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Factors for winning format battles: A comparative case study



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ABSTRACT

The outcome of battles between competing interface formats shapes technology fields and implies success or failure for the companies involved. Recently, this journal published a paper, which proposes a new framework of factors that impact the outcome of such battles. We apply this framework to three format battles: for wired connectivity in home applications, for wireless connectivity in home applications, and for multi-channel sound. The framework appears to be more complete than earlier frameworks, and therefore provides a better understanding of interface format battles. Firms can use this framework to make more accurate forecasts about the winner, if any, of a format battle, and can adjust their strategies by exploiting certain factors to enhance their chances of success.

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1. Introduction

Why did QWERTY become the dominant keyboard layout format instead of DVORAK? Why did VHS win the video format war and why did Blu-ray defeat HD-DVD? Which fourth generation mobile communication format will we use in the future? Battles between formats emerge time and time again. For every party involved it is important to understand the likelihood of a specific format achieving dominance, since betting on the format that turns out to be unsuccessful can result in high losses [1].

Several studies [2–4] have analyzed these battles in depth and have proposed factors that explain their outcome [5–7], but most focus on a subgroup of the set of possible factors for format dominance [8]. Moreover, most of this literature lacks empirical evidence for the factors that contribute to format dominance, and a small number of empirical studies focus on only a few factors. In this study, we take a more comprehensive approach by building on a study by Van de Kaa et al. [9] which was recently published in this journal. They conducted an extensive literature study resulting in a framework for

format dominance consisting of a large number of factors. They claim that it is the most complete framework and that it can be used to analyze any format battle. The objective of this study is to explore the completeness of the framework and the relevance of the factors in this framework by confronting it with empirical data. In this paper, we study three cases in depth [10,11]. This may confirm the framework or result in new factors that have not previously been mentioned in the literature. This research aims to add to the growing body of literature focusing on interface formats, dominant designs and standardization, and builds on the findings of Suarez [5] and Schilling [6,8].

Interface formats are codified specifications defining the interrelations between entities in order to enable them to function together [9]. These can be called dominant when they achieve the largest market share among new products sold (in which one or more of the competing formats are implemented¹) in a certain product category for a certain amount of time [9]. We concentrate on the period beginning

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¹ If two competing formats are implemented in one product, the market share of both formats increases so that the sum of the market shares of the two formats may be more than 100%. The format with the largest market share is the dominant one.

with the first format being released until one of the formats becomes dominant, i.e., the 'era of ferment' [12].

The paper proceeds as follows. We begin by exploring several theoretical perspectives on format dominance in Section 2. Section 3 provides our methodology. We present the results from three case studies in Section 4 and discuss our findings in Section 5. In Section 6, we present our conclusions.

2. Theory

Many industries are characterized by forces, which lead to a single format attaining dominance. In these industries, positive direct network externalities apply where technology becomes more valuable for an individual user when more people use it [13,14]. Most markets in which these effects exist are 'two sided' in that they consist of complementary goods for which the technology defines communication [15]. Examples include the markets for VCRs [3] and video game consoles [16,17]. An increase in the availability of complementary goods has a positive effect on the installed base of the technology [8]. If we take the case of Blu-ray vs. HD-DVD, if more popular movies are available on Blu-ray compared to HD-DVD, the demand for Blu-ray players and disks will be high [18]. These markets are often path dependent, meaning that random historical events can determine which technology rises to dominance [2,19]. Evolutionary economists place technology selection in the context of natural selection [20]. Technological artefacts advance over time whereby incremental changes occur until a major breakthrough appears in the market. Due to these 'technological discontinuities' market uncertainty increases and the industry may be changed significantly [21]. Consequently, a new 'technological paradigm' arises. Therein, various technological paths can develop, resulting in technological designs competing for format dominance [22]. The technology that eventually achieves dominance is often referred to as the 'dominant design' [23,24].

Various researchers have analyzed how actors compete in these so called 'network markets' [25,26] and use the term 'format war', 'platform war' or 'standards battle' to refer to a situation in which two or more interface formats battle for dominance [1]. Because the firm that establishes dominance with its technology can profit from a 'winner-take-all' situation and can accrue monopoly rents with its technology [27], it is important for firms to understand which factors affect the outcome of format wars. Building on the resource-based view of the firm [28,29], scholars in the area of strategic management have emphasized firm capabilities that are needed to successfully commercialize a technology. Teece [30] uses the label 'complementary assets' to describe factors such as reputation, production capacity and distribution channels which can be exploited to reach a dominant format [5]. Furthermore, firms need to invest in knowledge acquisition, otherwise they run the risk of being locked out of the market [6,8]. Scholars have also focused on strategies that can be applied in network industries and that impact the expansion of an early installed base [26]. Various authors seem to agree on the significance of marketing communications to positively influence customer expectations regarding the format [16,31–33]. Others focus on the price of the product in which

the format is implemented [31,33], the availability of complementary goods [34,35], appropriability strategies [36,37], and the timing of market entry [6,8]. Standardization scholars emphasize technical characteristics such as a format's quality in terms of e.g., bandwidth capacity and the compatibility that it enables [38]. They also focus on the importance of other stakeholders such as standard development organizations. Government involvement in standardization may provide the format with a certain degree of authority or legitimacy and is beneficial for its diffusion [39]. Governmental agencies may also use their power to prescribe a format [40]. For example, the (US) Federal Communications Commission (FCC) used its power in the battle for a color television format [27] and in the battle for an HDTV format [41]. Van de Kaa et al. [9] conducted an extensive literature review with the objective of reaching a framework of factors for format dominance. Table 1 presents and defines the twenty-nine factors.

3. Methodology

We studied three historical cases of format wars to explore the completeness of the framework presented in Table 1 and the relevance of the factors for format dominance. The unit of analysis was the format that was vying for dominance. We created a list of cases and chose three cases by following two selection criteria. First, the formats vying for dominance should be comparable in terms of the interoperability that these formats enable [42]. Second, one format should have achieved dominance (i.e., we made sure that the case studies were truly historical). We selected the battle between FireWire and USB for peripheral interconnectivity to the PC, the battle between DECTPRS, Wi-Fi, and HomeRF for wireless connectivity in the home, and the battle between MPEG-2 Audio and AC-3 for a multi-channel sound format. These battles were fought in diverse industries including Information Technology (IT), Telecommunications (TE) and Consumer Electronics (CE).

We first gathered secondary data for each format war by analyzing the press releases of the companies involved and by examining several online news archives including Factiva and Lexis-Nexis. Primary data was collected through face-to-face semi-structured interviews with key figures in the format war. We interviewed two kinds of experts for each format: those who were involved in the development and/or promotion of that format, and an expert who was not involved but who had studied the format war closely (i.e., an 'outsider' in the battle). The majority of the interviews were conducted face-to-face. We asked all interviewees to provide secondary sources in the form of reports, presentations, news articles, etc., which were analyzed and resulted in a reconstruction of the three cases.

We interviewed four respondents about the battle for peripheral interconnectivity to the PC, six respondents about the battle for a wireless format for the home, and five about the battle for a multi-channel sound format. For privacy reasons, we do not provide their names.

We began each interview with an open question and asked the respondents to describe the most important events in the format war in chronological order. In their description, respondents mentioned several factors, explicitly or implicitly. In subsequent questions, we asked the interviewees

Table 1
Factors explained.

Description	Effect	
<i>Characteristics of the format supporter</i>		
1 Financial strength	Current and future financial condition of the group of format supporters [based on [58]].	+
2 Brand reputation and credibility	The opinion that people have about a group of format supporters, based on what has happened in the past [based on [59]].	+
3 Operational supremacy	The characteristics of the group of format supporters that allow them to exploit resources better than their competitors [based on [8]].	+
4 Learning orientation	The extent to which the group of format supporters expand their knowledge and skills base and improve their ability to assimilate and utilize future information [based on [6]].	+
<i>Characteristics of the format</i>		
5 Technological superiority	A format is technologically superior when it can outperform other formats [60].	+
6 Compatibility	Compatibility concerns the fitting of interrelated entities with each other so that they can function together [61].	+
7 Complementary goods	The 'other' goods that are needed to successfully commercialize a format [30]. When more complementary goods are available for a format, a positive effect on the installed base of the format is created [8]. Firms can also diversify and offer their own complementary goods.	+
8 Flexibility	The extent to which the format can be changed to suit new conditions or situations [59].	+
<i>Format support strategy</i>		
9 Pricing strategy	The technique of offering low prices to early customers to build up an installed base and influence the choices of later adopters [31].	–
10 Appropriability strategy	The actions that firms undertake to protect their format from imitation that can take place by competitors [7].	–
11 Timing of entry	The time when a format is introduced in the market [based on [5]].	∩
12 Marketing communications	All actions taken to influence customer expectations [based on [5]]. These actions can also increase potential installed base as people become more aware of the format [62]	+
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 [63]].	+
14 Distribution strategy	The extent to which a firm strengthens its distribution system [based on [58]].	+
15 Commitment	An obligation or pledge to carry out some action or policy or to give support to some policy or person [64]. A format has a higher chance of achieving dominance when it is supported by an actor that is committed to the format.	+
<i>Other stakeholders</i>		
16 Current installed base	A collection of users of a certain format [61].	+
17 Previous installed base	Users that might upgrade to the new format [33].	+
18 Big fish	An actor that may have substantial power by promoting or financially supporting a format or by having buying power that is so great that it contributes strongly to the market position of the format [53].	+
19 Regulator	The actor that can prescribe a format in the market [53].	+
20 Judiciary	The judges of a country or state when they are considered as a group [59] which can prohibit certain formats from achieving dominance for reasons of anti-trust policy.	–
21 Suppliers	Actors that are producing complementary goods and/or services [30].	+
22 Effectiveness of the standard development process	The degree to which the objectives of format developers are achieved and the extent to which targeted problems are solved during the format development process. This applies both to the contents of the agreed-upon solution and to characteristics of the process such as stakeholder involvement and speed.	+
23 Diversity of the network	The extent to which stakeholders from different relevant industries are represented in the group of format supporters. A format will have a high chance of reaching a dominant position if that format is supported by a network that is diverse and in which actors are represented from each relevant industry for which the format serves a defining role [65,66]. For example, in the battle between Blu-ray and HD-DVD, the formats are implemented in products from different industries (e.g., high definition DVDs, movies aired in movie theaters, and video games). By attracting firms from those diverse industries (such as movie studios [67]) to their network, firms can offer more diverse products that implement their format and thereby create a larger overall installed base for their format [18].	+
<i>Market characteristics</i>		
24 Bandwagon effect	The effect that the adoption of a specific technology by a set of users stimulates other users to adopt this technology [33].	+
25 Network externalities	Network externalities occur when the value of a good increases with the number of other consumers that have adopted that good [14]. According to Gallagher [68], network effects apply to all formats. It is one of the causes of bandwagon effects.	+
26 Number of options available	The more competing formats there are in the market, the lower the chances of one of them becoming dominant [69].	–
27 Uncertainty in the market	The extent to which firms and customers are unwilling to take the risks of choosing one particular format, and shelve their decision [70–72].	–
28 Rate of change	The speed of progress in an industry with respect to technology and market [73]. A high speed negatively affects the selection of a dominant format [74].	–
29 Switching costs	Costs that are required to switch from one format to another [5] such as the 'learning curve costs' of a new format [75]. The higher these costs are, the more reluctant a company's potential clientele will be to switch from the competitor's format to theirs, and the more 'loyal' its own customer base is. The higher these costs, the longer it takes for a format to achieve dominance.	–

more directly which factors played a role in the battle and which had led to the success or failure of the format. We asked them whether the company they worked for had a particular format support strategy and if so, to evaluate this strategy. We also asked them why the competing formats had either won or lost the battle. At the end of the interview, we listed the factors that the respondents had not mentioned and asked them whether each of these factors could also have influenced the outcome of the battle. Interview guidelines were used for all interviews to ensure consistency and reliability. We then asked open-ended questions to allow respondents to generate new factors (i.e., factors not included in the framework presented in this paper). Respondents did not receive the questions before the interviews took place so their answers to the open-ended questions would not be biased. All interviews were tape-recorded, and transcribed before the data were analyzed. In each interview, we determined which factors had been implicitly or explicitly mentioned and assessed the value of each factor (high, low, many, few, etc.) for each of the competing formats. Value refers to the strength of the format in terms of that factor compared to other formats in the battle. For example, if the value for installed base of a format is high, then this installed base is bigger compared to competing formats. In the analyses, we only focus on firm-level factors since the values of environmental level factors do not differ per format that competes in a particular battle. For example, the rate of change in a particular industry as well as the uncertainty that exists in that industry affects all competing formats equally. The results of each interview were processed and interviewees were requested to check them for consistency.

To assess whether a particular factor played a role in the outcome of a format war and, if so, to determine its role, we also analyzed the documents provided by each respondent, and examined the news archives for evidence. Then we compared these findings with those from the interviews. We triangulated evidence obtained from each of the three sources of data. In other words, we collected information from multiple data sources and tried to corroborate that a particular factor led to the success or failure of a particular format. Using this information, we determined which factors had played a role and which role they had played. A factor played a role when an interviewee indicated that it had contributed to the success or failure of a particular format, and when both the documentation and the archival records confirmed this. Moreover, the interviewees were asked to verify the results.

Data was analyzed according to Miles and Huberman's [43] suggested three stages: 'data reduction', 'data display', and 'conclusion drawing and verification'. We analyzed data pointing to a particular format winning or losing the battle and determined whether these data could be categorized under the factors for format dominance in the framework presented in this paper. Data that could not be categorized under these factors were either defined as random idiosyncratic events that occur in format wars, or were defined as new factors for format dominance. To determine whether a factor could be defined as new, we did a cross-case analysis to assess whether and to what extent the factor played a role in multiple format wars. Quotations from non-English-speaking interviewees were translated into English by the authors.

4. Results

In this section, we describe the cases in depth. We begin with a short chronological description of the format war and continue with a within-case analysis to explain the outcome of each battle in terms of the factors in the framework presented in this paper. Finally, we perform a cross-case analysis.

4.1. Case study 1: FireWire vs. USB

4.1.1. Case description

With the emergence of different peripheral PC devices in the 1990s, there was a need to connect these devices to the PC. In 1986, Apple started to develop FireWire to enable data transfer between digital devices, especially video equipment, e.g., to connect IT and CE devices to PCs. This transfer requires a high bandwidth capacity. In 1995, the Institute of Electrical and Electronics Engineers (IEEE) laid down the format in its IEEE 1394 standard.

In 1992, DEC and Intel started to develop the Universal Serial Bus (USB) format to enable data transfer for which a low bandwidth capacity is sufficient. It can be used to connect different peripheral devices such as a keyboard to a PC. FireWire and USB (1.0) were introduced in the market in 1987 and 1995 respectively.

In 1998, Apple introduced its iMac computer, which had two USB ports and no FireWire ports. After that, many more complementary goods were introduced that could only be connected through the USB format. In 2000, a new generation of the USB format (version 2.0) was introduced. It enabled a higher bandwidth capacity than the earlier version, which made it a direct competitor to the FireWire format. During this time, representatives of the CE and the IT industry met and tried to agree on one universal format which could be used in both industries. This led to friction across business units within the CE companies such as Sony, Toshiba and Panasonic because these companies also produced computers and computer parts. A common format was never achieved because actors in both industries wanted to position their products at the center of the home network. As one respondent said: *"Microsoft's vision was that the personal computer would be the center of the home network and that CE products (for example, cameras, televisions, video, and DVD) could be connected to the personal computer"*. However, representatives of the CE industry wanted CE products to be central and IT products to play a peripheral role. One of them 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 format [44]. It became the first choice format in the PC market [45], and is especially used to connect personal computers to peripheral devices for which a low bandwidth capacity is sufficient. FireWire has been improved with respect to data rate and is now still being used in the niche market for peripherals requiring a high-bandwidth data connection (e.g., video cameras).

4.1.2. Case analysis

The battle between FireWire and USB was basically a battle between the CE and the IT industry. If the promoter of

one format can gather enough actors (from both industries) to support its format, it can become dominant in the end. Because USB was mainly developed by IT firms, CE firms were reluctant to support the USB format. They were afraid that this would result in a more central position for IT in the home (devices would be connected to the PC rather than to the television). That is one of the reasons why CE firms supported FireWire rather than USB. In fact, once it was clear that USB would become dominant, they still did not support it because they were afraid that USB would become dominant in their industry (CE) as well. Microsoft also wanted the PC to become the center of the home network and therefore it needed a format that was developed by firms that were active in the IT industry (USB).

The CE industry consists of several important manufacturers whereas the IT industry is dominated by a few big firms such as Intel and Microsoft. This is relevant for the battle since when one of these actors chooses a particular format, other players frequently have to follow to survive. Since Intel and Microsoft both supported the USB format for communication between peripheral devices and PCs, smaller players developing peripheral devices had no choice but to also support USB. After the first introduction of the formats, both FireWire and USB continued to evolve. FireWire developed and introduced seven revisions compared to USB's 25 revisions.

Comparing the two formats with respect to their technological capabilities, we notice a few differences. FireWire was more reliable and could handle content with a high bandwidth capacity. This is an important reason why CE companies supported FireWire instead of USB as they needed reliable data connections for their products. Although FireWire was technologically superior compared to USB, it did not win the battle for dominance. When FireWire was introduced, high bandwidth capacity was not yet in demand. According to one respondent: *"At that time, it [FireWire] was complete and utter overkill for the PC industry"*. Another respondent explained that IEEE 1394 was launched at a time when *"CE consumers weren't ready for a home network solution"*. In this respect, FireWire's market entry was too early since the infrastructure outside the home was not yet ready to support a format with a high bandwidth capacity.

It seems as if Apple and Philips were not fully committed to the success of FireWire. In the midst of the battle (1998), FireWire's main promoter, Apple, introduced products that supported the competing USB format. Offering a competitor's interface is not necessarily a signal of a lack of commitment but this depends on the phase of the battle.

At that time, the battle between USB and FireWire was still being waged. Apple noticed that there were far more complementary goods available for the USB format and so the company decided to develop its iMac computer with two USB ports, since its iMac computer needed to be compatible with as many peripheral devices as possible to become successful. Philips was involved in the FireWire format but also played an important role in the development of USB. One respondent noted: *"Several presentations at the USB developer conferences emphasized the role of Philips in the development of USB audio"*. Another interviewee stated: *"The CE divisions within Philips supported IEEE 1394 and the PC divisions supported USB. This led to internal controversy within Philips"*.

Another respondent mentioned: *"Internally there was a lot of discussion at Philips (...). Personally, I was a proponent of USB and I promoted this format. Eventually, I managed to convince other people within Philips to invest in the format"*. The General Manager System Architectures at Philips Consumer Electronics explained: *"Internally, [in Philips], there was a clash between two industries [...] this led to several strategies that co-existed"*. Thus, internally there was a different level of commitment for one or the other format.

In 1999, Philips and Lucent joined the USB group. With Philips, Lucent, and Intel supporting the USB format, the network of this format consisted of representatives from the CE, IT and TE industries, and therefore several firms from these industries chose to follow these companies and to support USB. Yet, the network of actors that promoted the FireWire format was also somewhat diverse and consisted of reputable companies such as Apple, Philips, and Sony.

To conclude, the outcome of this battle was determined by flexibility, technological superiority, timing of entry, commitment, complementary goods and diversity of the network.

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

4.2.1. Case description

The first step to commercial wireless communication was in 1985 when the FCC opened up industrial, scientific and medical radio bands for wireless communications applications [46]. In 1988, the European Telecommunications Standards Institute (ETSI) introduced the Digital Enhanced Cordless Telephone (DECT) format for digital wireless voice telecommunication. ETSI further developed this format into the DECT Packet Radio Services (DECTPRS) format for wireless local area networks. The DECT Forum was responsible for the promotion of this format. In the years that followed, the growing popularity of the Internet increased demand for wireless data communication in the home.

In the late 1980s, NCR, a company engaged in the wiring of transaction terminals for retail department stores, studied the feasibility of wireless communication. In 1988, NCR approached IEEE and in 1990, IEEE started to work on the development of formats for wireless data communication. In 1997, the first version of Wi-Fi (IEEE 802.11) was introduced. In the years that followed, different generations of this format were developed and introduced by the IEEE 802.11 Working Group, each with a higher bandwidth capacity. Initially, only the business market was targeted.

In 1997, Compaq, Ericsson, HP, Intel, and Microsoft formed the HomeRF Working Group to develop an interoperable wireless voice and data communication solution which was affordable for consumers [47]. This consortium, which grew to over 100 firms, developed the HomeRF format for wireless networks. The reason for developing HomeRF was the assumed insufficient telephony support offered by IEEE 802.11 [48]. HomeRF enabled both voice and data communication. In 2000, the HomeRF Working Group received permission from the FCC to increase the bandwidth for frequency hopping in the 2.4-GHz band from 1 MHz to 5 MHz [49]. This enabled a bandwidth capacity increase from 1.6 Mbit/s to 10 Mbit/s. Consequently, the Working Group introduced a new generation of the format, HomeRF 2.0, which could compete with Wi-Fi and DECTPRS. Nevertheless,

in March 2001, Intel decided to use IEEE 802.11b instead of HomeRF in its home networking product line because IEEE 802.11b was more cost-effective. Intel had been one of the six major promoter companies of HomeRF and its decision to leave the group caused many companies to follow until the HomeRF Working Group was disbanded in 2003. Wi-Fi became the dominant format for wireless networks in homes and in offices. DECTPRS was never really a success [50].

4.2.2. Case analysis

The timing of market entry is important for a format's market acceptance. When the first product that implemented DECTPRS was introduced,² in 1992, there was no demand for wireless data communication. There were no products that supported wireless data communication so customers were not interested. In the late 1990s, Wi-Fi entered the business market and gained support. When Wi-Fi expanded to the consumer market, wireless networks of PCs and peripheral equipment such as printers and faxes were already being used in offices and many people were familiar with the format. One respondent reported; *"Wi-Fi first introduced the format in the business world and after it had become well-known and accepted, they made a home version"*. Many people who worked with the application at the office also wanted it at home, which contributed to the success of Wi-Fi considerably.

The HomeRF Working Group failed to promote its format effectively. One interviewee stated; *"HomeRF had to convince the market that one system for both voice and data was less expensive than buying two different systems for the applications."* In contrast, the DECT Forum promoted DECT applications and highlighted the benefits through effective marketing campaigns.

HomeRF was positioned in the market as a low cost format [46]. In 2001, the retail price of network interface cards implementing HomeRF was \$80 compared to \$130 for Wi-Fi. However, according to one respondent: *"HomeRF was too expensive considering its bandwidth capacity"*. Technically, HomeRF and Wi-Fi were comparable in most aspects [51]. However, Wi-Fi was more flexible than the other formats. Wi-Fi introduced 15 new versions compared to HomeRF's one [44]. Also, a larger number of complementary goods were available for Wi-Fi. More complementary goods give a higher chance of achieving dominance [8].

Although Intel was the leading firm behind HomeRF, it also invested in other formats, which led some companies to question Intel's commitment to HomeRF. Some of the other firms were also clearly not fully committed. One of the smaller adopters of HomeRF stated: *"We expected that HomeRF would fail, but someone had to be there in case it became successful"*. The promoter of HomeRF reported: *"Some of the companies [in the developing process] had some serious doubts about the format."* The actors behind DECTPRS also seemed to have been more committed to DECT than to the newer version. One respondent indicated: *"DECTPRS offered too much that companies did not really need"*. The actors behind DECT were more committed to promoting the Voice Over DECT format since it was expected to lead to more

immediate advantages. HomeRF also offered both voice and data communication functionality. However, there was no demand for a format that also supported wireless voice communication [46]. One respondent stated: *"The market was not interested or ready for data and voice transfer. They only cared about data transfer and 802.11 did an excellent job."* HomeRF was able to guarantee a 10 Mbps bandwidth capacity after the 2000 FCC ruling, but by that time Wi-Fi offered comparable bandwidth capacity [44].

Both Wi-Fi and HomeRF were promoted by a diverse network of actors both from IT and CE industries. However, one company had full control of a specific part of the HomeRF specification making the format partly proprietary, which contributed to the format's failure. In this respect, the promoters of Wi-Fi and DECTPRS followed a more open appropriability strategy as their formats were less proprietary. During the development of the DECTPRS format, there were several disagreements about the technical aspects of the format, which decreased the speed of the development process considerably. The parties involved had conflicting ideas about how to develop the format. Although initially the HomeRF development process was very efficient, later meetings held by the group were less effective [44].

To conclude, the outcome of this battle was determined by timing of entry, marketing communications, pricing strategy, flexibility, complementary goods, commitment, diversity of the network, appropriability strategy, and effectiveness of the format development process.

4.3. Case study 3: MPEG-2 Audio vs. AC-3

4.3.1. Case description

In 1988, Philips, France Telecom, the Institut für 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 MPEG-1 Audio format. At that time, there was an increasing demand for multi-channel sound provisioning. People wanted to watch digital television as well as DVDs with multi-channel sound. In 1993, the MPEG responded by developing a new generation of the format: MPEG-2 Audio. Due to the success of MPEG-1 Audio, MPEG-2 Audio was made backwards compatible with the previous version.

In the beginning of the 1990s, Dolby Laboratories (Dolby) developed the Audio Coding 3 (AC-3) format which was a direct competitor to MPEG-2 Audio. In 1992, this format was first used in movie theaters, and in 1995 it was introduced to home video. In Europe, MPEG-2 Audio and AC-3 co-existed, while in the rest of the world only AC-3 was used. AC-3 was the global winner of this battle.

4.3.2. Case analysis

Dolby foresaw that the multi-channel audio sound that was common in movie theaters would also be in demand in homes. And since films that are aired in movie theaters are eventually also be played in the home, Dolby knew that a prerequisite for gaining dominance in the home was to get acceptance in the movie industry. The United States (and Hollywood, in particular) was the market leader in the film

² NET3, a wireless LAN [50].

Table 2
Cross-case analysis.

Factor	Case study 1		Case study 2			Case study 3	
	FireWire (F)	USB (S)	DECTPRS (F)	Wi-Fi (S)	HomeRF (F)	MPEG-2 Audio (F)	AC-3 (S)
<i>Characteristics of the format supporter</i>							
1 Financial strength	NR	NR	NR	NR	NR	NR	NR
2 Brand reputation and credibility	NR	NR	NR	NR	NR	Low (the bug in MPEG-2 Audio damaged MPEG's reputation considerably)	High (Dolby had actively built up a high reputation among Hollywood film companies.)
3 Operational supremacy	NR	NR	NR	NR	NR	NR	NR
4 Learning orientation	NR	NR	NR	NR	NR	NR	NR
<i>Characteristics of the format</i>							
5 Technological superiority	Very high (more reliable, Data rate: 400 mbps, later 3200 mbps)	Low (less reliable, Data rate: 12 mbps, later 480 mbps)	NR	NR	NR	Low (due to backwards compatibility and a bug)	High (AC-3 was technologically superior.)
6 Compatibility	NR	NR	NR	NR	NR	Yes (with MPEG-1 Audio)	Not applicable (no previous version)
7 Complementary goods	Some (e.g., PCs, laptops, external hard drives, cameras)	Many (e.g., PCs, laptops, keyboards, external hard drives, cameras, printers)	Few (e.g., wireless routers)	Many (e.g., wireless routers, PCs, laptops, printers, telephones)	Few (e.g., wireless routers)	Some (e.g., DVD players)	Many (e.g., DVD players, multimedia content for PCs and films aired in film theaters.)
8 Flexibility	Low (7 revisions)	Very high (25 revisions)	Medium (10 revisions)	High (15 revisions)	Very low (1 revision)	NR	NR
<i>Format support strategy</i>							
9 Pricing strategy	NR	NR	NR	High (\$130 for a network interface card)	Low (\$80 for a network interface card)	NR	NR
10 Appropriability strategy	NR	NR	Open	Open (many companies)	Closed (one company had full control of a specific part of HomeRF)	NR	NR

11	Timing of entry	Too early (1987)	Good (1994)	Too early (1988)	Good (1997)	Good (1998)	NR	NR
12	Marketing communications	NR	NR	Effective (Successful marketing campaign)	Effective (Successful marketing campaign)	Ineffective (No marketing campaign)	Ineffective (due to low marketing budget)	Effective (due to high marketing budget)
13	Pre-emption of scarce assets	NR	NR	NR	NR	NR	NR	NR
14	Distribution strategy	NR	NR	NR	NR	NR	NR	NR
15	Commitment	Low (Apple introduced USB products, conflicting interests among CE companies)	High (Intel and Microsoft were exclusively involved in USB)	Low (DECT Forum was less committed to DECTPRS)	High (leading actors exclusively promoted Wi-Fi)	Low (Intel also promoted other formats)	Very low (main companies failed to get unconditional support from business units)	Very high (Dolby was highly committed as AC-3 was Dolby's only format)
<i>Other stakeholders</i>								
16	Current installed base	NR	NR	NR	NR	NR	NR	NR
17	Previous installed base	NR	NR	NR	NR	NR	High (users of MPEG-1 Audio)	Not applicable (no previous version)
18	Big Fish	NR	NR	NR	NR	NR	NR	NR
19	Regulator	NR	NR	NR	NR	NR	NR	NR
20	Judiciary	NR	NR	NR	NR	NR	NR	NR
21	Suppliers	NR	NR	NR	NR	NR	Few	Many (Dolby convinced film companies to implement the format.)
22	Effectiveness of the format development process	NR	NR	Ineffective (delayed due to technical discussions)	Ineffective (developing the first version of Wi-Fi took 7 years)	Ineffective (delayed due to technical discussions)	NR	NR
23	Diversity of the network	Low (industries involved: initially 1 increasing to 2)	High (industries involved: initially 1 increasing to 6)	Low (industries involved: initially 1 increasing to 2)	High (industries involved: initially 1 increasing to 5)	High (industries involved: initially 5 decreasing to 0)	Low (industries involved: 2)	High (industries involved: initially 1 increasing to 4)

industry. Dolby therefore positioned AC-3 as an American format in a battle against the European MPEG-2 format. Dolby established many contacts with major Hollywood filmmakers and used the American image to persuade them to use the AC-3 format for their films. Many Hollywood film companies joined the Dolby network, which increased network diversity to two industries. Dolby then convinced the film industry that the AC-3 format 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 many film companies had already opted for AC-3. Eventually multi-channel sound was incorporated in the home just as Dolby had predicted, and the existing support for AC-3 in Hollywood contributed to the success of AC-3. Dolby also established alliances with many different manufacturers of complementary goods to ensure that they would apply AC-3 in their products. For example, in 1996 it allied with Microsoft to incorporate AC-3 multi-channel sound in the PC, and in 1998 it teamed up with Toshiba to incorporate AC-3 in Widescreen TV sets. Thus, in 1998, Dolby's network was diverse as it consisted of four industries. Eventually, many different types of complementary goods for AC-3 were available in large quantities, which increased the installed base. For example, with more movie titles available in the AC-3 format, more film theaters started to support AC-3, and more manufacturers of DVD players decided to implement it.

MPEG-2 Audio was made backwards compatible with MPEG-1 Audio to take advantage of its existing large installed base in Europe. However, this also meant that no fundamental changes could be made to the underlying design of the format. In the end, this backwards compatibility became a disadvantage: the four-year old technology underlying the MPEG-2 Audio format could not be upgraded. One respondent explained: *"At the time, we could have incorporated new technology, but due to the compatibility requirement we were a little bit restricted; this was the most important disadvantage"*. The developer of AC-3 agreed: *"Because of the backwards compatibility requirement, it [MPEG-2] was never really accepted"*. From this case, we can conclude that making a format backwards compatible does not necessarily mean that it 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 could not be repaired in time. When this became public, MPEG's reputation was considerably damaged. One respondent explained: *"Shortly before the decoder was delivered, we found a bug. We didn't have time to repair it.... This was a reason that people said: you see, the Dolby system is better than the MPEG multichannel. We were not able to remove the bug before the test"*.

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 MPEG's, which also affected the outcome of the battle. Furthermore, Dolby was more committed to the success of its format than the MPEG. AC-3 was Dolby's only format while for the MPEG it was only one of their many activities. At a certain moment, the FCC had to vote on which multi-channel sound technology would be used for digital television in the United States. Dolby and the Massachusetts Institute of Technology (MIT), that

offered another technology, agreed to share royalties if either technology were selected. Dolby even paid firms to vote for its format [52]. One interviewee remarked: *"Ray Dolby had good contacts with several US senators. He would have used these contacts if Dolby had been unsuccessful"*.

One of the main companies behind MPEG-2 Audio failed to get unconditional support from all its business units. One of the interviewees at the company indicated: *"I did not receive unconditional support from the whole firm. Our company is very big and there were multiple conflicting interests"*.

To conclude, the outcome of this battle was determined by suppliers, diversity of the network, complementary goods, compatibility, previous installed base, technological superiority, brand reputation and credibility, marketing communications, and commitment.

4.4. Cross-case analysis

Table 2 provides an overview of the three format wars using the factors listed in Table 1. In the second column, we mention each factor explained in Table 1, and in the other columns, we give the values for each factor. S refers to success and F refers to failure. Thus, in terms of format dominance, FireWire was a failure and USB was a success. NR refers to not relevant, meaning that the factor did not play a role in the success or failure of the format or its impact was negligible.

We can conclude that the set of applicable factors differs per format battle. No additional factors were found. Apparently the framework that is presented in this paper can be used as a checklist.

Each time a format was successful, three factors contributed to this success: commitment, the diversity of the network of the format, and the availability of complementary goods. For each winning format, actors were fully committed and the network of the format was diverse since it included actors representing each of the technological systems to be interconnected via an interface specified by the format. Complementary goods were available in high quantities for each winning format.

5. Discussion

5.1. Completeness and relevance of the framework

In Table 3, we compare our results with the literature. The first three columns list the factors mentioned in prior frameworks for format dominance from Suarez [5], Schilling [6], and Lee et al. [7]. In the next columns, we present the factors mentioned in prior case studies analyzed in the literature. The last three columns show the results from the current study.

We notice that five factors that were not mentioned in the three prior frameworks [5–7] were relevant in the format battles that we studied: flexibility of the format, the commitment of the group of format supporters, previous installed base, effectiveness of the format development process, and diversity of the network of stakeholders supporting the format.³ Thus,

³ Although Suarez [5] stresses the importance of reaching agreement with different types of stakeholders including manufacturers of complementary goods, we stress the importance of attracting stakeholders from different industries.

and distribution strategy have never been studied empirically and they did not play a role in our three cases. Therefore, these factors might be less relevant.

Finally, we notice that a subset of the total set of factors affected the outcome of each battle in our cases. In the 16 prior empirical studies, the average number of factors that played a role was 6.2, with a maximum of 13. This means that when analyzing a format war, it would be best to consider the total set of factors for format dominance. By just considering a subset, there is a risk of forgetting one or more factors that actually play a role in the battle for dominance.

[illegible]

5.2. Limitations and recommendations for further research

Our study was limited to three cases. Future research might examine more cases using the same approach so that the completeness and relevance of the framework presented in this paper can be further explored. The qualitative data could be compared quantitatively, leading to more knowledge about patterns in factors for format wars. Cases already described in the literature can be used. Our lens may shed new light on format battles and enrich our understanding of these cases. For such more quantitative research different approaches can be used such as Knowledge Engineering, Knowledge Acquisition using Machine Learning, and Factors Analysis.

In particular, researchers can examine whether the factors that applied in all our cases, commitment, the diversity of the network of stakeholders supporting the format, and the availability of complementary goods are necessary conditions for achieving dominance. Commitment was not mentioned in 14 out of 16 previous studies, the diversity of the network was not mentioned in 9 of these studies, and the availability of complementary goods was not mentioned in six previous case studies, but this does not imply that these three factors did not play a role. Scholars might not have been aware of the factor or the research design may have limited the set of factors in advance. The first factor, commitment, seems to be essential in format wars. The second factor, network diversity, may be important in many cases, but perhaps not always needed – in some cases a dominant player can push a format (like Microsoft did with its Windows operating system). It can be argued that the third factor, availability of complementary goods, is indeed a necessary condition for achieving dominance because a format specifies interfaces between entities. The more availability of diverse entities, the more demand there is for this interface. Then, network effects both at the supplier and at the user side enhance this effect [54]. Increasing the number of cases should show which factors apply more often, and which are specifically informative for the outcome of a format battle.

Another limitation of this study is that we only focus on the influence of individual factors on format dominance. However, in format wars these factors are often interrelated. For example, Schilling [6] showed that the size of the installed base and the availability of complementary goods reinforce each other. Furthermore, Van den Ende et al. [44] found mutual reinforcement of format flexibility and network diversity. Environmental factors can also moderate the influence of some firm level factors. For example, when a market is characterized by network externalities, the format with a higher installed base than its competitor has a higher chance of achieving dominance [5]. In the cases we analyzed, several factors were interrelated. For instance, in the battle between MPEG-2 and AC-3, Dolby established a diverse network which increased the number of complementary goods. Furthermore, the fact that MPEG-2 Audio was made backwards compatible with the previous version negatively affected technological superiority. In the other two cases, there are similar interrelations among factors. Analyzing to what extent factors influence each other could be an interesting area for further research. Scholars could also examine other possible combinations of factors for format dominance by studying format wars through case studies.

In each case, the format that achieved dominance had more factors with a high value (high, many, etc.) than the unsuccessful formats. This might suggest that just counting the 'high valued' factors for each case would be sufficient to determine the winner of a format war. However, a small subset of the applicable factors can be decisive for winning, and thus just counting factors is not appropriate. Future research could assess the importance of factors for format dominance. However, this study suggests that every battle for format dominance is unique and therefore general 'weights' per factor do not apply. Future research could examine whether this is true. Maybe patterns of weights do apply in certain areas. This could be examined by using a multi-criteria decision analysis method such as the analytic hierarchy process. Discovering such patterns would make it easier to predict the dominance of future formats within that particular area (for a first attempt to assign weights to factors for format dominance see [83,84]). Another limitation of this study is that we only study the period beginning with the first format being released until one of the formats has become dominant. Thus, we do not address the period before a format is introduced in the market. Further research could investigate how formats are developed, managed, and negotiated by the stakeholders involved.

Last but not the least, a limitation of our study is that the outcome of each battle was already known. This may have biased our respondents' assessments of the factors. Since they knew which format had been successful and which one had failed, they may have assessed the factors too favorably or too negatively, respectively. We tried to mitigate this effect by seeking evidence from other sources. An alternative research design would be to do longitudinal studies of current format battles. Then the researcher can be the independent observer, or alternatively, may actively be involved: action research.

USB achieved dominance over FireWire but both interface formats continue to co-exist. This differs from many other battles for interface format dominance where a single format remains, mainly because of network externalities [13,14]. Gallagher [18] argues that multiple formats may co-exist when the price difference between core products and complementary products is low as in the case of gaming consoles and games. In our case, some products involved in the battle between USB and FireWire can implement multiple formats facilitating the co-existence of multiple formats. For example, some digital cameras implement both FireWire and USB. De Vries et al. [55] label these as multi-channel end systems and claim that this is one of the factors that may cause multiple designs to remain, although other factors seem to predict a clear winner. Another factor for multiple designs, also applicable in our case, is that distinct features may be important for certain customers: FireWire established a sustainable position in the market for peripherals requiring a high-bandwidth data connection. Using the case of smart phone operating systems, Riegman and De Vries [56] add even more factors for multiple designs. This suggests that three situations may apply: (1) co-existence of two or more designs, each with a substantial market share (examples: game consoles [16], flash memory cards [55]), (2) one clear winner but one or more losers with a good or even a major share in one or a few niche markets (USB versus FireWire), and (3) one winner taking all: no more new products in which the losing

formats are applied (the other cases in this paper). These three situations result from an interplay between different factors. Our paper focuses on the factors pointing at a clear winner. However, other factors may point towards multiple formats and in some cases, these may weigh more heavily, resulting in outcomes 2 or 3 instead of 1. This topic deserves more case-based research.

5.3. Implications

Our study gives first empirical evidence of the applicability of Van de Kaa et al.'s [9] framework for winning format battles. Managers can use this framework to gain more insight into current format wars in which their company may be involved. It provides the opportunity to reduce the uncertainty attached to choosing which format should be supported by estimating the value of each factor (high, low, etc.) for each of the competing formats. This evaluation will result in a better understanding of the battle and may help to predict which format will achieve dominance. It shows the strengths and weaknesses of the competing formats and allows practitioners to adjust their strategies by exploiting certain factors to enhance their chances of success. It also helps competing companies to identify when to take action.

As mentioned before, we began our interviews with an open question about relevant factors, and at the end of each interview, we listed the factors that the respondents had not mentioned and asked them whether each of these factors could also have affected the outcome of the battle. In this way, the interviewees became aware of factors which they had not initially considered. The interviewees concluded that the interviews had increased their understanding of the format war in which they had been involved or which had been their topic of research. This signifies the added value of the framework for business practice.

The question arises whether the outcome of the battles analyzed in this paper could have been different if the losing parties had used the framework that is presented in this paper. For example, would FireWire have won the battle instead of USB if it had been introduced somewhat later? Would the outcome of the battle for wireless connectivity in home applications have been different if the actors behind DECTPRS and HomeRF had been more committed to the formats? Would AC-3 have won the battle for multi-channel sound if MPEG had been more committed and if it had also tried to attract Hollywood film companies to its network at an early stage? By applying the framework, companies in these format wars might have adjusted their strategy in time and might have even won the format battle. Although it would appear that firms can adjust their format support strategy, other categories of factors seem to be more difficult to change. However, our cases also provide examples of companies that faced internal difficulties to align departments and pursue a common and consistent strategy.

This research also has implications for public policymakers. If a firm wins a format war, the competitive position of the country in which that firm is active may become stronger. A new industry could arise around the format consisting of different manufacturers of complementary goods. This may bring along additional societal benefits such as higher employment. Thus, it is clearly in a nation's best interest to influence

the outcome of a format war in favor of a local format. Seo [57] provides an example of this in her comparative study about Japanese and South Korean governmental policies on formats for wireless telecommunication. Governmental agencies may use our framework to assess the position of local firms compared to their (foreign) competitors. Also, on a more international level, anti-trust policymakers (e.g., in the European Commission) can apply the framework to assess the chances that a format war may result in a monopoly for one of the companies involved. These policymakers can intervene, for instance, by influencing the regime of appropriability in such a way that the level of openness of the format is increased. That may result in a more balanced division of power after the battle is over.

6. Conclusion

In this study, we explored the completeness and relevance of a framework for format dominance by applying it to three format wars. Our study confirms the applicability of this framework to understand format battles. The three frameworks described in prior literature missed several factors that proved to be relevant in our case studies. We did not find new factors. This signifies that Van de Kaa et al.'s framework [9] is a more complete tool for explaining format wars than existing frameworks.

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