market
Respondent 1	Home automation
Respondent 2	Outsider (scientist not active in any particular product market)
Respondent 3	Outsider (scientist not active in any particular product market)
Respondent 4	Telecommunications
Respondent 5	Information Technology
Respondent 6	Telecommunications
Respondent 7	Telecommunications
Respondent 8	Telecommunications
Respondent 9	Consumer Electronics
Respondent 10	Home automation

Each interview started with a short description of the type of standard (standards battles for home networking) and the respondents were asked to (pairwise) compare the different categories and factors. The respondents were asked: "*How much more strongly does category/factor A influence the chances that a particular home networking standard reaches dominance compared to category/factor B?*" The objective of each interview was to establish weights for the different categories and factors for standard dominance.

5.4.3 Empirical study, Part 2

To explore whether the influence of factors for standard dominance is modified by the type of standard AHP, Hierarchy 2 in Figure 5-2 was used. A separate questionnaire was developed in which the respondents were asked to compare the three types of standards with each other and, for every factor, evaluate how important the factor is for the dominance of that type of standard. Thus, it was evaluated whether the importance of factors differed for different types of standards. One of the questions that was asked at this level was: "*How much more important is it for the group of standard supporters that support subsystem standards to have a high reputation and credibility compared to the group of actors that support system standards?*". Four of the ten standardization experts participated in this part.

5.4.4 Empirical study, Part 3

In Study 3, the case study methodology (Yin, 2003) was applied in which the AHP served as a data collection and analysis technique, and Hierarchy 3 was used. The framework was applied to three case studies of historical standards battles. In these case studies, the unit of analysis is the standard that is vying for dominance. In each case study the outcome of the battle was determined in that one dominant standards was reached (i.e. the case studies chosen were truly historical). Also, the cases were as diverse as possible, increasing external

validity. In each of the three standards battles, home networking standards were vying for dominance. For each type of standard, a representative case study was chosen.

The first case study, which consists of subsystem standards, includes HAVi, IrDA, and Bluetooth. In 1999, the Home Audio Video Interoperability (HAVi) standard was introduced to the market. This standard connects digital audio and video devices but can potentially also be used to connect these "subsystems" to other subsystems in the home. The IrDA standard was introduced in 2003. Infra-red wireless Data communication is a standard which was originally designed for interoperable universal two way cordless infrared light transmission data ports. It can be used to transport data over a short sight of vision distance. Nowadays, IrDA has a set of protocols covering all layers of data transportation and can thus potentially also be used for communication in a home network. Bluetooth, introduced in 1999, is a standard for wireless connectivity and is based on a low-cost, short-range radio link. When two Bluetooth equipped devices come within 10 meters range of each other, they can establish a connection together. Bluetooth can be embedded into a variety of wireless communications devices, including cellular phones and hands-free headsets, laptops, PDAs, and a host of other devices. Two-way Bluetooth transmitters can be integrated into a variety of electronic devices, which can then communicate using radio waves over short distances.

The second case study, which consists of evolved subsystem standards, includes WIFI, DECT, and HomeGate. WIFI is the popular name for the standard IEEE 802.11. It is used for a wireless local area network. WIFI was introduced to the market in 1997 as a standard with which personal computers could communicate to peripheral devices. Over time, an increasing number of technologies made use of the WIFI standard to communicate with each other. Examples include PDAs, Gaming consoles, and mobile phones. Thus, the WIFI standard was originally developed for one particular subsystem within the home network; the PC, but has evolved and can now also be used to connect other home devices such as TVs and gaming consoles. The Digital Enhanced Cordless Telephone (DECT) standard, which was introduced in 1992, enables communication between cordless handset telephones. Nowadays, it can also be used for communication with other systems in the home network. In 2003, the HomeGate standard was developed. Originally, this standard was used in gateways to translate a wide area network protocol to a local area network protocol.

The third case study, which consists of system standards, includes HiperLan2, HomeRF, and HomePNA. The High Performance Radio Local Area Network (Hiperlan2) standard, introduced in 2000, is, as the name suggests, primarily used in local area networks. It can be used in most fixed networks to connect mobile phones, portables, and laptops, amongst other things, to a fixed access point. The HiperLAN2 standard is

a system standard because this standard was originally developed for home networking (in the original 1999 specification it says: the standard "*creates a wireless infrastructure for home devices e.g. Home PCs, VCRs, Cameras, Printers, etc*."). In 2001, the HomeRF standard was introduced to the market. The main player behind this standard is the Home Radio Frequency Working Group which also developed the SWAP (Shared Wireless Access Protocol) with which a range of consumer devices can be connected. The HomePNA standard, introduced in 1998, implements a home network using existing phone lines, creating a home network for file, peripheral, and internet sharing, and multi-player gaming.

A panel consisting of both practitioners and academics (that were not part of the group of ten standardization experts) was formed which evaluated which standards were dominant (see Table 5-3 where an asterix denotes that the standard achieved dominance). The DECT standard, although dominant as a subsystem standard, has been classified as an evolved subsystem standard and thus is not dominant. Three questionnaires were developed (one for each type of standard) in which the respondent was asked to rate the three standards on how they score on each factor. Since in the year 2003 each of the standards existed next to each other the standards were compared in that year. For the compatibility factor, for instance, the respondents were asked: "*In 2003, how much more compatibility did standard A guarantee compared to standard B?*" Three respondents that also participated in Study 1 and that were experts in the field of home networking filled in the questionnaire.

Table 5-3: Summary of standards used

Type of standard	Name of standard
Subsystem standards	HAVi
	IRDA
	Bluetooth*
Evolved subsystem standard	WIFI*
	DECT
	HomeGate
System standards	HyperLan2
	HomeRF
	HomePNA*

5.5 Results

5.5.1 Results, Part 1

The weights for the categories and underlying factors that influence the chances that home networking standards achieve dominance are presented in Table 5-4. For the purposes of clarity, the categories are presented

in bold text. The categories 'characteristics of the standard supporter' and 'other stakeholders' both have high weights, indicating that the respondents judged these two categories as important. The 'standard support strategy', on the other hand, was judged less important by the respondents. Finally, the 'characteristics of the standard' was judged to be the least important category.

Table 5-4: Results study 1

	Average weight (n=10)
Characteristics of the standard	**0.11**
Technological superiority	0.22
Compatibility	0.37
Complementary goods	0.22
Flexibility	0.18
Other stakeholders	**0.36**
Current installed base	0.08
Previous installed base	0.08
Big fish	0.14
Regulator	0.20
Judiciary	0.12
Suppliers	0.12
Standard developers	0.08
Diversity of the network	0.18
Characteristics of the standard supporter	**0.34**
Financial strength	0.26
Brand reputation and credibility	0.59
Learning orientation	0.15
Standard support strategy	**0.18**
Pricing strategy	0.29
Appropriability strategy	0.16
Timing of entry	0.23
Marketing communications	0.13
Commitment	0.19

Within the category 'characteristics of the standard' the compatibility that the standard provides was judged to be the most important factor. The other three factors that constitute this category are judged to be less important. This is not a surprise: in complex systems, multiple established subsystems have to be interconnected to form one system, which is only possible when the standard specifies the interface. In the "other stakeholders" category, the regulator was judged to be the most important factor. Probably, the regulator is at the top of this list because this stakeholder can use its power to prescribe a certain standard which would determine the outcome of the standards battle. As one respondent indicated, the regulator can make a reference to a standard

that prescribes that tubes that are installed in homes will not exceed a certain capacity, so, standards requiring a higher tube capacity will not be used in houses and thus these standards will have a lower chance of achieving dominance. The respondents judged the diversity of the network of actors to be the second most important factor in the stakeholder category. Within the category 'characteristics of the standard supporter', the experts judged the brand reputation and credibility of the standard supporter as the most important factor. Apparently, financial strength is less important. Whether an actor invests in learning or not was rated as the least important factor by the respondents. Finally, in the 'standard support strategy' category, the experts judged the pricing strategy to be the most important factor and marketing communications to be the least important factor.

5.5.2 Results, Part 2

In this section, the results of Part 2 of the empirical study are presented. This part explores whether the influence of the factors differs between different types of standards. In Table 5-5 the results are presented. Each number in Table 5-5 can be interpreted as the importance of a particular factor for a particular type of standard. For instance, the compatibility factor has a value of 0.47 for subsystem standards. Thus, it appears that for actors that support subsystem standards it is more important to guarantee compatibility than for actors that support system standards or evolved subsystem standards. It also appears that within the category characteristics of the standard, compatibility is the most important factor contributing to a subsystem standard achieving dominance.

Table 5-5: Results study 2

		subsystem standard	evolved subsystem standard	system standard
Characteristics of the standard				
	Technological superiority	0.39	0.27	**0.34**
	Compatibility	**0.47**	0.34	0.19
	Complementary goods	0.37	0.33	0.31
	Flexibility	0.22	**0.54**	0.24
Other stakeholders				
	Current installed base	0.46	0.28	0.26
	Previous installed base	**0.47**	0.26	0.27
	Big fish	0.32	0.29	0.39
	Regulator	0.37	0.26	0.37
	Judiciary	0.43	**0.34**	0.23
	Suppliers	0.28	0.25	0.48
	Standard developers	0.32	0.30	0.38
	Diversity of the network	0.29	0.22	**0.50**
Characteristics of the standard supporter				
	Financial strength	0.30	**0.30**	0.40
	Brand reputation and credibility	**0.38**	0.26	0.35
	Learning orientation	0.27	0.27	**0.46**
Standard support strategy				
	Pricing strategy	**0.53**	0.19	0.28
	Appropriability strategy	0.27	0.35	0.37
	Timing of entry	0.38	0.24	**0.38**
	Marketing communications	0.40	0.27	0.33
	Commitment	0.32	**0.41**	0.28

Within each category and for each type of standard it was determined which factor was rated by the respondents as the most important factor influencing standard dominance. The values of those factors are indicated in bold in the table. As can be seen in the table, for each type of standard and within each category another factor is rated as the most important factor influencing standard dominance. For instance, consider the category “other stakeholders”. For subsystem standards the most important factor is the previous installed base (weight: 0.47) whereas for system standards the most important factor is the diversity of the network (weight: 0.50) and for evolved subsystem standards the most important factor is the judiciary (weight: 0.34).

5.5.3 Results, Part 3

For each group of standards, we have analyzed which standard has the highest chance of achieving dominance. Three respondents were asked to rate each standard on the twenty factors that are distinguished. The results are presented in Table 5-6.

Table 5-6: Results study 3

Standard	Weight	Ranking from AHP	Actual ranking
Subsystem standards			
HAVi	0.19	(2)	Failure
IrDA	0.14	(3)	Failure
Bluetooth	0.37	(1)	Success
Evolved subsystem standards			
Wifi	0.35	(1)	Success
DECTprs	0.23	(2)	Failure
HomeGate	0.11	(3)	Failure
System standards			
Hyperlan2	0.29	(3)	Failure
HomeRF	0.30	(2)	Failure
HomePNA	0.41	(1)	Success

The table provides the chances (in weights) that a standard within a particular group reaches dominance. The data is based on those factors from which data per standard could be collected. When the data in Table 5-6 is compared with the success of the standard (as rated by our panel of experts), a clear correlation between the two sets of data can be observed.

5.5.4 Interpreting the results

From Study 1, it appears that the dominance of the group of standard supporters, as well as other stakeholders, plays an important role. The superiority of the standard, as well as the strategy of the standard supporter, is less important in comparison to the other categories of factors. This is supported in the literature, where it is argued that the superior standard will not necessarily become the dominant one (David, 1985). Apparently, in home networking, this is also the case. In each category, one or two factors appear to be especially important. For example, within the 'other stakeholders' category, the regulator and the diversity of the network are especially important and in the 'characteristics of the standard supporter' category, brand reputation and credibility is the most important factor.

To obtain global weights for each factor, we multiplied the weights of the categories by the weights of the underlying factors. The results are presented in Table 5-7. It appears that the brand reputation and credibility of the firm is the most important factor. Prior research also emphasizes the importance of this factor, where it is argued that a group of standard supporters with a good reputation will find it easier to attract other stakeholders to join the group (Foray, 1994), resulting in an increase in the standard's installed base. Also, it appeared that the financial strength of the group of standard supporters, their learning orientation and diversity, and the regulator are especially important. Apart from the regulator, these factors all relate to the strength of the group of standard supporters. This category "characteristics of the standard supporter" also appeared to be the most important category.

Table 5-7: Factors for standard dominance sorted by their importance

Factor	Average weight (n=10)
Brand reputation and credibility	0.20
Financial strength	0.09
Regulator	0.07
Diversity of the network	0.07
Learning orientation	0.05
Pricing strategy	0.05
Big fish	0.05
Judiciary	0.04
Compatibility	0.04
Suppliers	0.04
Timing of entry	0.04
Commitment	0.03
Current installed base	0.03
Standard developers	0.03
Previous installed base	0.03
Appropriability strategy	0.03
Complementary goods	0.03
Technological superiority	0.03
Marketing communications	0.02
Flexibility	0.02

In Part 2 of our empirical study, the data clearly shows that for each type of standard and within each category a different factor is rated as the most important factor influencing standard dominance. This leads us to believe that the influence of factors for home networking standard dominance is modified by the type of standard. These results are difficult to explain with the available literature since the moderating role of standard types has not been studied before. However, we can try to make an attempt. Within the category "characteristics of the standard", for subsystem standards the most important factor is compatibility, while for system standards

this is the least important factor. One possible explanation for this could be that subsystem standards enable communication in one subsystem and actors that support these standards should thus focus on increasing the compatibility that the standards enables to other subsystems that are part of the complex system. System standards are newly developed and already enable communication between two or more subsystems that are part of the complex system. Furthermore, backwards compatibility will be less important for system standards since these standards usually are newly developed and will not have a previous generation. Therefore it could be argued that the importance of this factor is low for system standards.

Also, for system standards, diversity in the network is the most important factor, while for subsystem standards, the installed base is most important. The major strength of a subsystem standard, as compared to a system standard, is that the subsystem standard can have an installed base. One characteristic of system standards is that they will lack a previous installed base of users. One important aspect of system standards is that these standards already define communication between several product markets. It is possible that these system standards have been developed by groups of standard supporters that represent different product markets whereas the other type of standards are supported by group of standard supporters that represent less different product markets. If so, this diversity is their major strength as compared to subsystem standards. Through these diverse actors, these standards can make use of the potential installed base in these product markets, which gives them an advantage over subsystem standards. Thus, within the 'other stakeholders' category, respondents rated the strengths of the standards as the most important factors for these types of standards.

A similar observation can be made about the characteristics of the standard supporter. Subsystem standards may have already proven themselves in the single product markets from which they originate and they may be supported by major firms that have a high reputation. This is their strength. However, system standards can be supported by diverse members and these members could try to learn from each other and incorporate changes in the standard that satisfy the needs of everyone involved. This could be their major strength. The results in the strategy category are more difficult to explain.

Finally, from Part 3 of our empirical study, we can conclude that, by using the AHP, the experts could determine the winning standard for every standards battle (representing the three different standards). Thus, it appears that the framework of factors proposed in this study can, by applying AHP, be used to effectively predict the chances that a standard will achieve dominance.

5.6 Discussion

5.6.1 A qualitative approach to AHP

When multiple decision-makers are interviewed, their judgments will differ and they should, as a group, take all criteria into consideration and seek a political consensus (Belton and Stewart, 2003; Vargas, 1990). This works well in a decision situation where one decision has to be made and the group of decision-makers is homogeneous; in situations where the group is heterogeneous it is difficult to come to a consensus. In these situations, a group discussion often takes place (Wind and Saaty, 1980). If consensus cannot be reached through these discussions, the group may try to reach a compromise. If a compromise cannot be reached because every decision-maker has different objectives or decision makers can for instance not meet to discuss the decision, separate interviews should be conducted and an average should be calculated (Dyer and Forman, 1992). Here, the analyst can choose to create separate models or to integrate the decision-makers into the decision model. In the latter situation, the analyst can choose to assign weights to the importance of decision-makers by, for instance, pair-wise comparisons of decision-makers (Ramathan 1994). In this study, the decision-makers are very heterogeneous and have different objectives in that they represent practitioners from different product markets that are converging in the home network market. It is difficult (if not impossible) to assign weights to decision-makers based upon the product market that they represent, since each of these product markets are equally important in the home network context. Therefore, in the current analysis, a choice was made to create separate models and compute the arithmetic mean of judgments, as was explained in Section 5.4.1. Although following these guidelines will ultimately contribute to the quality of the group decision and is even preferable to the Delphi method (Lai, Wong and Cheung, 2002), individual differences between decision-makers are analyzed in none of the procedures. However, the question is: does one want to reach one decision or does one acknowledge the fact that different experts will have different opinions, accept these and analyze them. Clearly, by averaging the judgments valuable information could be lost.

Belton and Stewart (2003) note that in multiple criteria decision analysis, there does not exist one right answer. Then, judgments from multiple decision-makers should always, apart from being analyzed quantitatively, be analyzed qualitatively. Although qualitative extensions to AHP in the literature have been suggested, none of these extensions focuses on the qualitative analysis of differences of judgments between multiple respondents. One extension to AHP that could be marked as qualitative is the application of fuzzy set theory to multiple criteria decision making, where every alternative has some degree of membership in a group

of “good” values for each criterion. The higher the membership of this group, the more it is preferred as an alternative. The judgments are in the form of fuzzy numbers (Van Laarhoven and Pedrycz, 1983). However, according to Steward (1992), applying fuzzy set theory to multiple criteria decision models gives rise to misunderstandings between the decision-maker and the analyst and should be avoided.

In this study, apart from computing the average, differences in the judgments given were analyzed qualitatively. The weights given by the practitioners from each different product market were compared with the average that was computed in the results section. When multiple respondents are affiliated with the same product market, the weights were averaged (see Table 5-8). From this data, it can be concluded that there appear to be differences in judgments given by respondents that represent different product markets. Within each category and for each product market that was represented by one or a group of respondents, it was determined which factor was rated as the most important factor in that category. These values were indicated in bold in the table. The approach is similar to the approach that was followed in Part 2 of our empirical study. The table shows that each respondent(s) representing a particular product market rated at least one factor as most important in a particular category of factors, while the respondent(s) representing each other product markets rated other factors as most important. These weights are underlined in the table. For instance, the respondents that represent the home automation product market rated technological superiority as the most important factor in the category characteristics of the standard, whereas respondents representing each other product markets rated other factors as more important. A qualitative interpretation would try to explain these derivations from the average. However, that is not the intention of the current study. Here, it is only stressed that differences in judgements given exist and that these differences can be quite large. These differences may be attributed to the characteristics of the respondents, in terms of the product market that they represent. That would mean that the weights that people assign to factors for standard dominance are influenced by the product market in which they operate. Perhaps, the weights that respondents assign to factors could also be influenced by other individual characteristics.

Table 5-8: Differences in judgments given by respondents active in different product markets

		Home Automation (n=2)	Telecommunications (n=4)	Consumer electronics (n=1)	Information technology (n=1)	No affiliation (n=2)	Average
Characteristics of the standard		0.058	0.12	0.168	0.05	0.160	0.11
	Technological superiority	**0.386**	0.28	0.060	0.11	0.072	0.22
	Compatibility	0.324	**0.36**	0.188	**0.59**	0.444	0.37
	Complementary goods	0.088	0.22	**0.535**	0.04	0.303	0.22
	Flexibility	0.203	0.14	0.217	0.25	0.182	0.18
Other stakeholders		0.573	0.26	0.178	0.58	0.338	0.36
	Current installed base	0.032	0.06	0.070	0.03	0.218	0.08
	Previous installed base	0.103	0.10	0.017	0.07	0.045	0.08
	Big fish	0.073	0.09	0.096	0.12	0.352	0.14
	Regulator	0.214	0.18	**0.353**	**0.38**	0.048	0.20
	Judiciary	0.050	**0.25**	0.030	0.03	0.028	0.12
	Suppliers	0.161	0.07	0.096	0.22	0.127	0.12
	Standard developers	0.132	0.08	0.133	0.02	0.032	0.08
	Diversity of the network	**0.237**	0.18	0.206	0.12	0.152	0.18
Characteristics of the standard supporter		0.224	0.34	0.570	0.26	0.404	0.34
	Financial strength	0.176	0.25	**0.637**	0.28	0.167	0.26
	Brand reputation and credibility	**0.649**	**0.55**	0.258	**0.65**	0.744	0.59
	Learning orientation	0.176	0.21	0.105	0.07	0.090	0.15
Standard support strategy		0.147	0.28	0.075	0.11	0.099	0.18
	Pricing strategy	**0.297**	**0.34**	0.175	0.26	0.285	0.29
	Appropriability strategy	0.274	0.06	0.071	**0.51**	0.098	0.16
	Timing of entry	0.123	0.28	**0.321**	0.03	**0.301**	0.23
	Marketing communications	0.102	0.15	**0.321**	0.06	0.061	0.13
	Commitment	0.204	0.17	0.112	0.13	0.256	0.19

Clearly, when judgments from multiple respondents are widely dispersed, they should not just be averaged but rather investigated more closely. The qualitative approach to AHP leads us to conclude that when multiple interviews are conducted, an additional step would need to be followed where the differences in the weights provided are analysed and explained (see Appendix 9.4).

5.6.2 Contributions

In the current study, a decision making approach is applied to standard selection, bridging the literature on decision theory and standardization. In the literature, it is argued that multiple criteria decision making

processes should be embedded in a wider process of problem structuring where objectives, criteria, and alternatives are explored (Belton and Stewart, 2003). The current study attempts to do so. In prior research, a list of factors for standard dominance was formed and based upon similarities the factors were grouped into five categories, resulting in a framework for standard dominance. The completeness and relevance of the framework was explored, resulting in a more complete framework. A first indication of the strength of the factors for the case of home networking was provided and, by so doing, a contribution has been made to the empirical literature on standardization.

The methodological contribution of the study lies in the successful application of AHP to attempt to predict which standard will become dominant. An important question is how closely the results match the real "decision" already made in the market (Saaty, 1980). Most studies that use AHP do not include a comparison with the decision actually made. In the current study, we could make this comparison and we conclude that in each group of standards the outcome of the AHP resembles the judgments made by the panel of experts. Thus, it appears that the AHP can be used to predict which standard will become dominant.

It has been illustrated that when multiple respondents participate in an AHP study their results can differ based upon their individual characteristics (such as their frame of reference) and therefore should be analyzed qualitatively and compared with the average to test for differences and explain these differences. Future studies that apply the AHP methodology and conduct multiple interviews should, apart from analyzing the results in a quantitative manner, analyze the results in a qualitative manner.

'The learning and understanding which results from engaging in the whole process of analysis is far more important than numerical results' (Belton and Stewart, 2003) and here also lies the practical contribution of the approach that was applied in this study. The results of this study are especially useful for standardization strategists. These practitioners have to make the decision as to which standard a firm should support and they can learn more about which factors are important in different product markets. They can use the method that is proposed here in their own investigations to decrease uncertainty. In fact, during the conduction of the interviews and after the results were communicated to the respondents, they were asked whether this study has helped them in making decisions as to which standard they should support and their responses were all positive. To apply the proposed method correctly, the analyst should interview a group of practitioners at a firm and differences in judgments should be discussed with the objective of reaching one overall judgment for each pair-wise comparison. It will not only increase the practitioners understanding of the standards battle but also will provide them with a first indication as to which standard will have the best chances of achieving dominance.

5.6.3 Limitations

Saaty (1977) has studied the integration of judgement into actual decision-making and, although he supposes that the judgments that are derived from the decision-maker represent the actual decision, other authors (Kahneman and Tversky, 1979) show that there is a difference between judgement and choice. In AHP, respondents are asked to judge the importance of different elements in a hierarchy. However, this does not have to mean that eventually they will also choose one element over another element when the actual decision has to be made. In this study, Saaty (1977) is followed and it is assumed that judgments represent decisions. In the descriptive approach to decision making, however, this could be seen as a limitation.

When the consistency ratio of the judgments given by the respondents was too high, the arithmetic methods suggested by Saaty (1980, 65-66) for judgmental revision were applied and these changes were communicated to the respondents. However, raising consistency should never be an objective in itself and judgments should only be revised if it results in a more accurate representation of the respondent's judgments. This was also communicated to the respondents and when judgments were revised this was done in close cooperation with them. Still, it is possible that some judgments that were revised resulted in a decrease in the accurateness in our data.

Inevitably, asking respondents to rate factors in the past creates a potential risk of retrospective bias and this is a limitation. Another limitation concerns the relatively small number of interviews that were conducted. This is also one of the major critiques of the AHP. In the literature, it is argued that one cannot derive valid quantitative evidence from just a small number of respondents. According to Saaty (1980), in an application of the AHP, one respondent is enough as long as this respondent is consistent in its judgments. The AHP does not claim to be a purely quantitative method, but rather a combination of both qualitative and quantitative methods. Furthermore, in multiple studies, the AHP has been successfully performed with only a couple of interviews and these studies have resulted in valid results (Cheng and Li, 2001; Lam and Zhao, 1998). Still, in the literature, a clear recommendation as to what should be the ideal number of respondents to be interviewed is lacking. Since a group of respondents often makes a better decision than a single member of that group (Surowiecki, 2004), multiple interviews were conducted. For every new interview, the average weights for each factors were computed. This was compared with the average when that new interview was not taken into account and the standard deviation was computed. In Figure 5-3, the results are presented.

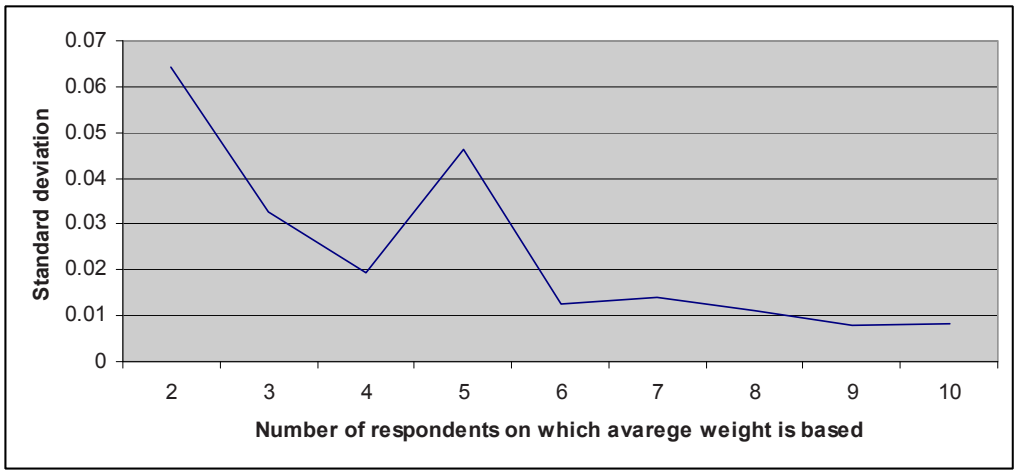

Figure 5-3: Decrease of standard deviation of average weights based upon number of respondents

As can be seen, after the sixth interview the average standard deviation remains at 0.01. This seems to indicate that six interviews is sufficient to come to valid results. After four additional interviews, the standard deviation remains roughly the same. Although six interviews is enough for the purpose of the current study, this study is still a first attempt at providing weights for factors and to come to more valid weights for factors for standard dominance, more interviews should be conducted - this is also a recommendation for future research.

5.7 Conclusion

Although the AHP method has been applied in many research areas (Shim, 1989; Vaidya and Kumar, 2006; Vargas, 1990), it has never been applied in the area of standard selection in complex systems. The AHP method provides us with relative weights for factors that affect the chances that standards achieve dominance. Furthermore, it appears that the influence of the factors on standard dominance is modified by the standard type.

This study also provides an indication as to which standard would have the highest chance of achieving dominance (for subsystem standards, this is Bluetooth; for evolved subsystem standards, this is Wifi; and for system standards, this is HomePNA). In each group of standards, a resemblance can be observed between the outcome of the AHP analysis, in terms of which standard has the highest chance of achieving dominance, and the successfulness of each standard, as rated by the panel of experts. Thus, we provide a first indication that the framework of factors proposed in this study can, by applying AHP, be used to explain and predict the chances that standards achieve dominance.

6 STANDARD SELECTION IN CONVERGING TECHNOLOGIES: THE INTERPLAY BETWEEN NETWORK AND SYSTEM

Abstract

Most literature on standard selection focuses on compatibility standards for single products or large but single systems that are developing, such as the internet or a telecommunications network. In this study[8], we focus on systems that connect multiple existing subsystems and new subsystems to form a new complex system. We hypothesize that in these systems, the diversity of the networks of actors that are supporting the different competing standards plays an important role in establishing dominance. We also hypothesize that the flexibility of the standard has a positive effect on this diversity. We test these hypotheses using data that comes from a database that we have created for this study and we find support for these hypotheses.

6.1 Introduction

There is a broad stream of literature that focuses on standards battles that have occurred in single product markets, where only a small number of actors are involved (Christensen, Suarez and Utterback, 1998; Funk, 2003; Lee, O'Neal, Pruett and Thoams, 1995; Schilling, 1998; Shapiro and Varian, 1999b; Tripsas, 1997). In these and other studies, factors which influence the dominance of standards have been suggested, where the focus lies on the individual firm and its environment (Suarez, 2004). With the increasing complexity of systems, the extent to which individual firms can influence these factors will decrease. This is because an important characteristic of these systems is that a higher number of stakeholders tend to be involved (Keil, 2002). These stakeholders originate from multiple converging product markets, which greatly increases the environmental uncertainty for the stakeholders involved (Koka, Madhavan and Prescott, 2006). Oshri and Weeber (2006) argue that in this situation of technological convergence, it will become more difficult for firms to develop and/or promote the technology alone. For example, in the home networking industry, stakeholders originate from the information technology, telecommunications, consumer electronics, and home automation product markets,

[8] This chapter is based on Van de Kaa, G., De Vries , H. J. and Van Heck, E. 2009. Standard Selection in Converging Technologies: The Interplay Between Network and System. Paper to be presented at the *Academy of Management Annual Meeting*, Chicago, Illinois. An earlier version of this chapter has appeared in Van de Kaa, G., Van den Ende, J., De Vries, H. J. and Van Heck, E. 2008. Standard adoption in converging technologies: the interplay between network and systems. Paper presented at the *15th International Product Development Management Conference*, Hamburg, Germany. An earlier version of this chapter has appeared in Van de Kaa, G. and Van den Ende, J. 2007. Standard Adoption in Converging Technologies: The Interplay Between Network and System. Paper presented at the *5th International Conference on Standardization and Innovation in Information Technology*, Calgary. An earlier version of this chapter has appeared in Van de Kaa G. & Van den Ende J. 2007. A framework for the evaluation of standards for generic B@Home architecture in which the influence of business networks is analyzed. B@Home project deliverable 2.33.

which all provide elements of the home network (Van de Kaa, Den Hartog and De Vries, 2007). When uncertainty becomes too great, firms are unwilling to take the risks which are attached to choosing a particular standard and postpone their decision (Jakobs, 2006; Leiponen, 2008; Schmidt and Werle, 1998). To counteract this uncertainty, more inter-organizational relationships are formed (Tushman and Rosenkopf, 1992), which can decrease the risks considerably (Gulati and Gariulo, 1999; Tidd, 1995). We therefore propose that in complex systems, the actors that support the standards and their inter-organizational relationships play an important role in whether this standard will reach dominance in the market (Kogut, 2000; Zhu, Kraemer, Gurbaxani and Xu, 2006).

The assumption in this study is that networks of actors affect the market position of standards in two ways. First, networks of actors can provide information from diverse sources (Beckman and Haunschild, 2002). This information can be used to adapt the standard to the requirements related to different applications of the standard, facilitating the growth of its installed base. Second, networks of actors can create the collective action (Marwell and Oliver, 1984; Smith, 1976) required to create a strong market position for a standard. If all members of a network adhere to a standard in the products they produce or apply, the installed base of that standard will grow.

The objective of this study is to gain a better understanding of the influence of the characteristics of the *network of a standard* and the flexibility of the standard on the chances that standards achieve dominance in the case of *complex systems.* We define a complex system as one in which there are multiple interactions between many different components (Rind, 1999) that can be systems in their own right (Simon, 1962; Soh and Roberts, 2003) and that originate from multiple converging product markets (Baker, Green, Einhorn and Moon, 2004; Duysters and Hagedoorn, 1998). Such systems usually consist of established systems that all have their own installed base. Examples of complex systems include home networks, office building automation systems, airport systems, and the inland transportation system for maritime containers. In this study we focus on the home network.

In Section 6.2, we will analyze different theoretical streams of literature on standard dominance. In Section 6.3, we will use concepts from social network literature and standardization literature to come to a definition of a network of a standard. In Section 6.4, we will present hypotheses about the relationship between the diversity within the network of a standard and the chances that the standard achieves dominance; and between the flexibility of the standard and the diversity within the network of a standard. In Section 6.5, we will

present the methodology of this study. In Section 6.6, we will present the data. Finally, in Section 6.7, we will provide a conclusion and discussion.

6.2 Theory

According to evolutionary economists, the survival of a firm is the result of a process of natural selection (Arthur, 1989). Technology evolves through periods of incremental change until, at some point in time, a major breakthrough occurs in the industry. These so called technological discontinuities increase the uncertainty in the industry and usually change it considerably (Tushman and Anderson, 1986). As a result, a new technological paradigm emerges. Within a new paradigm, different technological paths can be developed, resulting in designs that compete with each other for dominance (Utterback and Abernathy, 1975). Our study focuses on the period beginning with the technological discontinuity until one design has become dominant.

Standardization literature distinguishes between three stages in the standardization process: development, selection, and implementation. Thus, according to the standardization literature, we focus on the second stage; standard selection. Several studies have paid attention to the adoption of standards by individual organizations (Martina and Bunduchi, 2005; Roy and Craparo, 2001; Weitzel, Wendt, Westarp and Konig, 2003) and to the role of standards organizations (SOs) on these adoption decisions (De Vries, 1998). Some authors in this field study the topic of standard selection from a game theory perspective (Belleflamme, 1999; Farrell and Saloner, 1988; Park, 2005).

There is a vast body of literature that approaches the topic of standard selection by making use of concepts from industrial economics and network economics in particular (David and Greenstein, 1990; Farrell and Saloner, 1985; Katz and Shapiro, 1985; Katz and Shapiro, 1994). These scholars argue that some technology becomes more valuable when more people use it. Most markets in which network externalities exist are ‘two sided’ in that they consist of complementary goods for which the standard defines communication (Gallaugher and Wang, 2002). Examples include the markets for VCRs (Cusumano, Mylonadis and Rosenbloom, 1992) and video game consoles (Gallagher and Park, 2002; Schilling, 2003). When more complementary goods are available for the standard, this has a positive effect on the installed base of that standard (Schilling, 2002).

Other scholars analyze the topic using institutional theories and focus on how individual firms can increase the possibility that their technology will become dominant (Cusumano, Mylonadis and Rosenbloom, 1992). A firm can try to strategically position its technology so that it will become dominant. Willard and

Cooper (1985) examine the influence of several strategic variables on survival in the TV industry and find that strategic factors influence market dominance, provided they are matched with the firm's resources (including, its size and strength) and are effectively implemented.

Scholars in the field of technology management have developed several frameworks for standard dominance, integrating concepts from both industrial economics and institutional economics (Lee, O'Neal, Pruett and Thoams, 1995; Schilling, 1998; Suarez, 2004). Some authors have performed literature reviews of the different factors that contribute to standard selection (Shapiro and Varian, 1999b; Suarez, 2004). However, these focus on particular technological paradigms (Dosi, 1982) in which only specific factors apply. The framework developed by Suarez (2004), for instance, applies mainly to the information and communication industry. In this industry, network externalities exist and factors such as the installed base of users and the availability of complementary goods become extremely important. In industries that are not characterized by network externalities, other factors may be more important, which results in an overlap of factors. What most studies do have in common is that a distinction is made between factors that can and cannot be influenced by the firm. Lee (1995) refers to these latter as 'external conditions'. They characterize the market in which the battle is fought. In this study, we will distinguish between firm level and environmental factors (Suarez, 2004). The characteristics of the market do not directly influence the outcome of the battle; they affect the magnitude of the effect of the firm level factors on standard dominance. For example, in an industry characterized by network externalities, an actor developing a technology for which complementary goods do not exist will have a low chance of achieving dominance with that technology (Schilling, 1998). Apart from other aspects these scholars emphasize the characteristics of the standard (such as its compatibility) and other technical characteristics.

Although not explicitly mentioned in any particular literature stream, several studies in different areas (including standardization, technology management, and institutional economics) mention the influence of other stakeholders in the standards battle. Often, stakeholders other than the group of standard supporters can be influential. Firms can establish cooperation with these stakeholders, thereby decreasing the uncertainty that exists for each of the firms (Gulati and Gariulo, 1999). The influence of cooperation on the establishment of a dominant standard has been illustrated in multiple examples of standards battles. One form of cooperation is a licensing agreement, which can help build an installed base quickly and can increase the acceptance of a firm's standard. This was the primary reason behind the success of Matsushita in the video standards battle (Cusumano, Mylonadis and Rosenbloom, 1992) and Microsoft in the operating systems battle (Wonglimpiyarat, 2005). Licensing agreements have also played a role in the workstations industry (Garud and Kumaraswamy,

1993) and the video game industry (Gallagher and Park, 2002). When firms license their technology to other firms, they can acquire additional distribution channels and thus increase their installed base (Bekkers, Duysters and Verspagen, 2002). Another form of cooperation is the inter-organizational relationship. This includes vertical relationships between buyers and suppliers, horizontal relationships between competitors, and diagonal relationships between firms operating in different product markets (Nooteboom, 1998). In the case of digital recording technology, two competing standards existed: DCC (Philips) and Minidisc (Sony). Since the consumer waited for one of the standards to become dominant, neither standard has become dominant. In another situation, Philips and Sony worked together and developed one standard which achieved dominance: the compact disc (Hill, 1997). A special kind of inter-organizational relationship is that between a firm and a manufacturer of complementary goods (Cusumano, Mylonadis and Rosenbloom, 1992; Khazam and Mowery, 1994; Willard and Cooper, 1985). An advantage of inter-firm relationships is that firms can learn from the actors with which they are connected (Schmidt and Werle, 1998). For complex systems, the advantage of cooperation is that firms can gain access to new product markets (Hagedoorn, 1993). They can gain access to complementary resources from firms in different product market and learn from them. A disadvantage of joining a network is that the firm's influence on the standardization process may decrease.

In social network literature, it is argued that the performance of actors depends on the network in which they participate (Burt, 1992; Burt, 1997; Coleman, 1988; Granovetter, 1973). Accordingly, different aspects of a network influence the performance of actors within it. Recently, social network literature has been applied to standard selection (Suarez, 2005; Weitzel, Beimborn and Konig, 2006). We apply it to standard selection in complex systems. One of the aspects concerns the density of the network, which refers to the amount of actual links in proportion to the amount of possible links within the network (Coleman, 1988). Dense networks create benefits in the form of an increased capacity for coordination (Reagans and Zuckerman, 2001), improved communication (Baker, 1984), and trust among members of the group (Coleman, 1988). A related concept, the cohesiveness of a network, relates to the degree to which actors are connected directly to each other by cohesive bonds (Gargiulo and Benassi, 2000). In dense networks, relationships between actors can be strong. The strength of a relationship is determined by many constructs, such as the emotional closeness and the frequency and duration of the relation (Marsden and Campbell, 1984). One other aspect that determines the strength of relations is the amount of novel information that is communicated (Granovetter, 1983). Groups of actors that support standards that define communication in a single product market can consist of actors that all represent the same product markets. These networks tend to be dense and relations between actors are often strong.

Groups of actors that support standards that define communication between different product markets can consist of actors that are active in the different product markets for which the standard defines communication. If we apply Granovetter's theory on the strength of weak ties (1973) to this situation, the relationship between firms that represent different product markets would be called "weak" in the sense that two groups of actors are connected that were otherwise unconnected. Through these relations a lot of novel information is communicated between the two groups that would otherwise be unconnected.

In Table 6-1, we summarize the different research streams discussed above and identify where they place their emphasis. The focus in this study lies in the application of social network theory to standard selection in complex systems.

Table 6-1: Streams of literature explained

Research stream / theoretical approach	**Factors for standard dominance**	**Explanation of standard dominance**
Industrial economics / network economics	Market mechanisms (such as network externalities, uncertainty, rate of change)	Standards achieve dominance through environmental factors that cannot be influenced by the firm.
Institutional economics	Characteristics of the firm (such as financial strength, brand reputation and credibility Strategy (such as timing of entry, appropriability strategy)	Individual firms can increase the possibility that their technology will become dominant by the possession of superior resources and by strategically positioning their technology so that it will become dominant
Technology Management	Characteristics of the standard (such as compatibility, complementary goods, technological superiority) (and market mechanisms, characteristics of the firm, strategy, stakeholders)	The outcome of standards battles is determined by firm level factors and environmental factors. Environmental factors also moderate the influence of some firm-level factors.
Institutional Economics / Technology Management / Standardization	Stakeholders (such as regulator, suppliers of complementary goods)	Although not explicitly mentioned in any particular literature stream, several studies in different areas (including standardization, technology management, and institutional economics) mention the influence of other stakeholders in the standards battle.
Social network literature	Composition and structure of the network of a standard	The outcome of a standards battle is determined by the composition and structure of the network of the standard.

6.3 Network of a standard

A social network can be defined as consisting of two or more nodes that are connected to each other through one or more ties (Wasserman and Faust, 1994). A tie establishes a relationship, which can be formed by more or less regular communication between nodes. The nodes range from individuals to firms. When actors belong to groups of actors two types of modes exist: actors and 'events' (Wasserman and Faust, 1994). An event is a social collectivity in which two or more actors participate, such as a meeting or an activity. In social network literature, these networks are called two mode affiliation networks (Scott, 2000). In this study, following Leiponen (2008), the concept of a two mode affiliation network will be applied to the area of standardization. We will define the actors and the events with which the actors are affiliated. Actors are the companies, governmental institutions (other then governmental standardization organizations, academic institutions, and non profit institutions) that have in common that they develop, maintain and/or promote the same standard. Events are SO, which, in terms of network theory, can be defined as connections between two or more actors with the aim of the mutual development, maintenance, and/or promotion of the standard (Mulder, 1992 as cited by Egyedi, (2003)). Examples of SOs include consortia, formal SOs, sectoral SOs, governmental SOs, and professional SOs (De Vries, 1999, pp. 18-21). In an SO the vast majority of the actors support the standard that is developed and or promoted by that SO (in exceptional cases, an actor may join to counteract a standard (Nickerson and Zur Muhlen, 2006)). We can thus define the network of a standard as the set of actors that are involved in an SO, which serves the objective of developing, maintaining, and/or promoting that standard. In this study, we focus on the consortium which can refer to:

- An organization that performs standards-related activities without actually developing standards (Weiss and Cargill, 1992), such as a promoting consortium that either promotes consensus standards or de facto standards.
- An organization that actively develops new technologies that are intended to form the basis for either de facto or consensus standards, such as a development consortium that can develop options for consensus standards to be evaluated and possibly approved by formal standardization organizations. These consortia also include organizations that develop de facto standards (in which case promotion and maintenance of the standard is left to other SOs).
- An organization that both develops and promotes de facto standards.

- A standardization alliance, which is a contractual agreement (Burgers, Hill and Kim, 1993) between two or more actors to jointly sponsor a technological standard (Hill, 1997) with the aim of making this standard the de facto standard in the market. The main distinction between alliances and other types of consortia is that the latter are organized in a hierarchical way.

6.4 Hypotheses

6.4.1 Network diversity

The diversity of the network of a standard can be defined as the amount of different product markets that are represented in the network. The impact of network diversity on firm performance is said to be positive due to the fact that in networks that are diverse, firms will have access to more diverse information (Beckman and Haunschild, 2002); (Gilsing and Nooteboom, 2005), which leads to greater levels of learning (Dussauge, Garrette and Mitchel, 2000). In networks that are diverse, complementary technological capabilities can be matched (Hagedoorn, 1993). On the other hand, diversity can potentially lead to decreasing mutual understanding (Nooteboom, Vanhaverbeke, Duysters, Gilsing and Van den Oord, 2007), a lack of trust, and unfamiliarity between actors in the network (Goerzen and Beamish, 2005).

In the network of a standard, novel information can be gained from the different product markets that converge. By gaining access to novel information, actors can learn from each other and incorporate the novel information into the standard, thus increasing the chances that the standard achieves dominance (Schilling, 2002). Markus (2006) has studied vertical information systems standards which connect information systems from user organizations of different structural types and proposes that collective participation of representative members is necessary to reach a standard that will meet the needs of each of these organizations. For a standard to become dominant in a complex system, it is important that its network covers all product markets that are converging (Gomes-Casseras, 1994) so that the standard can be adapted to the requirements of every product market involved. Furthermore, when the network of the standard includes actors that represent different product markets that are converging, the potential installed base of the standard increases as it can make use of the installed base of each of the different actors that are involved. We conclude that diversity is important for a standard becoming dominant. In other words, the network of a standard that connects subsystem X to subsystem Y benefits from the inclusion of manufacturers from both subsystem X and subsystem Y.

Hypothesis 1: The more divers the network of the standard, the more likely the standard will become dominant.

6.4.2 Market Power

We expect that the more powerful actors are involved in the network of a standard, the higher are the standard's chances of achieving dominance (Axelrod et al., 1995). We therefore assume that the market power of the network positively influences the chances that a standard becomes dominant. We define the market power of a network as the sum of the market powers of the individual members of the network. We propose:

Hypothesis 2: The higher the market power of the network of a standard, the more likely the standard will become dominant.

6.4.3 Flexibility

The flexibility of the standard refers to the incremental cost and time needed to adapt a standard due to new developments, such as changes in customer needs or technological improvements (Thomke, 1996). The technology management literature indicates that flexibility facilitates the adaptation of a product to customer requirements, and thus has a positive influence on the installed base of products (Thomke, 1996). Ideally, a match with user requirements can be reached. Standardization literature addresses the topic of flexibility as well and implicitly assumes a more flexible standard adds to technological superiority and thus, ceteris partibus, to standard dominance (De Vries, 1999; Hanseth, Monteiro and Hatling, 1996). The modification of the standard can result in an increase in technological superiority (in terms of bandwidth capacity, for instance). This can increase the installed base of the standard. Thus, we hypothesize that when a standard is more flexible, the chances that the standard will become dominant will increase.

Hypothesis 3: The higher the flexibility of the standard, the more likely the standard will become dominant.

Sometimes standards are modified with the goal of including other actors to the network of the standard. For example the French company Thomson initially did not want to support the HDTV standard since it owned to little patents in this area and therefore could not guarantee profits on the long term. However, the group of HDTV standard supporters knew that with the support of Thomson the chances that the HDTV standard would achieve dominance would increase and therefore the group modified the standard and incorporated a French packetswitching system that was technically inferior to the existing British system. This was done with the goal of attracting Thomson to the group of HDTV standard supporters. (Simons and Vries de, 2002)." By doing so the chances that the French would chose for the standard increased considerably and that would also have a positive effect on other southern European countries. When the standard is modified to realize communication with other systems, this increases the compatibility that the standard enables. When a standard enables compatibility with multiple systems (from different product markets), the actors that develop products for these systems can choose to support the standard. This will increase the diversity of the network of the standard. Thus, standards are sometimes changed to realize communication with other systems, so to include representatives of those systems and increase the dominance of the standard. At the same time, when those actors (representing different product markets) choose to join the network of that standard, they will also try to change the standard to increase compatibility with products from their own market.

Therefore, we argue that diversity and flexibility reinforce each other and a self-reinforcing cycle arises: diversity increases the flexibility of the standard and vice versa. We hypothesize:

Hypothesis 4: the diversity of the network of a standard and the flexibility of the standard reinforce each other

Our hypotheses are shown in the research model in Figure 6-1.

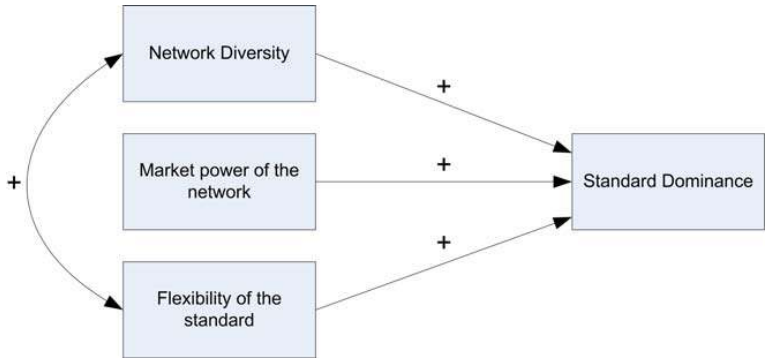

Figure 6-1: Research model

6.5 Methodology

6.5.1 Unit of analysis

Since consortia play an important role in the outcome of standards battles, this study focuses on their role. In consortia, all actors involved are expected to have a full commitment and we can thus measure 'involvement' in an unambiguous way. However, the group of active members in the consortia can be much smaller than the total membership. What most of these consortia have in common is a group of actors that set the strategic objectives of the consortium. This is the highest organizational unit in the consortium (in most cases the board of directors). Usually, this unit decides about the final approval of the specifications that are drafted in the various committees and working groups. Therefore, in most consortia, these actors are the most important actors when it comes to the adaptation of the standard. By representing the consortium with this group of actors, we take into account those actors that we expect to be actively involved in the standards process. Organizations can be represented by their board of directors (see for instance Davis, 1991). Similarly, we represent SOs by their board of directors.

6.5.2 Data

For this study, we created a database that covers the time period from 1996 to 2006. In the database, each record represents one SO. The database contains membership information on the SOs, the actors that are members of the SOs, and the standards that are being developed, maintained and/or promoted by the SOs. Data sources that were used to construct the database include the internet pages of the different SOs being studied as

well as press releases both on these and other sites, the Lexis-Nexis archives, annual reports of companies, and the Thomson one banker database of company profiles. The data is collected by performing a retrospective search using the internet archive. The internet archive is an online library that consists of archived versions of web sites which can be freely used by researchers. In each year at multiple points in time the internet archive scans the websites for changes. By consulting the homepage of each consortium, the network could be reconstructed over time from the moment that it was founded until the moment that it was dissolved. For each year it was determined at which time the webpage was first updated and the members (of the board of directors) that were present in the network at that time were recorded in the database. When membership information from one year was not available, it was assumed that the membership did not change. We focus on the fifty-five consortia that promote home networking standards.

6.5.3 Context: the home networking market

This study focuses on the home networking market. Home networks combine components and technologies from the consumer electronics (CE) product market (such as, TV, audio and gaming consoles), the information technology (IT) product market (such as, personal computers), the telecommunications (TE) product market (such as, smart phones), and the home automation (HA) product market (such as thermostats and door chimes). Firms that are active in home networking come from each of these four product markets, making this an ideal research context.

6.5.4 Variables

Standard dominance: this is measured by assessing whether the SO that supports the standard still exists or not in a particular year. Firm survival is frequently used in the literature to operationalize standard dominance (Christensen, Suarez and Utterback, 1998; Suarez and Utterback, 1995; Willard and Cooper, 1985). Here, the dominance of the standard is determined by analyzing whether the organization (that promotes the standard) survives the standards battle or not. The SO does not survive the battle when it is announced that the standard has become obsolete or that the SO was dissolved. We treat mergers of SOs as censored exits. To determine the point in time that the exit occurs, we have analyzed secondary sources in which this information is communicated (in particular news archives).

Network diversity: For each actor, we collect information regarding the industry in which it operates primarily. For each actor, we collect its (primary) standard industry code, which is a four digit number used to

categorize actors according to the industry in which they primarily operate. This information is retrieved from the Thomson one banker database. We use that code, together with the company's description, to determine into which of the four product markets that are converging in the home network industry the actor can be categorized. For the actors for which both the SIC codes as well as the company's description could not be retrieved, we analyzed other sources (such as, other company reports, databases, and the internet). In total, we categorized 482 actors. Network diversity is measured by counting the number of different product markets that are represented in each of the SOs that develop, maintain, and/or promote the standard. This variable ranges from 1 (meaning that one relevant product market is represented) to 4 (meaning that each relevant product market is represented).

Market power of the network: This is measured by counting the annual sales of the actors. This information is also retrieved from the Thomson one banker database. This variable not only measures market power in the home networking market, but in all markets that the firm is active in. The firm can use its power in other markets to establish a dominant standard in the home networking market. Intel, for instance, can use its power in the semiconductor market to try to establish a dominant standard in the home networking market.

Flexibility of the standard: This is measured by counting the total number of times that a new version of the standard was released since the year that the first version of the standard was released. This has been done for the time period from 1996 to 2006. Whenever it was announced in the press that a new standard specification was released, we regard this as a new version.

6.5.5 Control variables:

Board size: One important characteristic of networks is their size (Gilsing and Nooteboom, 2005). The more actors are involved in the network of a standard, the higher are the standard's chances of achieving dominance (Axelrod, Mitchell, Thomas, Bennett and Bruderer, 1995). However, if more actors are involved, the complexity of the network increases (Van de Ven, 1976). Consensus formation is negatively correlated with group size, since larger groups suffer from problems related to control and coordination (Smith, Smith and Olian, 1994). Therefore it is assumed that board size has a negative impact on standard dominance. We measure the size of the board by counting the number of firms that sit in the board of directors of the SOs. A higher number of actors in the board will result in more communication channels making it more difficult to reach consensus.

Timing of entry: This can be essential for achieving dominance in a market (Kristiansen, 1998; Lieberman and Montgomery, 1998; Mitchell, 1991). In most studies, it is argued that early entry can create an installed base and contribute to dominance (Katz and Shapiro, 1985; Lieberman and Montgomery, 1988; Suarez and Utterback, 1995). We measure the timing of entry by looking at the moment in time that the SO was formed.

6.5.6 Method

To test the first three hypotheses, we use logistic regression on the likelihood that an SO will exit the home networking industry in any given year (Christensen, Suarez and Utterback, 1998). We regress the event indicator on the time indicators (D1 trough D11) and the predictor variables. For every record in the dataset, the event indicator takes on either the value 0 (the SO still survives in that year) or 1 (the SO did not survive in that year). In the first year of the existence of the SO the time indicator D1 is set to 1 and the other time indicators are set to 0; in the second year of its existence, the time indicator D2 is set to 1 and the other time indicators are set to 0, and so on. The general model used can be written as:

$$\text{logit } h(t_j) = [\alpha_1 D_1 + \alpha_2 D_2 + \ldots + \alpha_{11} D_{11}] + \beta_1 Diversity + \beta_2 MarketPower + \beta_3 Flexibility + \beta_4 TimeofEntry + \beta_5 Size$$

where $h(t_j)$ is the hazard at time t_j, D_1 to D_{11} are dummy variables which refer to the time period (there are 11 time periods in the dataset), *Diversity*, *MarketPower*, *Flexibility*, and *Size* are time varying predictor variables, *TimeofEntry* is a time-invarying variable, and α_i and β_k are the parameters that are estimated. This model can be fitted using logistic regression (Singer and Willett, 2003).

6.6 Results

Using a person period dataset consisting of 297 records, the life table, the hazard function, and the survival function were manually computed. In Table 6-2, the life table describing the number of years a consortium survives for a sample of fifty-four consortia is presented.

Table 6-2: Life table describing the number of years a consortium survives for a sample of fifty-four consortia[9]

		Number of				Hazard function			Survival function		
year	time interval	Standards organizations at the beginning of the year	Standards organizations that experienced the event during the year	Censored standards organizations at the end of the year		Estimated hazard propability	Standard error		Estimated survivor probability	Term under the square root sign	Standard error
0	[0,1)	---	---	---		---	---		1	---	---
1	[1,2)	54	0	2		0.00	0.00		1.00	0.00	0.00
2	[2,3)	52	0	13		0.00	0.00		1.00	0.00	0.00
3	[3,4)	39	3	5		0.08	0.04		0.92	0.00	0.04
4	[4,5)	31	3	0		0.10	0.05		0.83	0.01	0.06
5	[5,6)	28	2	4		0.07	0.05		0.77	0.01	0.07
6	[6,7)	22	3	0		0.14	0.07		0.67	0.02	0.08
7	[7,8)	19	2	5		0.11	0.07		0.60	0.02	0.09
8	[8,9)	12	0	3		0.00	0.00		0.60	0.02	0.09
9	[9,10)	9	0	3		0.00	0.00		0.60	0.02	0.09
10	[10,11)	6	0	2		0.00	0.00		0.60	0.02	0.09
11	[11,12)	4	0	4		0.00	0.00		0.60	0.02	0.09

[9] Manual computation using person period dataset consisting of 289 record

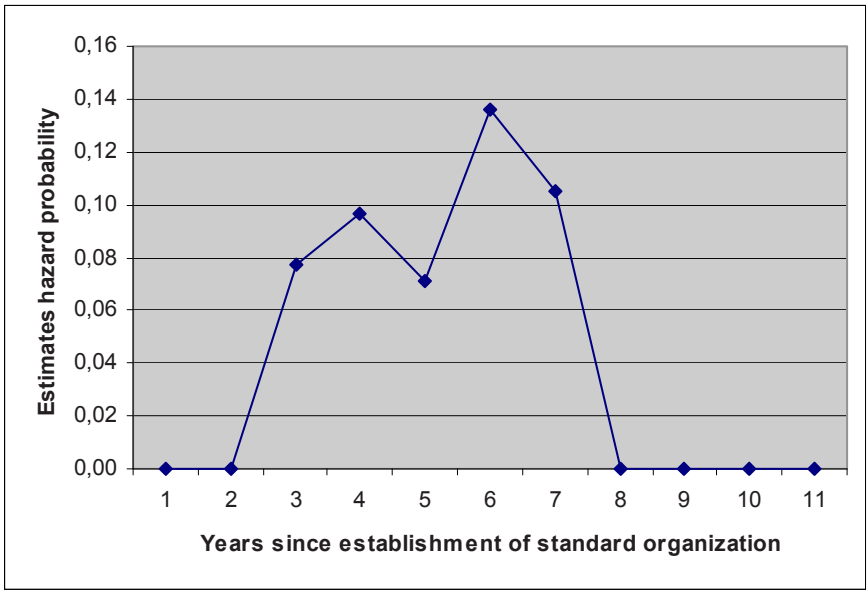

Figure 6-2: Estimated hazard functions

Figure 6-3: Estimated survivor functions

In Figure 6-2 and Figure 6-3, the estimated hazard function and the estimated survival function are presented. To estimate standard error of the survival probabilities, we applied Greenwood's approximation (Singer and Willett, 2003 see page 350). Since standard errors cannot be trusted for any time period in which the size of the risk set drops below twenty years 8 through 11 are not interpreted. Since the estimated survival function does not reach 0.5, the estimated medium life time could not be computed, which means that less than half of the population is predicted to experience the target event by Year 8.

The hazard function is non-monotonic in that it has multiple distinctive peaks and troughs (Singer and Willett, 2003). In the first two years, hazard is zero. However, from Year 3 to Year 8, hazard increases and reaches two distinctive peaks in the fourth and the sixth year. This same pattern is also shown in the survival function, where, in the first two years, estimated survival probability is 1 (meaning that every consortium survives). In the years that follow, estimated survival probability declines to 0.5711. It seems that, ceteris paribus, in the first years of the existence of a consortium, the chances that the consortium will leave the market are low, but in the years that follow they increase.

Table 6-3 contains the means, standard deviations, samples size, and correlations of the variables. To test Hypothesis 4, we created a one year lag variable for both the diversity variable (diversity at t+1) and the flexibility variable (flexibility at t+1). Both correlations between diversity and the flexibility lag variable and flexibility and the diversity lag variable were positively correlated indicating support for Hypothesis 4. Multicollinearity was tested for by analyzing the correlations among the variables at the median time of entry (2000) across all observations. It does not seem to be a problem.

Table 6-3: Desciptive statistics

	Mean	S.D.	N	1.	2.	3.	4.	5.	6.	7.
1. Board size	10.10	5.94	289							
2. Timing of entry	1997.29	4.38	289	-.28**						
3. Diversity	2.55	1.06	289	.47**	-.07					
4. Market power	25.84	0.87	289	.39**	-.06	.42**				
5. Flexibility	1.03	0.87	217	.19**	-.29**	.24**	.17*			
6. Diversity lag	2.58	1.06	234	.44**	-.05	.89**	.40**	.22**		
7. Flexibility lag	0.97	0.86	178	.20**	-.36**	.23**	.17*	.93**	.21*	

** p < 0.01 * p < 0.05 level

To test hypotheses 1, 2, and 3, we performed a discrete time-event analysis. In Block 1, we enter the time dummy variables together with the control variables. In Block 2, we enter the predictor variables. When we could not retrieve an actor's annual sales, we estimated the sales to be zero. We computed the series mean for

entries that have total sales of zero. We took the natural logarithm of both sales and flexibility. This results in the two models as presented in Table 6-4.

A negative sign for a parameter indicates that the higher the parameter, the lower the risk of event occurrence. Its magnitude estimates the size of the vertical differential in logit hazard corresponding to a 1-unit difference in the parameter. In Model 2, the timing of entry parameter is positive (p = .040), indicating that the earlier the timing of entry, the lower the risk of event occurrence. Board size is insignificantly related to the risk of event occurrence. The diversity parameter is negative (-.92). The Wald based chi square hypothesis test for diversity provides a value of 4.09, which is significant at the .04 level. Thus, the diversity estimate is significantly related to SO survival (meaning that higher values of diversity will result in decreased hazard of event occurrence, thereby increasing the chances of survival). Thus, in every year from 1996 to 2006, consortia that are more diverse are less likely to leave the industry than consortia that are less diverse. Antilogging the diversity estimate yields an estimated odds ratio of .40 with a confidence interval of .16 to .97. Thus, for every one unit increase in diversity, the estimated odds that a consortium leaves the market are 60 percent lower. This provides strong support for Hypothesis 1. We reject Hypothesis 2 because it appears that market power is insignificantly related to SO survival. The flexibility parameter is negative (-2.35) and significant (Wald based chi square hypothesis test is 4.02, p = .05). The flexibility parameter is also quite strong since antilogging yields an estimated odds radio of .095, with a confidence interval of between .01 and .95. Thus, we find strong support for Hypothesis 3.

Model B has a higher deviance, indicating that model B is a better fit when compared to the baseline model. Also, the variables in the model explain a lot of the variance in the data (R^2: .695) signifying a good fit.

For sixteen SOs, we could not retrieve data concerning the flexibility of the standard. This was mainly due to the fact that for some proprietary standards, data concerning the flexibility of the standard was only available for members of the consortia. Excluding these SO from our account reduces our sample size from 296 to 217. We performed a separate analysis on the full dataset without the flexibility variable. In this model the magnitude of the diversity estimate is similar, but its significance increases from .05 to .02.

Table 6-4: Results of fitting two discrete-time hazard models to the data

Parameters	Model 1	Model 2
Timing of entry	.13	.41*
Board size	-.17	.08
Diversity		-.91*
Market power		-.82
Flexibility of the standard		-2.35*
Goodness-of-fit		
Deviance (-2LL)	53.03	42.86*
# parameters[1]	13	16
N	217	217
R^2	.68	.69
Wald Based Hypothesis Test		
H_0: $\beta_{diversity} = 0$		4.08*
H_0: $\beta_{Market\ power} = 0$		1.50
H_0: $\beta_{Flexibility\ of\ the\ standard} = 0$		4.02*

* $p < .05$, [1] in this model the 11 time dummies were included

6.7 Conclusion

In this study, we have concentrated on standardization processes where different product markets converge. We have argued that the resulting system that can be realized is complex due to the different established subsystems that are connected within the system. We developed a model for the influence of the characteristics of the networks of firms and the flexibility of the standard, on the chances that it becomes dominant. We have studied the dynamics of the network of actors per standard. We have tested our hypotheses by developing a database using secondary sources. Our study bridges the literature on firm networks and standardization processes. We have found that the diversity of the network of the standard has a significant positive effect on the chances that the standard achieves dominance. Thus, it appears that when standards are supported by more diverse networks in terms of product market representation, the chances that these standards reach dominance will increase. Further, it appears that if the standard is more frequently adapted to user requirements the chances that it will become dominant increase. It would seem that a standard should not be too 'standard', but should be flexible enough so that it can be changed to realize communication with other systems, resulting in a higher chance that the standard achieves dominance. Finally, it appears that flexibility and network diversity reinforce each other. Thus, it appears that when a standard is more flexible, the network of that standard can become more diverse and vice versa.

One limitation concerns the operationalization of some variables. For example, we operationalized standard dominance in terms of the survival of the SO. In literature, standard dominance is often operationalised by market share per standard (Majumdar and Venkataraman, 1998; Mitchell, 1991; Tegarden, Hatfield and Echols, 1999; Wade, 1995). To measure market share one could count the number of products that adhere to the standard and divide this by the total number of products in the applicable product category. However, in many cases, we do not know in which context the products are used. Consider a company that is active in the consumer electronics industry and supports the WIFI standard. It could use this standard in its TV sets in order to realize communication with PCs in the home. Alternatively it could use this standard in its DVD player to realize communication with the TV set. In the first situation, the company uses the standard to realize a home network; whereas in the latter situation, the company does not. Another difficulty with respect to market share is that it is difficult to measure, since the list of companies that supports the standard is not always available. We measured flexibility by counting the number of new versions of the standard that were released. It should be noted that when a new version of a standard is released, this does not always mean that the contents of the standard have been changed. Therefore, one should look at whether changes have actually been incorporated into the standards. However, since most of the time specifications are not freely accessible, this was impossible to do. However, we have analyzed a sample of the specifications that were available and in most cases the different versions of the standard differed considerably. Finally, we measured timing of entry by the date at which the SO was formed. Almost in every case, the date at which the standard is released is the same as the date at which the SO is formed. For instance, the WiFi alliance was formed in 1999 and the 802.11a standard was introduced in the same year. However, in some cases the year that the SO is formed is not the same as the year that the standard was introduced (and there are one or two years in between).

Relationships can differ with respect to their degree of formality (Van de Ven, 1976) where personal relations are less formal then corporate relations for instance (Burt, 1997; Marsden and Campbell, 1984). A limitation of this research is the fact that those relations that have a small amount of formality tend to be difficult to measure whereas these relations could play a prominent role in reaching a standard for complex systems. An example is the battle for the standard for next generation DVDs, where Microsoft Chairman Bill Gates met with Sony's CEO Howard Stringer and discussed Microsoft's possible adoption of the Blu-ray standard for high definition DVD (Porto, 2005).

An area for further research is the importance of the power of individual actors over other actors within the network. This can be either in the form of mere influence to domination of one actor over another (Knoke,

1990). Sometimes in networks supporting standards one actor controls the other actors. The advantage here is that decisions can be taken quickly. It would be interesting to study whether this situation is preferred over a situation where actors have more equal roles. Future research could fruitfully examine this subject.

Finally, we have focused in this study on home networking standards. Further research could try to replicate these findings in other areas where standards compete for dominance. As such the generalizability of our findings can be assessed.

7 CONCLUSION

7.1 Introduction

This book began with a number of illustrations of standards battles that have been fought over the years. We observed that the standards battles occur for systems that are becoming more complex with respect to the different product markets that are involved. In this book, we have studied standards battles for these complex systems and we have come to several conclusions that will be presented in this chapter.

We will begin with a short overview of the key findings. Then we will focus on each research question. We will conclude with our contributions, limitations and suggestions for future research.

7.2 Key findings

The central question asked in this study is: "*What are the most important factors which determine the outcome of battles of standards for complex systems that consist of established subsystems?*" Scholars have pointed to many factors that affect the outcome of standards battles (Schilling, 1998; Shapiro and Varian, 1999b; Suarez, 2004). However, the literature is fragmented and does not provide us with an overall framework in which all relevant factors are included. Factors that are mentioned include, for example, a firm's marketing communications, a standard's installed base, and network externalities. It is unclear which factors are most important. Furthermore, little empirical research exists on factors for standard dominance. To answer our central question, we first wanted to reach a complete framework of factors for standard dominance. We accomplished this by conducting an extensive literature review of standard selection literature resulting in a framework consisting of twenty-nine factors, which were grouped under five categories. We applied the framework to several standards battles and it appeared that the framework can be used to explain these standards battles better, when compared to existing frameworks in the literature.

We came to the conclusion that the sets of applicable and of important factors differ depending on the standards battle. So, although weights for factors could not yet be established, the framework can be used as a checklist. One factor, the diversity in the network of actors that support a standard appears to be especially important. For the standard to become dominant in a complex system, it is important that its network covers all product markets that are converging (Gomes-Casseras, 1994), so that the standard can be adapted to the requirements of every product market involved. Furthermore, when the network of the standard includes actors

that represent different product markets that are converging, the potential installed base of the standard increases as it can make use of the installed base of each of the different actors that are involved.

To better understand the importance of different factors, weights for factors affecting standard dominance should be established. We applied a multi-attribute utility approach to standard selection and provide a first indication of weights for factors. From this study, it appears that the influence of the factors on standard dominance is modified by the standard type. It also appeared that the brand reputation and credibility of the group of standard supporters, their financial strength, their learning orientation and their diversity are especially important. We also found the regulator to be of significant importance. Apart from the regulator, these factors all relate to the strength of the group of standard supporters. This category "characteristics of the standard supporter" also appeared to be the most important category. However, this is based on only ten interviews, so it would go too far to conclude on the basis of this study alone that these factors are the most important factors.

At this point, we can not give a definite answer to our central research question. To answer the question, further research is needed in which additional cases are studied. Other scholars can use the same approach that we applied in the three case studies to gain further insight into factors for standard dominance. By doing so, the framework can be tested and perhaps then a definite answer can be found for the central research question. There is also a need to better understand the influence of individual factors on standard dominance. In this study, we have studied two factors: the diversity in the network of actors that support a standard; and the flexibility of the standard. We provide a first indication that these variables influence standard dominance positively and reinforce each other.

Thus, although we cannot give a definite answer to our central research question, our results do suggest that one factor, diversity in the network of actors that support a standard, appears to be especially important. The reason why this particular factor has not been mentioned in prior frameworks (and is only rarely mentioned in prior case studies of standards battles) could lie in the fact that the number of different stakeholders increases as systems become more complex. Especially in industries that consist of established converging product markets, multiple firms come together that had previously only operated in these product markets. To decrease uncertainty these stakeholders tend to organize themselves in networks of actors. Thus, with the increase in the number of different stakeholders involved in the standards battle, the importance of the networks of these standards increases.

7.3 Summary of findings

In this book, six research questions were addressed. Firstly, we investigated "*which factors affect the selection process of standards in systems that do not consist of established subsystems"*. To answer this question, we began with an initial literature review of different existing frameworks for standard dominance. We came to the conclusion that these frameworks are overlapping and incomplete, which led us to conclude that we could not rely on any one of the existing frameworks. Instead, we had to develop a complete framework for standard dominance which took into account each factor that is mentioned in the literature. We started a review of standard selection literature and analyzed 127 articles, resulting in the identification of twenty-nine factors for standard dominance. We have grouped these factors under five categories. We have determined the influence of each factor on standard dominance.

To answer our second research question: "*What are the specifics of systems consisting of established subsystems with respect to the standard selection process?*", we conducted a descriptive study of the home network. By applying a step-by-step approach to the identification of standards for home networking, we found three dimensions which are characteristic of home networks: the layer in the architecture of the system for which the standard defines communication (application supporting, communication service, network infrastructure), the type of standard, with respect to the level in the system for which the standard defines communication (subsystem standard, evolved subsystem standard, and system standard) and the product market for which the standard defines communication (information technology, consumer electronics, home automation, and telecommunications - or a convergence between two or more of these product markets).

The third research question was: "*What are the implications for the factors affecting the dominance of standards for systems that consist of established subsystems?*" To answer this research question, we began with a study of three standards battles to explore which factors played a role in these battles. We came to the conclusion that some factors (such as, the diversity in the network of actors that support a standard) appear to be especially important, while other factors appear to be less relevant. Next, we applied the framework to three standards battles for the home network by using a multi-attribute utility approach to standard selection (Chapter 5). Respondents rated the importance of categories and factors for standard dominance. It appeared that some factors (such as, the technological superiority of the standard) are less important than others (such as, brand reputation and credibility). Thus, the fact that a standards battle takes place for complex systems implies that some factors appear to be more important than others (see Table 5-4).

The fourth research question ("*Does the selection process of standards differ when both established and new standards have to be taken into account instead of only new standards?*") was also answered in Chapter 5. Respondents rated the importance of factors for different types of standards. For each type of standard and within each category of factors another factor was rated as the most important factor influencing standard dominance. Thus, 'standard type' appears to be a moderator variable and it would appear that the influence of the factors on standard dominance is modified by the standard type. Within the category "characteristics of the standard", for subsystem standards, the most important factor appears to be the compatibility; whereas for system standards, the most important factor appears to be the technological superiority; while for evolved subsystem standards, the most important factor appears to be the flexibility. Within the category "other stakeholders", for subsystem standards, the most important factor appears to be the previous installed base; whereas for system standards, the most important factor appears to be the diversity of the network; while for evolved subsystem standards, the most important factor appears to be the judiciary. Within the category "characteristics of the standard supporter for subsystem standards", the most important factor appears to be brand reputation and credibility; whereas for system standards, the most important factor appears to be learning; while for evolved subsystem standards, the most important factor appears to be financial strength. Finally, within the category "standard support strategy", for subsystem standards, the most important factor appears to be the pricing strategy; whereas for system standards, the most important factor appears to be timing of entry; while for evolved subsystem standards, the most important factor appears to be commitment.

It appears that the AHP can be successfully applied to predict the outcome of standards battles. By applying the AHP, we also studied the effect of factors for standard dominance for different types of standards and we provide a first indication that the type of standard has a moderating influence on the factors that affect standard dominance. In applying the AHP to standard selection, we also analyzed the differences in the judgments given qualitatively. This analysis shows that there appear to be differencess in judgments given by respondents that represent different product markets. Based upon this, we conclude that when judgments from multiple respondents are widely dispersed, they should not just be averaged but rather investigated more closely to determine why the judgments are so highly dispersed. This qualitative approach to AHP has led us to conclude that when multiple interviews are conducted, an additional step would need to be followed in AHP where the differences in the weights provided by the respondents should be analyzed and explained.

The fifth research question was: "*What is the influence of the characteristics of the network of the standard and the flexibility of the standard on the outcome of the standards battle?*". From our descriptive

study, it appears that one characteristic of the network, diversity, could be especially important. We explored to what extent diversity of the network of a standard played a role in the standards battle (in chapters 4 and 5). It appears that this characteristic plays an important role. In a separate chapter, the hypothesis was formulated: "*the more diverse the network of the standard, the more likely the standard will become dominant*". To test the hypothesis, a database was created, covering the home networking industry since 1996 and we applied logistic regression to examine the likelihood that a standards organization (SO) will exit the home networking industry in any given year. We provide a first indication that a more diverse network in terms of the product markets that it represents will increase standard dominance. We also provide a first indication that when a standard is more flexible, the chances that the standard will achieve dominance increase. We also provide a first indication that both variables reinforce each other. In Table 7-1, we provide an overview of the results of each chapter in the study.

Table 7-1: An integrated overview of the results of this study

			Chapter 2	Chapter 4			Chapter 5	Chapter 6
			Direction	USB vs Firewire (this study)	WIFI vs HomeRF vs DECTprs (this study)	AC-3 vs MPEG2 (this study)	global weights of factors (using AHP)	estimate (discrete time-event analysis using logistic regression)
Characteristics of the standard supporter								
1	Financial strength		+				0,09	
2	Brand reputation and credibility		+				0,20	
3	Operational supremacy		+					
4	Learning orientation		+				0,05	
Characteristics of the standard								
5	Technological superiority		+				0,03	
6	Compatibility		+				0,04	
7	Complementary goods		+				0,03	
8	Flexibility		+				0,02	-2.35*
Standard support strategy								
9	Pricing strategy		-				0,05	
10	Appropriability strategy		-				0,03	
11	Timing of entry		∩				0,04	.41*
12	Marketing Communications		+				0,02	
13	Pre-emption of scarce assets		+					
14	Distribution strategy		+					
15	Commitment		+				0,03	
Other stakeholders								
16	Current installed base		+				0,03	
17	Previous installed base		+				0,03	
18	Big Fish		+				0,05	
19	Regulator		+				0,07	
20	Judiciary		-				0,04	
21	Suppliers		+				0,04	
22	Eff. of standard development process		+				0,03	
23	Network of stakeholders		+				0,07	-.91*
Market characteristics								
24	Bandwagon effect		+					
25	Network externalities		+					
26	Number of options available		-					
27	Uncertainty in the market		-					
28	Rate of change		-					
29	Switching costs		-					

We can partly answer our sixth research question: "*Which methods are appropriate to determine the most important factors which influence the outcome of standards battles for complex systems that consist of established subsystems*". In this study, we have applied three methods: a case study approach, an AHP study, and a quantitative database analysis. Each of these methods can be used to determine important factors for standard dominance. If the research objective is to explain standard dominance (in a historical standards battle where the outcome of the battle is known) then a case study approach (as conducted in Chapter 4) may be an appropriate method. If the research objective is to both explain and predict standard dominance (in a current standards battle where the outcome of the battle is unknown) then an AHP study (as conducted in Chapter 5) may be more appropriate. If the objective is to test whether particular factors play a role in general, then a quantitative analysis (as conducted in Chapter 6) may be appropriate. To fully answer the question more methods should be applied.

7.4 Theoretical contributions

The first theoretical aim of this study is to review different streams of literature and integrate these streams into a framework consisting of factors for standard dominance. Some authors have performed literature reviews of the different factors that contribute to standard selection (Shapiro and Varian, 1999b; Suarez, 2004). However, they focus on particular technological paradigms (Dosi, 1982) in which only specific factors apply. The framework developed by Suarez (2004), for instance, applies mainly to the information and communication industries. Here, network externalities exist and factors such as the installed base of users and the availability of complementary goods become extremely important. In industries that are not characterized by network externalities, other factors may be more important, which results in an overlap of factors. In our search for literature, we took Suarez (2004) as our starting point and we conducted a search for factors resulting in a list consisting of twenty-nine factors for standard dominance. Based upon a literature review, we distinguish between five categories of factors for standard dominance. Based on similarities between the factors, we grouped them under the five categories, resulting in a framework for standard dominance. The contribution lies in the integration of the different research streams into a common framework that is more complete than existing frameworks.

Our second aim was to apply our framework to standards battles for complex systems to assess its completeness and relevance and to understand whether it can be used to explain and predict standard dominance in these types of systems. Only fifteen papers (of a total number of 127) analyzed in Chapter 2 report empirical

data, indicating that further empirical research is definitely needed in this field, particularly on factors that have mainly received theoretical treatment so far (such as, the compatibility of the standard), although some of those factors (such as, commitment and uncertainty in the market) are difficult to measure empirically. Therefore, we have performed multiple empirical studies and, as such, we have contributed to research on standard selection. By conducting the empirical studies, we also accomplished our second aim. We first applied the framework to three case studies of standards battles to explore both its completeness and relevance. This resulted in a core framework, consisting of twenty factors. That framework was applied to three groups of home networking standards and it appears that the framework can be used to explain and predict dominance of standards for complex systems. This may be considered a contribution to the literature on standardization for complex systems.

The third theoretical aim was to test the influence of characteristics of networks of actors on standard dominance. To accomplish this aim, we examined three case studies of standards battles and came to the conclusion that (especially) the diversity in the network of a standard in terms of the product markets that are represented seems to be important. In a separate study, we tested the influence of network diversity on standard dominance and found a positive influence of network diversity on standard dominance.

Multiple studies address the relationship between network structure and innovation adoption (Davis, 1991). Some studies focus on the impact of a firm's position in a network on its market share (Bekkers, Duysters and Verspagen, 2002), while other studies link a firm's network position to its innovation output (Ahuja, 2000). Here, it is argued that a firm can learn from actors and obtain external knowledge, increasing its innovation output (Powel, Koput and Smith-Doerr, 1996). The studies that apply network literature to standardization mostly study the impact of networks of end users on standard diffusion. For example, Weitzel (2006) studies the impact of network topology and density on standard diffusion. Other authors study the diffusion of standards among actors by drawing upon social network literature and network economics (Abrahamson and Rosenkopf, 1997; Suarez, 2005). These researchers have in common that they focus on the social network of end users that may adopt a certain standard. Some authors also focus on the formation of standard setting alliances. For instance, Vanhaverbeke (2001) has studied the formation of inter-organizational networks around proprietary RISC designs and Axelrod (1995) relates a firm's incentive to join a standard setting alliance to the size and composition of the alliance. Other authors study the influence of a firm's position in a network on its formal standard setting influence (Leiponen, 2008).

Little research has been conducted on the influence of a network of actors that develops and or promotes a standard on the chances that the standard will become dominant in the market (one notable exception is the qualitative study performed by Markus (2006)).

Another factor that has received limited theoretical and empirical attention in standardization research is the role of flexibility. The technology management literature indicates that flexibility facilitates the adaptation of a product to customer requirements, and thus has a positive influence on the installed base (Thomke, 1996). Although standardization literature addresses the topic of flexibility (De Vries, 1999; Hanseth, Monteiro and Hatling, 1996), it does not link it directly to standard dominance. We contribute to the standardization literature by studying the influence between the flexibility of a standard and standard dominance.

Furthermore, we add to the literature by concentrating on cross industry networks. Although some authors have explored the relationship between firms representing multiple industries (Hagedoorn and Schakenraad, 1992), most empirical research in the area of inter-organizational networks concentrates on networks in specific industries (Ahuja, 2000)

While most studies that examine networks of actors focus on only one point in time, there are exceptions. A good example is the qualitative work done by Soh and Roberts (2003) who studied alliances of firms in the US data communications industry from 1985 to 1996 at three points in time. By analyzing the network at multiple points in time, we could study the network dynamically and analyze how changes in both the composition of the network of actors supporting the standard and the flexibility of the standard influence standard dominance and reinforce each other.

Thus, this research adds to both standardization and (social and interorganizational) network literature in four ways: first, by integrating different streams of literature into a framework that is more complete than existing frameworks; second, by focusing on the influence of networks of actors on standard selection; third, by studying networks of actors at multiple points in time; and fourth, by studying cross industry networks of actors. Also, we have contributed to empirical research on standards selection by conducting several different empirical studies.

7.5 Managerial contributions

The practical aim of this research is to reduce the uncertainty for practitioners with respect to the decision as to which standard should be supported for complex systems and home networks in particular.

By developing a framework for standard dominance and applying it to three historical case studies, we composed a checklist for developing a company strategy for standards battles. The case studies were analyzed in cooperation with Philips. As a result of our project, our case company (Philips) has incorporated our framework as a checklist in their decision making process. We recommend that other companies do the same and use the framework to gain more insight into current standards battles in which their company participates. A manager can decrease the uncertainty attached to the decision as to which standard should be supported by rating each of the factors for the standards that are competing in the battle. By doing so, the practitioner takes every factor into account and can come to a better understanding of the case, making a well informed choice as to which standard should be supported. In practice actors do not have complete information at their disposal and thus they can not make fully informed decisions. Inevitably the values of some factors may be unknown to the actor that has to make the decision which standard to support. The decision that is made thus also depends upon the factors for which information is available and depending upon for which factors information will be available the weights for factors will also differ. Still, by applying the framework the uncertainty can at least be decreased to a minimum by evaluating those factors for which information is available. By applying the framework to three groups of standards for home networking, the chances that these standards achieve dominance have been analyzed. The results of our analysis resemble the actual outcome of each battle and thus it appears that our framework can be used by practitioners to predict which standard will become dominant. Using this approach the practitioner can estimate the chances that standards achieve dominance, which further reduces the level of uncertainty attached to the decision as to which standard should be supported.

Furthermore, by developing a categorization and using it to classify home networking standards, we reduce the level of uncertainty by bringing a certain amount of order to the wide variety of standards that exist in the home networking industry. A clear recommendation to actors in this industry is to cooperate across product markets and, as such, increase the diversity in the networks of standards in which they participate. Also, firms should try to frequently adapt the standard to changing user requirements.

7.6 Limitations

There are some limitations in this study. One limitation concerns the operationalization of both the flexibility of the standard and standard dominance. We measure the level of flexibility of the standard by counting the total number of times that a new version of the standard was released since the year that the first version of the standard was released. However, when a standard is flexible, this does not necessarily have to

mean that this standard will also be changed. Also, when a new version of a standard is released, this does not always mean the contents of the standard have been changed. Therefore, one should look at whether changes have actually been incorporated into the standards, but since most specifications are not freely accessible, this would decrease the sample size considerably. However, for the specifications that were available, we have analyzed a sample of them and, in most cases, the different versions of the specifications differed considerably.

We measured standard dominance by SO survival. Another operationalization would be to use market share. To measure market share one could count the amount of products that meet the standard and divide this amount by the total amount of products in the applicable product category. However, in many cases, we do not know in which context the products are used. Consider a company that is active in the consumer electronics industry and supports the WIFI standard. It could use this standard in its TV sets in order to realize communication with PCs in the home. Alternatively it could use this standard in its DVD players to realize communication with TV sets. In the first situation, the company uses the standard to realize a home network; whereas in the latter situation, the company does not. Another difficulty with respect to market share is that it is difficult to measure, since the list of companies that supports the standard is not always available.

A practical limitation exists with respect to the applicability of the framework as a checklist in the decision making process. Theoretically, if every firm that participates in the standards battle applied the framework, the competitive advantage for the individual firm could decrease to a negligible level. However, at the same time, the uncertainty with respect to which standard will win is reduced, leading to a higher speed and likelihood of standard dominance.

7.7 Suggestions for future research

This research has resulted in a framework for standard dominance. Using this framework, future research could analyze which of the different home networking standards mentioned in Figure 3-4 will become dominant. Apart from analyzing current standards battles, a recommendation for further research would be to analyze additional past battles using the framework. Academics can use the same approach that we applied in the three case studies to gain further insight into factors for standard dominance. By doing so, the framework can be tested. This analysis could also possibly lead to new insights about the battle. In even the most studied standards battles, new insights could be reached. As was mentioned in the introduction, an example of a standards battle that has been studied extensively in the literature is the video standards battle. We have applied the framework to this standards battle. We have reviewed eleven papers discussing this battle and its obvious

final outcome. In Appendix 9.6 the results are shown. The first three papers concentrate primarily on the VCR battle as such, mentioning many relevant factors, whereas the remaining papers address other battles as well and focus on just a couple of factors in detail. Compared to those described in Chapter 2, no additional factors were found. This underlines the completeness of our framework (although some studies that are used in this analysis were also used in our literature study). We have found that twenty factors played a role in the video standards battle. The most complete paper discusses seventeen factors. On average, 7.55 factors were found per paper. This implies that authors considered a part of the total of 20, but none of them is complete. New insights could be reached by analyzing the extent of the role the nine factors that were not mentioned before played in the battle.

Suarez (2004) proposes that the importance of factors for standard dominance differs depending upon the stage in the technology life cycle. For instance, he argues that before a standard is actually introduced in the market technical superiority plays an important role but once the standard is introduced in the market and once the 'decisive battle' begins it can build up installed base and that factor becomes more important. We focus on the decisive battle but we acknowledge the fact that in this stage the importance of factors could also differ depending upon time. Further research could explore the importance of factors for standard dominance through time. Another interesting area for further research is to explore under which conditions multiple standards can coexist next to each other.

In this research, we have focused on the relationship between the composition of the SO and standard dominance. Further research should also take into account how the different SOs are connected. By using social network analysis, the structural characteristics of the network of actors involved in home networking could be related to standard dominance. A first exploratory study is included in Appendix 9.7, in which we analyze how the network of actors active in home networking changes through time. First of all, we observe that in every year, there appears to be a group of companies that are close to each other and active in a lot of different SOs. Although initially we thought density would be low in this subset of the network, the density is actually quite high. In 1996 and 1998, mostly companies active in the IT product market (such as Intel, Microsoft, and IBM) were close together. In the years that followed, companies representing different product markets moved closer together. Thus, in the home networking industry, firms from different product markets tend to collaborate with each other. We also observe that the distance between firms representing different product markets seems to decrease over time. For instance, the distance between Microsoft and Philips in 2006 was far smaller than that in 1996. This provides a first illustration that the four product markets tend to converge over time. We also see that

through time, more and more SOs exist next to each other, increasing the number of standards. In future research, it would be interesting to study the reasons behind the fact that so many SOs survive. This is because we think this is one of the reasons behind the fact that no home networking standard has reached dominance in terms of market share. One explanation could be that powerful actors want to spread the risk and as a result support as many (sometimes competing) standards simultaneously as possible. Since these actors are powerful and have high financial resources at their disposal, they can afford the fees that accompany such memberships. At the same time, when powerful actors are members of an SO, they can use their dominance to increase the chances that the SO survives. When analyzing the powerfull actors in the fifty-four SOs used in Chapter 6, we see that most of these actors are members of multiple SOs at the same time (also see Appendix 9.7). Further research could explore this topic in more detail.

Another area for further research concerns the importance of the power of individual actors over other actors within the network. This can be either in the form of mere influence of one actor on the other to domination of one actor over the other (Knoke, 1990). Sometimes in networks that lie behind standards, one actor controls the other actors. The advantage here is that consensus can be reached quickly. It would be interesting to study whether this situation is preferred over a situation where every actor has the same control over other actors in the network. Future research could delve more into this subject.

According to social network literature, the type of network that we discuss in this research would be categorized as a 2-mode network, where the actors are firms and the events are SOs. However, it can be argued that these types of networks are in fact 3-mode networks where the third mode is the standard itself. In this sense, we introduce a new type of affiliation network so far not described in the social network literature. Further research could make an attempt to study these types of 3-mode networks in more depth.

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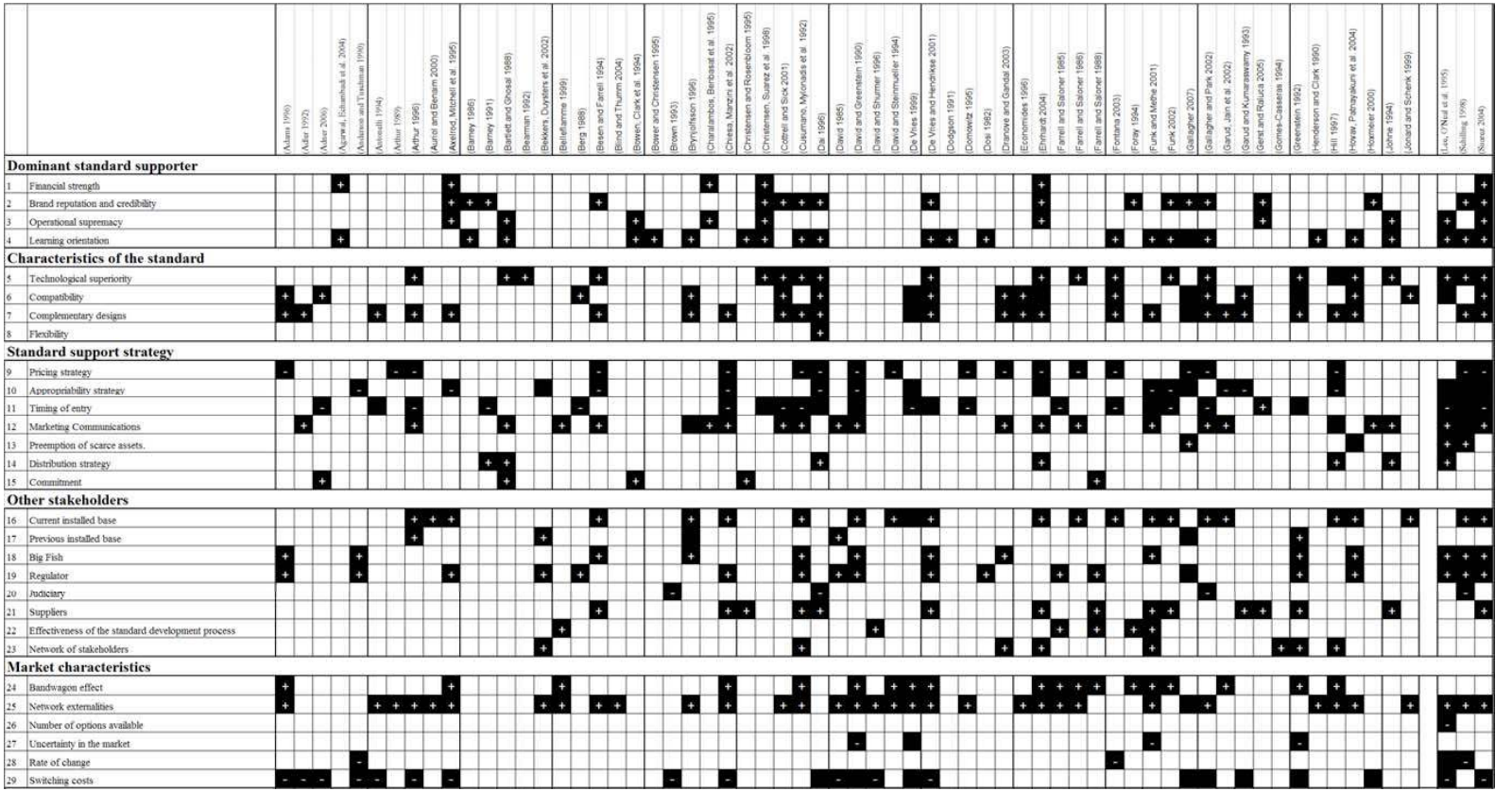
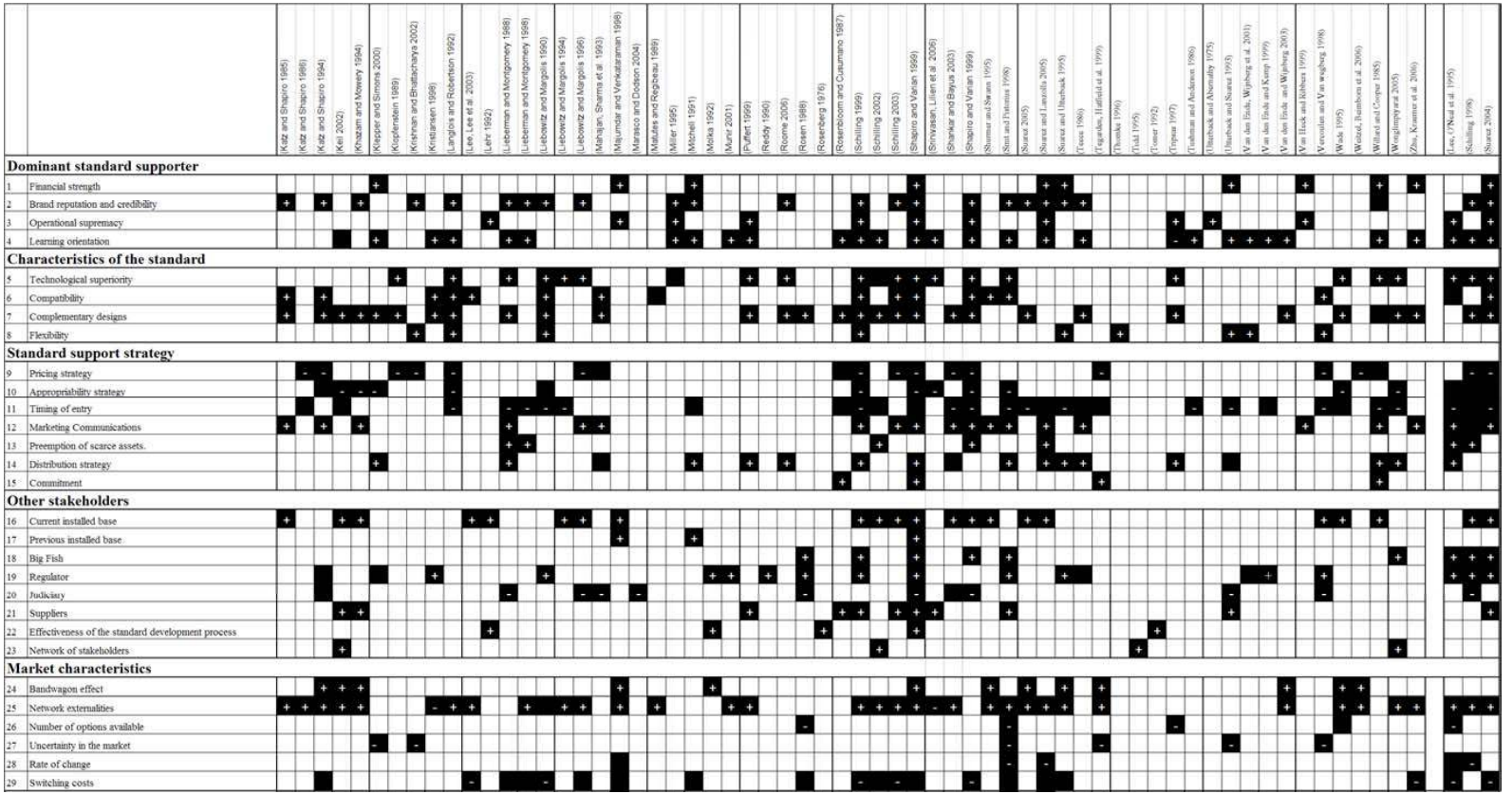
9 APPENDIX

9.1 A matrix relating factors to the publications in which they were found





* This matrix relates the factors (rows) to the publications (columns) in which they were found. When a cell is filled, that factor was mentioned in the publication. In the last two columns, we present three frameworks that already existed in the literature. We also present the direction of the effect of each factor on standard dominance. If the direction was not specified or reported to have two directions, we indicated this with leaving the cell blank. One can analyze the rows in this matrix and observe the amount of time particular factors are mentioned or one can analyze the columns and count the total amount of factors mentioned per publication.

9.2 Questionnaire, Chapter 4

General part

1. Are we allowed to record this interview?
2. What is your name?
3. What is your function?
4. What work did you do at the time that the standards were developed?
5. At what organization do (did) you work?
6. With which of the standards were you involved?
7. Can you describe, in chronological order, what the most important events of the standards developed were (from the begining of the development of the standard to its establishment)?
    a. How many parties were involved in the development cycle?
        i. Were there any problems during the development of the standard?
        ii. Was there any pressure from stakeholders, who wanted to have some influence in the development process?
    b. When was the beginning of the battle for dominance? And what was the trigger for this battle?
    c. Who took the initiative?
    d. What was the course of the battle?
    e. Who (by name) were the stakeholders behind the standard?
        i. How was the power divided within the partnership?
        ii. Was there a form of cooperation between the stakeholders? Which companies were working together?
        iii. How did they approach these companies and how were they selected?
        iv. How was the cooperation? How did the parties communicate?
        v. What were the pros and cons of cooperation for the biggest players?
    f. What was your interest in this battle, and what did you do to achieve this?
    g. What was the reason for you (your company) to be involved/ uninvolved in cooperation?
    h. Was this cooperation based on historical cooperation?
    i. When and how did it become clear to you which standard would win the battle?
    j. Were there any remarkable changes during the process?

k. Were there one or more parties who had a greater influence in the process?

8. For which application was the standard originally meant?
9. Was there any change in the originally application?
10. Were there already previous generations of the standard?
11. If this was the case, what were the differences between the previous standard(s) and the new standard?
12. Were there companies which possessed or had obtained relevant patents? If yes, what kind of patents were they and how did they influence the process?
13. What was, according to you, the most relevant factor for the outcome of the battle?
14. Which factors played a role in the battle? What were, according to you, the success or fail factors of the standard?
15. Did the winning party have a special strategy for winning the battle?
16. Why was this strategy so (un)successful?
17. Why is it that the competing standards lost the battle?

Specific part

1. What were your expectations before the battle started?
2. What was the final result?
3. Did the final result that you expected come true?
4. If so, which factors (that had an influence on becoming a dominant design) were known from the beginning?
5. If not, which factors (that had an influence on becoming a dominant design) had a negative influence on the process?
6. Continuing, were these caused by coincidences, unforeseen circumstances or incorrect assessments?
7. With the knowledge that you have now, what would you have done different?
8. Did you ever have the feeling during the standards battle that the company lost control over the situation?
9. Were there decisive factors that could be identified before the battle started?
10. Were there any turns by the development of the standard that determined failure or success?

Conclusion

1. We present a few factors that may have been overlooked or are incalculable.
2. In your opinion, are there factors which should be added to the list of twenty-nine factors because they would be decisive success factors in a specific case or factors for failure?

3. Do you have documentary concerning this standards battle for dominant design or standard that could be useful for our case study?

4. May we contact you in the future after processing the interview by phone, email or otherwise and present the results of the interview to correct misinterpretations or other details?

9.3 Characteristics of respondents (Chapter 4)

Standards battle 1: IEEE 1394 vs USB
Main actors IEEE 1394: Apple, Philips and Sony
Main actors USB: Intel and Microsoft

Standard	Function	Type of involvement in standard development and or promotion
USB	Project leader	This person coordinated his company's input in the standardization of USB.
IEEE 1394	General Manager, Systems Architectures	As general manager of the systems architectures group at a major CE company, this person was responsible for the promotion of the IEEE 1394 standard within that company. Among other things, he made the choice to use IEEE 1394 for the interconnection between the company's products and the PC
USB	Researcher	Working at a major IT company, this person was partly responsible for the development of USB
Outsider	Manager, research lab	As manager of a research lab in Silicon Valley, this person studied and researched each standard. However, he was not responsible for the standards and can be considered to be an outsider in the standards battle.

Standards battle 2: DECTPRS vs. WiFi vs HomeRF
Main actors DECTPRS: ETSI, DECT forum
Main actors WiFi: IEEE, WiFi alliance
Main actors HomeRF: HomeRF working group

Standard	Function	Type of involvement in standard development and or promotion
HomeRF	Strategy manager	This actor represented a small semiconductor company in the HomeRF working group. The person was present at all meetings that were held and observed all discussions that were held
HomeRF	Project leader	This person was a manager at the digital systems lab of a major CE company. He represented that company in the HomeRF working group
DECTPRS	Standardization manager	This person worked for the wireless connectivity department of a major CE company and was the expert on DECT within that company. He represented the company in the DECT forum and, as such, was heavily involved in the promotion of DECTPRS
DECTPRS	Chairman	In his function as chairman of the ETSI working group on DECT, this person was responsible for the development and direction of the DECTPRS standard
WiFi	Strategy Manager	As manager of strategy and standards, this person was heavily involved in the WiFi standard. He was also a member of the IEEE 802.11 working group
Outsider	Standardization manager	This person was the head of all standards activities for a major CE company in Europe and studied each standard closely but did not participate in the standards battle
Outsider	Researcher in home networking	This person was a researcher at the research lab of a national telecommunications provider. He studied each standard closely but did not participate in the standards battle

Standards battle 3: MPEG-2 audio vs. AC-3
Main actors MPEG-2 audio: Moving Pictures Expert Group (Philips, France Telecom, Institut für Rundfunktechnik)
Main actors AC-3: Dolby Laboratories

Standard	Function	Type of involvement in standard development and or promotion
MPEG-2 audio	Standards developer	This person was one of the developers of the MPEG-2 audio standard
MPEG-2 audio	Standards developer	This person was one of the developers of the MPEG-2 audio standard
MPEG-2 audio	Manager	This person was the manager of the MPEG
AC-3	Standards developer	This person was the lead developer of the AC-3 codec
Outsider	Researcher	This researcher studied both MPEG-2 audio and AC-3 at a technical university

9.4 The Analytic Hierarchy Process (AHP) Method

The AHP is a method that is used to derive the optimal solution to a complex decision problem, where multiple criteria are to be taken into consideration (Saaty, 1988). In AHP, both qualitative and quantitative approaches are combined into one empirical method (Cheng and Li, 2001). It posits a relative importance to both the different criteria and alternatives taken into account by comparing those elements pair-wise. The AHP consists of the construction of a structural hierarchy (step 1), the comparing of different criteria and alternatives in that hierarchy (step 2), the synthesis of the results (step 3), and checking the consistency of the data (step 4). Steps 2 through 4 are performed for each level of the hierarchy defined in step 1. Finally, in step 5 of the AHP, the global results can be computed.

Step 1: The Structural Hierarchy

The complexity of a decision can be reduced by structuring the decision into a hierarchy of different criteria and alternatives where the objective of the decision is located at the top of the hierarchy. The criteria are located under the objective and the alternatives are located under the criteria. The criteria, as well as the alternatives, can in turn consist of multiple levels depending upon the complexity of the decision (Zahedi, 1986). The first step is one of the most important and the hierarchy must therefore be thoroughly developed (Zahedi, 1986).

Step 2: Pair Wise Comparisons

Once the hierarchy has been set up, the different elements are compared to each other with respect to the element that lies above the two elements. That is done for each level in the hierarchy. The elements are compared by making use of a nine point scale developed by Saaty (1988). That scale is used since it includes the widest range of options that can be considered simultaneously by respondents (Miller, 1956; Wind and Saaty, 1980). When comparing two elements, the answers range from 9 to 1/9. The intermediate values 8, 6, 4, 2, 1/2, 1/4, 1/6, 1/8 can be chosen when a compromise is needed between two judgments. The comparisons are put into reciprocal matrices, where A_{ij} corresponds to the priority of element i over element j.

Step 3: Calculation of Results

To obtain the results, the reciprocal matrix is first normalized. The elements in each column of the reciprocal matrices are divided by the sum of the elements in that column. Then, for each row i, the eigenvector (E_i) of the normalised matrix is computed. The eigenvector of the normalized matrix provides us with the relative weights of each element.

Step 4: Consistency Check

For every matrix, the degree of the consistency of the answers provided by the interviewees is calculated. To compute this value the consistency matrix is computed first by multiplying the reciprocal matrix with the eigenvector to get c_{ij}. Next, the consistency index (CI) is computed from the consistency matrix using:

[1]
$$CI = \left(\left(\sum_{i=1}^{n} \left(\frac{\sum_{j=1}^{n} c_{i,j}}{E_i} \right) \right)^{\frac{1}{n}} - n \right)^{\frac{1}{n-1}}$$

The consistency index reflects the internal consistency of the respondent's answers in the matrices. The consistency index is divided by the random consistency to obtain the consistency ratio (CR). Saaty (1988) has computed these random consistencies by taking, at random, judgements ranging from 1/9 to 9 and then computing the consistency index. If the consistency ratio falls into the acceptable range (< 0.10), the matrix is consistent. Where the consistency ratio is above 0.10, arithmetic methods suggested by Saaty (1980, 65-66) for judgmental revision can be applied and new priority vectors can be computed.

Step 5: Obtaining Global Weights

When the consistency is at an acceptable level, global weights can be calculated by multiplying the local weights at a particular level of the hierarchy by the weight of the element that lies directly above that element.

Additional step 6: aggregation of judgments from multiple decision makers

When multiple decision-makers are interviewed which have different objectives and / or cannot meet to discuss the decision, separate interviews should be conducted and an average should be computed (Dyer and Forman, 1992). *Apart from computing this average, the judgments should be qualitatively analyzed and explained.*

9.5 Description of database used in Chapter 6

In prior research, we studied the influence of networks on standard dominance. In this appendix[10] we present the structure and the collection procedure of the database that was used in that study. The Actor-Network-Standard (ANS) database is a relational database in which data is recorded about the cooperation of actors in organizations that support standards. In this report, we will explain the database as well as providing information about how the data that is present in the database has been collected. At the end of this report we will present the detailed data collection protocol that was followed.

The network of a standard can be defined as the set of actors that are involved in one or more standards organizations (SOs) which serve the objective of developing, maintaining, and/or promoting that particular standard. Thus, the network of a standard consists of three main concepts: the actor, the SO, and the standard. These three concepts are the three entities that make up the core in the database as will be seen in the next section. For every standard we collect each of the SOs that develop, maintain, and or promote that particular standard.

The data is stored in a relational format so that it is possible to perform analyses on several subsets of the complete data. The database consists of three entities: the standard, the SO, and the actor. In Figure 9-1, the relational database schema is presented. The three entities are circled in red. We will now, for each of the entities, describe the tables that are associated with them as well as their attributes. Furthermore, we will discuss how we collect the data.

[10] This appendix is based on Van de Kaa G. (2007). Standard Adoption in Converging Technologies: The Interplay Between Network and System, a database study. B@Home project deliverable 2.35.

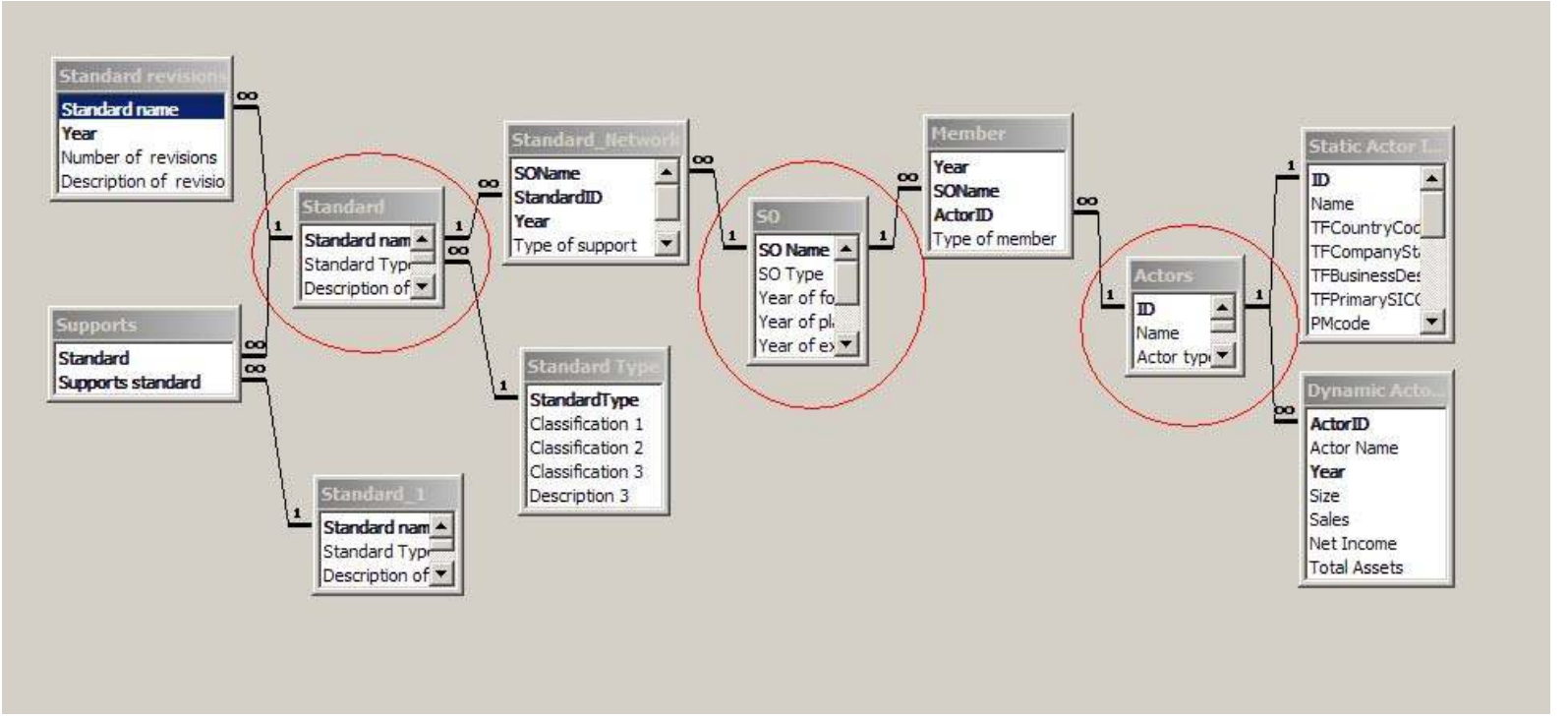


Figure 9-1: Relational database schema of the ANS database

9.5.1 Standard entity

In (database) tables “Standard”, “Standard revisions”, “Supports”, “Standard_1”, and “Standard Type” we focus on the part of the database that is about the standard. For each table, we will provide a description. The table “Standard” consists of the attribute “Standard name” and Standard Type”. The Standard Type attribute is linked to the key of the Standard Type table in which the three dimensions that were discussed in Chapter 3 are presented and described. Some standards define communication at a particular level in the architecture of a system but, at the same time, support other standards at other levels within that architecture. This is recorded in the table “Supports” which is linked to the dummy table standard_1. In this table, we record for each standard which standards are supported by that standard. In the Table ‘standard revisions’ we record the different revisions that were developed and introduced into the market for the standard.

9.5.2 SO entity

In (database) tables “SO”, “Standard_Network”, and “Member” we focus on the part of the database concerning SOs. The main table is the SO table. The attribute SO Type provides the SO type (Consortium, formal standardization organization, sectoral standardization organization, etc (see Section 6.3 for the possible types)). The table Standard_Network is used to link the standard to an SO. For each standard, we include the SO that develops, promotes, or maintains that standard. Through the Standard_Network table there exists an n to n relation between standard and SO because one standard can be developed, maintained, and or promoted by multiple SOs and one SO can develop, maintain, and/or promote multiple standards. The year is included since the standards that a SO supports can change per year and the SOs that support a particular standard can also change per year. Furthermore, the type of support which can be promoting, developing or both promoting and developing is included. In the member table, we include the different actors that were member of that SO in that particular year – for every year and for every SO. We also include the type of member. Most SOs distinguish between promoting members and adopting members. Updegrove (2006) distinguishes between four different levels of membership: strategic members, which usually have a guaranteed position in the board, and that set the strategic objectives of the consortium; technical committee members, that can elect board representatives and that can directly influence the standards that are being developed; advisory members that participate in the standard setting process but do not have voting rights and thus cannot directly influence the process, and

informational members that receive periodic updates about progress being made in the organization. We focus on the first type of members: strategic members. For each year, we record these members

9.5.3 Actor

In (database) tables “Actors”, “Static Actor Information”, and “Dynamic Actor Information” we focus on the part of the database that is about the actor. In the “Static Actor Information” table attributes include TFCountryCode which represents the country in which the actor has its headquarters, TFCompanyStatus which can be active or inactive, TFPrimarySICCode which is the Standard Industry Code of the actor, and PMCode in which we record the product market in which the actor is primarily operating. In the table: dynamic actor information the information for each actor over time is recorded. Attributes include size (number of employees in the company), sales (Total Revenue), net Income, and total assets.

9.5.4 Data Collection protocol

The data collection protocol consists of the following four steps:

1. Search for standards that are relevant to include in the database
2. For each standard, search for every SO that develops, maintains or promotes that standard, determine the types of members for the SO and put the information in the comments attribute of the SO table
3. For each SO, collect information about the actors that were a member of that SO from 1996 to 2006
4. For each actor, collect information about its characteristics from 1996 to 2006

We now discuss each step in depth and focus on the secondary data sources that will be analyzed to come to the data.

Search for standards

To fill in the database, we begin by searching for the standards that are relevant to include in the database. In Chapter 3, we have performed a descriptive study of home networking standards, which resulted in a total of sixty-four standards. Our database contains information from the network of each of these standards. Each of these standards is studied in depth by making use of different sources of secondary data. This resulted in

other standards that have been included in the database. Data about revisions in the form of new versions of the standard are collected by consulting the webpages of the SOs that have developed the standards.

Search for SOs

For each standard, we will analyze which SOs develops/maintains/promotes the standard. To come to a list of SOs, we will make use of the descriptive study mentioned before, as well as press releases concerning the establishment and dissolvement of SOs[11]. Most information for SOs is located on their internet pages. Information about SO type, founding year, year of planned exit, and year of exit can also be found here.

Data that is located in the member table is collected by analyzing the member section on the internet page of the SO. Since we started collecting data in 2006, we have consulted the internet archive to collect the data retrospectively. The internet archive is an online library that consists of archived versions of web sites which can be freely used by researchers. We can, by consulting the homepage of each SO, reconstruct its network over time from the moment that it was founded until the moment that it was dissolved. For each year, we have looked at the first time that the webpage was updated and we recorded the members that were present in the network at that time. When the data is not available through the internet archive, we make use of other secondary sources such as news archives on the SOs internet pages and on other sources such as specific journals that report on business events (e.g., The Financial Times, Business Week, etc.). We also consult specialized databases that report alliance and consortium activities from year to year. Where SOs will not give away membership information publicly, we contacted them directly and asked whether they want to share their information.

For standard development organizations, we collect information regarding the different standards that the standard development organization develops, promotes and/or maintains. We will use information from the descriptive study to accomplish this goal. However, we will not collect information for the members of the standard development organizations.

Search for actors

For each actor, we will collect the static information (to be put in the actor table and the static actor information table). We also collect dynamics information for the actors (to be put in the dynamics actor

[11] Among other sources the following sources were used http://www.consortiuminfo.org /news/cat.php?CID=1, http://www.consortiuminfo.org/ news/cat.php?CID=7, http://www.consortiumnews.com/

information table). We make use of specialized databases (such as, Thomson one banker and Datastream). These databases provide static as well as dynamic information on companies.

9.5.5 Summary data collection protocol

- Step 1: collect standard information
    - 1.A: For each standard, collect information regarding their characteristics and determine the type of standard (according to three classifications) using descriptive studies, internet pages, specific technical reports on the standards, etc.
    - 1.B: determine, per year, the number of revisions of the standard by consulting news archives (descriptive studies, consortiuminfo.org, consortiumnews.org, SO pages, etc.) and the homepage of the SO that developed, promotes, and or/maintains the standard
    - 1.C: Analyze other standards that were found during steps 1A and 1B
- Step 2: collect SO information
    - 2.A: for each standard, determine the SO that develops/maintains/promotes the standard (descriptive studies, press releases concerning the establishment and dissolvement of SOs (consortiuminfo.org, consortiumnews.org))
    - 2.B: For each SO, collect static information
- Step 3: collect membership information
    - 3.A: Collect membership information by analyzing the member sections on SOs internet pages using the web archive
    - 3.B: Collect membership information by analyzing the news archives on the SOs internet pages
    - 3.C Collect membership information by searching through specific journals that report on business events
    - 3.D: Collect membership information by consulting specialized databases that report alliance and consortium activities from year to year
    - 3.E: Collect membership information by contacting the SO by telephone
- Step 4: collect actor information

- 4.A: for each actor collect static and dynamic information from the Thomson One Banker and Datastream databases

9.6 Application of the framework for standard dominance on the video standards battle

		(Cusumano, Mylonadis and Rosenbloom, 1992)	(Grindley, 1995)	(Dai, 1996)	(Roome, 2006)	(Economides, 1996a)	(Klopfenstein, 1989)	(Johne, 1994)	(Bartlett and Ghosal, 1988)	(Cottrell and Sick, 2001)	(Puffert, 1999)	(Ohashi, 2002)
Dominant standard supporter												
1	Financial strength	■	■									
2	Brand reputation and credibility	■	■	■	■					■		
3	Operational supremacy											
4	Learning orientation	■	■	■		■		■	■		■	■
Characteristics of the standard												
5	Technological superiority	■	■	■	■	■	■	■		■	■	■
6	Compatibility			■						■		
7	Complementary goods	■	■	■	■	■	■			■	■	
8	Flexibility											
Standard support strategy												
9	Pricing strategy	■	■	■			■					■
10	Appropriability strategy	■	■	■		■	■			■		
11	Timing of entry	■	■	■						■		■
12	Marketing Communications	■					■	■	■	■		
13	Preemption of scarce assets.											
14	Distribution strategy											
15	Commitment		■	■								
Other stakeholders												
16	Current installed base	■	■									
17	Previous installed base											
18	Big Fish	■	■	■								
19	Regulator	■		■								■
20	Judiciary											
21	Suppliers	■	■	■								
22	Effec. of the standard development process	■										
23	Network of stakeholders	■										■
Market characteristics												
24	Bandwagon effect	■	■	■								
25	Network externalities	■	■	■	■					■	■	■
26	Number of options available											
27	Uncertainty in the market											
28	Rate of change											
29	Switching costs			■								

9.7 A graph theoretic analysis of the Data used in Chapter 6

In Figure 9-2, Figure 9-3, and Figure 9-4, we present a graph theoretic layout of the network of actors involved in home networking in the years 1996 to 2006[12]. To reduce the clutter in the graphs we removed the pendants (firms that sit in the board of a single SO). Thus, we only focus on actors that sit on multiple boards at the same time. To arrive at the layout presented in the figure we applied the "spring embedding" algorithm (using UCInet and Newdraw). This algorithm applies iterative fitting to allocate positions to nodes in a 2 dimensional space. As layout criteria we chose node repulsion and equal edge length to increase clarity in the picture. Furthermore, we applied the gower scaling as a starting position for the nodes and we chose 100 iterations.

The graphs should be interpreted as follows: nodes that are closer together have smaller geodesic distances then nodes that are further apart (the geodesic distance is the smallest shortest path between two nodes). Thus, actors that are close together are similar in that they work together in the same set of SOs. In the graphs, the circles represent companies and the colors of the circles represent the product market in which the company primarily operates (yellow = CE, red = IT, blue = TE, and green = HA). The triangles represent the SOs where the up triangle represent those SOs that still exist in 2006 and the down triangles represent the SOs that did not exist anymore by 2006.

[12] To save space we omitted the uneven years, patterns were similar in these years. The data is available upon request.

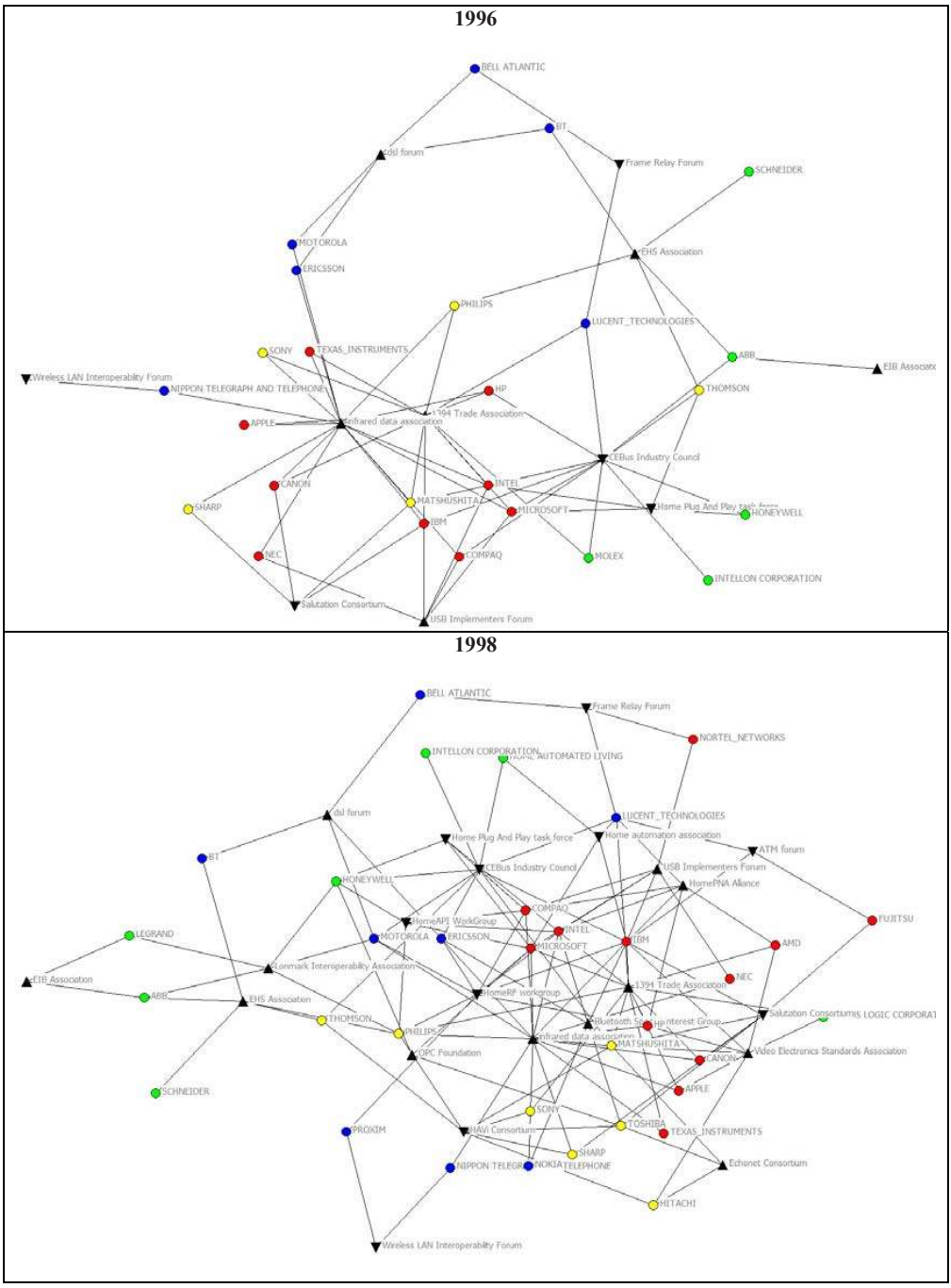


Figure 9-2: The evolution of the network of firms active in home networking over time (1996, 1998)

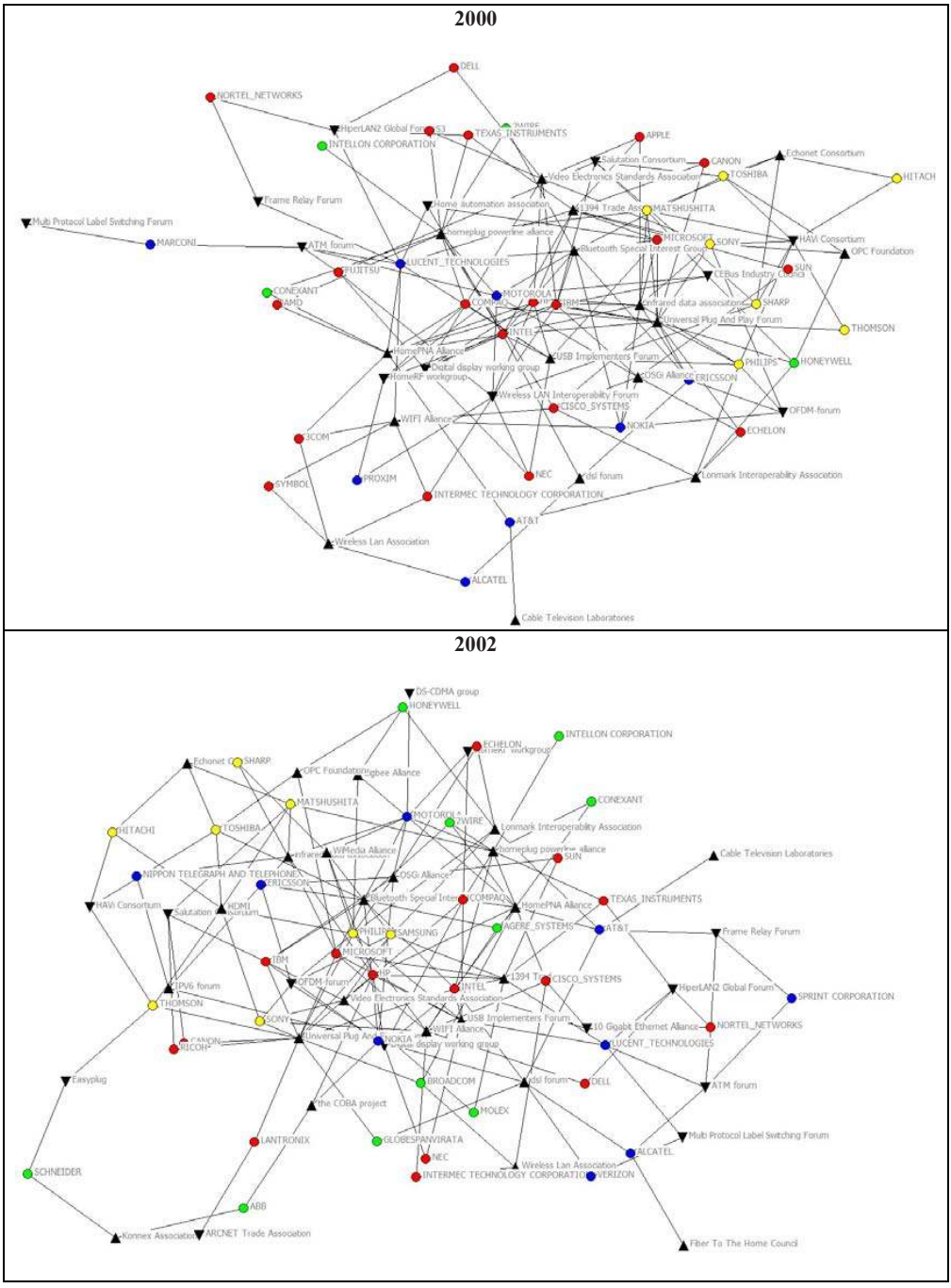


Figure 9-3: The evolution of the network of firms active in home networking over time (2000, 2002)

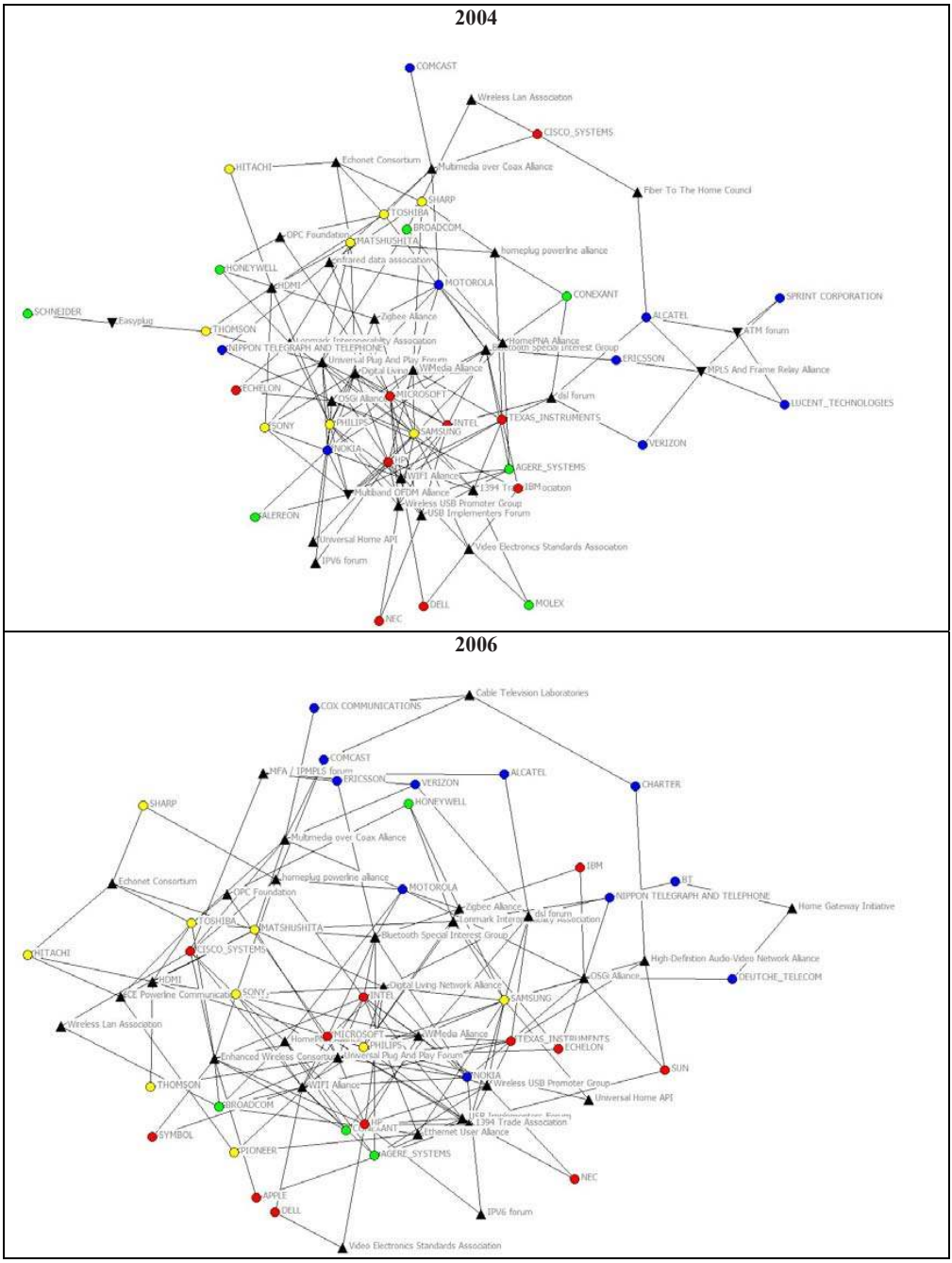


Figure 9-4: The evolution of the network of firms active in home networking over time (2004, 2006)

ABSTRACT

Home networks combine components and technologies from different product markets including consumer electronics (such as, TV, audio, gaming consoles), information technology (such as, personal computers), telecommunications (such as, smart phones), and home automation (such as, thermostats and door chimes). Irrespective of the fact that the home network has been technically possible for many years and that there seems to be a demand for it (Wacks, 2002), it has not become a practical reality. A major reason is the lack of generally accepted common standards for the interconnection between the subsystems of a home network (Rose, 2001; Wacks, 2001; Wacks, 2002). Such standards are a prerequisite for home networks to emerge because the different subsystems must meet a common set of standards in order to be able to communicate with each other. Multiple competing standards exist next to each other and there is a need to be able to explain and predict which standard will have the highest chance of achieving dominance so that the uncertainty attached to adopting a particular standard is reduced.

One of the characteristics of complex systems (such as, home networks) is that they consist of established subsystems that originate from multiple product markets that are converging with each other. The main objective of this research is to develop a framework for the selection of standards for these types of systems and to assess which factors are important. This translates to the following central research question: What are the most important factors which determine the outcome of battles of standards for complex systems that consist of established subsystems? This research question has been addressed for home networks in particular.

Chapter 2:

The literature on standard selection is fragmented and does not provide us with an overall framework in which all relevant factors are included. Studies that do propose frameworks tend to be incomplete and focus on a subset of the total set of factors. A complete overview of factors is missing. Therefore we began by developing such a list based on the available literature. We performed an extensive literature study of 127 papers from standard selection literature, resulting in twenty-nine factors for standard dominance. We grouped these factors into five categories: characteristics of the standard supporter, characteristics of the standard, standard support strategy, other stakeholders, and market characteristics. By performing a meta-analysis of the literature we specified the direction of each factor on standard dominance. This resulted in a framework with which it is possible to explain the outcome of standards battles. The framework appears to be more complete when

compared to three frameworks mentioned in prior literature (Lee, O'Neal, Pruett and Thoams, 1995; Schilling, 1998; Suarez, 2004)

Chapter 3:

To better understand the specifics of systems consisting of established subsystems with respect to the standard selection process, we performed a descriptive study of the home network. We started by developing a categorization of home networking standards. Next, we provided an overview of the different standards organizations (SOs) that are involved. Subsequently, for each SO, we provided the standards and we classified them according to the categorization developed.

Chapter 4:

In this chapter, we explored the completeness and relevance of the framework developed in Chapter 2 by applying it to three standards battles. We did not find new factors and the framework thus appears to be complete. We noticed that two factors not included in prior frameworks for standard dominance were important in our cases. Both the diversity in the group of standard supports and the commitment of the group of standard supporters were important in at least one of the three case studies. Thus, it seems that our framework can better and more completely explain standard dominance when compared to prior frameworks. We also notice that the factors operational supremacy, pre-emption of scarce assets, and distribution strategy have never been studied empirically and also didn't play a role in any of the three standards battles studied. We might expect that these factors are less relevant in standards battles.

Chapter 5:

The objective of Chapter 5 is to explore whether the framework developed in Chapter 2 can be used to explain and predict the outcome of battles of standards for complex systems. The Analytic Hierarchy Process is used to compute weights for the different factors that are distinguished and to determine whether the influence of factors for standard dominance is modified by the type of standard. The framework is applied to three historical cases of standards battles. The results show that there is empirical evidence that (1) the AHP is a useful tool to determine the relative weight of factors; (2) for each of the types of standards, different dominant factors emerge; (3) for three standards battles (representing the three different standards) the experts using the AHP were able to determine the winning standard by identifying relevant factors and their weights.

Chapter 6:

The objective of this chapter is to gain a better understanding of the influence of the characteristics of the network of a standard and the flexibility of the standard on the chances that standards achieve dominance in the case of complex systems. We form several hypotheses and we test these by developing a database using secondary sources. It appears that the diversity of the network of the standard in terms of the product markets that are represented in the network has a significant positive effect on the chances that the standard achieves dominance. Also it appeared that if the standard is more frequently adapted to user requirements the chances that it will become dominant increase. Finally, it appeared that the flexibility of the standard reinforces network diversity.

SAMENVATTING

Een communicatienetwerk in een woonhuis verbindt verschillende technologieën en componenten met elkaar die hun oorsprong vinden in verschillende productmarkten. Het gaat hier om consumentenelectronica zoals televisies en spelcomputers, informatietechnologie zoals personal computers, telecommunicatie zoals smartphones, en domotica zoals de thermostaat. Ondanks het feit dat zulke communicatienetwerken technisch gezien al geruime tijd mogelijk zijn worden ze nog niet op grote schaal toegepast. Dat komt voornamelijk omdat er nog geen keuze is gemaakt voor de standaarden die de communicatie in zo'n netwerk mogelijk maken. Voordat de verschillende apparaten in één huis met elkaar kunnen communiceren, zullen ze dezelfde standaard moeten ondersteunen. Er bestaan meerdere standaarden naast elkaar en er is een behoefte om te kunnen verklaren en voorspellen welke standaard de hoogste kans heeft om succesvol te worden. Zo kan de onzekerheid die gepaard gaat met de keuze om voor een standaard te kiezen worden verkleind.

Het communicatienetwerk in een huis is één van de voorbeelden van een complex systeem dat bestaat uit "bestaande" subsystemen die afkomstig zijn vanuit verschillende productmarkten die met elkaar convergeren. Het hoofddoel van dit onderzoek is om een raamwerk te ontwikkelen voor de selectie van standaarden voor dit type systemen en om te bepalen welke factoren daarvoor belangrijk zijn. Dit leidt tot de volgende centrale onderzoeksvraag: Wat zijn de belangrijkste factoren die de uitkomst bepalen van standaardisatiegevechten voor complexe systemen, die bestaan uit bestaande subsystemen? Hierbij richten we ons voornamelijk op het communicatienetwerk in huis.

Hoofdstuk 2:

De literatuur over de selectie van standaarden is gefragmenteerd en geeft ons geen allesomvattend raamwerk waarin alle relevante factoren zijn opgenomen. Bestaande onderzoeken die dergelijke raamwerken voorstellen zijn meestal incompleet en richten zich op een subset van de totale set van factoren. Een compleet overzicht van factoren ontbreekt. Daarom beginnen we in dit hoofdstuk met het ontwikkelen van een dergelijke lijst gebaseerd op de beschikbare literatuur. Om te komen tot een dergelijke lijst van factoren hebben we een uitgebreid literatuuronderzoek gedaan van 127 artikelen uit de literatuur over de selectie van standaarden. Dat resulteerde in 29 factoren voor dominantie van standaarden. We groeperen deze factoren in 5 categorieën: kenmerken van de ondersteuner van de standaard, kenmerken van de standaard, strategie van de ondersteuner van de standaard, andere betrokken partijen, en kenmerken van de markt. Door het uitvoeren van een meta-analyse van de literatuur komen we tot de richting voor de factoren voor dominantie van standaarden. Dit

resulteert in een raamwerk waarmee het mogelijk is om de uitkomst van standaardisatiegevechten te verklaren. Ons raamwerk blijkt completer dan drie raamwerken genoemd in de voorgaande literatuur.

Hoofdstuk 3

Om de verschillende aspecten met betrekking tot het standaardselectieproces van systemen die bestaan uit bestaande subsystemen beter te begrijpen, verrichten we in dit hoofdstuk een beschrijvende studie van het communicatienetwerk in een huis. Daarbij beginnen we met het ontwikkelen van een categorisering van standaarden voor communicatienetwerken in huis. Daarna geven we een overzicht van de verschillende standaardisatieorganisaties die een rol spelen. We zoeken uit welke standaarden door die organisaties worden aangehangen en we classificeren die standaarden op basis van de ontwikkelde categorisering.

Hoofdstuk 4

In dit hoofdstuk verkennen we de relevantie en compleetheid van het raamwerk dat we in hoofdstuk 2 hebben ontwikkeld, door het raamwerk toe te passen op drie standaardisatiegevechten. We vonden geen nieuwe factoren en het raamwerk lijkt dus compleet te zijn. We kwamen erachter dat twee factoren die niet zijn meegenomen in vorige raamwerken belangrijk zijn in de standaardisatiegevechten die we hebben bestudeerd. Zowel de diversiteit in de groep van ondersteuners van de standaard, als de betrokkenheid van de groep van ondersteuners van de standaard, waren belangrijke factoren in tenminste één van de drie cases. Het lijkt zo te zijn dat het raamwerk de dominantie van standaarden beter en completer kan verklaren ten opzichte van bestaande raamwerken. We kwamen er ook achter dat de factoren 'operational supremacy', pre-emption of scarce assets', en 'distribution strategy' nog nooit empirisch zijn onderzocht en dat deze factoren geen rol speelden in de drie standaardisatiegevechten die wij hebben bestudeerd. We zouden kunnen verwachten dat deze factoren minder relevant zijn in standaardisatiegevechten.

Hoofdstuk 5

Het doel van hoofdstuk 5 is om te verkennen of het in hoofdstuk 2 ontwikkelde raamwerk kan worden gebruikt om de uitkomst van standaardisatiegevechten voor complexe systemen te verklaren en te voorspellen. We passen de 'Analytic Hierarchy Process' (AHP) toe om gewichten voor de factoren te bepalen en om te onderzoeken of de invloed van factoren wordt gemodificeerd door het type standaard. Het raamwerk wordt toegepast op drie historische cases van standaardisatie gevechten. De resultaten laten zien dat er empirisch

bewijs is dat (1) de AHP een nuttig gereedschap is om de gewichten van factoren vast te stellen; (2) voor elk type standaard verschillende factoren belangrijk zijn; (3) door gebruik te maken van de AHP de deskundigen voor drie standaardisatiegevechten (die de drie typen standaarden representeren) konden bepalen welke standaard wint door de relevante factoren te identificeren en hun gewichten vast te stellen.

Hoofdstuk 6

Het doel van hoofdstuk 6 is om de invloed van twee zaken beter te begrijpen: de diversiteit van aanhangers van een standaard, en de flexibiliteit van de standaard. We stellen verschillende hypotheses op en testen deze aan de hand van een database die we hebben opgebouwd door gebruik te maken van secundaire bronnen. Het blijkt dat wanneer de groep van ondersteuners van een standaard divers is voor wat betreft de productmarken waaruit ze afkomstig zijn dat dit een significant positief effect heeft op de kans dat een standaard dominant wordt. Ook blijkt het dat naarmate de standaard vaker wordt aangepast aan de eisen van de gebruiker de kans dat de standaard dominant wordt groter wordt. Tenslotte blijken de flexibiliteit van de standaard en de diversiteit binnen de groep van aanhangers van de standaard elkaar wederzijds te beïnvloeden.

ABOUT THE AUTHOR

Geerten van de Kaa was born on 28 March 1979 in Breda, the Netherlands. He received his secondary education diploma from the Katholieke Scholengemeenschap Etten-Leur in 1998. From 1998 to 2003, Geerten studied Informatics and Economics at Erasmus University Rotterdam. After his studies, he was an IT consultant at Impuls IT, a software company in Dordrecht and later he was an application manager at B&S International, a wholesale company in Dordrecht. In 2004, he started a PhD project on standardization for home networks. This project was conducted at the department of Management of Technology and Innovation of Rotterdam School of Management, Erasmus University between October 2004 and September 2008. During this time Geerten taught a bachelor course and he supervised master students. Geerten's research spans the areas of strategic management of technological innovation, standards and dominant designs, and social networks.

Geerten has presented his work at leading international conferences such as the Academy of Management Annual Meeting, Hawaii International Conference on Computer Sciences, International Product Development Management Conference, and the International Conference on Standardization and Innovation in Information Technology.

From 2004 until 2008 he was a member of the B@Home project and of the larger Freeband program which was coordinated by the Telematics Institute. Freeband Communication is a Dutch national research program aiming to create a leading knowledge position for the Netherlands in the area of ambient, intelligent communication. Together with other people he was responsible for the research conducted on home networking standards. He has both published and presented several white papers in the project. In October 2008, he started working as an Assistant Professor of Strategy and Innovation at Delft University of Technology.

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STANDARDS BATTLES FOR COMPLEX SYSTEMS
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Home networks combine components and technologies from the consumer electronics industry, the information technology industry, the telecommunications industry, and the home automation industry. Irrespective of the fact that the home network has been technically possible for many years, it has not become a practical reality. A major reason is the lack of generally accepted common standards.

In this dissertation we develop a framework with which we can explain and predict which standard will have the highest chance of achieving dominance. We applied the framework to several standards battles and it appeared that it can be used to explain these standards battles better, when compared to existing frameworks in the literature. We applied a multi-attribute utility approach to standard selection and provide a first indication of weights for factors. Also, we have studied two factors in depth: the diversity in the network of actors that support a standard; and the flexibility of the standard. We provide a first indication that these variables influence standard dominance positively and reinforce each other.

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