The Strategic Choice between "Standardization" and "Differentiation" in R&D

by

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Submitted to the MIT Sloan School of Management
in Partial Fulfillment of the Requirements for the Degree of

Master of Science in Management of Technology
at the
Massachusetts Institute of Technology

June 2006

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ABSTRACT

In today's world of advanced technology and global reach, one company cannot necessarily make a significant technological innovation. A company that pursues a technological advantage needs to manage global collaboration or competition appropriately. Over the years, the "standardization" of technology has been one of the major strategies with which to encourage technological innovation and acquire a competitive advantage. However, a standardized technology does not necessarily contribute to creating a competitive advantage, and the "differentiation" of technology sometimes provides a better competitive advantage than standardization can.

This thesis focuses on the strategic differences between the "standardization" and "differentiation" of a technology. The purpose is to gain insight into standardization and differentiation, looking them as drivers of R&D activities in a company pursuing technical competence. The thesis suggests advantages and disadvantages of each strategy and analyzes circumstances that affect strategic differences. The first part of the thesis establishes the fact that the strategic difference has a less impact on business activities and commercial success than on R&D. The second part clarifies the impact of the difference on R&D activities, and it consists of three case studies from the technological areas in which the author has experience.

The observations from the case studies lead to a decision matrix for the strategic choice between standardization and differentiation. If a market requirement is uncertain, the differentiation better facilitates effective R&D by means of its flexibility; the technology consolidation linked to standardization would not work well in this situation. Also, if technology elements which satisfy market requirements or target performance are immature, differentiation makes R&D more effective because of its relative lack of restrictions; inherent competition and selection to avoid redundant work linked to standardization would not work well in this situation.

Thesis Supervisor: Michael A. Cusumano
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Acknowledgments

My thesis project for the MIT Sloan Fellows Program in Innovation and Global Leadership is the culmination of my eleven years of experience in the technology-oriented business world. This work at MIT Sloan has given me broader perspectives and opportunities to enhance my capabilities as a senior engineer and a business leader for my upcoming challenges. I really appreciate this wonderful program and wish to acknowledge the following individuals and groups:

Professor Michael A. Cusumano, my thesis advisor, for his invaluable insights, comments, and guidance throughout this work;
Senior Lecturer Henry Birdseye Weil, my thesis reader, for his thought-provoking comments and advice on this work;
The faculty of the Sloan School of Management, for providing me with the insights into and views of business and technology management;
Mr. Stephen J. Sacca, Director of the Sloan Fellows Program in Innovation and Global Leadership, for his great coordination and help throughout the year;
My fellow Sloan Fellows classmates, for their useful discussions, great help, and sharing of precious experiences during the year; and
My colleagues at NTT DoCoMo, for creating the opportunity for me to participate in this highly rewarding Sloan Fellows program.

Finally, I wish to express sincere and heartfelt thanks to my dearest wife, Kaori, and my beloved son, Kenichiro, for supporting my life and work in Cambridge and completing me.

Cambridge, Massachusetts
May 2006

Table of Contents

Figures and Tables

Chapter 1

Introduction

In today's world of advanced technology and global reach, one company cannot necessarily make a significant technology innovation, and it may need collaboration from multiple companies or organizations. On the other hand, it is critical for a technology-oriented company to create and retain its own technological advantage to survive in the competitive business world. A company that pursues such an advantage needs to know the state-of-the-art technologies in the world and manage global collaboration or competition appropriately.

Over the years, the "standardization" of technology, that is, the collaborative creation of a commonly shared technology, has been one of the major strategies for a technology-oriented company to encourage technological innovation and to acquire a competitive advantage through its technology. Standardization has been perceived as a key activity that facilitates continuous innovation in a company, collaborative development between companies, and broad deployment of technology in an industry.

However, a standardized technology does not necessarily contribute to creating a competitive advantage with the technology. The standardization of a technology may result in an unexpected, belated, or useless standard, even though the companies participating in the standardization do not want it at all. On the other hand, the "differentiation" of technology, that is, the single-handed pursuit of proprietary technology, sometimes provides superior innovation, faster development, and successful deployment of a technology than standardization could provide.

Why is “standardization” sometimes ineffective when used to congregate and diffuse state-of-the-art technologies (contrary to its purpose) when “differentiation” contributes to creating and spreading advanced technologies? What circumstances spoil the advantage of “standardization” and makes “differentiation” more effective for creating a widely-used technology? This thesis focuses on the strategic difference between the “standardization” and “differentiation” of a technology. The thesis suggests advantages and disadvantages of each and analyzes circumstances that affect strategic differences. The purpose of this study is to gain insight into standardization and differentiation, looking at them as drivers of R&D activities in a company pursuing technical competence. Thus this study focuses on the impact of standardization and differentiation on R&D activities, rather than on the impact of a technology on consequent business activities and commercial success.

The study divides into two parts. The first part establishes the fact that the strategic difference has a more significant impact on R&D activities than on business activities and commercial success. This discussion is based mainly on prior research. This part also clarifies the definitions of “standardization” and “differentiation” and discusses basic ideass about their advantages and disadvantages in order to explain the focus of the study. The second part clarifies the impact of the difference on R&D activities; it consists of three case studies from the technology-oriented areas in which the author has been involved and has experience.

The first case study compares two outcomes of international standardization in the same business category. This study discusses the international standards for video-coding technology, MPEG-2 and MPEG-4. They are the results of a series of standardizations that has been executed by a public international standardization body, the International Organization for Standardization and International Electrotechnical Commission (ISO/IEC). The MPEG-2 is considered more successful because of its coding efficiency and it is widely used for retail media and commercial broadcasting. On the other hand, MPEG-4 was expected to be a breakthrough coding standard for use in narrow-band and wireless video communication, but it failed to achieve a significant improvement in coding efficiency and is not as widespread as MPEG-2. Comparison of the circumstances of these standardization activities, from the viewpoint of effects on the execution of corresponding R&D, illustrates causes for the different results.

The second case study is used to contrast the difference between collaborative standardization and single-handed differentiation. This study discusses the Mobile Internet service protocols for mobile phones, the i-mode and WAP. The i-mode is the name of a service that NTT DoCoMo, a Japanese mobile phone operator, is providing. WAP is the name of a data communication protocol that WAP Forum, a standardization body established by the major mobile phone manufactures in the world, has standardized. Although WAP is a standard that competitive players in the market have drafted and agreed, it could not achieve as significant commercial success as the i-mode did, and its technical evolution has been less efficient than that of the i-mode. The causes of this difference between collaborative standardization and differentiation are discussed to clarify the impact of the two on R&D.

The third case study looks at the causes of the transition from differentiation to standardization. The study discusses the transition observed in the embedded software operating system (OS) of mobile phones. The embedded software has been developed as in-house-developed, "differentiated" software, but mobile phone manufactures are shifting to the use of commonly-use, "standardized" software. Changes in the market are discussed to understand the advantages and disadvantages of the transition in terms of consequences to R&D.

After Chapters 3, 4, and 5 discusse these case studies, the last chapter summarizes findings from the studies to illustrate the strategic differences between "standardization" and "differentiation" in terms of their impact on R&D. The chapter suggests ways to take advantage of the difference for R&D management and proposes a decision matrix. The chapter also discusses some remaining issues for further study.

Chapter 2

The "Standardization" and "Differentiation" of Technology

2.1 A Standard, Standardization, and the Categorization of Each

What do a standard and the standardization of a technology generally mean in terms of technology-oriented strategy? This chapter discusses the significance of standards and the standardization of a technology from the viewpoint of the execution of R&D, using findings observed in prior research. Generally, "standardization" means an act of unification of the form (or format), quality, and dimension of a technology or a product. Its purpose is to simplify, minimize, and organize a matter that inherently tends to complicate, diversify, and disorder. A standard means a specification that is defined through standardization. A standard could be involuntary or voluntary, but an involuntary standard should be called a regulation.

The word "standard" can be used in several ways regarding emerged and converged technologies. The standardization process can divide a standard into two major categories. One is the so-called *de jure* standard, and the other is the so-called *de facto* standard. The phrase *de jure* (which means "by law" or "by right" in Latin) standard describes a public technology that is determined by an agreement reached through negotiation in a standardization body. A standardization body works as a mediator that facilitates voluntary consensus-building about conflicting requirements from multiple stakeholders of a technology. The phrase *de facto* (which means "in fact" or "in practice") standard describes a technology that wins market competition, and the technology is handled like an authorized *de jure* standard. It is a standard formed in a market without mediation by a standardization body. Therefore, if a differentiated proprietary technology is broadly accepted in a market, it can be considered a *de facto* standard. In this paper, for the sake of comparison, only the *de jure* standard is assumed to be called a "standard" or "standardized" technology, and a *de facto* standard is called a "differentiated" technology.

In addition to the two categories of standards, a "forum standard" may exist in between *de jure* and *de facto*. It depends not on a public standardization body, but on a standardization forum, which is organized by multiple stakeholders in a technology, aggregates their technologies, and facilitates commercialization of the technologies by *ex-ante* coordination between stakeholders. However, its standardization process is quite similar to the process of the *de jure* standard, except for the process of establishing the standardization body itself. Therefore in this paper, a "forum standard" is considered to be involved in a *de jure* standard.

2.2 Advantages and Disadvantages of Standardization

A standard provides many kinds of benefits, such as economical or social ones. This section provides the generally perceived advantages and disadvantages from the viewpoint of technology strategy as a basis for discussion. Standardization may include the following advantages:

Aggregation of Advanced Technology

Standardization gathers superior technical candidates that contribute to achieving the purposes of a standard, and it defines a set of advanced technologies. It helps the cooperative consolidation of technologies instead of producing costly competition in a market.

Avoiding Redundancy and Inefficiency

Having a standard eliminates redundant technology and unnecessary rivalry in a market by simplifying the classification and categorization of a technology and sharing information about the technology. It can also contribute as a coordinator between industry requirements and market needs. It enables higher productivity and allows companies to concentrate on truly necessary technological innovations.

Ensuring Quality, Performance, and Compatibility

A standard defines a certain level of quality and performance of a technology, interfaces between components and information, and eases their exchange and transitions. It contributes to reducing development and operational costs on both the business side and the customer side in an industry and a market.

The Diffusion of Technology

Standardization defines some dimensions of a technology, such as performance, quality, and test method, and it facilitates the exchange of such information. This process of definition and facilitation assists with the adoption and use of the technology in an industry and a market. The diffusion of the technology gives valuable feedback and facilitates further R&D of the technology.

In contrast, standardization may bring the following disadvantages:

Heated Technical Competition

To win adoption of a technology as a mandatory part of a standard, multiple technical candidates from multiple contributors may try to defeat other technologies, rather than collaborate to create a superior standard.

Preventing Diversification and Competition

When a standard dominates the industry and market, it reduces room for diversification and can pose an obstacle to competition. It may prevent the R&D from finding technical alternatives and then slow the evolution of technologies.

Time Required to Standardize

Standardization requires time for the participating industries or businesses to make compromises and to agree on specifications. It may impede technical evolution, instead of facilitating it, when progress of a technology is rapid and its lifecycle is short.

Inefficiency Caused by Rules

A standard requires its adopters to conform to its specifications. It may reduce the flexibility of use of a technology and prevent producers and users from taking the best combination or usage of technologies. It may also cost them time and effort to understand and conform to the specifications.

Many of the above-mentioned advantages and disadvantages are supposed to be reversed if a technology is differentiated instead of standardized. Overall, standardization can be seen as a tool for R&D to facilitate effective and superior technical efforts, avoiding redundant and unnecessary ones; yet it possesses the limitations and obstructions to technological evolution caused by its process and resulting specifications.

2.3 Characteristics of the Standardization Process

As described above, standardization, including the *de facto* kind, which is considered "differentiation" in this paper, includes several types of processes. What kinds of characteristics can be observed in each type of standardization? Oya analyzes different characteristics of each type of standardization (Oya, 2000). In this analysis, the Production Possibility Frontier (PPF) illustrates the utility of each type of standardization. Figure 2-1 shows the proposed PPF of speed versus consensus of organizations for standardization.

Oya reported that public standardization, especially one which is executed by an international standardization body such as International Telecommunication Union-Telecommunication Standardization Sector (ITU-T), is effective for technologies such as telecommunication-oriented, infrastructure layer, and hardware-based ones, which require higher compatibility or stringency; but the standardization requires a technology to stay in the process of standardization until its completion, in order to achieve consensus between the participants in standardization.

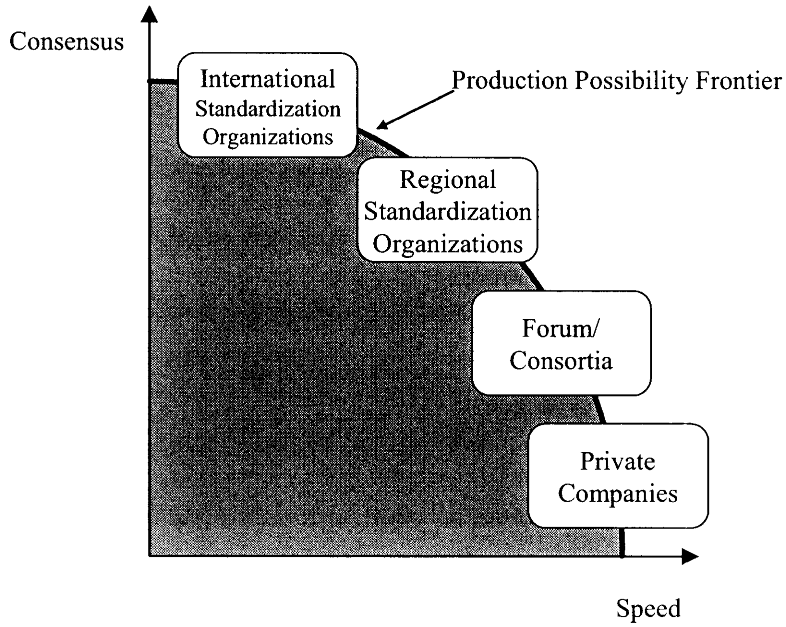

Figure 2-1 Speed versus Consensus of Standardization Organizations (Oya, 2000)

Public standardization has the disadvantage of requiring time for standardization. It seriously damages the evolutionary speed of technologies such as Internet-related, application layer, and software-based ones. Also, those technologies do not necessarily need a broad consensus for effective usage of the technologies. Therefore, being a proprietary technology that is "differentiated" or being "loosely" standardized by a specific forum, rather than being publicly standardized, is suitable for these technologies.

However, the evolutionary speed of technologies is growing also for ones that need higher compatibility or stringency, such as telecommunication-oriented technologies. Faster-evolving technologies such as Internet-related ones do not necessarily disregard higher compatibility or stringency. Therefore, many efforts have been put into the public standardization processes to expand the boundary of PPF. Process improvement to facilitate consensus development and adoption of new types of specifications, such as Publicly Available Specifications (PAS), to import a *de facto* standard into public standards are examples of these efforts.

2.4 A Standard and its Commercialization

Standardization of a technology has advantages or disadvantages from the viewpoint of a technology-oriented strategy and the different characteristics of its process. What kinds of impact can be seen on the commercialization of a standard, that is, on the phase after active standardization? Do these above-mentioned factors affect commercialization? It seems that standardization contributes to commercial success better than differentiation does, because of the former's original purpose and the advantages that it produces a broad aggregation of advanced technologies and broad acceptance within the industry and market. However, prior research does not necessarily back up this assumption.

Gawer and Cusumano point out that acquiring market dominance depends on acquiring complements (Gawer and Cusumano, 2002). That is, getting partners and sharing information of a technology with partners are critical to achieving commercial success in a market. This partnership and sharing are possible between closed or contracted (licensed) partners of a technology, even if the technology is proprietary. Therefore, whether the technology is a publicly authorized standard or not seems not to make much difference here.

Christensen argues that modularization and disintegration will be more beneficial when the market for a technology is mature (Christensen, 2003). This argument may suggest that in this situation, the modularization leads to the standardization of an interface, and then public standardization will be more beneficial than differentiation will be. However, standardization here can be proprietary instead of achieved by a public standard. Therefore, standardization is not necessarily more advantageous than differentiation is.

Cusumano's research on the marketing battle between VHS and Beta videocassette recorders analyzes a battle between two technologies over the position of a *de facto* standard (Cusumano, et al., 1992). Similarly, as Gawer and Cusumano show in their research, externality plays a critical role in determining the winner of the battle, even between two proprietary technologies. This finding suggests that even a non-standardized, differentiated technology is able to gain sufficient openness in its specification and facilitate externality, which are critical to winning the marketing battle. Having VHS as a public standard might have further facilitated the externality of VHS, but acquiring that position as a public standard might not have had a critical impact in this situation.

Utterback pointed out that "Dominant Design," that is, the product or design which has accomplished market dominance, is affected by collateral assets, industry regulation and government intervention, strategic maneuvering by individual firms, and communication between producers and users (Utterback, 1994). It means that public standardization is not the only factor that determines a dominant design, and in contrast, pursuit of differentiation is also not the only factor that results in market dominance. According to the concept of dominant design, innovation in a technology will result in a dominant design and then the major outcome of innovation will be shifted to the improvement of productivity achieved by process innovation. That is, as the commercialization of a technology proceeds and a dominant design emerges, the dominant design behaves as a standard or a basis of standardization. Therefore, whether a technology is originally a public standard or a differentiated proprietary technology does not carry much weight after the technology becomes a dominant technology.

Given these observations from prior research, the strategic choice between standardization and differentiation of a technology seems to have little impact on the commercial success or market dominance of the technology. It does not matter whether a technology is standardized or differentiated, but disclosing sufficient information (openness), acquiring complements (externality), and creating an "ecosystem" around the technology are critical to achieving commercial success or market dominance with the technology.

2.5 R&D Based on Standardization or Differentiation

As discussed above, standardization has advantages and disadvantages and has specific characteristics depending on its type of process. However, those properties do not seem to have a significant impact on the commercialization and market dominance of a technology. Then what impact do the properties have on the former stage of technology emergence and deployment, that is, the stage of active R&D? How does a contribution to standardization or the pursuit of differentiation affect R&D activities? What do the above-mentioned properties mean in the context of ongoing R&D? This paper explores these topics, referring to several cases about emerging technology.

The following chapters contrast the differing effects of standardization and differentiation on R&D though the use of case studies. Chapter 3 compares two standardized technologies that have different achievements. Chapter 4 contrasts a differentiated technology with a standardized technology. Chapter 5 studies a transition from being differentiated to being standardized. These studies are based on the literature and the experience and insight of the author, who has been involved in these technologies and their evolution.

Chapter 3

Case Study 1: International Standards of Video-Coding Technology

This chapter discusses factors given by standardization that may affect the execution of corresponding R&D efforts through a case study of international standardizations that have different achievements. The standards concern two video-coding technologies: Moving Picture Experts Groups 2 and 4 (MPEG-2 and MPEG-4).

3.1 MPEG; International Standardization for Video-Coding Technologies

The MPEG is the common name of a working group for video-coding technology standardization or resulting standards in ISO/IEC JTC1/SC29/WG11. The International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) are networks of the national standards institutes that target the international standardization of industrial products. The Joint Technical Committee (JTC) 1 is an organization to execute joint standardization between ISO and IEC on the area that covers areas of both ISO and IEC. Under JTC 1, more than 20 Sub Committees (SC) and affiliated Working Groups (WG) are conducting standardization, mainly on technologies of computers, communication, and media.

The MPEG standards are specifications of multimedia coding (that is, information compression) used for storage media, broadcast, and communication. Therefore, specifications of MPEG involve audio-coding technology that accompanies video, audio-video system organization technology, testing technology that evaluates conformance of an implementation to specifications, and so on. This chapter discusses only circumstances of video-coding technology standardizations.

International standardization of video coding technologies has been conducted also at the International Telecommunication Union-Telecommunication Standardization Sector (ITU-T), which is the specialized agency for the standardization of communication systems under the United Nations. MPEG and ITU-T are the two major standardization bodies of video-coding technologies, and a large number of companies and organizations that are involved in the digital video industry, such as Motorola, Siemens, Sony, and Matsushita, have been participating in one or both of MPEG and ITU-T standardizations. Several international standards have been standardized by turns at one of the two standardization bodies and sometimes standardized as a common specification from both bodies. They have also been encouraging the evolution of video-coding technologies. Figure 3-1 shows the video-coding standards of ISO/IEC and ITU-T and their domains of applicability.

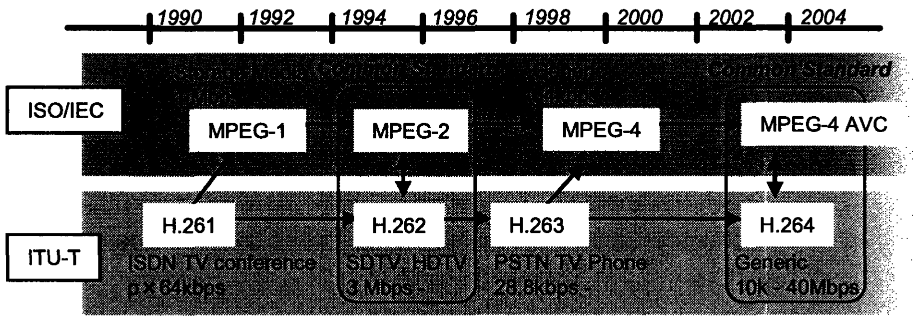

Figure 3-1 Video Coding Standards of ISO/IEC and ITU-T

and Their Domains of Applicability.

The first standard from MPEG was called MPEG-1 (the official number of the standard is ISO/IEC 11172), which was standardized in 1993. The MPEG-1 targeted a coding rate of 1Mbps (Mega bit per second) with the quality of a home-use video cassette recorder (such as VHS), and it has been applied to consumer electronics such as video CDs. The MPEG-1 was developed based on ITU-T H.261, which had been used for TV conference systems. The MPEG-1 uses two basic technologies for video coding, which are also adopted in H.261. One is inter-frame motion estimation, which compresses information by vector expression of image movements. The other is discrete cosine transform (DCT), which compresses information by frequency-domain expression of image texture.

Following MPEG-1, several technologies have been continuously standardized in MPEG. The MPEG-2 (ISO/IEC 13818) targeted a higher quality and coding rate than MPEG-1. In contrast, MPEG-4 (ISO/IEC 14496) targeted a lower coding rate and broader application than MPEG-1. Neither MPEG-7 (ISO/IEC 15938) nor MPEG-21 (ISO/IEC 21000) was an information-compression technology; both were technologies for handling coded data. Table 3-1 shows a list of MPEG standards.

Phase	Standard No.	Year	Target coding rate	Major applications
MPEG-1	ISO/IEC 11172	1993	around 1 Mbps	Video CD
MPEG-2	ISO/IEC 13818	1995	3 – 15 Mbps (SDTV)	DVD, Broadcasting
MPEG-4	ISO/IEC 14496	1999	64 kbps –	Mobile phone, Internet
MPEG-7	ISO/IEC 15938	2001	-	Multimedia search
MPEG-21	ISO/IEC 21000	2002	-	Multimedia handling

Table 3-1 MPEG Standards

3.2 MPEG-2: Standardization with a Practical Target

The MPEG-2 was standardized immediately following MPEG-1, and it targeted a higher quality and coding rate than MPEG-1; both the quality and rate are applicable to broadcasting and even high-definition television (HDTV). At the beginning of standardization, MPEG-2 was assumed to be for standard-definition television (SDTV) and another standard, MPEG-3, was planned to be standardized for HDTV. However, MPEG-3 was absorbed into MPEG-2 since technologies of MPEG-2 were found to be applicable also to HDTV. Standardization for MPEG-2 started in 1990. The key requirements of MPEG-2 included optimized video quality with a coding rate around 3 to 15 Mbps, applicability to interlaced video formats that had been widely used for broadcasting, and adaptability to a variety of underlying data transmission schemes.

The standardization of MPEG-2 assumed the adoption of inter-frame motion estimation and

DCT, which have both been adopted in H.261 and MPEG-1. The MPEG-2 targeted a higher quality of broadcast and HDTV video, which H.261 and MPEG-1 could not achieve, by effective use of these basic technologies with higher coding rates. Effective use of these technologies on interlaced video formats, which the former standards could not handle, and applicability to a wide variety of media along with various playback functions such as fast-forwarding and fast-rewinding were also key targets of the standardization.

The MPEG-2 aimed for an all-purpose standard of higher-quality video, which is applicable to a wide variety of media such as DVD storage media, digital satellite broadcast, and digital CATV. This all-purpose applicability could be accomplished by the formatting and the allocation of coded data, without any evolution of basic video-coding technologies. Furthermore, the requirements for video quality, which is also related to basic video-coding technologies, were that the decoded video quality should be equivalent to non-coded video quality. In other words, the coding distortion should not be perceptible. This requirement is easily evaluated and shared by the participants of MPEG-2 standardization. The requirements were reasonable and realistic.

The final draft of MPEG-2 was frozen in 1994 and was standardized in 1995. Almost in parallel to the completion of MPEG-2 standardization, digital satellite broadcasting was started in 1994, and the DVD video player was shipped in 1996. These events mean that the requirements for MEPG-2 should have been clear and realistic, and also that these coincidental developments of applications should have helped to further clarify the requirements. Both the ISO/IEC and ITU-T agreed to make MPEG-2 a common standard of both standardization bodies and MPEG-2 was approved as the H.262 standard from ITU-T in

1995. This fact confirms the broad acceptance of MPEG-2 in the industry.

3.3 MPEG-4: Standardization with a Challenging Target

In 1999, MPEG-4 was standardized, subsequent to MPEG-2. While MPEG-2 aimed for higher coding rates than MPEG-1, MPEG-4 targeted much lower coding rates than MPEG-1, which was supposed to be used for communication media of narrow bandwidth, such as mobile phones and the Internet. The primary target of MPEG-4 was the pursuit of coding efficiency, which would be strongly beneficial to video applications on mobile phones and the Internet, and use of both started spreading at that time. Just before the MPEG-4 standardization, ITU-T H.263, which was intended to use for TV telephony over analogue telephone line, public switched telephone network (PSTN), had been standardized in 1996. The H.263 had adopted some improved technologies for inter-frame motion estimation and DCT, such as half-pixel ("half-pel") motion estimation and AC/DC estimation of the DCT coefficient. The MPEG-4 was expected first to acquire innovative technologies that were superior to these H.263 technologies and then to considerably improve its coding efficiency.

There was much research on new coding technologies other than ones adopted in standards up to H.263, but these technologies lacked certainty in terms of moderate computational complexity for commercial products and universal coding efficiency for various types of video images. In these circumstances, MPEG-4 standardization intended to encourage and aggregate innovations on coding technologies based on the reputable MPEG standardization results and the consequent centripetal force of MPEG standardization. However, in the end, MPEG-4 standardization could not acquire such desired technologies.

It is worth noting that the researched technologies were immature and the possibility for MPEG-4 to acquire innovative coding technologies was quite low, since even today no alternative technologies have emerged to replace the inter-frame motion estimation and DCT. The latest video-coding standard, H.264/MPEG-4 Advanced Video Coding (AVC), which was standardized in 2003 as a common standard between ITU-T and ISO/IEC, has a coding efficiency two times higher than that of MPEG-4, but it is achieved by a further fractionated and diversified inter-frame motion estimation and DCT without replacing them, which requires a computational complexity of four times higher than that of MPEG-4.

It is also significant that MPEG-4 requirements were challenging. Lower-quality video had been used at that time in TV conference/telephony systems that adopted H.261/H.263, but the user's perception was not very positive because of the video quality, which was significantly lower than user-familiar TV broadcasting. Whether such kinds of lower-quality video could be accepted as new applications for mobile phones or the Internet and the level of quality improvement needed to make it accepted were definitely uncertain. Even the existence of such new markets was uncertain. In fact, the requirements of video quality had been eagerly discussed in MPEG-4 standardization, but no detailed requirement for video quality could be determined in the standardization.

Affected by these circumstances, MPEG-4 was finally standardized in 1999, adopting most of the technologies that had been adopted in H.263, without achieving significantly improved coding efficiency. By this time, major MPEG-4 targets had transformed into "coding functionality" that achieves error resilience for error-prone media, object-oriented coding for operability with computer graphics, and so on.

3.4 The Differences between MPEG-2 and MPEG-4: The Maturity of Requirements

As mentioned above, MPEG-2 and MPEG-4 were both standardized by the same public standardization body for video-coding technology, but their target and technical consequences were quite different. The MPEG-2 was based on the conventional technologies, inter-frame motion estimation and DCT. Next MPEG-2 standardization was expected to consolidate technologies, which further improves the efficiency of these basic technologies. Then MPEG-2 successfully achieved improved efficiency. On the other hand, MPEG-4 was expected to acquire technological innovation, which is stimulated by the standardization and outperforms the conventional technologies. Then MPEG-4 could not fulfill the expectation. This fact suggests that the aggregation of advanced technology, which is one of the advantages of standardization, was effective in the practical technology target for MPEG-2 but ineffective as in the uncertain technology target for MPEG-4. In fact, many alternative "differentiated" technologies, such as Windows Media by Microsoft and Real Video by RealNetworks, have emerged in the target application domain of MPEG-4, while MPEG-2 has dominated its target application domain.

The MPEG-2 standardization had the comprehensible quality requirement that the coding distortion should not be perceptible and its applications were under development for commercial use. Even mutual clarification and coordination of their technical requirements between the standardization body and application developers were possible. On the other hand, MPEG-4 was unable to clarify its acceptability to commercial markets with its distorted video, which is unavoidable under the very low coding rate, and even its major target has been transformed into "coding functionality" instead of "coding efficiency." This transformation reveals that the ensured quality and performance of a technology, which are the advantages of standardization, worked for MPEG-2 with its clear application, but did not work for MPEG-4, with its uncertain application. It seems that the different levels of uncertainty of technologies and market requirements played significant roles to create different technical consequences for these standards. It is difficult to leverage the advantages of standardization, if the prospective technologies and market requirements for a standard are uncertain. Therefore in this case, executing effective R&D that targets that standard is difficult.

3.5 Summary

This chapter compares the circumstances and consequences of MPEG-2 and MPEG-4, which are the standardization of video-coding technology by the same international standardization body. For MPEG-2, the basic coding technologies (inter-frame motion estimation and DCT), were assumed to be the basis of the standard and the technical target of standardization was the enhancement for adaptability of these basic technologies. Also the target applications of the standard, such as DVD and digital satellite broadcasting, were clear. On the other hand, for MPEG-4, the technical target was a significant improvement of coding efficiency although no breakthrough technology was foreseen. The target applications were described as video applications for the emerging media, but their marketability or required quality of service was uncertain. Moreover, even the target of the standardization was uncertain since the target was shifted from coding efficiency to coding functionality.

The difference between these levels of uncertainty seems to result in the differences of the levels of technical achievement through standardization. In MPEG-4, the standardization could not encourage technological innovation through R&D, since it was difficult to set an assertive direction of R&D that contributed both a technology and standardization. This observation suggests that the certainty of requirements and maturity of technology play important roles in executing the standardization successfully. Chapter 4 discusses the factors that make standardization and differentiation different, by contrasting a differentiated technology and a standardized technology.

Chapter 4

Case Study 2: The Standardization and Differentiation of Mobile Internet Technologies

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This chapter discusses, through a case study, the different technical consequences that come from the strategic differences between standardization and differentiation. The two technologies of mobile internet service are compared: the i-mode, a differentiated specification developed by a Japanese mobile phone operator, and Wireless Application Protocol (WAP), a forum standard standardized by the WAP Forum, which was organized by the major mobile phone manufacturers.

4.1 Mobile Internet Service

In this paper, "mobile Internet service" denotes mobile communication service on mobile phones that provide users data communication and browsing capability like Internet web browsing. The service also provides Internet access and Internet web browsing, but the major destination of a user's access is the contents, which are dedicated to mobile Internet service and prepared by mobile phone operators or individual content providers. Following the rapid diffusion of mobile phones in 1990, mobile Internet services had been introduced around the end of the 1990s. The services enabled mobile phone users to read newspapers, check bank balances and make bank transfers, reserve tickets, trade stocks, and play network games on the small displays of mobile handsets in addition to the usual voice communications.

At the beginning, these services were provided mainly with characters and without graphics or pictures on the existing black-and-white small displays of mobile handsets. Since then, services like the Internet web contents have been evolving, along with the increasing performance and functionality of mobile handsets. Color and larger displays, accompanying music/animation/videos, and flexible and interactive user interfaces enabled by Java software have been achieved as the services have evolved.

For implementation of such Internet-like services, a key consideration has been how to cope with the limitations inherent in mobile phones. One of the limitations comes from the mobile handsets. This limitation includes CPU performance, amount of memory, electricity (for battery-powered units), and input-output interface (display and keyboard), which are poorer than with PC's. Another limitation comes from mobile phone network. This factor includes transmission bandwidth, delay, and stability, which are significantly worse than in fixed-line phones. Unavoidable and frequent disconnection (in out-of-service areas) also matters a lot. With the emergence of mobile Internet service, two major technological evolutions arose that have different approaches to coping with the limitations. These are the i-mode and WAP.

4.2 The i-mode: Its Evolution as a Differentiated Technology

The i-mode is a mobile Internet service that started in 1999 and has been developed by a Japanese mobile phone operator, NTT DoCoMo, and its partner manufacturers. It is provided through its mobile phone network and DoCoMo-branded mobile handsets. The service is available only on handsets that are capable of the service, but today almost all of DoCoMo's handsets are i-mode-capable.

To enable an effective presentation of mobile Internet service on a limited display of mobile handsets, i-mode uses Compact HTML for its content description. Compact HTML is a subset of the widely-used Internet web description language, HTML. The i-mode also uses Internet data transmission protocols, HTTP and TCP/IP, for its data transmission. Compact HTML is defined as a subset of HTML by eliminating some specifications that are unnecessary for mobile Internet service. The description language, which is based on Internet web technology, helps content providers to modify their existing Internet web contents into i-mode contents, since it has backward compatibility with HTML. The Internet protocol of HTTP and TCP/IP also helps content providers to transfer content. This easy transfer from Internet web contents to i-mode contents has been assumed to be a key of the commercial success of i-mode.

However, although these technologies are based on the Internet technologies, they have been modified, proprietary-specified, and maintained by DoCoMo as i-mode service specifications. This control means the technology has evolved as a proprietary technology and it should be considered differentiated (as opposed to standardized). The i-mode was implemented on a packet-switched mobile communication network that was also developed by DoCoMo and its partner manufacturers under the leadership of DoCoMo. The packet-switched network provides the capability to allow intermittent multiple-user access on one connection and to charge users by packets instead of seconds. This network capability has largely contributed to the efficiency and success of i-mode service.

These facts show that i-mode is a differentiated technology that is developed by DoCoMo and its partner manufactures. The i-mode's status as an essential technology gives DoCoMo the strong initiative to lead service development and deployment. The i-mode definitely became a commercial success, and the number of subscribers had reached 10 million in 2000, just one-and-a-half years after the start of the service. Until now, it has made DoCoMo the largest Internet service provider in Japan, with its over 40 million subscribers.

4.3 WAP: Its Evolution as a Standardized Technology

Wireless Application Protocol (WAP) is a "forum standard" for mobile Internet protocols, which are defined by the WAP Forum. The WAP Forum is a technology standardization forum originally established by the major mobile phone manufacturers: Ericsson, Motorola, Nokia, and Unwired Planet (now Openwave Systems). While i-mode is based on existing Internet technologies, WAP is a set of dedicated technologies, from underlying transmission protocols to content description languages, which are suitable for mobile Internet service. For example, unlike HTTP and TCP/IP, WAP protocols enable effective data transmission under conditions of narrow bandwidth and limited receive buffer memory, by means of compressed-data transmission.

The WAP uses Wireless Markup Language (WML) and Handheld Device Markup Language (HDML) for content description. Both WML and HDML have syntax similar to HTML, but they are not compatible with HTML. This WML is defined by Extensible Markup Language (XML), which is a general-purpose markup language to define and describe the structure of computer documents and data. The HDML is a description language optimized for contents shown on a display of mobile devices. Both WML and HDML were designed to reduce the amount of data shown on displays of mobile devices that have relatively lower capability than PC's. The reduction is beneficial to data transmission over mobile phone networks of limited bandwidth.

On the other hand, since these WAP technologies are new and not compatible with the existing Internet technologies, content providers need to learn these technologies from scratch and create their contents based on these technologies instead of their existing Internet web contents. If users want to access existing Internet web contents, such access needs proxy servers that convert the Internet web contents into WAP-based contents, and then the conversion spoils the speed and transparency of Internet web access. These overheads are assumed to be obstacles to making WAP as commercially successful as mobile Internet service technologies like i-mode, even though WAP has been supported by many world-wide manufacturers and operators connected to mobile phones.

At the beginning of its service, WAP was implemented on conventional circuit-switched mobile communication networks. The circuit-switched network is not capable of intermittent user access and user charge by packets instead of seconds, and it made the service relatively more expensive than expected by users. Although this problem has been solved by the introduction of the new packet-switched network, General Packet Radio Service (GPRS), which started in 2001 in Europe, a critical difference in the level of overhead can be also pointed out here, since i-mode started with an original packet-switched network developed prior to the service.

The WAP is a standard, but it is a forum standard from a forum that is under the strong leadership of major mobile phone manufacturers such as Nokia. Specifically, it is not a technology led by a specific company like DoCoMo's i-mode, but it is not that different from the i-mode in that the initiative in technology innovation and development is dominated by a specific company or companies. In WAP, major mobile phone manufacturers exercised their initiative via a standardized technology, while in i-mode, DoCoMo executed its initiative via development of a differentiated technology.

4.4 The Differences between i-mode and WAP: An Approach to Uncertainty

Both i-mode and WAP are technologies for mobile Internet service and are more different than alike. They had different approaches to coping with the limitations of mobile phones mentioned in Section 4.1 and consequent uncertainties about technology performance and market acceptance. Table 4-1 shows the key factors in differences between the two technologies. Figure 4-1 shows the differences of the protocol stacks between the two technologies and the Internet web protocols. Basically, i-mode focused on keeping compatibility with the Internet web and developed the necessary modifications based on the Internet technologies. On the other hand, WAP embraced new standards, which are incompatible with the Internet technologies, in order to achieve effective data transmission via mobile phones.

	i-mode	WAP
Specification	NTT DoCoMo	WAP Forum
Transmission Protocol	HTTP, TCP/IP	WAP original
Description Language	Compact HTML	WML/HDML
Internet web protocols	Transparent	Need conversion
Connection	Packet-switched	Circuit/Packet-switched

Table 4-1 Key Factors in Differences between i-mode and WAP

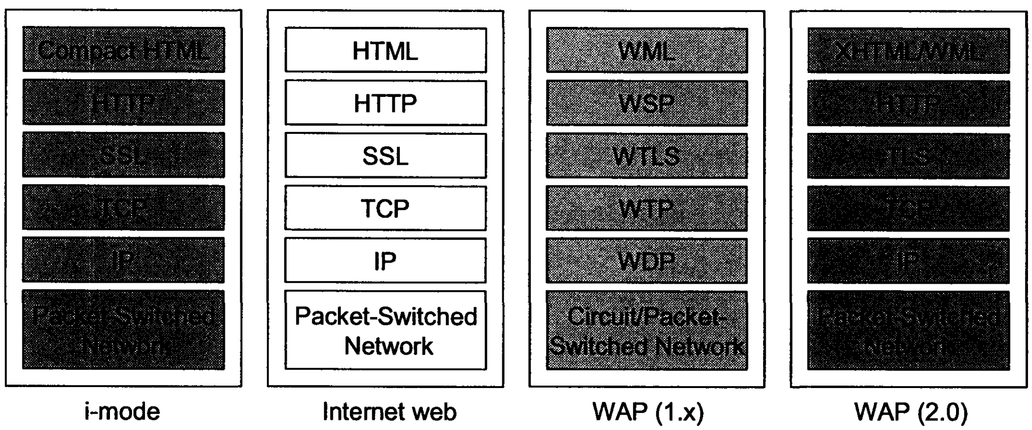

Figure 4-1 Differences between I-mode and WAP in terms of the Protocol Stacks between i-mode and WAP

Tables 4-2 and 4-3 show the chronological upgrade of the two technologies as specifications for mobile Internet service. At the beginning of mobile Internet service, a critical uncertainty existed in terms of user acceptance of data communication on the tiny black-and-white display of mobile phones and of the extent of the demand for such communication. The rapid growth of i-mode subscribers immediately proved that users could be attracted by specifically designed presentations of contents and moderate accessibility, but at the same time, a demand for a richer presentation of contents appeared.

Version	Release	Major functional extension
1.0	Feb. 1999	(First release)
2.0	Jan. 2000	Color display (contents), melody playback
3.0	Jan. 2001	Java application, SSL (Secure Socket Layer)
4.0	May 2002	Video playback
5.0	May 2003	Flash (animated graphics), Java application certification

Table 4-2 Chronology of Upgrades in i-mode Specifications (Source: NTT DoCoMo)

Version	Release	Major functional extension
1.0	Apr. 1999	(First release)
1.1	Jun. 1999	Security/reliability improvement, Minor changes
1.2	Feb. 2000	Push function (data delivery), Minor changes
1.2.1	Jun. 2000	Minor changes
2.0	Aug. 2002	TCP/IP, XHTML (including Compact HTML)

Table 4-3 Chronology of Upgrades in WAP Specifications (Source: WAP Forum)

Responding to the growing demand, i-mode has been steadily incorporating functional extensions for the demanded richer presentations and updating its specification. The tiny black-and-white display became a color display and is now capable of fine QVGA resolution (240 x 320 pixels). The service added Java application capability as "i-appli" service in 2001; this capability enables real-time and flexible presentations and transactions such as stock-trading and network-gaming. The service keeps extending along with the improved performance of mobile phones. One of the latest extensions is the IC card functionality as "Osaifu-Keitai" (which means "wallet mobile phone"); this extension enables e-commerce on mobile phones. Figure 4-2 shows the first and the latest i-mode handsets. The latest handset is much more sophisticated than the first handset with the large color QVGA display, Java applications, 3D graphics, TV-telephony, and so on. The i-mode specification has been upgrading along with this growing functionality.

F501i (1999) F902i (2005)

Figure 4-2 The First i-mode Handset and the Latest i-mode Handset

In contrast, WAP decided to change its direction to emphasis compatibility with the Internet web (similar to the direction of i-mode), after it made some small upgrades. The second version, WAP 2.0, was standardized as a specification that adopts the Internet web technologies, such as TCP/IP, and XHTML, which is a technology evolved from HTML.

This version of WAP 2.0 also incorporated the Compact HTML of i-mode. This upgrade suggests that i-mode, which was developed with Internet compatibility and flexible functional extension, clarified the existence of the market and demand for mobile Internet service, and WAP caught up with the proven trend. Even though WAP was standardized through the aggregation of R&D results from the major mobile phone players, the early results were not the ones that the emerging market accepts, because of the standardization's direction toward new standards and Internet-incompatibility.

Facing an immature or unclear market, the way of i-mode, which uses accepted protocols of the Internet and does not intend to publicly standardize the technology, seems to have been advantageous for starting the new mobile Internet service. The differentiation of the technology facilitated DoCoMo's optimized aggregation of protocols and fast deployment and upgrade of the service responding to the emerging market requirements, while the standardization of the technology could not provide such flexibility to cope with the uncertainty. However, with clarification of the existence and demands of the market and its expansion, being a differentiated technology maintained by one company became disadvantageous for further diffusion of the service (such as expansion of i-mode to the overseas market outside Japan, in terms of which DoCoMo has been facing difficulty). But at the same time, the advantage of being differentiated still seems beneficial to the rapid functional extension that is continuously seen on i-mode service. If R&D sees mobile Internet service mature with its current functionality, standardization will help make R&D stable and diffusive. On the other hand, if R&D sees the service still rapidly changing, differentiation will help R&D cope with uncertainty about any new extension of the service.

4.5 Summary

This chapter compares two mobile Internet service technologies, differentiated i-mode and standardized WAP. At the time of R&D of these technologies, it was unclear whether the new mobile Internet access service needed definitive innovation. The kind of service that could be provided on a small, black-and-white display on mobile phones in the market was also unclear. Furthermore, the required quality of service was a third uncertainty. In this situation, i-mode was developed based on the proprietary set of technologies by NTT DoCoMo and its partner manufacturers, and it then achieved fast deployment to the market and received feedback from the market. Development led by the one company helped i-mode to achieve timely upgrades responding the emerging requirements such as the hardware evolution of phones and functional improvements requested by content providers. On the other hand, WAP was standardized by consensus among many companies under the uncertain requirements of quality and technology. It could not achieve the results of standardization that receive market acceptance at the beginning. Under uncertain requirements from the market, differentiation appears to work better to conduct effective R&D by fast deployment of a technology and prompt feedback from the market. The advantages of standardization, such as aggregation of advanced technologies, seem not to work well in this circumstance because the uncertainty of requirements and immaturity of technologies make it difficult to determine the right direction for technological innovation. Chapter 5 discusses a transition from a differentiated technology to a standardized technology to further illustrate the factors that affect the difference between standardization and differentiation of a technology.

Chapter 5

Case Study 3: Embedded Software for Mobile Handsets

This chapter studies a case of transition from differentiated to standardized technology and analyzes factors that cause the transition. Through the analysis, this chapter illustrates the key factors that have an impact on the different choices in R&D between standardization and differentiation. The case concerns the embedded software operating system (OS) for mobile handsets. As for the OS, there has been no movement toward standardization in the industry. Therefore this case is not directly about a standardized technology. However, the case presents some interesting analogies to the process of standardization.

5.1 Embedded Software for Mobile Handsets and their OS

Today's mobile phone has not only the original voice telephony function but also many other attractive functions. These include mobile Internet service, the transmission of email, video games, multimedia players, and e-commerce. The mobile handset is becoming a processing and communication platform based on the fact that people always carry it and it enables access to the communication network from almost everywhere. Along with this growing functionality, the hardware performance and software size that are required to implement such functions are also growing. In its early days, the mobile handset had only a black-and-white display and showed mainly characters. Today it usually has a high-resolution color display and processes various complex tasks such as three-dimensional graphics and video-data decoding, which requires huge computing power.

To achieve this performance requirement, today's mobile handset has a sophisticated architecture consisting of high-functional modules like the PC's architecture. Figure 5-1 shows the general hardware architecture of today's advanced handset, and Figure 5-2 shows the general software architecture. As for hardware, a mobile handset has two processors. One, called the "Communication CPU," is dedicated to the execution of the telephony function. The other, called the "Application CPU," executes many of the functions required of mobile handsets. The processors' architecture and performance have been approaching those of a PC. The architecture of the software, in which the required functions are implemented, is also sophisticated and modularized like a PC's architecture.

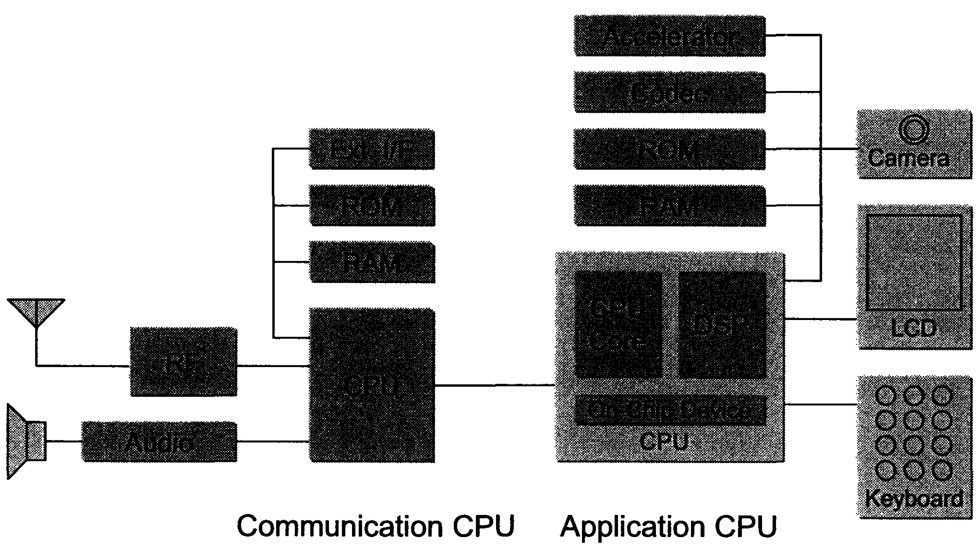

Figure 5-1 General Hardware Architecture of an Advanced Mobile Handset

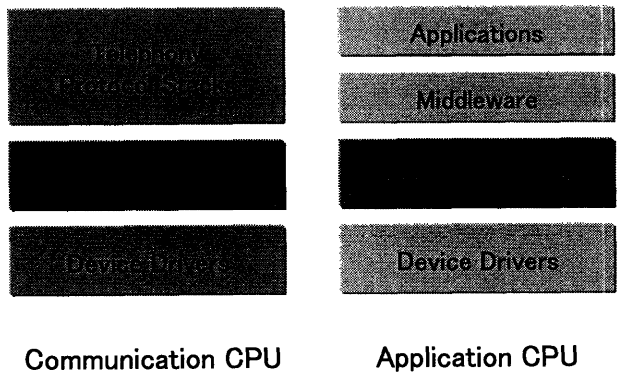

Figure 5-2 General Software Architecture of an Advanced Mobile Handset

Given the rapid functional growth of a mobile handset, it is essential to develop those required functions (such as software implementation) to achieve a timely launch. It is also important to have application management functions in OS, such as task management and memory management, to achieve effective implementation of those required functions. Therefore, today's embedded software for mobile handsets adopts so-called "sophisticated OS" developed by specialized software manufacturers or organizations and commonly adopted by multiple mobile phone manufacturers.

This architecture has become widespread relatively recently. A mobile handset and its embedded software were not sophisticated and modularized in their early days, and the commonly-used, sophisticated OS was not used. In those days, "one-chip CPU" processed every function including the telephony function, and OS was simplified OS that is developed by mobile phone manufacturers themselves.

5.2 Simplified, In-House-Developed OS's: Software Development in Vertical Integration

When a mobile handset had a one-chip CPU architecture, most of the mobile phone manufacturers adopted their in-house-developed proprietary one-chip CPU and in-house-developed real-time OS. They developed their own application software and then developed their mobile handsets. The Real-time operating system (RTOS) is a type of OS that is intended for real-time applications; it is implemented with functions that facilitate the real-time processing of tasks. Software systems for applications such as communications equipment and automobile-engine control systems need to achieve limited response times for proper execution of their tasks. Therefore the RTOS used for such applications has functions such as processing-time estimation and processing-time allocation to complete each task within the required response time, even if it conflicts with other tasks. On the other hand, the general RTOS does not have functions such as task management and memory management since it is not intended to execute multiple applications.

Most of the Japanese mobile phone manufacturers have been referring to μITRON specifications to develop their own OS's for mobile phones. The Real-time Operating system Nucleus (TRON) is the name of an academic-industrial cooperative project started in 1984 to define RTOS specifications. The word μITRON means "micro industrial" TRON and is one of the specifications of TRON for embedded devices. The μITRON is widely used in many kinds of embedded devices, since TRON specification is public and free. However, the TRON specification defines minimum functionalities of OS so that the implementations can have flexibility to achieve optimum performance on each type of hardware. Therefore not all implementations of a TRON specification are compatible and each can be seen as a different OS. That is, the specification is "standardized" but the implementation is "differentiated."

Mobile phone manufacturers have been developing their own OS's, achieving the necessary performance by designing their "differentiated" implementation to balance the limited performance and memory of their proprietary CPU's with the optimized functions and interfaces of their OS's based on μITRON specifications. This vertically integrated development and the consequent flexibility have helped them to effectively develop both telephony functions and accompanying functions such as phone books and mini games with the strictly limited resources of a mobile handset at the time. However, along with the growth of mobile phone functions, the necessary functions and performance of OS are becoming clarified and are also expanding. At the same time, the growth of mobile phone functions makes the size of the required software incredibly large, and the burden of developing software components (like applications and middleware and software development environment) is getting unaffordable for a single mobile phone manufacturer. Nevertheless, the manufacturer cannot share the burden with other manufacturers. The manufacturers have been developing software based on μITRON specifications, but it does not provide them compatibility for their software components or a good environment for sharing development with other manufacturers.

5.3 Sophisticated, Commonly-Used OS's: Software Development in Specialization

Following the expansion of mobile phone functions and the growing necessity of software components compatibility, so-called sophisticated OS's for mobile handsets have emerged. These OS's are developed by specialized software manufacturers or organizations and commonly used by multiple mobile phone manufactures and software manufacturers. In the Japanese mobile phone market, Linux and Symbian are adopted as replacements for the in-house-developed OS's.

Linux is the name of a PC OS that is well-known as a free and open software. Based on a kernel developed by a university student in Finland, Linus Torvalds, collaborative development in which many individuals participated has been driving the evolution of Linux toward becoming a sophisticated, multi-purpose OS. Today Linux is adopted not only in PC's but also in mainframes, servers, and embedded devices such as mobile phones. The name "Linux" originally meant only the kernel, which is the core software part in the OS. Now it also means the whole free system software developed around the Linux kernel, including the GNU Project software and the X Window System.

The advantage of adopting Linux as an OS for mobile phones is the availability of Linux and the accompanying software components. In particular, Linux has plenty of available software components for the Internet protocol, which is necessary to implement mobile Internet service. Because of the wide use of Linux, Linux programmers and the development environment are well-stocked, and this situation is also an advantage of adopting Linux.

Symbian is the name of an OS for handheld devices that was developed by a UK-based software manufacturer, Symbian. As an embedded OS, Symbian has a relatively advanced architecture similar to that of the PC OS. It has a micro-kernel architecture that enables the flexible expansion of OS functions, pre-emptive multitasking that facilitates parallel processing of multiple applications, and multi-threading that improves usage of the processor's resources with a complex application. The software manufacturer Symbian was established by the major mobile phone manufacturers, Nokia, Ericsson, Motorola, and Matsushita, and a PDA manufacturer, Psion, to enhance Psion's OS for handheld devices for use of high-functional mobile handsets. The adoption of Symbian OS was started by Nokia's high-functional mobile handsets called "smartphones," and since then the OS has been building its ecosystem with software components and a development environment provided by both Symbian and its partner manufacturers.

The advantage of adopting Symbian as an OS for mobile phones is its sophisticated architecture and functions that facilitate software development for high-functional mobile handsets. The availability of software components and a development environment that are dedicated to mobile handsets are also advantageous. The software development based on these sophisticated OS's enables distribution and specialization of the development. In other words, applications, middleware, and device drivers that activate hardware on the OS can be compatible with and shared by manufacturers, using the OS by confirming the common functions and interfaces provided by the OS. This distribution and specialization assist manufacturers to concentrate on development of the software components of their competence, to leverage other manufacturers' competence by adopting their components, and to mitigate their software development burden.

The sophisticated, commonly-used OS's discussed in this section are not standardized technologies. However, dynamics similar to standardization exist around the OS in terms of building a common technological base. In contrast to the in-house-developed OS described in Section 5.2, the commonly-used OS appears to software manufacturers as the base of mobile phone development. These manufacturers can pursue its advantages such as compatibility, technology aggregation, and redundancy avoidance, which are similar to the advantages of standardization. The commonly-used OS also provides disadvantages such as a fairly long time before OS release, reduced diversification, and inefficiency due to compliance, which are also similar to disadvantages of standardization. Moreover, both of the OS specifications depend on active participation of the OS users and partner manufacturers or programmers to determine their direction of functional expansion, although Linux and Symbian have differences: Linux is of open (public) specification and Symbian is of closed (proprietary) specification. These facts suggest that the commonly-used OS and its ecosystem are creating another kind of standardization process to facilitate technological aggregation and common technological base-building in the mobile handset industry.

5.4 The Differences between In-House-Developed OS and Commonly-Used OS: Clarification and Expansion of Market Requirements

The advantages of the in-house-developed OS are the flexibility and effectiveness of the mobile phone manufacturer's development when it is managed with their own hardware and software. On the other hand, the reason for the transition to the commonly-used OS is the rapid growth of the burden of software development; such growth is caused by the rapid expansion of functions required for mobile handsets. Table 5-1 shows the transition of OS's in major Japanese mobile phone manufacturers. The transition happened around 2002 and

2003 along with the continuous expansion of mobile phone functionality.

Year		2001	2002	2003	2004	2005
A	OS	In-house	In-house	In-house	Linux	Linux,
	CPU	In-house	Common	Common	Common	Common
B	OS	In-house	In-house	In-house	Linux	Linux
	CPU	In-house	Common	Common	Common	Common
C	OS	In-house	Symbian	Symbian	Symbian	Symbian
	CPU	In-house	Common	Common	Common	Common
D	OS	In-house	In-house	In-house	Symbian	Symbian
	CPU	In-house	In-house	In-house	Common	Common
E	OS	In-house	In-house	In-house	In-house	Symbian
	CPU	In-house	In-house	Common	Common	Common

Table 5-1 Transition of OS and CPU from In-House-Developed to Commonly-Used Status in Japanese Major Mobile Phone Manufacturers

(Source: NTT DoCoMo, The names of manufacturers are suppressed)

A transition from in-house-developed to commonly-used OS and CPU also appears on the hardware for mobile phones. Table 5-4 shows also the transition of CPU's (Application CPU) in major Japanese mobile phone manufacturers. The transition happened along with the transition of the OS's. As for the manufacturers shown in Table 5-1, all of the commonly-used CPU's are based on Acorn RISC Machines (ARM) architecture. The ARM is a sophisticated architecture for handheld device CPU that is developed by ARM, a UK-based microprocessor design company, and ARM-based CPU's are gaining dominance in the handheld device CPU market. That is, technology convergence can be seen in the hardware, and such convergence facilitates the transition to the commonly-used OS.

As for the context of the OS transition, two major circumstances can be pointed out along with the escalation of functional requirements for mobile handsets. One is the clarification of functional and performance requirements for the software and hardware along with the subsequent convergence of the technology factors that can achieve the requirement. The other is the sophistication of the necessary technologies for the functional requirement, along with the subsequent necessity for development of specialized software to mitigate the heavy burden of development. The transition to the commonly-used OS is inevitable to cope with these circumstances and to establish a technological base for effective development. In other words, the driving forces of the OS transition from the in-house-developed "differentiated" one to the commonly-used "standardized" one are the clarified market requirement that a mobile handset needs to be high-functional and the clarified technology requirements of converged hardware and software architecture and compatible software components. Originally, the development of vertically integration under differentiation is effective for the new and specific development of mobile handsets. However, along with the clarification and expansion of requirements for mobile handsets, development under standardization becomes the only way to execute effective and successful development of high-functional mobile handsets.

The drivers that encouraged the transition of OS are also encouraging the transitions of other components in the software architecture. In other words, the boundary of the common technological base in the software architecture shown in Figure 5-2 is expanding. Mobile phone manufacturers are faced with decisions to choose standardization or differentiation of such components. For example, middleware for such functions as multimedia data handling, mobile Internet service data handling, and User Interface (UI) framework are considered to be standardized, but at the same time manufacturers have strong concerns about diminished room for the diversification and flexibility of software development. In terms of R&D effectiveness, the decision criteria will be the clarity of market and technological requirements for the software components.

5.5 Summary

This chapter discusses factors around the transition of the software OS in mobile handsets from the in-house-developed OS to the commonly-used OS. The rapid expansion of mobile handset functions requires higher performance from the hardware and software of mobile handsets, and the OS transition occurs in order to achieve effective development of sophisticated software and mitigation of the burden of software development. That is, along with the clarification and increasing demands of market requirements for mobile phone, it becomes difficult to conduct R&D that covers the entire range of requirements in a differentiated manner. The transition suggests that it is essential for the manufacturers in the mobile handset market with clarified and demanding requirements to achieve specialized R&D and execute effective R&D, using a standardized technology base that the manufacturers can share.

Chapter 6

Conclusion

6.1 Key Observations from Case Studies

The case studies in earlier chapters illustrate some of the processes and outcomes of technological evolutions, which depend upon the differences that result when the technology is standardized or differentiated. Chapter 3 compares the circumstances and consequences in the cases of MPEG-2 and MPEG-4. For MPEG-2, the technical target of standardization was enhanced adaptability of the existing coding technologies, and the target applications of the standard were clear. On the other hand, for MPEG-4, the technical target was a significant improvement in coding efficiency although no breakthrough technology was foreseen, and the target applications and required quality of service were uncertain. The difference between these levels of uncertainty seems to produce the different levels of technical achievement through standardization. In MPEG-4, the standardization could not encourage technological innovation through R&D, since it was difficult to set an assertive direction for R&D that contributed both a technology and the standardization.

Chapter 4 compares two mobile Internet service technologies. At the time of R&D of these technologies, it was unclear whether the new mobile Internet access service needed definitive innovation; the kind of service that could be provided was also unclear. In this situation, i-mode was developed based on the proprietary set of technologies by NTT DoCoMo and the service achieved fast deployment to the market. Since then it has continuously achieved functional improvements requested by the market. On the other hand, WAP was standardized with the consensus of many companies under the uncertain requirements of quality and technology. At the beginning, it could not achieve the results of standardization that would receive market acceptance. Under uncertain requirements from the market, differentiation appears to work better both for conducting effective R&D by fast deployment of a technology and for eliciting prompt feedback from the market. The advantages of standardization, a breadth of knowledge and advanced technologies, seem not to work well in this circumstance with such uncertainty.

Chapter 5 discusses factors around the transition of the software OS in mobile handsets. The rapid expansion of mobile handset functions requires higher performance of both the hardware and software of mobile handsets. Next, the OS transition occurs to achieve the effective development of sophisticated software and to mitigate the burden of software development. That is, along with the mobile phone market requirements become clearer and more demanding, it becomes difficult to conduct R&D that covers all requirements in a differentiated manner. The transition suggests that it is essential for the manufacturers in the mobile handset market with clarified and demanding requirements to achieve specialized R&D and execute effective R&D, using a standardized technology base that the manufacturers can share.

These case studies suggest that the choice between standardization and differentiation of a technology concerns the clarity of market requirements and the maturity of the technology. In a situation of unclear market requirements and an immature technology, standardization seems to be ineffective as an activity that facilitates technological innovation.

6.2 The Decision Matrix for "Standardization" and "Differentiation" in R&D

The observations described above can lead to a decision matrix as shown in Figure 6-1. If a market requirement, or even the existence of a market, is uncertain, differentiation better facilitates effective R&D due to its flexible reaction to the situation, fast deployment of a technology, and prompt feedback from the market. In contrast, with standardization, technological consolidation will not work well in such an uncertain situation. Also, if technology elements that satisfy market requirements or target performance are immature, differentiation helps effective R&D more because of its flexibility and lack of restriction. The factors of competition and of selection to avoid redundant work that come with standardization will not work well in this situation.

In this matrix, the quadrant for certain requirements and immature technology is the area in which "needs-driven" (market or demand "pull") R&D will work well. The quadrant for mature technology and uncertain requirements is the area in which "seeds-driven" (technology or supply "push") R&D will work well. The difference between standardization and differentiation is unclear in these areas and it seems to depend on the characteristics of a technology and market requirements. Although these areas need further study, it is plausible that standardization better works in the area of needs-driven R&D and differentiation better works in the area of seeds-driven R&D, because of the requirement-oriented process of standardization that defines a target and aims at the convergence of technologies.

		Requirements for a technology	
		Uncertain	Certain
Technology	Immature	Differentiation	"Needs-driven " (Standardization)
	Mature	"Seeds-driven" (Differentiation)	Standardization

Figure 6-1 The Decision Matrix for Standardization or Differentiation in R&D

This matrix is consistent with an insight from prior research about the differences between standardization and differentiation. On the PPF that Oya shows, the area of a technology, such as telecommunication-oriented technology, is the existing technology area of certain requirements and mature technologies, and the area of such a technology as Internet-related technology is the emerging area of uncertain requirements and immature technology. Therefore, the decision matrix is consistent with the reported PPF.

6.3 Items for Further Study

The research and analysis for this paper identify some interesting viewpoints. The following paragraphs discuss them as the items for further study.

In considering the differences between standardization and differentiation, this paper studies the cases in which the author has been involved and proposes the use of the decision matrix above. Further validation of the proposed matrix as useful in other cases of technology standardization and differentiation will suggest other implications of the decision threshold and accompanying conditions. Although this paper applies simplified categories of standardization and differentiation for the sake of contrast, the realistic execution of R&D can face a middle category such as standardization with "weak" binding (like TRON OS specification) and differentiation executed by an alliance of multiple companies. The interpretation of the decision threshold in these situations will be a useful item to study.

Throughout this paper, the impact of the difference between standardization and differentiation on commercialization of technology has been eliminated since it is not significant. However, a study of the possible impact on commercialization and possible feedback to R&D could be interesting. For example, customers tend to adopt "standardized" technology to avoid "lock-in" by a "differentiated" company, and then the "differentiated" technology tries to improve "openness" on its specification. The effect of this requirement of "openness" in R&D would be an interesting topic to study further in terms of the differences between standardization and differentiation.

The dynamics of the companies involved in R&D of the standardized or differentiated technology is an interesting topic that this paper cannot sufficiently discuss. For example in the MPEG-2 case, even though standardization can help effective R&D, standardization cannot be successful if it cannot gain centripetal force and technology-leading participants. In the i-mode case, NTT DoCoMo's partner mobile phone manufacturers, which have been suppliers of the company, seem to play an important role in developing i-mode specifications and i-mode-capable equipment, so it may be difficult to pursue differentiation without such a partnership. Therefore, the source and balance of centripetal force and driving force around the companies involved in R&D and their impacts on both standardization and differentiation will be another important and interesting issue for study.

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