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DISTRIBUTED TUNING OF BOUNDARY RESOURCES: THE CASE OF APPLE'S IOS SERVICE SYSTEM[1]

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The digital age has seen the rise of service systems involving highly distributed, heterogeneous, and resource-integrating actors whose relationships are governed by shared institutional logics, standards, and digital technology. The cocreation of service within these service systems takes place in the context of a paradoxical tension between the logic of generative and democratic innovations and the logic of infrastructural control. Boundary resources play a critical role in managing the tension as a firm that owns the infrastructure can secure its control over the service system while independent firms can participate in the service system. In this study, we explore the evolution of boundary resources. Drawing on Pickering's (1993) and Barrett et al.'s (2012) conceptualizations of tuning, the paper seeks to forward our understanding of how heterogeneous actors engage in the tuning of boundary resources within Apple's iOS service system. We conduct an embedded case study of Apple's iOS service system with an in-depth analysis of 4,664 blog articles concerned with 30 boundary resources covering 6 distinct themes. Our analysis reveals that boundary resources of service systems enabled by digital technology are shaped and reshaped through distributed tuning, which involves cascading actions of accommodations and rejections of a network of heterogeneous actors and artifacts. Our study also shows the dualistic role of power in the distributed tuning process.

Keywords: Service system innovation, mobile platform, ecosystem, digital infrastructure, boundary resource dynamics, tuning, sociomateriality, iOS

Introduction

Service is increasingly recognized as the foundation of activities and value creation in the global economy (Pine and Gilmore 1999; Vargo and Lusch 2004; Zuboff and Maxmin 2002). In combination with digital technology, we are witnessing fundamental shifts in business models, collaboration, and work practices in all levels of economic activity (Barrett and Davidson 2008). We define *service* broadly as "the application of specialized knowledge skills through deeds, processes, and performances for the benefit of customers" (Vargo and Lusch 2004, p. 2). In the service economy, value is cocreated by customers who appropriate service provided by the firm, integrating it with other resources, some of which are provided through market and others provided privately or publicly (Vargo and Lusch 2010). Therefore, service is

[1]Michael Barrett, Elizabeth Davidson, Jaideep Prabhu, and Stephen L. Vargo were the accepting senior editors for this paper. The authors are listed in alphabetical order only.

The appendix for this paper is located in the "Online Supplements" section of the *MIS Quarterly*'s website (http://www.misq.org).

rendered through an interactive process that takes place in the context of a unique and complex set of relationships among different actors endowed with different resources. A *service system* is an interactive configuration of various resources and their mutual exchange to facilitate value cocreation that is institutionalized and regulated through institutional logics and standards (Maglio and Spohrer 2008; Vargo and Lusch 2011; Vargo et al. 2008). The notion of service system offers a general view of economic activities that can explain all types of economic transactions, ranging from the simple barter system of labor among individuals to a complex set of transactions in the global financial market (Vargo et al. 2008).

Service is increasingly rendered through digital technology (Barrett and Davidson 2008; Yoo et al. 2010), which in turn offers new opportunities for service system innovation. In fact, digital technology, through its inherent intangible and reprogrammable nature, makes the physical operand resources less important, while making intangible operant resources such as knowledge and skills more important (Vargo et al. 2008). Increasingly the focus of value creation has shifted to reprogrammable digital technologies that can mediate various forms of service. As such, we see service systems as sociotechnical assemblages of distributed, heterogeneous, and resource-integrating actors whose relationships are governed by shared institutional logics, standards, and digital technology (Orlikowski and Scott 2008). However, due to the unique characteristics of digital technology (Yoo et al. 2010), innovation in such service systems with digital technology faces inherent tensions. On one hand, a powerful trend of the democratization of innovation sees digital technology drastically lowering the barriers to entry for service systems (Chesbrough et al. 2006; von Hippel 2005; Zittrain 2006). It promises the ability to participate in the exchange of service to anyone who has access to the Internet. On the other hand, we are seeing increasing concentration of power and resources to a few companies such as Google, Facebook, and Apple that dominate the market through the construction and maintenance of large-scale global infrastructure that requires prohibitive amounts of financial and technological resources (Ciborra et al. 2001; Hanseth and Lyytinen 2010; Tilson et al. 2010). Individual innovators cannot effectively participate in service systems and their innovation without such infrastructure being controlled by a few powerful firms. Therefore, any theoretical attempt to deal with innovation in service systems with digital technology must be able to deal with the paradoxical tension of the generative and democratizing force of digital technology and the monopolistic and controlling force of digital infrastructure.

The notion of boundary resources has been proposed as a theoretical device to deal with this tension (Ghazawneh and Henfridsson 2013). Boundary resources refer to "the software tools and regulations that serve as the interface for the arm's-length relationship between the platform owner and the application developer" (Ghazawneh and Henfridsson 2013, p. 174). It is through boundary resources that a firm that owns the infrastructure can secure its control over the service system, while allowing diverse actors to participate in and contribute to the service system. Therefore, it is the boundary resources that resolve a paradoxical tension between the generativity and control of a service system with digital technology. The question, then, is how do boundary resources come into being and evolve over time? Given their central role, it is essential to understand how boundary resources are created, maintained, and evolve over time in order to understand the nature of innovations in service systems with digital technology.

To answer the question, we conduct an embedded case study by collecting and analyzing archival data of Apple's service system. We perform an in-depth analysis of 4,664 technical blog articles (Davidson and Vaast 2009) published from the inception of the service system in January 2007 through December 2011, reporting incidents related to contested innovations that involve disagreements and disputes between Apple and other actors. These instances link directly to public discussions in the blogosphere concerning Apple's decisions regarding what is allowed and not allowed in the iOS service system. From 45 incidents discovered, we identify 30 contested boundary resources, which were further grouped into six unique categories. From our case study, we uncover an underlying cocreative mechanism by which boundary resources are created, contested, and evolve by multiple actors who are endowed with different resources, have different goals, and represent different technological regimes. With more than one million apps and a rich and diverse service system built around iOS and iPhone hardware, Apple represents an ideal context to study service system innovation with information technology. Furthermore, given the unique nature of Apple, there is a significant body of publicly available secondary data about the iOS service system. This allows us to conduct an in-depth empirical analysis of secondary data.

In doing so, we draw on Pickering's (1993) notion of tuning, which was further developed in a digital technology context by Barrett et al. (2012). Based on the notion of tuning, innovation can be seen as the struggle of an innovator as a social actor seeking to exercise agency over materials through a dialectic of resistance and accommodation. The idea of tuning is a powerful analytical lens to understand how a

sociotechnical system comes into being. We particularly find the notion of tuning a useful analytical lens to make sense of the empirical data on iOS since a service system enabled by digital technology can be seen as a complex sociotechnical assemblage with heterogeneous actors with different technological resources, of which some are private and some are shared. In contrast, prior studies using the notion of tuning consider a singular technology and its innovation. Our study extends the existing notion of tuning in order to explain the cocreative and distributed dynamics of boundary resources evolution among a network of heterogeneous actors who are dealing with multiple interdependent technological artifacts, the changes of which create cascading "wakes" of influence throughout the service system. Furthermore, we note that actors who participate in a service system are not equal in power, in terms of the ability to influence other participants directly or indirectly. This power difference results in different degrees of agency over materials and other actors. The innovation in service systems with digital technology must therefore be understood in the context of a complex web of actions and reactions over time among technology artifacts and social actors with different resources and power.

The paper is organized as follows: First, we present and discuss prior research on innovations in service systems with digital technology. We then outline the theoretical foundation of the tuning of boundary resources in a service system. The research approach is then presented, followed by an analysis of the findings, which are subsequently discussed. Finally, we present our conclusions.

Related Research

Continuing developments of digital technology have created new opportunities for innovations in service systems (Yoo et al. 2012). Recently, scholars from different fields have paid a significant amount of attention to innovations in service systems enabled by digital technology. The existing literature on digital innovation can be characterized in multiple ways. Here, we focus on how different scholars see the role of digital technology in innovation by identifying three dominant streams that are contrasted by their stance on the nature of technology and the role of different actors.

The first view, which we refer to as the generative view, focuses on the generative aspect of digital technology and how this changes the dynamics of innovations. For example, Yoo et al. (2010) argue that the emergence of layered modular architectures enabled by digital technology has made generative innovation possible (Zittrain 2006). Furthermore, affordable and easy to learn digital technology has lowered entry barriers to service systems, allowing various individual actors and small firms to participate in service systems and thereby facilitating an open and crowd-sourced innovation process (Chesbrough 2006; Lakhani and Von Hippel 2003; von Hippel 2005; West and Gallagher 2006). From this point of view, the success of a service system with digital technology critically depends on the massive participation of heterogeneous actors who can create diverse innovations that often are not anticipated by those who created the service system in the first place (Zittrain 2006). User-created innovations in on-line communities, open source communities, on-line tournament sites, mobile app stores, and social media sites all represent the fundamental underlying dynamics of innovations as characterized by the generative view. These scholars argue that the emergence of such unbounded and generative innovations represents a fundamental departure from the earlier forms of innovations that are dominated by large firms (Faraj et al. 2011; Yoo et al. 2012).

The second view, which we refer to as the infrastructure view, notes the growing scale and scope of digital infrastructure that enable various forms of service in service systems (Benkler 2006; Hanseth and Lyytinen 2010; Hanseth et al. 1996; Tilson et al. 2010). Contemporary service systems for social media or mobile phones, for example, require digital infrastructures that are global in their scope and scale. These scholars note that digital infrastructures differ in their scope and scale from earlier forms of digital technology that were confined within the reach of a single organization (Ciborra et al. 2001; Ghazawneh and Henfridsson 2013; Lyytinen and King 2002). Building and maintaining such large global scale infrastructures is financially expensive and technically challenging. Thus, only a few large companies are able to successfully establish and maintain tight control over such extensive service systems. Using their exclusive and powerful position in the service systems, these firms exercise control or influence different forms of standards by which they manage access to the service system (Lyytinen and King 2006; Yoo et al. 2005).

These two views show the paradoxical impact of digital technology on innovations in service systems: the contemporary service systems with digital technology are simultaneously open to the crowd and tightly controlled by a few dominant actors. The third view, which we refer to as the integrative view, attempts to reconcile these contrasting views. Scholars adopting this integrative perspective characterize service systems enabled by digital technology as: multisided markets (Eisenman et al. 2006; Parker and Van Alstyne 2005), platforms (Baldwin and Woodard 2009; Boudreau 2010; Gawer 2009; Tiwana et al. 2010), and eco-

systems (Ceccagnoli et al. 2012; Iansiti and Levien 2004). These concepts all recognize the copresence of powerful firms that control the infrastructure and heterogeneous actors who maintain an arm's-length relationship with the infrastructure owner and leverage the infrastructure to create diverse innovations that are often unanticipated by the firms that created the infrastructure. Ghazawneh and Henfridsson (2013) suggest *boundary resources* as key resources that resolve the paradox of the simultaneous control and generativity. They note that in "software platform settings, such (boundary) resources typically consist of a software development kit (SDK) and a multitude of related APIs" (p. 175). It is these boundary resources that provide access to the core resources of the service system, stimulating generativity, while at the same time affording the firms that created the infrastructure control over the service systems. It is through boundary resources that the focal firms attempt to establish the boundary of the service systems, specifying what is allowed and what is not. According to Ghazawneh and Henfridsson, these boundary resources are designed by the firm that owns the infrastructure in order to attract the heterogeneous actors to join the service systems and encourage their innovation (they refer to this as resourcing), while at the same time allowing the focal firm to increase its control over the service system (referred to as securing). Ghazawneh and Henfridsson further note that when third-party actors feel the boundary resources offered by the infrastructure owner are limited, they sometimes build new boundary resources (referred to as self-resourcing). Their research shows the structural arrangement of service systems enabled by digital technology and how it allows firms to balance the tension between the control and generativity of the service systems. It is, however, not clear how boundary resources come into being and exactly how they evolve over time. In particular, Ghazawneh and Henfridsson give a privileged position to the owner of the infrastructure, who is depicted as the primary designer of the boundary resources, while noting third-party developers as passive recipients of these boundary resources. Although Ghazawneh and Henfridsson note that sometimes third-party developers create their own boundary resources when facing the limitations of existing boundary resources, their model is based on a relatively simplistic dialectic relationship between an owner of the infrastructure and a third-party developer, with a clear emphasis on the dominant role of the former. In reality, however, an owner must deal with third-party developers with different levels of power over other actors and materials.

Therefore, to offer a genuine theoretical explanation of the innovations in service systems with digital technology, one must start with a view of service systems as evolving webs of complex and overlapping relationships among distributed and heterogeneous actors and artifacts, with an explicit attention to the role of power and influence exercised (Jasperson et al. 2002; Silva and Backhouse 2003). Understanding the creation and evolution of boundary resources in this complex sociotechnical relationship, therefore, is essential for understanding innovations in service systems in the digital age. In this study, extending the work of Ghazawneh and Henfridsson, we seek to understand the underlying mechanisms by which boundary resources come into being and evolve over time in the context of on-going and multilayered interactions among heterogeneous actors. Our efforts seek to build on their analysis, which emphasizes structural arrangements, by foregrounding dynamic aspects.

Theory

To understand and articulate the dynamic and emergent process of how boundary resources come into being and evolve over time in service systems with digital technology, we draw on the theoretical framework of tuning, originally developed by Pickering (1993). Pickering studies the interplay between human and material agency in scientific practice and develops the notion of tuning to capture the dialectic process of resistance and accommodation "that is generative and entails tensions" (Barrett et al. 2012, p. 1450). It is through this tuning process that the contours of human and material agency temporally emerge. According to Pickering, resistance refers to the "failure in practice of human actors to achieve the intended capture of material agency" (Barrett et al. 2012, p. 1450). Resistances are liminal, being "always situated within a space of human purposes, goals and plans" (Pickering 1993, p. 577), thus making it impossible to know the trajectory of material agency of technology ahead of time. Instead, the material agency of technology reveals itself only as it resists human actors' attempts to domesticate and transform it, making it "inherently impure." Pickering further notes that although human actors do have certain future intentions, goals, and purposes, these only serve short-term purposes and do not decisively prescribe the destination. Instead, Pickering notes that the intentional structure of human actors is temporally emergent and contingently transformed as the actors actively respond to material resistance, which he refers to as accommodation.

Barrett et al. (2012) extend Pickering's concept of tuning in the context of digital innovation. Specifically, they note that digital innovation involves multiple, heterogeneous actors who often have conflicting interests, values, norms, competencies, and practices. They further note that innovation is rarely a singular entity. Rather, it is a "shifting assemblage of

multiple materialities" (Barrett et al. 2012, p. 1451). They argue that the actualization of digital innovation is neither inevitable nor necessarily associated with some predetermined outcomes. This is particularly due to the malleable nature of the technology and the way material agencies of technology artifacts play out in the tuning process.

Building on the work by Pickering (1993) and Barrett et al. (2012), we conceptualize the process by which boundary resources come into being and evolve in service systems enabled by digital technology as tuning. The tuning lens is particularly attractive in understanding the evolution of boundary resources in service systems enabled by digital technology as it explicitly embraces the unknowable and contested nature of digital innovation (Yoo et al. 2010). Boland et al. (2007) used the image of "wakes of innovation" to capture the complex and ever-changing nature of digital innovation. They show how innovations in heterogeneous and distributed sociotechnical systems, such as service systems enabled by digital technology, involve multiple technologies and heterogeneous actors who follow their own goals and trajectories. Therefore, changes in boundary resources in service systems must be understood not as a matter of creation by the firm that owns the infrastructure and the adoption by many independent developers, but rather how they evolve and collide with artifacts within and across multiple organizational and technological contexts. The idea of tuning thus provides a useful analytical lens to understand the dynamic nature of boundary resources in service systems.

Specifically, we note that service systems involve heterogeneous actors who struggle with their own technology artifacts, while at the same time, engaging with each other in shaping the boundary resources. Therefore, in our analysis of the tuning process of a service system, we attend to the tuning of boundary resources that involve multiple actors and local tuning processes by individual actors at the same time. Thus, our theoretical goal is to simultaneously move away from a dialectic view of a service system between a platform owner and third-party developers, on one hand, and a dialectic view of tuning between an actor and artifact, on the other hand, to a distributed network view of actors and artifacts that are intermingled in multilayered, overlapping, and on-going tuning processes. In so doing, we attempt to extend the theoretical model of tuning by explicitly incorporating multiple technological artifacts and how they interact and compete with each other, just as multiple actors interact in a service system, with its boundary being reconfigured. We see multiple competing artifacts contesting in a service system. Any theoretical and empirical analysis of the innovations in the service systems enabled by digital technology must directly deal with such multiplicity and contestants among technology artifacts as well as human actors. In this paper, we conduct an empirical study to explore how boundary resources come into being and evolve over time in a service system enabled by digital technology drawing on the data that we collected from Apple's iOS service system.

Research Approach

Case Selection

We adopt an embedded case study methodology (Yin 2009). The case study denotes a research strategy for understanding the dynamics of a phenomenon in a single setting (Yin 2009). Within an embedded case study design, there is more than one unit of analysis in a single case, and the design explicitly pays attention to variations across subunits within the case (Yin 2009). We use a case study method to develop a theory inductively, grounded in empirical data (Eisenhardt 1989). We choose this grounded approach to theory building for two reasons. First, there is a scarcity of theory describing the phenomenon in question. Current research emphasizes structural perspectives on the interactions within service systems. This provides an opportunity for theory to be developed inductively (Eisenhardt 1989). Second, the phenomenon that we study is inherently processual, which, given its sequential and changeable nature, makes it suited to a grounded approach to theory building. Theory that is both inductively built and grounded in empirical data has the added strength that it is often novel, logically coherent, and can easily be tested for empirical validity (Eisenhardt 1989).

We select Apple's iOS service system as the single locus for our embedded case study for the following reasons. First, Apple's iOS is a an exemplary digital service system, where large numbers of heterogeneous actors contribute to rich and diverse service and service system innovation through the use of digital technology. Second, Apple's service system is considered to be dynamic and innovative. It has the potential for providing ample examples of boundary resource creation and evolution to study. Last of all, given the popularity and the high profile of the company and the service system that it enables, a rich body of secondary data is generated, which allows for in-depth empirical analysis. Within the iOS case, we study the emergence and dynamics of boundary resources.

Data Collection

Our research is informed by empirical data collected from two publically available archival sources. First, we collect blog

entries originated from "Tech Bloggers" who are a particular type of knowledge blogger (Davidson and Vaast 2009). These blog entries provide extensive and rich information as they contain regular commentaries on technological innovations. These blog entries constitute a highly suitable secondary and tertiary source of information for the reasons of (1) relevance as many blogs providing factual reports on decisions and actions taken concerning the development of the iOS service system; (2) quality through cross-checking multiple blog sources and online corporate sources; and (3) flexibility in terms of rapid data search, access, filtering, and threading (Bar-Ilan 2005). To facilitate our data collection, we use a tech blog aggregator named Techmeme.com (Davidson and Vaast 2009). Blog aggregators tend to highlight the reports of the most influential bloggers (Vaast et al. 2013). The use of an online blog aggregator is particularly suitable for the purpose of our study as we are interested in our independent developers' influence of public opinion through the blogosphere. It also allows a neutral selection of blogs and entries. We collected blog data concerning events in Apple's service system occurring over the five-year period starting in January 2007 through to the end of December 2011. By the end of this process, our database contained 4,664 blog entries.

Second, we use two official sets of documents published by Apple that contain the rules that it applies in managing much of its service system. The first is the iOS Developer Program License Agreement (DPLA) (Apple 2011b), which details the obligations and responsibilities of third party developers as members of the Apple Developer Program. The second is the App Store Review Guidelines (ASRG) (Apple 2011a), which provides specific rules that are used as a basis to evaluate developer code in the App Store Review process. These public documents were updated several times by Apple over the five-year period forming the focus of our study, and we tracked the changes made.

Data Analysis

For our empirical analysis, we adopt Ghazawneh and Henfridsson's (2013) definitions of boundary resources and apps. Boundary resources refer to specific service system resources, in the form of "software tools and regulations that serve as the interface for the arm's-length relationship between [different members of the service system]" (p. 174). Apps refer to "executable pieces of software that are offered as applications, services, or systems to end-users of the platform" (p. 175) In the setting of Apple's service system, some boundary resources are made available by Apple, such as APIs that provide a conduit to the functionality of its operating system, the App Approval Process, and the rules and conditions in its iOS Developer License Agreement. Other boundary resources are made available by other actors, for example Adobe and Google, and provide developers with tools for functions such as application development or the enablement of advertising.

Boundary resources, which enable and constrain software code as service, are not always directly accessible for empirical observation. However, service, in the form of code made possible by boundary resources, is more directly accessible in an empirical analysis. Our approach to studying the dynamics of boundary resources is first to identify the code with which boundary resources are associated. Then by studying the discourse concerning disputes between developers and Apple over what code is permitted in Apple's service system, we discover those latent boundary resources and the wider process of their tuning. We treat the evolution of boundary resources as *latent constructs* while treating dispute incidents between Apple and developers as *indicator variables*. Our study, therefore, adopted three rounds of coding in order to obtain our goal of understanding and explaining the process for the evolution of boundary resources.

The first round of coding is concerned with identifying instances of developer code contested by both Apple and the developer. This serves as the foundation for subsequently uncovering latent boundary resources at the core of the disputes. Given the nearly one million apps developed over the timeline of our study, most cases are not disputed publicly. However, our analysis of 4,664 blog entries identifies examples of contested code. Three of the authors first examined a subset of the blog data covering events from October 2009 to September 2010 in order to establish a coding scheme. Once the three coders agreed on a coding scheme behind 11 contested cases identified in this period, the first author then completed the data analysis, which results in 45 instances of contested code (including the original 11).

The second round of coding focused on identifying the common boundary resources that lay behind each of the 45 instances of developer code being contested. We first clustered 45 instances of disputed code around common boundary resources. Second, we established time-lines on how these boundary resources changed and evolved over time. We then identified emergence of and changes to other associated boundary resources. Last, we identified a total of 30 boundary resources arranged in 15 clusters.

The third and final round of coding aimed at identifying latent mechanisms governing the process of cocreation and evolution of the boundary resources identified in the empirical data.

Table 1. Summary of Outputs by the Three Rounds of Coding Employed

iOS Apps	Blog Posts	Round 1: 45 Instances of Disputed Code	Round 2: 30 Boundary Resources in 15 Clusters	Round 3: Six Themes
1 million iOS Apps	4,644 Blog and Online News Articles discussing Apple's Service System	Jailbreakme	**A) Distribution of apps** BR1 – iOS Kernel DRM module (Changes) BR2 – Apple App Store (Emergent) BR3 – iOS SDK (Emergent) BR4 – App Approval Process (Emergent) BR5 – General DPLA rules (Emergent) BR6 – Alternative App Store (Emergent) BR7 – DPLA rule 3.2e (Emergent)	The Distribution of Apps Written in Native iOS Code
		Adobe Flash	**B) Executable Code** BR8 – Adobe Flash Plug-in (Not realized) BR9 – Safari codebase (No Change) BR10 – HTML5 (No change) BR11 – DPLA Rule 3.3.2 (Emergent)	The Migration of Installed Base
		C64 Emulator; Nescaline	**C) Platform Emulators**[†] BR11 – DPLA Rule 3.3.2 (Changes)	
		Adobe Developer Tools	**D) Cross Compilers** BR12 – Adobe cross compiler (Emergent) BR13 – DPLA Rule 3.3.1 (Change)	
		Ari David; Baby Shaker; EFF Updates App; Eucalyptus; Mark Fiore; Me So Holy; NinjaWords; Simply Beach; Someecards; Wallpaper Universe	**E) Objectionable Content** BR14 – DPLA Rule 3.3.18 (No Change) BR15 – General ASRG Rules (Emergent) BR16 – ASRG Rule 14.2(Emergent)	Negotiating the Equivocality of Content Controls
		Google Voice; GV Mobile; Opera; Podcaster; VoiceCentral	**F) Duplication of core iPhone functionality** BR17 – ASRG Rule 10.20 (Changes)	Contesting Revenue Cannibalization by Proxy
		3G Skype	**G) VoIP over 3G** BR18 – DPLA Rule 3.3.15 (Changes)	
		Financial Times; Google Books; Readability	**H) In-app subscription payments** BR19 – iTunes subscription payment mechanism (Emergent, No Change) BR20 – DPLA Rules Attachment 2 2.2 (Emergent) BR21 – ASRG Rules 11.12-11.14 (Emergent & Changing)	The Control of Customer Data
		AdMob	**I) Customer data analytics** BR22 – AdMob (No Change) BR23 – iAd (No Change) BR24 – DPLA Rule 3.3.9 (Changing)	
		Pulse News Reader; Routesy	**J) Apple's Legal Position** BR25 – DPLA Rules (No Change)	Status Quo (Not included in the analysis)
		Big Brother Security	**K) Customer Privacy** BR26 – DPLA Rules (No Change)	
		I am Rich	**L) Dubious Value** BR27 – DPLA Rules (No Change)	
		Convertbot	**M) Inappropriate look and feel** BR28 – DPLA Rules (No Change)	
		Sekai Camera; Tawkon; Wi-Fi Sync	**N) Use of private APIs** BR29 – DPLA Rules (No Change)	
		CastCatcher; EyeTV; Netshare	**O) Excessive Cellular Data Usage** BR30 – DPLA Rules (No Change)	
		Box Office; TrapCall; Trillian	**No boundary resource found in these examples of disputed code**	

[†]In the interest of keeping vignette length at a reasonable level, we have excluded our analysis of the platform emulators, but can make the analysis available upon request.

We conducted this process in two stages. First we applied the concepts from tuning (Barrett et al. 2012; Pickering 1993) to the evolution of boundary resources within the 15 clusters previously identified. From this, we identified the 9 cases out of 15 where boundary resources are subjected to change. These nine clusters of boundary resources are grouped into six common themes. However, we excluded the sixth theme as it captures instances that did not lead to any changes in boundary resources or where boundary resources could not be identified. Within and across the five themes forming the foundation for the further in-depth analysis, we were able to identify common characteristics that propel the evolution of boundary resources and this activity results in a model characterizing the tuning of boundary resources. The outcome of each of the three rounds of coding is summarized in Table 1.

Results

In this section, we describe the tuning process[2] of boundary resources in Apple's iOS service system based on the five themes: (1) distribution of apps written in native iOS code; (2) migration of installed base across service systems; (3) negotiation of content control; (4) use of boundary resources as proxies for control in associated and neighboring service systems; and (5) ownership and control of customer data. The time-line that makes up these events is summarized in Figure 1. The analysis references selected blog articles from the corpus of 4,664 articles as {web reference number} listed in Appendix A.

The Distribution of Apps Written in Native iOS Code (January 2007–)

One of the ongoing issues concerning Apple's service system is the different goals of members of the iOS service system concerning the distribution, installation, and execution of apps written in iOS native code. The distribution, installation, and execution of native code on iOS is controlled in part by a boundary resource, the DRM module (BR1) in the iOS kernel. The tension between the goals of the different actors unfolds over time in the tuning of the DRM module with regard to the scope of its control.

In January 2007, six months before the launch of the iPhone, Apple CEO Steve Jobs declares his intention that the device will not be open to native apps by third-party developers, citing reasons of protecting telecom partners' networks and the security of the phone itself {1a}. In early June, just prior to the launch of the iPhone, Apple makes it clear that the device will be open only to third-party web apps written in HTML5 and running within the confines of the Safari browser. Apple designs a DRM module (BR1) in the iOS kernel so that it resists attempts by third parties to install native code written by sources other than Apple. This announcement disappoints developers and consumers who prefer the performance and capabilities of native apps {1b}.

Following the launch of the iPhone in July 2007, different groups of hackers attempt to find a method to reengineer the DRM module (BR1) so that it does not resist attempts to install third-party native apps. The DRM module (BR1) initially resists the hackers' attempts until one month later, when a group of hackers find a means of overcoming its resistance through leveraging their technical expertise in reengineering and unlocking the operating system. A month later, an alternative and simpler means of hacking iOS is published, which enables regular iPhone users to open up their devices {1c}. For a short while, Apple is forced to accommodate its hacked operating system but soon leverages its financial and technical resources to respond. In September 2007, Apple releases an update to iOS on iPhones, which resists or prevents the established means of opening up the DRM module (BR1). This update disables the installed third-party apps, but as a side effect also "bricks," or renders inactive, some hacked iPhones. Jobs states that the company is engaged in a "cat and mouse" game of response and counter response with hackers {1d}. As a consequence of Apple's actions, the DRM module (BR1) once again resists all known methods to install third-party native code. Furthermore, the hacking community is forced to accommodate Apple's patch and find a new way to hack the DRM module (BR1). The attempts of the hackers are not resisted for long and a few days later, a new way of hacking is found, which has now taken the name "jailbreaking." This cycle of firmware updates with patches to block jailbreaking and subsequent jailbreaking to overcome these patches continues to the present day {1e}. Here, the DRM module (BR1) alternates between resisting and no longer resisting attempts by hackers to open up the module, and at the same time it resists and no longer resists attempts by users to install independent native code. At each turn, Apple is either forced to accommodate the hackers, developers, and consumers, or the hackers, developers, and consumers are forced to accommodate Apple.

Then finally, in late October 2007, nearly four months after the launch of the iPhone, Jobs announces that Apple intends

[2]While many of the interactions between the actors and artefacts that we saw in our empirical data could be described using the vocabulary of tuning, we only employ the terms *accommodation* and *resistance*, adhering to Pickering's definitions, for changes to the key boundary resources that we study in each vignette. In this way, we maintain our focus on the innovation of the service system.

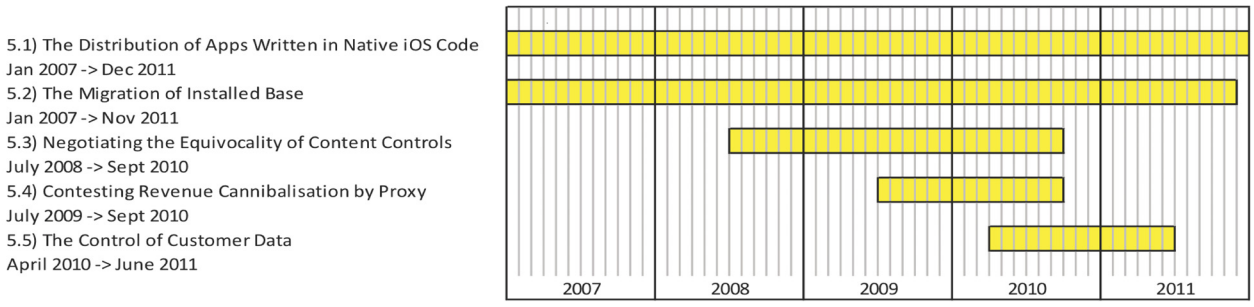


Figure 1. The Time-Line Outlining the Relative Chronology of the Five Themes Explored

to make an SDK available to third-party developers in April 2008 for the creation of apps in iOS native code. In so doing, he signals an intent that the official DRM module will be tuned so as to no longer resist the installation and execution of independent native code {1g}. Meanwhile, increasingly easier means of jailbreaking iPhones become available, and by the end of the month, it is estimated that more than 100,000 iPhone users have jailbroken their devices {1h}.

In late February 2008, Apple releases details of its SDK and its intent to distribute third-party native apps through an App Store, into which it will control the admission of select third-party code using an App Approval Process {1i}. This announcement heralds the emergence of three more boundary resources: the Apple App Store (BR2); the iOS Software Development Kit (SDK) (BR3); and the App Approval Process (BR4). Furthermore, it signals Apple's intent that the DRM module will continue to resist independent native code that is not approved by Apple and that is not distributed from the App Store. When the SDK is made available in beta form in early March, it is met with mixed reactions from developers, as it is accompanied by a further emergent boundary resource, the Developer Program License Agreement (BR5) that rules against the inclusion of certain types of apps in the App Store. As a result there is unease among the user and developer community, voiced through the blogosphere, over Apple's monopoly of the distribution of apps and its App Approval Process. This leads to speculation that Apple's creation of an App Store may reduce but not stop the demand for apps not approved by Apple and the process of jailbreaking in order to obtain, install, and execute them {1j}.

On July 10, 2008, the App Store and the SDK are officially launched. While this launch is met with enthusiasm, and the new version of the operating system resists attempts by hackers to open up the DRM module (BR1), a new means of jailbreaking is soon developed {1k}. Once again BR1, now in combination with the new boundary resources (BR2-5), no longer resists developers and users installing and executing unapproved code.

In February 2009, the range of actors involved in the debate over the distribution of native code increases. As part of a consultation activity regarding the revision of the Digital Millennium Copyright Act conducted by the U.S. Copyright Office, the Electronic Frontier Foundation (EFF), a consumer-lobby organization, requests that an exemption be made to the prohibition of the circumvention of copyright protection systems for access control technologies. EFF makes this request in order to influence Apple and stop its attempts at sanctioning iPhone users for jailbreaking their devices and prohibiting hackers finding new means of jailbreaking iOS. Apple then writes to the U.S. Copyright Office, stating that it believes that iPhone jailbreaking is a violation of the Digital Millennium Copyright Act (DMCA), and that it is an illegal activity {1l}. This is a clear example of Apple seeking to influence users and developers by trying to prohibit the practice of jailbreaking, while consumer interest groups and government bodies seek to limit Apple's controls over third parties from jailbreaking their devices or finding new methods to open up the DRM module (BR1). Users, developers, and other interested parties appeal to the external actors through the blogosphere with the result of influencing Apple to develop new boundary resources.

In March 2009, Cydia opens an Alternative App Store (BR6) as an alternative to Apple's official App Store, and positions it as a means for developers to distribute, and iPhone users to purchase, apps intended for jailbroken iPhones {1m}. In April, Apple responds by updating its iOS developer program license agreement. Among the changes is a specific new clause (3.2e) (Section 3.2e revision 20-10-08) (BR7), which prevents registered developers from facilitating the jailbreaking of devices or distribution of apps from any source other than the official App Store {1n}.

Table 2. Overview of the Boundary Resource Tuning with Respect to the Distribution of Native Apps

Date	Acts of Tuning and Influence
July 2007	BR1 resists installation of third party native code. BR1 resists being hacked. Frustration of iOS users and developers is voiced through blogosphere and influences Apple.
August 2007	BR1 is hacked through successful application of hackers' technical expertise. BR1 resists Apples fixes.
September 2007	BR1 is patched by Apple using its significant technical resources. BR1 resists installation of third party native code. BR1 resists being hacked. Frustration of iOS users and developers is voiced through blogosphere and influences Apple.
Cycle continues. BR1 first resists hackers and users and then resists Apple.	
July 2008	BR2–5 emerges to enable Apple to monopolize the distribution of select third party native code. New BRs placate demand by users and developers for third party native code. Apple uses boundary resources that it owns to control distribution of the third party apps. Apple uses warrantee policies to prevent users jailbreaking iPhones.
Cycle continues. BR1 first resists hackers and users and then resists. Apple driven by users' desire to access content not sanctioned by Apple.	
February 2009	EFF lobbies US copyright office to exempt jailbreaking in the DMCA. Apple attempts to influence the US copyright office to the opposite effect.
July 2010	U.S. Copyright Office sanctions the practice of jailbreaking by exempting it from the DMCA.
Cycle continues. BR1 first resists hackers and users and then resists. Apple driven by users' desire to access content not sanctioned by Apple.	

Then in late July 2010, nearly 18 months after the EFF's request is placed with the U.S. Copyright Office, the practice of jailbreaking is oficially exempted from the DMCA. The implications of this are that iOS users legally have the right to jailbreak their devices, and that hackers have the right to develop new means of opening up the DRM module (BR1) to non-Apple-approved apps {1p}.

The "cat and mouse game" between hackers and Apple with the DRM module (BR1) persists to the present day {1q}. Table 2 summarizes the events that have taken place during the ongoing process of tuning the DRM module (BR1) by Apple, hackers, and users. Figure 2 illustrates the relationships of tuning between actors and the DRM module (BR1), which is at the center of an on going process of changes, as well as leading to the emergence of BR2-BR5. The figure also indicates the relationships of influence between the key actors.

The Migration of Installed Base (January 2007– November 2011)

Adobe Systems Inc. is the developer of Adobe Flash, a software package used for authoring vector graphics, animation, games, and rich Internet applications (RIAs) that can be viewed, played and executed in Adobe Flash Player, a runtime platform. The platform became popular during the pre-smartphone era as a plug-in to web browsers, and Adobe generated a considerable installed base of developers using the platform, as well users consuming content on a range of personal computer operating systems including Microsoft Windows and Apple OS X. The vignette that follows concerns the tuning of boundary resources, a Flash plug-in (BR8) and an Adobe cross compiler (BR12), that Adobe intends to use to allow its installed base of code, content, and developer skills to operate on iOS.

In January 2007, six months before the launch of the iPhone, Steve Jobs is non-committal about supporting plug-ins in general, and a Flash plug-in (BR8) in particular, within the codebase of Safari (BR9), suggesting that alternative superior standards exist for accessing rich content {2d}. In June 2007, the iPhone launches without any Flash support within Safari, which instead supports HTML5 (BR10), an alternative emerging standard {2e}. In March 2008, Jobs signals that while it is still possible for the Safari codebase to support a Flash plug-in, Flash is seen as too demanding for the iPhone operating system and hardware resources such as battery power {2f}, and that the onus is on Adobe to create a plug-in that can be supported by iOS and iPhone hardware resources {2g}. Until this time the Flash plug-in (BR 11) had resisted

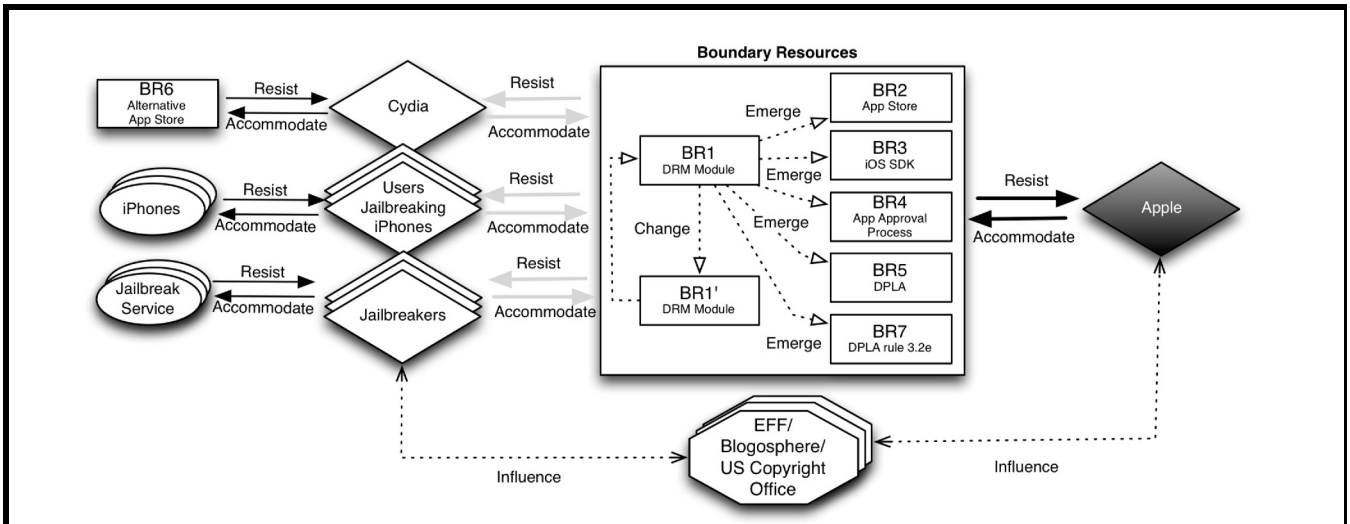


Figure 2. Relationships of Tuning and Influence in the Distribution of Apps Written in Native Code

Apple's goals for achieving a certain level of performance, and it has resisted Adobe's attempts to make it perform better to satisfy Apple. Apple has accommodated the performance of Flash by enabling the Safari code base (BR9) to support other standards in lieu.

In the 18 months that follow, Adobe continues to make statements that it is working on a suitable plug-in {2h,i} and is cooperating with Apple on the matter {2l}. During this time Apple launches the App Store (BR2), accompanied by the iOS Developer Program License Agreement (DPLA) (BR5). The DPLA (BR5), along with other controls, introduces Section 3.3.2 (BR11) to prohibit apps that enable executable code. Commentators increasingly speculate that Apple is excluding Flash as it is a service system in its own right enabling rich Internet applications, and therefore threatens Apple's control over their installed base by bypassing their ability to curate content and apps for the iPhone. They claim that controls such as Section 3.3.2 (BR11) are used to prevent this circumstance from materializing {2j}. BR11 therefore bolsters the resistance of the Flash plug-in (BR8) to Adobe's attempts to improve its performance.

In October 2009 at Adobe Max, a developer conference, Adobe announces that it has secured agreements enabling Flash plug-ins to be supported in other smartphone service systems, including Blackberry, Microsoft, and Android {2n}. At the same conference it announces plans for Adobe Flash Professional CS5, a development tool set for release in spring 2010 which will enable the authoring of Flash content. To be included within this tool is a cross compiler (BR12), enabling Flash code to be ported to iOS code {3a}. The announcement of this future additional boundary resource is well received by the Flash developer community, as it would mean that they can port their Flash-based applications to iOS native code with relative ease {3b}. Adobe also states that it will continue to work on a Flash plug-in for Safari to support viewing of video content and execution of rich Internet applications {2o}.

By spring 2010, a Flash plug-in has yet to materialize as it continues to resist Adobe's efforts to get it to perform on iOS to Apple's satisfaction. In February 2010, Condé Nast, reveals that it is running parallel development paths to enable their magazine *Wired* for the iPad. One version runs a rich version of the magazine based on Flash, developed in collaboration with Adobe. The other version is less feature rich and runs on standard iOS code {2q}. In this way, Condé Nast represents developers who share Adobe's goal of finding a way to overcome the resistance of the Flash plug-in. In contrast, online video platform provider Brightcove announces, in March 2010, that it will abandon producing video content based on Flash standards, and will instead adopt HTML5 in order to ensure compatibility with Apple's iPad {2r}. Brightcove represents developers whose changing goals accommodate the problems with the Flash plug-in by adopting alternative standards. The actions of developers like Brightcove pose a threat to Adobe in terms of its ability to maintain its installed base.

In April 2010, before the launch of Adobe Flash Professional CS5, Apple updates Section 3.3.1 (BR 13) of the iOS DPLA (BR5) to prohibit the use of cross compilers in the development of apps. The updated Section (BR13) now resists

Adobes attempts to introduce a cross compiler into Adobe CS5, for converting Flash code into iOS code {3c}. With a prohibition on two of Adobe's potential boundary resources (BR8 and BR12) facilitating Flash content and applications, a public war of words erupts between the two companies as they attempt to influence the opinion of users, developers, and the general public {2t, 3d}, culminating in two events. First, Jobs publically restates Apple's goals and makes a rational argument against adopting Flash in his "Thoughts on Flash" blog post {2u} claiming that (1) Flash is a closed platform; (2) it is out of date and does not perform well on iOS; (3) it drains battery power; (4) the effort to repurpose legacy Flash content for the iPhone would be better spent rewriting it in HTML5; and (5) using cross compilers to port Flash to iOS results in poor performance apps. Adobe responds two weeks later with an emotional advertising campaign in the United States, claiming "We Love Apple" {2v}.

With no movement from Apple concerning its goals and requirements on the performance of Flash and the ban on the use of cross compilers, reports emerge in April that the Federal Trade Commission (FTC) is starting an antitrust inquiry concerning Apple's updated policy on the use of cross compilers (BR13) {3i}. This is all but confirmed in August 2010, when the FTC refuses *Wired* magazine access to records on the matter claiming, "disclosure of that material could reasonably be expected to interfere with the conduct of the Commission's law enforcement activities." This is accompanied by reports of FTC lawyers interviewing app developers about the impact of the ban {3j}. Finally, in September 2010, it appears that the FTC's actions might have contributed to Apple changing its goals as it announces further changes in Section 3.3.1 (BR13) to allow cross compilers. Adobe announces the following day the recommencement of work on CS5 to enable the cross compiling of Flash to iOS native code {3l}.

Despite the relaxation of Section 3.3.2 (BR11), Apple retains its goals and requirements concerning the performance of a Flash plug-in (BR8), which continues to resist Adobe's efforts to make it function effectively. Despite the approval in November 2010 of innovative apps such as Skyfire, a browser that enables users to remotely stream Flash content in HTML5 on an iOS device, developers continue to abandon Flash and adopt HTML5 based standards {2w, 2x, 2aa}. In June 2011, Adobe updates and releases Adobe Flash Professional CS5 with the capability (BR12) of porting Flash to iOS native code, marking the emergence of one of their boundary resources {3ml}. This, however, is followed by an announcement in November 2011 that it is ceasing further development of the Flash plug-in for mobile devices given a dwindling installed base requiring Flash to enable rich media on the mobile {2ab}. In this way Adobe, is forced to accommodate the plug-in and, by implication, Apple's goals.

Table 3 summarizes the key events taking place concerning the tuning of Adobe's boundary resources and the migration of its installed base to iOS. Figure 3 illustrates the relationships of tuning between actors and the key boundary resources (BR8, BR12), which are at the center of this vignette, as well as indicating the relationships of influence between the key actors.

Negotiating the Equivocality of Content Controls (July 2001 – September 2010)

When Apple announces the App Approval Process (BR4), its App Store (BR2), and iOS DPLA (BR5), it explicitly states in Section 3.3.18 (BR14) that apps containing content that "may be found objectionable, for example, materials that may be considered obscene, pornographic, or defamatory" will be controlled for {7a}. In creating this boundary resource (BR14), Apple is clearly expressing its goal to keep objectionable content out of the App Store.

Within a month of its launch in July 2008, developers complain that their apps are being rejected or being pulled from the App Store for the reason that they contravene Section 3.3.18 (BR14), even though it is unclear how the content that they contain is objectionable. In effect BR14 is resisting developers' attempts to tune their own apps and get them into the App Store. Developers and commentators complain about the lack of transparency in the app approval process and the lack of clear rules, but Apple does not release an updated set of rules {7c}, even though it may be attempting to tune new rules behind closed doors. In this way, BR14 is also resisting developers' goals of a clearer policy.

Over time, the resistance of policy (BR14) to developers' goals of getting apps into the App Store is becoming increasingly inconsistent. For example, on May 21, the attempts of a developer to get an e-reader app called Eucalyptus, which provides access to texts published as part of the respected Project Gutenberg, into the App Store is resisted by BR14. The grounds for this resistance are that among the available texts on the e-reader is the "Kama Sutra of Vatsyayana," an ancient Hindu religious text, which is misinterpreted to contain sexual and thus objectionable content. After complaints by the developer, which are covered on the blogosphere and are met with incredulity by the public, BR14 no longer resists attempts to get the app approved, which is duly admitted into the App Store {7e}. However, Section 3.3.18 (BR14) continues to resists developers' attempts at getting it

Table 3. Overview of the Boundary Resource Tuning in Migration of Adobe's Installed Base

Date	Acts of Tuning and Influence
March 2008	BR8 resists Apple's performance and power consumption requirements. BR8 resists Adobe's attempts to engineer it to Apple's standards.
Flash Plug-in (BR8) continues to resist Apple's performance requirements, and Adobe's ability to engineer it to these standards.	
September 2008	Adobe makes a public statements that it is still working on a Flash plug-in.
October 2009	Adobe makes a public statements that it is still working on a Flash plug-in.
February 2010	The installed base of Flash developers signals its frustration at the lack of Flash support on iOS.
March 2010	The installed base of Flash developers starts to migrate to other standards.
April 2010	BR13 resists Adobe's attempts to launch a cross compiler. BR13 signals Apple's attempts at influence Adobe's installed base to adopt alternative standards.
April 2010	Steve Jobs makes statements about the unsuitability of Flash in his blog. Adobe places advertisements.
April 2010	FTC shows interest in Apple preventing cross compilers.
September 2010	BR13 no longer resists attempts to launch cross compilers. Evidence emerges that actors such as the FTC have influenced Apple.
June 2011	BR12 (Flash cross compiler) emerges.
November 2011	BR8 continues to resist Apple's standards. Adobe is forced to accommodate BR8 and abandons development of the Flash plug-in.

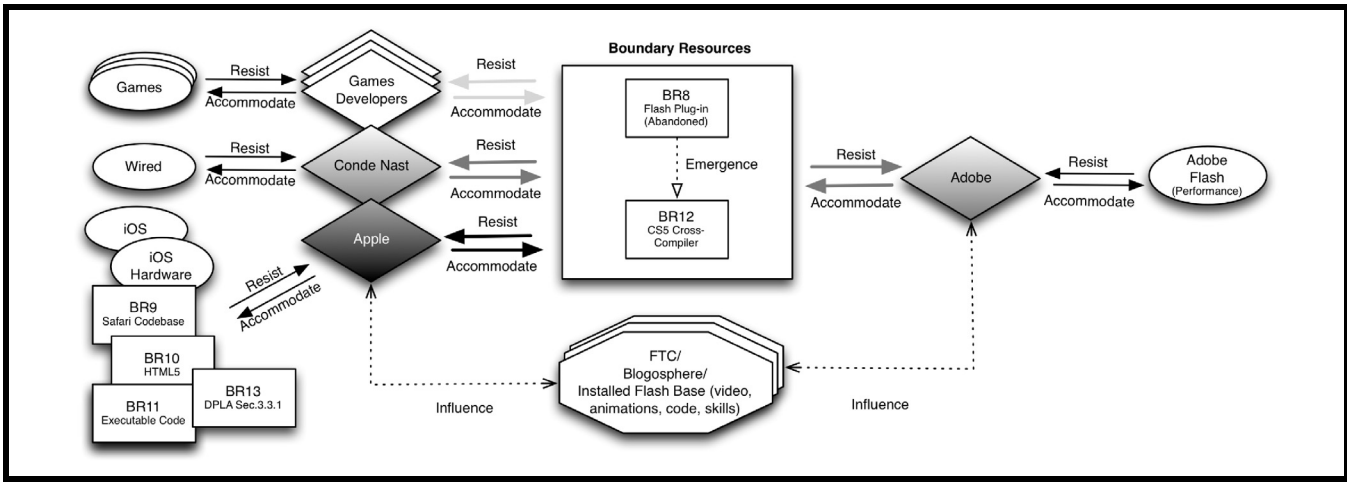


Figure 3. Relationships of Tuning and Influence in the Mitigation of Adobe Flash Installed Base

to explicitly change, and the text remains equivocal even though Apple clearly has the ability to alter its behavior.

Apple continues to face similar challenges in April 2010. On this occasion, political satirist Mark Fiore's attempt to get his app, featuring cartoons of politicians, into the App Store is resisted by BR14. At about the same time, Fiore becomes the first online journalist to win the Pulitzer Prize. News of the rejection of his app and Apple's apparent ignorance of Fiore's profession and fame spreads across the blogosphere. Apple is, in this case, as in the previous cases, clearly influenced by the social pressure of public opinion inflamed by reports of the developers' plight propagated across the blogosphere. As a result, Apple makes another exception and alters BR14 so that it gives up its resistance to Fiore's attempts to get his app into the App Store {7f}. A month later events repeat themselves when outspoken Republican politician Ari David has his attempts at getting an app approved into the App Store resisted. Again, after a similar public furor, his attempts are no longer resisted by BR14, and it soon appears in the App

Table 4. Overview of the Tuning of Content Control Boundary Resources

Date	Acts of Tuning and Influence
July 2008	BR14 resists attempts to get apps into the App Store.
May 2009	BR14 resists attempts to get Eucalyptus into the App Store. Frustration of developer & interested parties is voiced through blogosphere. Apple changes BR14 to make an exception for Eucalyptus.
April 2010	BR14 resists attempts to get Mark Fiore's app into the App Store. Frustration of developer & interested parties is voiced through blogosphere. Apple changes BR14 to make an exception for the app.
April 2010	BR14 resists attempts to get Ari David's app into the App Store. Frustration of developer & interested parties is voiced through blogosphere. Apple changes BR14 to make an exception for the app.
September 2010	BRs 15 & 16 emerge to make Apple's controls on objectionable content less equivocal.

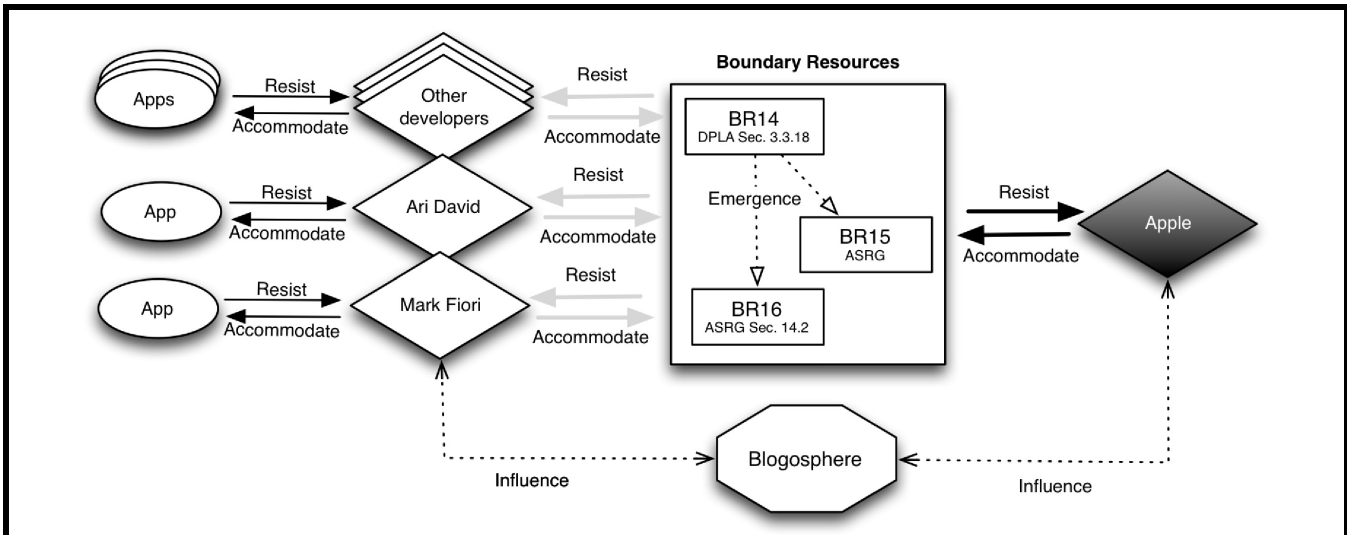


Figure 4. Relationships of Tuning and Influence in Negotiating the Equivocality of Content Controls

Store {7g}. These two cases highlight the continuing equivocality of BR14, which resists the efforts of developers to make it less equivocal.

Finally, in September 2010, after continuing confusion and upset among developers over the equivocality of Section 3.3.18 (BR14), Apple releases the App Store Review Guidelines (ASRG) (BR15). This emergent boundary resource provides explicit rules that make clearer Apple's goals with regard to the type of objectionable content that the company does not want in its App Store. For example, Section 14.2 (BR16) of the ASRG explicitly states, "Professional political satirists and humorists are exempt from the ban on offensive or mean-spirited commentary" {7h}.

Table 4 summarizes the events that took place in order for Apple's content control to become less equivocal. Figure 4 illustrates the relationships of tuning between actors and the boundary resources (BR14, BR16), which are at the center of this vignette, as well as indicating the relationships of influence between the key actors.

Contesting Revenue Cannibalization by Proxy (July 2009 – September 2010)

Apple's iOS service system contains a broad range of different actors who facilitate service in many different ways beyond the provision of apps. Network providers, such as AT&T, form an important set of actors within this service system. Their importance goes beyond simply carrying the voice and data traffic of iOS users as it extends to the sales and distribution of iOS hardware as part of the mobile contracts that iOS users sign. The relationship between network

providers, Apple, and third-party app providers is complex as the services that some apps enable can work against the commercial interests of network providers.

Google Voice is a voice telephony service that Google launches on March 11, 2009 {9a}. In late July 2009, Google announces that Apple is not allowing its Google Voice App onto the App Store. Apple also pulls other Google Voice based apps, created by independent (and less powerful) developers. Apple justifies these actions by claiming that these apps duplicate the functionality of the iPhone Dialer that Apple bundles with the iPhone by default, although this policy is not explicitly stated in the DPLA (BR5). This prohibition on apps that duplicate functionality acts as a boundary resource (BR17) that resists Google's attempts to get Google Voice into the App Store. Google and its fellow developers, along with the blogosphere, seek to exercise influence by questioning how Google Voice and its ilk duplicate iOS functionality. Commentators claim it is AT&T, Apple's network launch partner, that is behind the decision to block these apps, and that it has nothing to do with the duplication of Apple functionality {9b}.

At this point, a separate and independent group of developers and users have differences with Apple over a separate boundary resource, Section 3.3.28 (BR18) of the DPLA (BR 5), which resists the development of applications that enable Voice over IP (VoIP) over 3G networks. Just four months earlier in March 2009, commentators, consumers, and consumer advocates voiced frustration about the limitations that Apple and its telecom partners place on developers of VoIP apps. One group of consumer advocates, the Free Press, asks the U.S. Federal Communications Committee (FCC) to investigate whether Apple and AT&T are violating federal rules by limiting the use of Skype and a whole host of other VoIP apps. The response of AT&T is to claim that it "has every right not to promote the services of a rival" and also to "expect vendors not to facilitate the services of competitors." While Google Voice does not employ VoIP at this point in time, it does share the possibility in common with VoIP apps that it might cannibalize AT&T's voice revenues {8g}.

At the end of July 2009, following complaints by users and developers over the rejection of Google Voice, it is reported that the FCC is investigating the matter. To that end, the FCC requests information from AT&T, Apple, and Google {9d}. AT&T continues to deny any part in the decision. Apple denies it actually rejected Google Voice and that it is still considering the app. At the same time, Apple admits that it has an agreement with AT&T "not [to] take affirmative steps to enable an iPhone to use AT&T's wireless service to make VoIP calls" in order to protect AT&T revenues {9f, 8h}. This statement reveals that the material characteristics of AT&T's network, which prevent it from metering and billing VoIP traffic, ripple out and resist developers' attempts to get VoIP apps into Apple's service system. At the end of August, the FCC announces a full investigation into innovation in the wireless industry, thus extending its inquiry into the rejection of Google Voice {9h}. Apple and Google publically exchange denials and accusations over whether Apple actually rejected Google Voice {9i}. At the same time, efforts of developers to get Google Voice and VoIP apps into the App Store continue to be resisted by BR17. On October 6, AT&T backs down and changes its policies so that it no longer resists the use of VoIP on its mobile network. Commentators speculate that AT&T's move is as a result of FCC scrutiny resulting from the Google Voice case, as well as a competitive response to other U.S. telecom carriers enabling Google Voice and mobile VoIP {8i}.

From December 2009, third-party developers (followed by Google a few months later) capitalize on the generative nature of iOS and use jailbreaking and HMTL5 as a means to accommodate Apple's controlling boundary resources and distribute their functionality through alternative channels {9k}. In January 2010, following an update of the SDK and the iOS DPLA, Section 3.3.28 (BR 24) no longer resists the development of apps that enable VoIP over 3G. However, Google Voice and related apps, which do not use VoIP, are still resisted by BR17 and there is still no sign of them being readmitted to the App Store {8j}.

Google Voice and similar apps remain excluded from the App Store for another eight months until September 9, 2010, when Apple releases the App Store Review Guidelines. Within these guidelines are an unequivocal set of rules, Section 10.20 (BR17), which prohibit apps that duplicate the functionality of apps bundled with the iPhone {9l}. Just over a week later, and with no explanation from Apple, the policy preventing the duplication of functionality gives up its resistance to the attempts of developers to get Google Voice and related apps recognized, and they appear in the App Store {9m}.

Table 5 summarizes the events related to the tuning of the boundary resource (BR17) resisting Google and other developers' attempts at getting their apps into the App Store. Figure 5 illustrates the relationships of tuning between actors and BR17, as well as indicating the relationships of influence between the key actors.

The Control of Customer Data (April 2010 – June 2011)

After the launch of the App Store in July 2008, Apple's iOS service system gradually evolves from enabling basic apps to

Table 5. Overview of the Tuning of Revenue Cannibalization Boundary Resources

Date	Acts of Tuning and Influence
July 2009	BR17 (an unwritten policy) resists developers' attempts at getting Google Voice apps into the App Store. Frustration of developers & interested parties is voiced through blogosphere. Media speculation about Apple's real motivation for blocking applications.
July 2009	The FCC investigates Apple's actions.
August 2009	FCC announces a full investigation.
October 2009	AT&T allows use of VoIP on their mobile networks.
December 2009	BR17 continues to resist developers' attempts at changing it & getting Google Voice apps into the App Store. Developers find different ways to accommodate BR17 by finding alternative distribution channels.
September 2010	BR17 no longer resists developer attempts at getting Google Voice apps into the App Store.

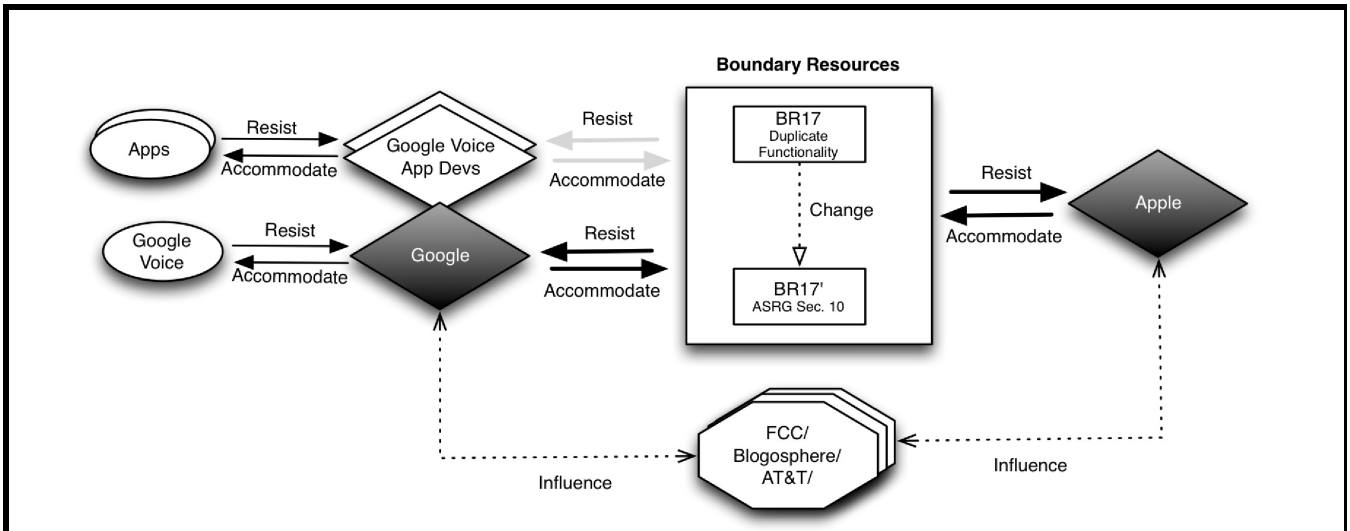


Figure 5. Relationships of Tuning and Influencing in Contesting Revenue Cannibalization by Proxy

facilitate the purchase of additional content in the form of additional functionality or access to digital media. Apple simultaneously extends its iTunes mechanism to enable consumers to purchase content from content providers from within an app without having to exit the app and purchase online. The basic iTunes terms with content providers remain the same, namely the revenues generated from sales are split on a 70:30 basis between content provider and Apple. In addition, as part of the terms, content providers are provided with customer information generated from sales limited to customer name, Apple ID, and e-mail address only.

Until 2010, there had been little or no mention of Apple developing the iTunes mechanism (BR19) to enable the purchase of subscription content, such as digital press or membership services, within apps distributed through the App Store (BR2). Apps, such as the Financial Times app launched on the App Store in July 2009, allow viewers to sign up for subscriptions using the publisher's own web-based mechanism outside of the app itself. There are no controls on revenue share, and there are no controls on what customer data the owner of both app and content is able to access through such transactions {6d}.

In February 2010, Steve Jobs seeks to convince the U.S. printed press industry to distribute their content via iTunes. He is particularly interested in getting them to sell subscriptions through iTunes, to agree to the standard iTunes revenue model and to accept the limited customer data that is offered through the standard iTunes transaction mechanism. Some publishers, such as Condé Nast, are enthusiastic, as it offers an easy, convenient mechanism for consumers to access

content. Other publishers are not so welcoming of the idea as it limits potential revenues and denies them control over access to valuable customer data for marketing campaigns. Many publications, such as *The Wall Street Journal*, continue to get around Apple's revenue sharing model by offering free apps that direct the users, at some inconvenience, to web sites to purchase content {6f}.

In the background, a parallel debate regarding customer data erupts. Google is waiting for clearance from the Federal Trade Commission (FTC), having announced its intent to acquire mobile advertising platform AdMob (BR22) in November 2009. The FTC has concerns regarding the potential for Google to dominate of the mobile advertising industry following this acquisition {5c}. In January 2010, Apple acquires Quattro Wireless, another mobile advertising platform {5d}. This is followed in April by Apple's announcement of iAd (BR23), its in-house advertising platform. The announcement causes interest among commentators, as iAd will be deeply integrated into the iOS platform. Jobs states that all user interaction with advertisements will be conducted within the app, so that users are not forced to leave it when they click on an advertisement banner. In addition iAd will be deeply integrated into the iOS SDK, facilitating developer use of the platform. Commentators speculate that this may soften the FTC's view of Google's purchase of AdMob, which is a more open platform {5f}.

In April 2010, Apple updates Section 3.3.9 (BR24) to restrict the collection of customer data: "third party software in Your Application to collect and send Device Data to a third party for processing or analysis is expressly prohibited." The concern among the mobile advertising industry is that this rule will resist developers' attempts to get apps that use advertising platforms other than iAd into the App Store. It is reported that Google informs the FTC of its concerns. Aside from AdMob, there are numerous other mobile analytics companies that might be affected, such as Flurry, MediaLets, and Simple Geo {5g}.

In May 2010, the FTC closes their investigation into Google's proposed acquisition of AdMob, allowing the deal to go ahead. The FTC said, "As a result of Apple's entry (into the market), AdMob's success to date on the iPhone platform is unlikely to be an accurate predictor of AdMob's competitive significance going forward, whether AdMob is owned by Google or not" {5h}.

In June 2010, Apple announces the July launch date for iAd {5i}. This is followed a day later by a revision in Section 3.3.9 (BR24) of the iOS DPLA so that it no longer resists attempts by "independent" advertising companies to collect analytics data from users, as long as they have granted permission to do so. AdMob's CEO announces his concerns given that his organization is no longer an independent advertising company {5jh}. His fear is that Section 3.3.9 might still be used to resist developers' attempts to employ AdMob. Following on from this, in early September Section 3.3.9 is modified further by Apple to remove language that might seem threatening to Google {5li} so that it is clear that the use of AdMob will not be resisted.

Just as events concerning the use of customer data for marketing analytics are resolved, the debate returns to Apple's plans regarding in-app subscriptions and the fears of the printed press that Apple will put boundary resources in place resisting their access to customer data. In November 2010, reports emerge that Newscorp's forthcoming iPad oriented news publication *The Daily* is going to pioneer the new recurring subscription billing facilitated through iTunes. However, much of the publishing industry continues to be nervous about Apple's plans {6h}.

On February 2, 2011, the launch of Newscorp's *The Daily* on iOS heralds changes to Apple's subscription mechanisms. This news is met with concern within the media industry {6i}. Less than two weeks later, Apple officially launches its subscriptions capability on iOS, at the same time as it introduces Attachment 2 Section 2.2 in its iOS DPLA (BR20) and Rules 11.12-11.14 in its ASRG (BR21) to reflect its subscriptions program. As expected, Apple demands a 30 percent cut of new revenues generated through the capability. More controversial are the conditions that accompany this revenue model. First, Apple demands that any app offering a subscription is limited to using Apple's mechanism (BR19) alone. Second, that links to external pages to sign up for subscriptions are banned. Third, that the subscription price offered on Apple's platform must match what is offered externally. Last, that only limited customer information, namely user name, e-mail address, and zip code, is to be made available to the content provider {6j}. These conditions are codified in BR20, which resists attempts by developers to introduce apps that do not adhere.

In the run up to the launch of its new in-app subscription model, Apple attempts to influence media companies to embrace its plans by lobbying them directly, and by partnering with powerful media companies to produce exemplars of what the new regime can enable. Media companies attempt to influence Apple about their concerns directly, through traditional and digital media, and by means of regulatory bodies. Apple's new subscription rules rapidly draw the attention of the FTC regarding potential antitrust issues. Although no formal investigation is started at this stage, the range of actors involved in the debate is further increased. It is also reported that the Newspaper Association of America

Table 6. Overview of the Tuning of Customer Data Control

Date	Acts of Tuning and Influence
Prior to February 2011	Apple lobbies media regarding its plans for in-app subscriptions. Media voices mixed opinions about Apple's proposals.
February 2011	BR20 and BR21 emerge to resist attempts by media to use other in app subscription methods. In response to media concerns, the FTC expresses interest in Apple's actions
March 2011	BR20 & BR21 resist attempts by media at change. Media accommodate BR20 & BR21 in different ways. Some media pull their installed base from the app store.
June 2011	Apple tunes BR21. It no longer resists the inclusion of alternatives to the official in app subscription model. BR20 continues to resist change, preventing media access to customer data.

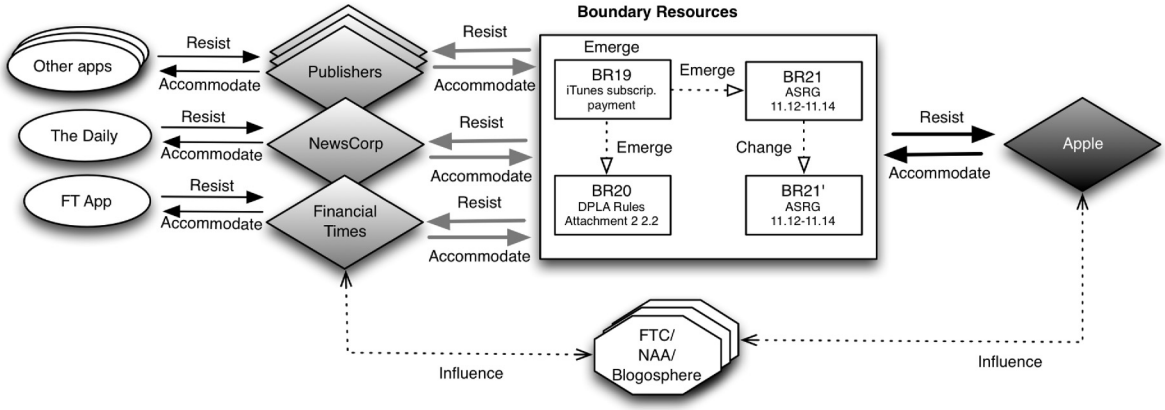


Figure 6. Relationship of Tuning and Influence in the Control of Customer Data with In-App Subscriptions

has been pressing the FTC for some months to investigate Apple's reticence to share customer data with publishers and also the potential harm that the revenue sharing agreement could do to the publishing industry {6k}.

A month later, in March, the publishing industry's compliance to Apple's new rule is divided, and they accommodate the rule in different ways. Many, such as Condé Nast and Hearst, adopt Apple's in-app subscription mechanism (BR19). Others, such as Financial Times, decide to accommodate and change their goals and to capitalize on the generativity of iOS. They do so by removing their content, apps and installed base from the App Store and distributing them as HTML5 web apps, thereby bypassing Apple's subscription mechanism and the associated rules {6l}. In spite of this reaction, these rules resist any immediate change to meet the concerns of the press.

In June 2011, four months after the introduction of its new rules and after increasing pressure from numerous parties, Apple changes its policies (BR21) so that they no longer resist the publishers' interests. Publishers no longer need to offer their publications on iTunes at the same price or less. More importantly, they are no longer required to offer subscriptions within Apple's framework on the condition that they do not offer direct links from within iOS apps to external mechanisms for purchasing content {6m}. While the restrictions concerning the sharing of customer data resist change and remain the same (BR20), the press is free to generate new subscriptions and collect customer data outside of an app. Following this, most publications including *The New York Post* and *The Wall Street Journal* fall in line and adopt Apple's in-app subscription mechanisms {6n}.

Table 6 highlights the events related to the tuning of the boundary resources (BR20 & BR21) that are introduced to resist efforts of media companies to use in-app subscription methods that do not comply with Apple's new in-app subscription mechanism based on iTunes. Figure 6 shows the

tuning of boundary resources related to control over customer data with in-app subscriptions.

Discussion

We draw on the embedded case of Apple's service system for iOS apps to uncover the evolutionary dynamics of a service system through the tuning of its boundary resources. Based on our empirical analysis, we propose a model of *distributed tuning* as a theoretical framework to understand the dynamics of boundary resources in service systems with digital technology.

Distributed Tuning of Boundary Resources

Innovations in service systems with digital technology involve an apparent paradox of open-ended, generative and democratic aspects of digital technology (Yoo et al. 2010; Zittrain 2006) and the monopolistic and controlling aspects of digital infrastructure (Hanseth and Lyytinen 2010; Tilson et al. 2010). An integrative view has emerged that emphasizes the multisided nature of service systems (Parker and Van Alstyne 2005) and boundary resources (Ghazawneh and Henfridsson 2013) as a way to reconcile this paradox. Building on these integrative views, we offer a process model explaining the underlying mechanisms that account for the emergence and evolution of boundary resources and of the wider service system. The theoretical core of our model is the process of *distributed tuning* of boundary resources, driven by the distributed dialectic participation of actors and artifacts, in a context of shifting power through digitalization, and the paradox of control and generativity.

The participation of the actors involved in the tuning of boundary resources is both distributed and dialectic in form. Distributed tuning emerges from on-going tensions among dispersed heterogeneous actors who deal with a set of technology artifacts in a network of dialectic interrelating as shown in all five themes. For example, the case of the boundary resources managing the coordination of app distribution involves dialectic interrelating between Apple and a loosely coupled global community of so-called jailbreakers, an alternative boundary resource owner, and iOS device users jailbreaking their devices. The focus of their dialectic is a boundary resource, a DRM module in the iOS kernel, which is intensely contested by these parties. Apple seeks to dominate the control of the boundary resource so that it resists all unapproved apps on the iPhone. Jailbreakers and a proportion of the iOS users, however, do not accommodate the resistance of DRM and continue seeking to break the resistance of the boundary resource, which hinders the installation of all apps written in native code, both approved and non-approved. Throughout the tuning process, the focal boundary resource can neither resist the jailbreakers' goal of reengineering it, nor Apple's goal of altering it to block further attempts at jailbreaks. The boundary resource is the central party in an ongoing distributed tuning where both parties take turns at asserting their respective goals. Furthermore, behind each actor there are different technology resources that compete and want to be connected with the boundary resource. In the case of Apple, at first these are web apps and, later, officially sanctioned native apps. In the case of the jailbreakers and their user community, these are native apps that are not approved by Apple, as well as a boundary resource of an alternative service system, Cydia, which is an alternative app store for jailbroken iPhones.

Similarly, in the distributed tuning of boundary resources supporting the migration of an installed base of Adobe Flash content, code, and skills into the iOS service system, Apple and Adobe are joined by many other actors and associated technology artifacts. Many developers and users want an Adobe Flash plug-in as a boundary resource that would work with the Safari codebase, a boundary resource in its own right created by Apple. However, the Safari codebase consistently resists any attempt by Adobe to incorporate the Flash plug-in, while it does not resist Apple's attempts to integrate other rival boundary resources for enabling rich content, such as HTML5. Behind the Flash plug-in is a coalition of Adobe and Flash developers. Similarly, there is participation by numerous actors in the tuning of the Adobe's developer tools (Adobe Flash Professional CS5) to include a cross compiler, a boundary resource enabling the porting of Flash code to iOS. A large constituency of computer game developers supports CS5 as a boundary resource as this will more directly enable the transcoding of their applications onto iOS. Again, what we see in the case of two boundary resources promoted by Adobe is that the shaping of a boundary resource emerges through an on-going tension between Adobe and Apple, who in turn deal with other actors and artifacts simultaneously.

Finally, in the case of distributed tuning of boundary resources that regulate the ownership of customer data, Apple is seeking to get the entire global printed press industry to accommodate new boundary resources: an in-app subscription mechanism and associated rules. The promoted boundary resources not only resist the existing web-based subscription mechanisms, they also resist the printed press industry's attempts to own and access user data. While some members of the industry accommodate the new boundary resources, others try to avoid them by seeking to distribute their content through web apps accessible within the Safari browser. The abandonment of native code provided a conduit to their

preferred web-based subscription mechanisms as an alternative boundary resource to accommodate their ownership and control of customer data.

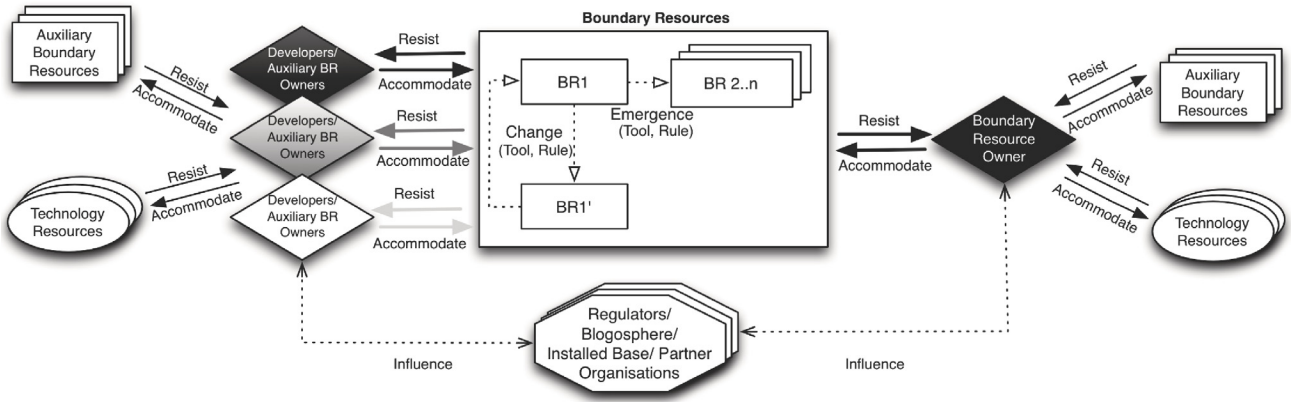
As demonstrated in the results of our embedded case study, the tuning of boundary resources in a service system involves emergent, mutual, and interpenetrating processes of resistance and accommodation across heterogeneous and distributed actors and technology artifacts. In this process of distributed turning, the human actors "seek to channel material agency to shape the actions of other human agents" (Jones 1998, p. 297) and, as a result, boundary resources evolve and emerge. Therefore, distributed tuning of boundary resources is simultaneously and inseparably political and material. It is important to note that distributed tuning of boundary resources in a service system takes place in an artificial world (Simon 1996), rather than in the natural one. Thus, the resistance offered by the technology artifacts is not always pure, but often hybrid. For example, the iOS DRM module's resistance to third-party native apps is not purely material, but mixed with Apple's deliberate strategic intent to control the service system. Actors dealing with the materiality of technology artifacts in an artificial world often deal with other actors indirectly, who in turn are channeling their strategic goals through the artifacts with which they are dealing. Furthermore, the dialectics of resistance and accommodations in the distributed tuning is emergent and situational. Therefore, a powerful actor who can mobilize technical, financial, and legal resources can sometimes overcome the resistance of an artifact in ways that less powerful actors cannot.

Based on the results of the embedded case study of the iOS service system, we propose a general model of the distributed tuning of the boundary resources that serves as a latent mechanism governing the evolution of a service system (Henfridsson and Bygstad 2013) (see Figure 7). In our model, we make a distinction between boundary resources, auxiliary boundary resources, and technology resources. By technology resources, we refer to all sorts of hardware components, operating systems, middle-ware, software code, etc. that actors participating in a service system attempt to tune. Boundary resources constitute a subset of technology resources that serve as the interface for the arm's-length relationship between the platform owner and the application developer of a service system. Auxiliary boundary resources refer to technology resources that participating actors are tuning, but are peripheral to the focal service system. For example, the alternative app store for jailbroken phones, or a variety of the iOS boundary resources when Adobe, Apple, and a range of other actors engages in the distributed tuning of the Flash plug-in and the CS5 cross compiler are auxiliary boundary resources of the iOS service system. In our model, the boundary resource owners engage in their own local tuning of auxiliary boundary resources and technology resources, simultaneously attempting to tune the focal boundary resources. At the same time, third-party developers (some of which have their own auxiliary boundary resources) engage in their own local tuning of technology resources and auxiliary boundary resources, while attempting to tune the focal boundary resources.[3] In their simultaneous efforts to tune boundary resources, both the owner and third-party developers attempt to influence the other party's agency by channeling the material agency of the boundary resources. In this process, our model also stipulates that external actors (such as regulators, an installed base of users, partner organizations, or the public opinion expressed within the blogosphere) can seek to exercise power over the tuning process. Alternatively, the owner or third-party members can attempt to mobilize the power of external actors in order to shape the distributed tuning process. Through the iterative process of distributed tuning, a boundary resource (BR1) can change over time (BR1') or new boundary resources can emerge (BR2 to BRn).

Conceptualizing the service system dynamics in terms of the distributed tuning of boundary resources allows us to expand on Ghazawneh and Henfridsson's (2013) platform-owner centric model and propose a boundary-resource centric model. The image that emerges from our model is a cascading set of localized tuning events as each of these events further shape and reshape what other actors and technology artifacts can do in the service system. Individual actors who are separated in time and space engage in their own tuning of artifacts through a dialectic of resistance and accommodation as Pickering depicts. While Apple has to overcome the material resistance of its technical resources, such as the iPhone hardware with limited battery performance, Adobe has to deal with the resistance of its own technology, the Flash plug-in, to function satisfactorily within these hardware constraints. These individual tuning events are interconnected as the actors engage in on-going negotiations and public debate within the blogosphere (Davidson and Vaast 2009), forming a network-like image that involves heterogeneous actors and artifacts intermingled in an ever-changing manner.

This theoretical shift also produces a more symmetrical treat-

[3]The model represents the heterogeneity of the actors through shading the object representing actors. This shading does not constitute a theoretical statement beyond the indication of the heterogeneity of actors from global organizations commanding ownership of large collections of boundary (black), over large, important enterprises, possibly with some boundary resource ownership (grey), to small independent companies or even individuals (white).



The model shows the process of tuning the central boundary resources in terms of a diversity of actors engaging in their own local tuning of technical and auxiliary boundary resources and in the tuning of the central boundary resources. External actors, such as regulators, installed base of users, partner organizations, or the blogosphere of public opinion, can seek to exercise power and influence over the participating actors. The shading of actors indicates heterogeneity: black = global organizations commanding ownership of large collections of boundary; grey = large, important enterprises possibly with some boundary resource ownership; and white = small, independent companies or even individuals.

Figure 7. Conceptual Model of the Dynamic Process of Distributed Tuning of Boundary Resources

ment of the different actors engaged in the tuning rather than the central role previously provided by one particular boundary resource owner. The analysis still distinguishes between a given boundary resource owner in terms of an actor with a key role of defining and redefining the boundary resource. However, we suggest re-centering the analysis of service system dynamics from focusing on the duality between one boundary resource owner and a group of complement developers as in Ghazawneh and Henfridsson, toward a distributed view of the tuning of boundary resources. This re-centering involves a range of possible actors, including developer organizations of all sizes, other boundary resource owners, and user communities. In addition, it also includes these other actors' local tuning processes.

In this way, we can more closely account for the wakes of innovation (Boland et al. 2007) where reshaped goals in one part can influence the tuning processes in another part of the service system. In the case of Adobe and its Flash plug-in boundary resource, for example, this is seen by the emergence of an additional boundary resource: the Flash cross compiler. The cross compiler is initially met with resistance due to the poor performance of the code compared with code written using traditional SDKs, but is later accommodated in the service system.

Our model also suggests that in order to understand the underlying dynamics of the tuning process of boundary resources, one must look beyond the immediate dialectic relationship between an actor and an artifact as their actions are often prompted by the results of other tuning activities. For example, behind Apple's rejection of Google Voice and VoIP apps, there is the tuning of AT&T's infrastructure to accommodate AT&T's attempts to meter and bill data usage. The concept of distributed tuning, therefore, provides a deeper understanding of the complex, mutually constitutive, sociomaterial nature of a service system.

Barrett et al. (2012, p. 1464) extend Pickering (1995) through emphasizing that the actors engaged can be multiple and heterogeneous. Our analysis and discussion takes this further. Our domain of study inherently consists of multiple, highly heterogeneous actors spanning from individual app developers to large global businesses. All five vignettes demonstrate that the tuning of boundary resources is a highly distributed process. Rather than observing tuning as the process of the resistance of a single artifact and the accommodation of an individual actor (Pickering 1993), or even as a dialectic between a number of collocated actors and a single artifact (Barrett et al. 2012), we find that tuning involves dialectical interrelating among distributed and heterogeneous actors and resources participating in a common service system. Furthermore, we find that an actor's tuning often involves the channeling of material agency to restrict other actors' agency (Jones 1998), suggesting the hybridity of digital innovation in a service system cannot be separated from the political context in which these actors and artifacts are embedded.

The Role of Controlled Generativity of Distributed Tuning in Service System Innovation

Scholars have noted that the use of digital technology in service systems makes the innovations in these service systems generative and unbounded (Yoo et al. 2010; Zittrain 2006). This comes about not only through the provision and enabling effect of boundary resources, but also through the way they resist actions by other actors, produce contradictions, ruptures, and incompatibility within the service system. It is precisely through the repair of these tensions emerging from action and reactions that enables new forms of resource integration and service provision.

Jailbreaking epitomizes this tension between control and generativity. It came into being as a result of the iPhone generative capacity in order to overcome a regime of autocratic control imposed by Apple. The relative simplicity for an end-user to jailbreak a handset, using downloadable code or embedded web-page scripts, was an influencing factor for Apple deciding to become more open and support independently sourced native apps through the App Store, enabled and protected by an extensive set of boundary resources (Isaacson 2011). By changing its means of control, the service system becomes more generative, which gives rise to one million apps by June 2013. The continued cycles of jailbreaking and patching reflect this tension.

In the case of Google Voice and Voice over IP, Apple's attempt to control forces developers of all sizes to leverage the generativity of iOS to resist the restrictions imposed by the boundary resources. As a result, Google and GV Mobile release HTML5 web app variants of native apps, and VoiceCentral release their app to the jailbreaking community. Similarly, Financial Times leverage the wider generativity of iOS and HTML5 as a means of avoiding Apple's boundary resources and setting up their own boundary resources to distribute content.

Similarly, the distributed tuning of boundary resources resisting challenges by Adobe result not only in the resistance of the Flash standard, but also in Adobe developing a cross compiler, Adobe Flash Professional CS5, which in turn enables porting of Flash-based games into iOS. The distributed tuning also leads to the development of innovative apps, such as Skyfire, providing on-the-fly server-side transcoding of some Flash content, thereby rendering it accessible from within the Safari browser on iOS.

Dialectic interrelating in distributed tuning highlights the constructive and generative role that contradictions and tensions play in the evolution of boundary resources. Distributed tuning involves multiple and overlapping actions of accommodation and resistance by distributed heterogeneous actors and artifacts. These actions, counteractions, and their consequences constantly shape and reshape the landscape of the service system. As a result, this landscape continues to shape and be shaped by the tuning events from other actors and other technology artifacts. What is plausible and what is strategically advantageous is, in advance, decisively unknowable to the participating actors; rather, it emerges as insights from the distributed tuning.

In this way, our case study of Apple's iOS service system demonstrates how some companies are changing their approach to innovation. Rather than focusing on developing singular products to meet specific customer needs, they enable a service system that can be leveraged by others to innovate a multiplicity of services, which in turn meet a wide range of customer needs. Our study develops further insight into service thinking. It explains how the notion of distributed tuning of boundary resources is central to facilitating that multiplicity of service innovation by numerous providers for a broad range of users in different contexts within a service system.

Digitality and the Dynamics of Power

In the service system literature (Vargo and Lusch 2011), there is no explicit discussion of power and its role in how the service system evolves over time. Furthermore, recent research on digital innovation suggests the "democratization" of the innovation process as an important consequence of digitality (von Hippel 2005; Zittrain 2006). While we sympathize with the spirit of such ideas, our research suggests that power and influence play an important role and we must explicitly incorporate this role in our attempt to better understand innovations in service systems enabled with digital technology.

Jasperson et al. (2002, p. 399), quoting Hall (1977, p. 110), suggest that generally "power has to do with relationships between two or more actors in which the behavior of one is affected by the behavior of the other." They argue that influence is often subsumed in definitions of power when an actor cannot directly impose its interests by force but rather frames another actor's choices (Jasperson et al. 2002, p. 401-402). Similarly, Benson (1977, p. 7) argues that power is the "capacity to control the direction of events."

Service systems with digital technology are ripe with political tensions among different actors trying to leverage their resources to influence others. The shaping of boundary resources often emerges from on-going actions and reactions

among actors who are trying to frame each other's actions. While powerful actors can forcefully frame others' choices (Jasperson et al. 2002) through the material agency of boundary resources which they design, less powerful actors, such as individual developers, might find themselves in a position where their choices are restricted and have to accommodate these boundary resources by changing their goals (thus, indirectly the intent of the powerful actors). At the same time, parties such as regulators, interest organizations, and the public opinion influenced by the blogosphere who are beyond direct engagement in distributed tuning all seek to exercise their influence in the tuning process as well. The degree to which such influence represents power will vary across the heterogeneous actors and also be relational depending on the specific situation and combination of actors involved. An individual developer is not as powerful as a large organization, such as Google or Apple, that engages in complex maneuvers to gain power while avoiding regulatory intervention. The strategy seems to be one of exercising power through the design of boundary resources and seeking to be perceived as equitable and rational by regulators, the blogosphere, and partner organizations. As an example, while the blogosphere speculated on Apple's power-driven and control-obsessing motives, Apple, especially through Steve Jobs, always evoked rational, technical arguments. The arm's-length tuning relations provide a rational power similar to that exercised in standard setting (Backhouse et al. 2006). The dynamics of influence and the power of a regulator vary depending on how close large organizations, such as Google and Apple, collaborate. Yet even actors with relatively less power and influence can leverage this through appealing to the public opinion via the blogosphere.

Our study also shows that in service systems with digital technology, the power dynamics among actors with different power is balanced by the unique material characteristics of digital technology. Specifically, digitality can destabilize the power structure of service systems in two distinct ways: (1) through the technological mediation of open communication and associated mobilization of public opinion through social media, such as the blogosphere (Davidson and Vaast 2009; Vaast et al. 2013); and (2) through hacking enabled by programmability (Kallinikos et al. 2013) and layered modular architectures (Yoo et al. 2010) challenging boundary resources established by powerful actors.

The cases of small independent developers, such as Ari David and Mark Fiori, offer striking examples of how open communication and the mobilization of public opinion can change the dynamics of power in distributed tuning of boundary resources. The differential of power could hardly be more striking. A powerful global corporation, Apple, and a couple of independent developers engage in the distributed tuning of boundary resources stipulating what content is acceptable within native iOS apps. Given the ambiguous and equivocal nature of Apple's rules, there is considerable uncertainty for the developers involved. The rules are altered as the result of developers leveraging digital media, specifically the blogosphere (Davidson and Vaast 2009), to create a public opinion pushing against the boundary resource. The arbitrariness, and at times farcical nature, of Apple's decisions make the company look foolish and clumsy in the media—an aspect rapidly covered across the blogosphere by webs of inter-linked postings. The end-result directly negates Apple's official advice to developers stated on the first page of the App Store Review Guidelines: "If your app is rejected, we have a Review Board that you can appeal to. If you run to the press and trash us, it never helps" (Apple 2011a).

In the case of the jailbreak community, the ability to engage in hacking enabled by the programmability and layered modularity of the digital technology (Yoo et al. 2010) allow independent developers to continuously circumvent Apple's control over the distribution of native apps within the service system.

While digitality appears to contribute to the altering of power dynamics in the process of distributed tuning, it is not the only factor observed within our data. Large and powerful actors can also seek to involve regulators and the political system to challenge autocratic behavior. In the case of competing advertisement within iOS, the perception of the boundary resource being able to resist attempts to openness can be seen as one of the reasons for the FCC deciding to allow Google to acquire AdMob. In another case, the tuning of boundary resources acting as proxies for control in neighboring service systems involves three fairly equally powerful actors—Apple, Google, and AT&T—each possessing complex technologies. However, the involvement of the regulator, the FCC, seems to alter the relative power differential resulting in AT&T backing down from the prohibition of the use of VoIP apps.

The power asymmetry between different actors can also be altered through technological and/or financial resources. These resources can assist an actor in circumventing a boundary resource hindering certain activities. For example, in the distributed tuning of boundary resources controlling ownership of and control over customer data, Apple is facing a powerful printing industry, but is able to divide and conquer as some actors are enthusiastic and adopt its new boundary resources, while others abandon it and circumvent the controls through web-app solutions. Here, the ability of Financial Times to invest financial and technological resources into the construction of a highly sophisticated HTML 5.0 web-app allows it to circumvent Apple's new boundary resources. A pragmatic compromise is reached through distributed tuning

with a number of publishers. This compromise seems to appease most critics, although Financial Times remains within the open HTML5 part of the service system. This compromise allows the coexistence of in-app and extra-app subscriptions as long as these are not linked directly from within the native iOS app.

Within the distributed tuning arrangement, participants can draw power from a number of sources. The owner of a particular boundary resource will have the direct power to channel interests into material agency in order to shape the coordination at arm's-length. However, as our examples clearly demonstrate, such power can be countered by a number of other factors when the distributed tuning of central boundary resources unfolds. When other actors engage in the distributed tuning, material resistance will trigger changed goals, which in turn can trigger further localized tuning activities, which in turn can lead to changed goals. The boundary resources form obligatory passage points (Backhouse et al. 2006, p. 415) in the form of liminal standards that are subject to negotiation.

Technological competence, the ability to finance new development, the ability to shape public opinion, and strong political connections can all play important roles in the distributed tuning process as material resistance leads to new goals. However, various actors external to the direct tuning activities can seek to exercise influence over decisions made: Regulators and various interest organizations can seek to influence actors toward certain behavior; an installed base of users, code, contents, and skills can provide a participant with power and influence; a service system partner can seek to indirectly exercise influence and power to protect its own interests; and last, but central to this paper, the blogosphere offers a highly interactive means of shaping public opinion, which allows some degree of leveling of power between large and small participants.

Contributions and Limitations

Our study makes three important contributions to the literature on service innovation in the digital age. First, we uncover an underlying process of evolution of boundary resources in service systems with digital technology. Boundary resources serve as critical elements in distributed and heterogeneous actors coordinating their cocreation of service through resource integration. Understanding how such boundary resources evolve is, therefore, essential for the understanding of how innovation takes place in the digital age. Our distributed tuning model describes the process of boundary resources coming into being and evolving, as well as alternative boundary resources emerging through on-going actions and reactions of accommodation and resistance by heterogeneous actors and artifacts. The boundary resources are in this manner placed at the center of analysis rather than at the periphery.

Second, our study extends the idea of tuning offered by Pickering (1993) and Barrett et al. (2012) by demonstrating how boundary resources emerge and change as a result of a distributed tuning process involving a complex web of resistance and accommodation cascading across the service system. We show that in complex service systems with digital technology, individual actors make sense of the technology and make independent choices, which in turn may influence other actors' tuning processes. Our model challenges the dialectic relationship between an artifact and an actor (or actors), and suggests a network view of tuning.

Finally, our study contributes to the service systems literature by demonstrating the political and contested nature of service systems. Our study emphasizes the complex interplay between actors with uneven distribution of power within the service system. The notion of distributed tuning of boundary resources could perhaps offer a viable perspective to understand digital infrastructure dynamics in general (Tilson et al. 2010), for example, in conjunction with the analysis of how interests between participating actors are negotiated through tussles over control points (Elaluf-Calderwood et al. 2011; Pagani 2013). We also show how the digitality of the service system allows actors to redress this power difference.

Our study is not without limitations. First, we are exclusively relying on a single embedded case of Apple's iOS service system. While Apple's case certainly represents a rich and dynamic setting to study the evolution of boundary resources, future research should consider other service systems.

Second, our study relies on publicly available archival data. We have not been able to source incidents from an internal process as Apple is traditionally highly secretive. Therefore, we cannot make a comparison between developers successfully raising issues internally with Apple, as opposed to those achieving success through challenging Apple's decisions publicly. We do, however, have clear indications that among the cases discussed by technology blogs, those developers insisting on resisting are more likely to influence a change in boundary resources than those who choose not to resist.

Finally, the act of sampling data from aggregated technology blogs as opposed to a range of other sources may have resulted in a sample bias in that we only have data on cases raised in the public sphere. Future studies can extend our study by including a more systematic and extended collection of other forms of available data.

Conclusion

Large-scale global cocreation is a key feature of service innovation in the digital age. This paper advances our understanding of one of the important aspects of such cocreation: The emergence and dynamics of the boundary resources enabling such activities. Our study shows multilayered, overlapping, and contradicting actions by heterogeneous actors and artifacts form the foundation of the distributed tuning of boundary resources. In this sense, boundary resources in service systems are themselves cocreated. This offers a contribution to existing research.

Apple's iOS service system is a complex sociotechnical assemblage of heterogeneous actors and artifacts that are constantly in the process of becoming through on-going production, reproduction, and transformation. Apple's striking success with the iOS service systems has become the envy of the industry and many competitors attempt to emulate its success. While Apple's deliberate attempt to control its service system through its own set of boundary resources plays an important role, the coalitions of other actors and competing technology artifacts and their attempts to reject Apple's attempts collectively serve as a critical part of the engine of innovation in the service system. Our results show that part of Apple's success can be subscribed to unplanned, distributed tuning of boundary resources.

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MIS Quarterly

SPECIAL ISSUE: SERVICE INNOVATION IN THE DIGITAL AGE

DISTRIBUTED TUNING OF BOUNDARY RESOURCES: THE CASE OF APPLE'S IOS SERVICE SYSTEM

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Appendix A

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